

## **Chapter 3: Construction Methods and Activities**

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### **3.1 INTRODUCTION**

This chapter describes the construction methods and activities for the Hudson Tunnel Project's Preferred Alternative. The Preferred Alternative has two overarching components: (1) the construction of a new trans-Hudson tunnel (the Hudson River Tunnel) and associated surface and rail system improvements; and (2) the rehabilitation of the existing North River Tunnel. To ensure that the passenger rail system continues to operate at existing service levels during construction, the new tunnel would be constructed and put into operation before the rehabilitation of the North River Tunnel occurs.

The Project Sponsor that will advance the Project through final design and construction, including compliance with mitigation measures, has not yet been identified. The Project Sponsor may include one or more of the Port Authority of New York & New Jersey (PANYNJ), the National Railroad Passenger Corporation (Amtrak), New Jersey Transit Corporation (NJ TRANSIT), and/or another entity that has not yet been determined.

This chapter provides an overview of the likely construction methods that would be used for the Preferred Alternative, a discussion of locations where construction would occur, and a description of the potential sequencing and schedule for construction. For the new Hudson River Tunnel, this includes construction of surface tracks in New Jersey from Secaucus to the new tunnel portal in North Bergen; a new tunnel consisting of two tracks in two separate tubes beneath the Palisades, the Hudson River, and the waterfront area in Manhattan; and track modifications near Penn Station New York (PSNY) in Manhattan; and construction of ventilation shafts and fan plants in both Hoboken and Manhattan.<sup>1</sup> The rehabilitation of the North River Tunnel includes conventional demolition and construction methods to replace tunnel elements and rail systems.

Information presented in this chapter and analyzed throughout this Environmental Impact Statement (EIS) is based on conceptual engineering (10 percent design) and is likely to evolve as the Project team advances the engineering. Accordingly, the preliminary sequencing plan and overall construction schedule developed for the proposed construction activities represents a reasonable estimate of how the Preferred Alternative could be constructed, based on conceptual engineering; this plan is likely to change as engineering evolves. Potential environmental impacts that could result from Project construction, as well as mitigation measures to lessen their effects, are evaluated and discussed in subsequent technical chapters of this EIS, based on reasonable, worst-case assumptions about the Project's construction activities. As final design and construction advances, the Project Sponsor will identify opportunities to advance the Project more efficiently and with reduced impact through innovation and use of improved technologies, and to leverage private-sector partnerships for procurement methods, project delivery, and long-term maintenance, where possible.

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<sup>1</sup> The new Hudson River Tunnel would consist of two separate single-track tunnels, referred to as "tubes" throughout this EIS. This is similar to the North River Tunnel, which also consists of two separate single-track tubes.

This chapter contains the following sections:

- 3.1 Introduction
- 3.2 Overview of Construction Methods
  - 3.2.1 Mining or Tunneling Techniques
  - 3.2.2 Ground Improvement Techniques
  - 3.2.3 Description of Surface Structure Elements
  - 3.2.4 Other Anticipated Construction Measures
- 3.3 Description of Site-Specific Construction Activities
  - 3.3.1 New Jersey Surface Alignment
  - 3.3.2 Palisades Tunnel
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  - 3.3.4 Tunnel Beneath Hoboken and the Hudson River
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  - 3.3.10 Rehabilitation of North River Tunnel
- 3.4 Overall Construction Schedule
- 3.5 Summary of Construction Activities by Site

## **3.2 OVERVIEW OF CONSTRUCTION METHODS**

As described later in this chapter, other than the surface features of the Project where new embankments, viaducts, tracks, and ventilation structures are situated on the surface, or measures to implement ground stabilization or soil improvement are effected from the surface, much of the construction activity for this Project would be occurring underground. Where possible, construction activities and associated worker and trucking movements would be concentrated at one or more of three construction staging areas to minimize disruptions at the surface. The three principal staging sites, described in greater detail below, would be located at: (1) the new and existing tunnel portal locations, with staging areas on either side of Tonnelle Avenue (U.S. Routes 1 and 9) in North Bergen, New Jersey; (2) the Hoboken shaft site and staging area in Hoboken, New Jersey; and (3) the Twelfth Avenue shaft site and staging area in Manhattan, New York.

In the Palisades, the two tubes of the new Hudson River Tunnel would be constructed underground in hard rock. The construction access and ventilation shaft would be constructed from the surface through soils and rock at a site located on the south side of West 18th Street at the convergence of the municipal boundaries of Hoboken, Weehawken, and Union City, New Jersey. (The site is located in all three municipalities, but predominantly in Hoboken, with the shaft itself completely in Hoboken.) The Hoboken shaft site is bordered on the south by the tracks of the Hudson-Bergen Light Rail (HBLR). From the Hoboken shaft site continuing under the Hudson River to the Manhattan bulkhead, the tunnel would be constructed underground through various types of rock and mixed-face ground conditions. East of the Manhattan bulkhead, the tunnel would be constructed through mixed-face soils, some of which would require stabilization for the excavation, to the Manhattan shaft site. All of these construction activities would be accomplished by one of several mining techniques, described below in Section 3.2.1. In some areas, cut-and-cover construction would also be needed to build portions of the tunnel and other features that require street-level access or that cannot feasibly be mined because there is not enough cover above the tunnel area.

Surface construction would also be required where the new track surface alignment would be constructed, at the shaft sites from which soil and rock would be excavated, and where ground improvement and underpinning of buildings, roadways, or other structures would be required. Above-ground construction would also be required for such ancillary facilities as vent shafts, fan plants, and electrical substations, and other above-ground construction operations, as described in more detail below. Staging areas for construction material and personnel would also be required for both the construction of the new tunnel and for the rehabilitation of the existing North River Tunnel.

The methods and techniques that would be used to construct the Preferred Alternative are described below. **Figure 3-1** provides an overview of the construction methods that would be used for the Preferred Alternative. **Figures 3-2a** and **3-2b** show more detailed views of the project construction sites and activities in New Jersey and Manhattan, respectively.

### 3.2.1 MINING OR TUNNELING TECHNIQUES

Most of the alignment for the new Hudson River Tunnel—consisting of two “tubes” each containing one track—would be constructed using a combination of four principal mining or tunneling techniques:

- Mined tunnel construction with a tunnel boring machine (TBM);
- Mined tunnel construction using Sequential Excavation Method (SEM);
- Other conventional forms of underground mining, including “drill-and-blast” construction; and
- Excavation using cut-and-cover construction.

In some areas, protective measures would be used to support a variety of foundation structures (e.g., roadways, buildings, HBLR track beds, bulkheads, and sewers), as necessary, before tunnel or ventilation shaft site excavation.

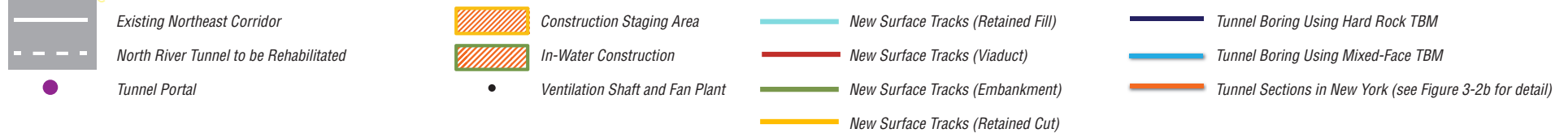
Mined tunnel construction, including the use of a TBM, SEM, and other mining techniques, allows for tunnel excavation to occur below the surface without substantially disrupting the surface above. Typically, the only visible evidence of a mining operation to the general public occurs where a vertical shaft connects the ground surface to the tunnel below, and where associated lay-down areas for equipment and supplies are located. For the Hudson River Tunnel, two vertical shafts would have to be constructed, one in Hoboken, New Jersey and one in New York. Generally, the shaft sites would be enclosed or protected by fencing, and would be open to the surface level to permit materials and workers to enter and exit the tunnel. Cranes and other construction machinery would be located alongside each shaft. As explained in detail below, these shafts are necessary for inserting tunneling equipment and removing the spoils, and would also be the locations where ventilation fan plants and emergency egress would be located for the new tunnel.

A basic description of mined tunnel construction methods is provided below.

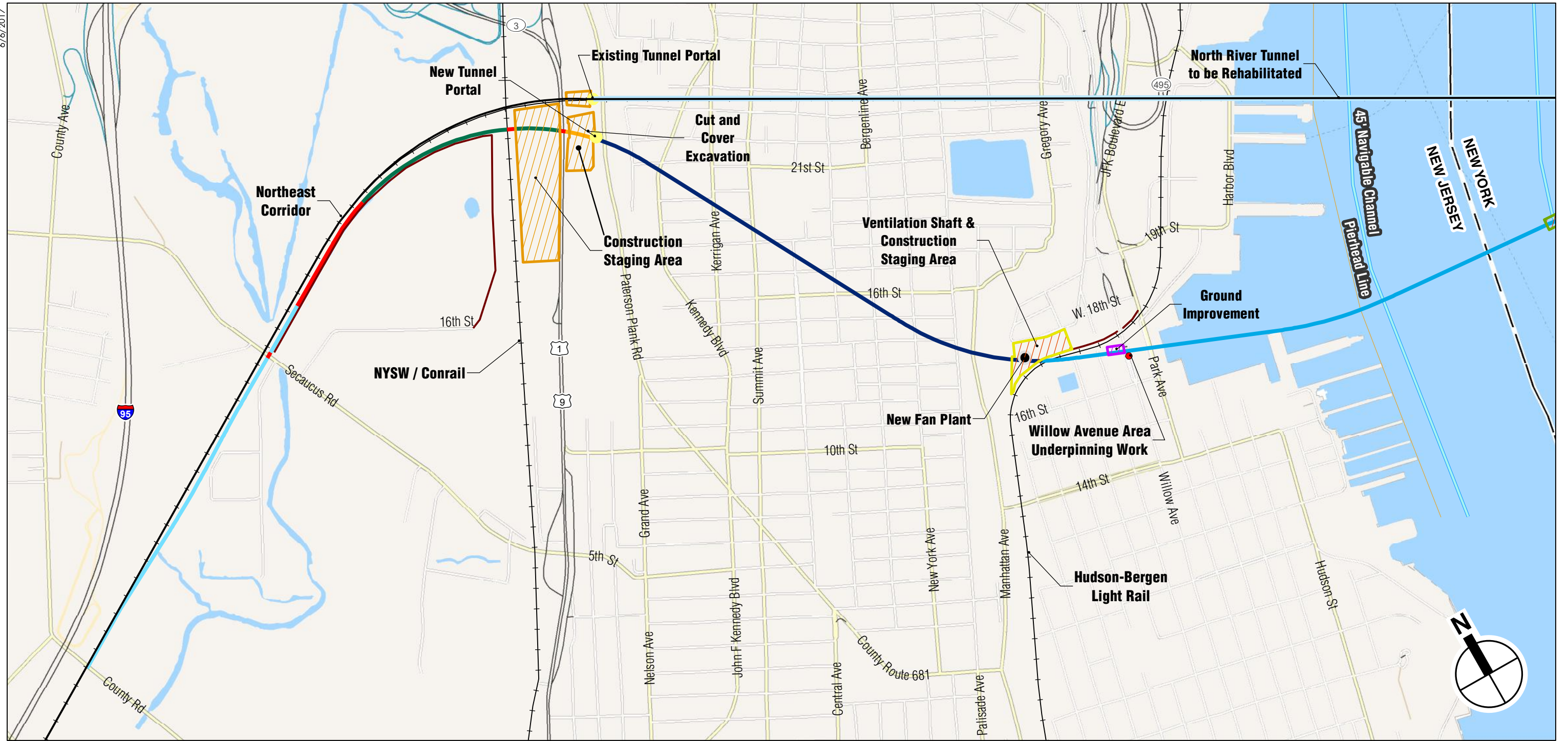
#### 3.2.1.1 TUNNEL BORING MACHINES

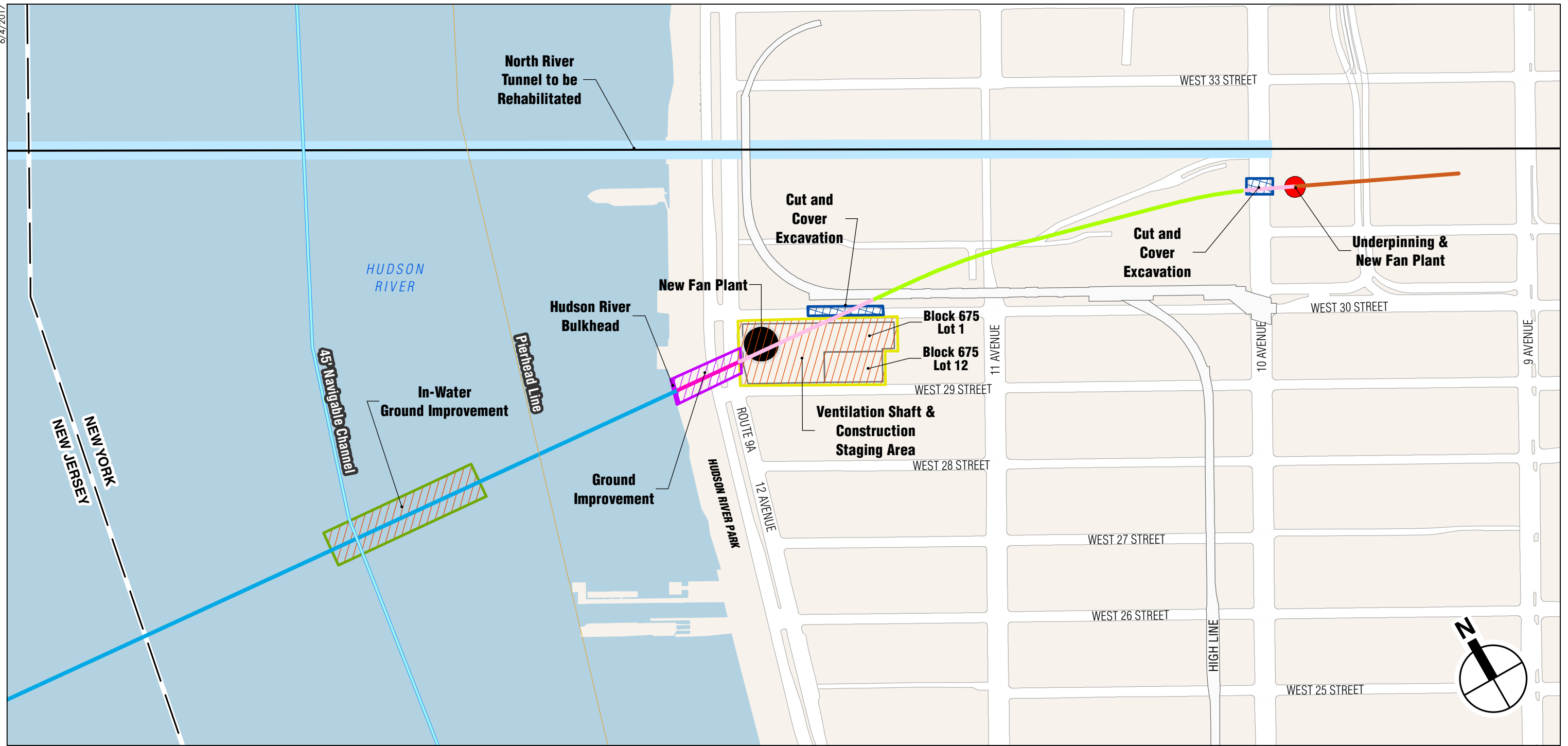
**TBM**s are large-diameter horizontal drills that continuously excavate predominantly circular tunnel sections. Different machines are designed for different geological conditions. In rock, a rock TBM is used; in soil and degraded rock, a different type of TBM is used that is specifically designed for drilling through materials that are not self-supporting. Examples of TBMs used in soil include earth-pressure-balance boring machines (EPBMs) and slurry shield TBMs, discussed below. Multi-purpose machines that combine the attributes of both rock and soft-ground machines can also be used through both ground types, as well as through mixed-face



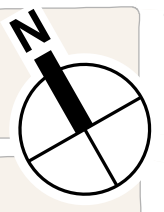
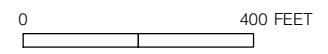








- Existing Northeast Corridor
- North River Tunnel to be Rehabilitated
- Construction Shaft and New Fan Plant
- Underpinning
- Ventilation Shaft & Construction Staging Area
- Ground Improvement
- Cut-and-Cover Excavation
- In-Water Construction
- Tunnel Boring Using Mixed-Face TBM
- Tunnel Construction Using SEM Techniques and Mixed-Face TBM in Frozen Ground
- Tunnel Construction Using Cut-and-Cover
- Fit-Out of Previously Constructed Tunnel Box with Track and Rail Systems
- Track Work





(i.e., rock and soil within a single excavation section) conditions. A combination of these machines would be used for different segments of the new Hudson River Tunnel.

A TBM is able to move below ground, generally avoiding removal of surface elements, although construction with a TBM may require **underpinning** (i.e., stabilizing or reinforcing the support of a structure from below) or other removal of subsurface elements.

Both rock and soft-ground types of TBMs consist of a cutter head followed by several hundred feet of machinery; this machinery powers the cutter head, conveys the excavated rock and soil (referred to as "spoils") to the back end of the TBM, and propels the TBM forward. Soft-ground TBMs also include a shield at the cutter head that supports the ground. **Figure 3-3** illustrates a typical TBM used in the boring process.

Behind the cutter face, TBMs have extended compartments (trailing gear) that may contain computerized control rooms from which the boring operations are conducted. Behind those compartments, trailing equipment on wheels supports the drilling operations. This equipment includes pumps, transformers, and grouting equipment, as well as mechanisms for removing the excavated rock or soil and conveying it back behind the machine either by rail or conveyor.

Using either type of TBM, concrete tunnel liners, either pre-cast or cast in place, are put in position to complete the tunnel. This is done immediately in a soil tunnel but may be a follow-up operation in a rock tunnel. After the concrete tunnel liner is placed, voids between the lining and the rock are sealed by injecting cement grout, under pressure, into the voids. The grout fills any voids between the tunnel lining and the excavated opening, thereby reducing the amount of settlement at or near the ground surface.

TBMs are powered by electricity brought to the machine from substations near or along the tunnel route. This power is supplied to a substation generally located at the ground surface by a direct feed from the local electric utility provider (PSE&G in New Jersey or Consolidated Edison in New York).

With all these components, TBMs are very large pieces of equipment that are brought to the start of the tunnel operation and lowered into the ground in pieces, where they are assembled at the start of the tunnel. TBMs are normally manufactured for projects, according to the project's specific dimensions and site conditions, and can take approximately 18 months to manufacture and mobilize. The TBMs for the Preferred Alternative would be approximately 30 feet in diameter, with trailing gear extending several hundred feet behind the cutting face. The TBM for the section of the Hudson River Tunnel between Tonnelle Avenue and Hoboken would be a hard rock TBM and would be assembled at the Tonnelle Avenue tunnel portal; the TBM for the section of the Hudson River Tunnel between Hoboken and the Twelfth Avenue shaft site would be a mixed-face TBM and would be assembled at the bottom of the Hoboken shaft.

### 3.2.1.2 SEQUENTIAL EXCAVATION METHOD MINING

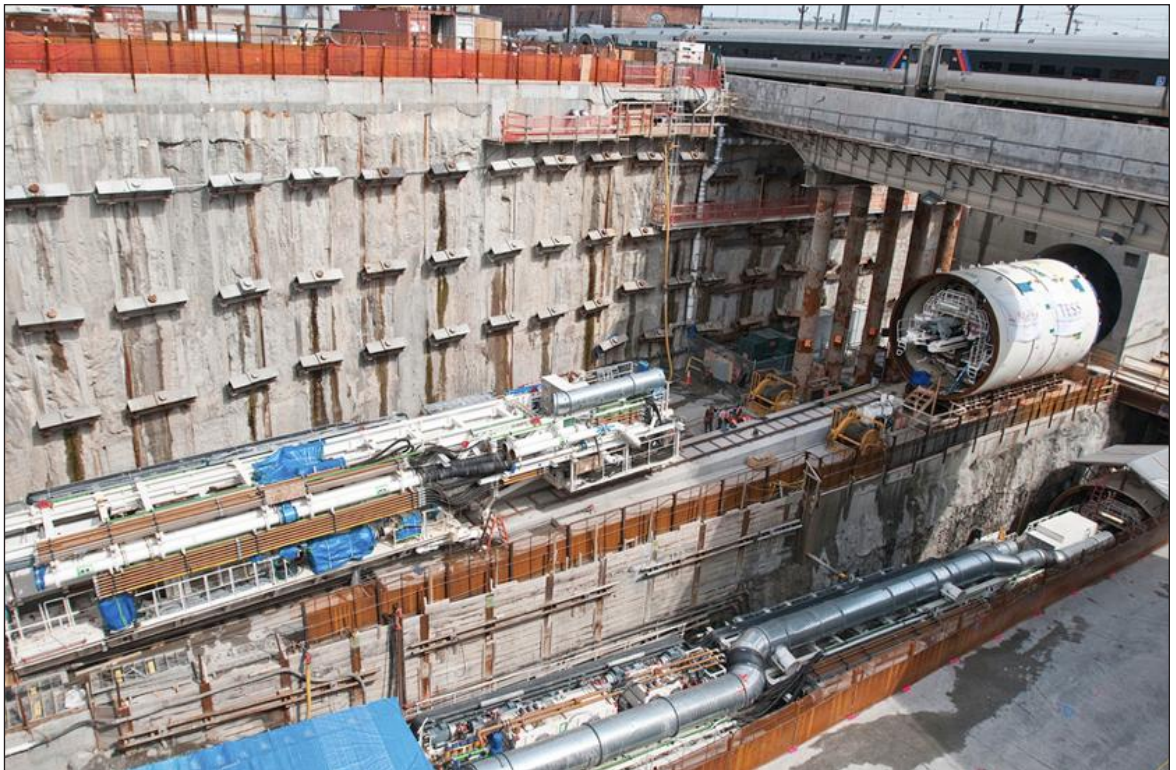
**Sequential Excavation Method (SEM) mining** is a technique in which a tunnel is sequentially excavated in phases and supported in a controlled manner. The excavation can be carried out with common mining methods and equipment, chosen according to the soil conditions. This underground method of excavation divides the space to be excavated into segments, then mines the segments sequentially, one portion at a time. While TBMs can only excavate a fixed (generally circular) shape, SEM mining permits a tunnel of any shape or size to be excavated. This makes it useful in areas where ground conditions would not allow for tunneling using a TBM, or where the tunnel shape or size needs to change (see **Figure 3-4**).

SEM involves the sequencing of the excavation as well as installation of supports. **Shotcrete** (a kind of concrete sprayed from high-powered hoses) may be used to line the tunnel or support the face, and **grouting** (the injection of a cementing or chemical agent into the soil) may be used



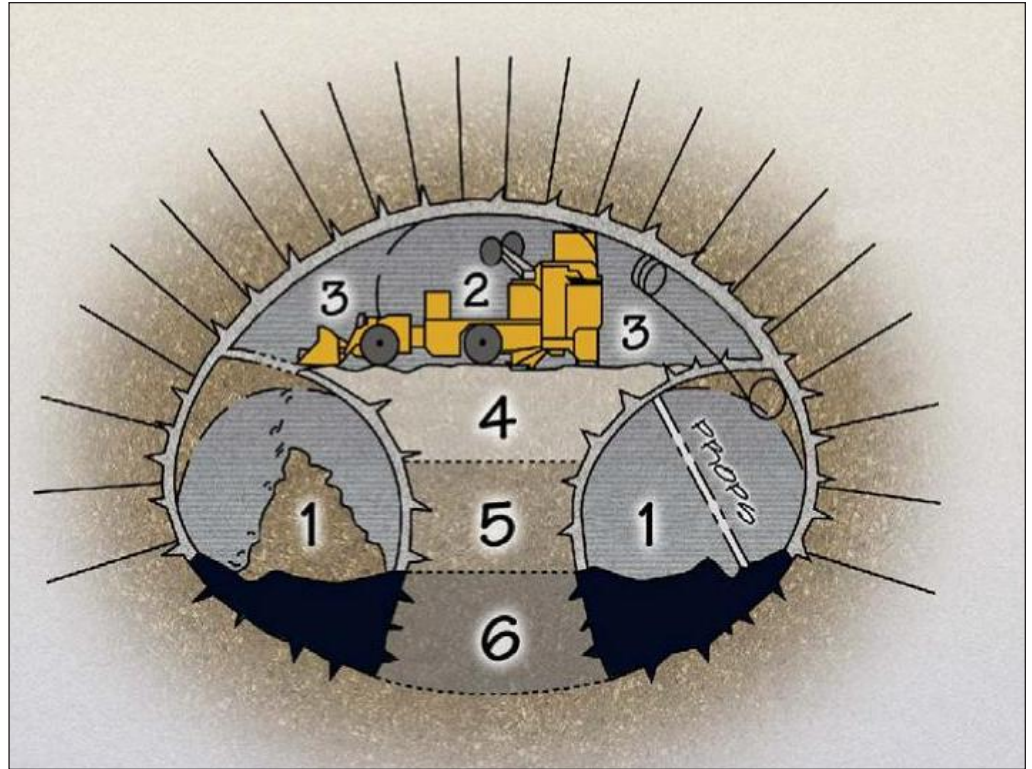


Hard Rock TBM 1



Mixed-Face TBM 2





Typical SEM Excavation Sequence 1



SEM Operation at a Tunnel Portal 2

Typical Sequential Excavation Method (SEM)  
Mining Sequence  
**Figure 3-4**

to increase the soil's strength and reduce its permeability. Another technique that can be used to increase the strength of soils in an area where SEM mining is to be used is ground freezing, described below. The permanent support installed for this type of tunnel excavation, similar to those used for TBMs in soft soils, is usually a cast-in-place concrete lining.

### 3.2.1.3 CONVENTIONAL MINING METHODS

**Conventional mining methods** refer to a variety of non-mechanized mining methods including drill-and-blast (described below), hand excavation, and excavation by road-header. Hand excavation is excavation performed by workers using hand tools and/or small mechanical tools. A road-header is a piece of excavating equipment consisting of a cutting head mounted on a boom, a loading device usually involving a conveyor, and a crawler traveling on track to move the entire machine forward into the rock face.

**Controlled drill-and-blast** is also a conventional excavation technique, in which a series of holes are drilled into the rock mass and loaded with a small amount of explosives. Under carefully controlled and monitored conditions, the explosives are detonated sequentially, breaking the rock while spreading the release of energy from the explosives over a period of several seconds.

### 3.2.1.4 CUT-AND-COVER EXCAVATION

**Cut-and-cover excavation** is a construction method in which a trench is excavated from the ground surface and a tunnel is constructed within the trench, and then covered over. A cut-and-cover tunnel may require temporary stabilization of the ground to support the excavation. When the excavation is complete, the tunnel structure is constructed within the excavated trench, the remaining space is backfilled and the surface is restored. Temporary supports for cut-and-cover construction typically consist of vertical support walls, including the following:

- **Soldier piles with timber lagging:** piles installed at regularly spaced intervals combined with timber planks or steel sheeting;
- **Slurry walls:** concrete walls constructed through the use of a slurry of bentonite, a natural, clay-like liquid material that is poured into the void and then replaced by concrete poured afterward;
- **Sheet piles:** steel sheet sections with intersecting edges that are driven in place similar to piles; or
- **Secant piles:** individual drilled holes filled with concrete and steel, reinforced and installed adjacent to one another to form a continuous wall.

During construction of cut-and-cover tunnel segments, street crossings and adjacent areas may be decked to allow unimpeded traffic and use of properties above the cut.

## 3.2.2 GROUND IMPROVEMENT TECHNIQUES

In the process of constructing tunnels, it is often necessary to improve or strengthen soils through which tunnel boring or mining operations would be undertaken to make the process easier or the soils less prone to collapse during tunneling operations. The two types of ground improvement techniques most likely to be used for the Preferred Alternative are described below.

### 3.2.2.1 JET GROUTING

**Jet grouting** consists of drilling a pattern of small-diameter holes into the soil and then injecting cement grout and optionally air and water in a mixture under high pressure into the ground. Once the grout sets, it forms columns that are designed to overlap each other and form a block.



This process produces a stronger, solidified cemented soil with a consistency equivalent to a hard clay. For the Preferred Alternative, the majority of jet grouting would be used at a short segment of the alignment where the new tunnel would be relatively shallow beneath the bottom of the Hudson River, discussed below in Section 3.3.5. Secondary areas of jet grouting would be at the Hoboken shaft and starter tunnels, where the presence of major utilities requires ground stabilization during excavation.

### 3.2.2.2 GROUND FREEZING

**Ground freezing** is a ground improvement technique in which subsurface pipes are installed and a refrigerated brine (e.g., calcium chloride and water) is circulated through the pipes so that the ground is literally frozen. The hardened, frozen soil can then be excavated using conventional mining techniques such as SEM or left in place to support adjoining construction activities. For the Preferred Alternative, ground freezing is proposed in three principal areas: the cross passages under the river in soft clay soils discussed in Section 3.3.4.3; the Manhattan bulkhead area, discussed in Section 3.3.6; and the tunnel section just west of the Twelfth Avenue shaft, where a major sewer on steel piles needs to be underpinned, also discussed in Section 3.3.6.

### 3.2.3 DESCRIPTION OF SURFACE STRUCTURE ELEMENTS

For the surface tracks included in the Preferred Alternative, the track support systems to be constructed would include the following:

- **Viaducts** are multi-span bridges, consisting of piers with steel or concrete girders spanning between the piers. Viaducts are constructed by driving foundation piles (defined below in Section 3.2.4) into the earth where the viaduct support piers would be located and then constructing the foundations and support piers on top of the piles. Once the piers are built, the individual spans of the viaduct can be constructed and finished with the necessary surface treatment to carry, in this case, the associated track system.
- **Embankments** are raised sections of railroad infrastructure above the surrounding grade. They are constructed as filled areas of compacted soil. The soil can be compacted mechanically using heavy rollers and other equipment. Another way of compacting the soil is to “surcharge” the embankment. Surcharging involves placing additional fill material (i.e., gravel, soil, and stone) on top of the embankment so that the weight of that material compacts the embankment. The extra material is left in place for a period of time (usually several months) and then is removed. Embankments are sloped on the side so that they are structurally stable without the use of walls.
- **Retained fill** segments of railroad infrastructure are raised sections like embankments, but supported by retaining walls rather than a side slope. The retaining walls may be cast-in-place concrete or mechanically stabilized earth walls.
- **Open cut** segments of railroad infrastructure are depressed sections where the tracks are below the surrounding grade and where side slopes support the surrounding grade.
- **Retained cut** segments of railroad infrastructure are depressed sections like open cuts, but where space is insufficient for full side slopes and the surrounding grade is supported by retaining walls.

### 3.2.4 OTHER ANTICIPATED CONSTRUCTION MEASURES

The Preferred Alternative would also involve the use of some other construction methods to address specific conditions along the alignment. These are described below.

- **Deep foundation installations** involve the installation of **piles** deep into the earth to support various types of structural elements above. Depths vary depending on soil type, and can either go to bedrock, or to depths of 50 feet or more. Piles are long post-like cylinder foundation members made of a strong material—commonly composed of timber, steel, or concrete—that are driven into the ground to act as a steady support for structures built on top of it. For the Preferred Alternative, piles would be used for supporting the viaducts, bridge abutments, retaining wall and overhead catenary, signals, communications, and other rail systems along the surface alignment in New Jersey. They would also be used for underpinning the Willow Avenue viaduct, several buildings that the tunnel would pass beneath, and at the shaft and fan plant buildings to support those structures. Piles would also be required to support temporary and new sewer lines that would be affected by construction in Manhattan at West 30th Street and at Tenth Avenue.
- **Cofferdams** are watertight structures designed to facilitate construction projects in areas that are normally submerged. They are typically constructed of **sheet piling**, which consists of steel sheet sections with intersecting edges that are driven in place similar to piles. Cofferdams can be used to allow the construction zone to be dewatered so that the construction area is dry. They can also be used to contain an area of water to prevent waterborne pollutants from migrating to the surrounding area. For the Preferred Alternative, cofferdams would be used in the shallow area of the Hudson River (see Section 3.3.5 below).
- **Underpinning** is a process in which structural support (often using piles) is added to support an existing foundation and permit project construction below. For the Preferred Alternative, underpinning would be used above the tunnel alignment in Hoboken at and near the Willow Avenue viaduct, including beneath the PSE&G building just west of the Willow Avenue viaduct. Additionally, underpinning would be used in Manhattan in the vicinity of the building at 450 West 33rd Street (the Lerner Building), where modifications would be made beneath the building, and also to support sewer lines that are above the tunnel alignment.
- **Dewatering** is a process used to remove water from a construction site. Dewatering is typically accomplished by pumping groundwater from wells or sumps and conveying to discharge points away from the area to be excavated. For the Preferred Alternative, dewatering would be required in the Meadowlands area of New Jersey where surface tracks would be constructed. Within the new Hudson River Tunnel, limited inflow of groundwater is expected. Inflow water collection and disposal from the excavations would include some combination of sumps, pumps and sediment-settling tanks at construction staging sites and access shaft sites. Water pumped from excavation sites would be pumped, tested, and treated before disposal under applicable permits and in conformance with applicable discharge limits.
- **Utility relocation** involves moving buried or overhead utilities (i.e, electric, gas, water, sewer, storm water, and communication infrastructure) that fall within the footprint of the construction zone, such as in an area where excavation of a streetbed is required. In some cases, utilities can be supported in place; in other instances, they would be relocated in close proximity. Temporary outages to service may occur during relocation.
- **Soil and erosion control measures and Best Management Practices (BMPs)** would be used at the various Project construction sites. Erosion and sediment control and stormwater management plans set forth the practices and measures that will be followed to prevent or reduce erosion on construction sites and minimize the impacts of sediment, turbidity, and hydrologic changes off-site. Such plans are typically part of a Stormwater Pollution Prevention Plan (SPPP) that ensures that erosion and sediment control is appropriate for the planned use of the site. Construction contracts would include provisions for developing and implementing soil and erosion control plans at surface construction sites, to ensure that all

applicable laws and regulations pertaining to stormwater pollution prevention are addressed. Standard soil erosion and other control measures (e.g., silt fences and barriers, soil tarps, hay bale checks) would be implemented, as necessary, to prevent soil from leaving the work zone.

- A **Project-wide Soils and Materials Management Plan (SMMP)** would be developed to manage contaminated materials encountered during construction. SMMPs provide procedures for materials handling during construction activities, including procedures for stockpiled or containerized material and testing procedures for sampling material prior to off-site disposal or on-site reuse. In addition, the Project contractor will implement BMPs related to landslide prevention as well as other BMPs developed specifically for the various construction sites.
- **Rodent control programs** would be used at the various construction sites. Rodents can become a nuisance when construction activities disturb earth. Construction contracts would include provisions for a rodent (mouse and rat) control program. Before the start of construction, the contractor would survey and bait the appropriate areas, including construction staging areas, and provide for proper site sanitation. During the construction phase the contractor would carry out a maintenance program, as needed. Coordination would be maintained with appropriate public agencies and the contractor would be required to perform rodent control programs in a manner that avoids hazards to persons, domestic animals, and non-target wildlife.

### 3.3 DESCRIPTION OF SITE-SPECIFIC CONSTRUCTION ACTIVITIES

This section describes the site-specific construction activities that would occur for the Preferred Alternative, including for the surface tracks, new tunnel, fan plants, and other components, and the anticipated schedule for that work.

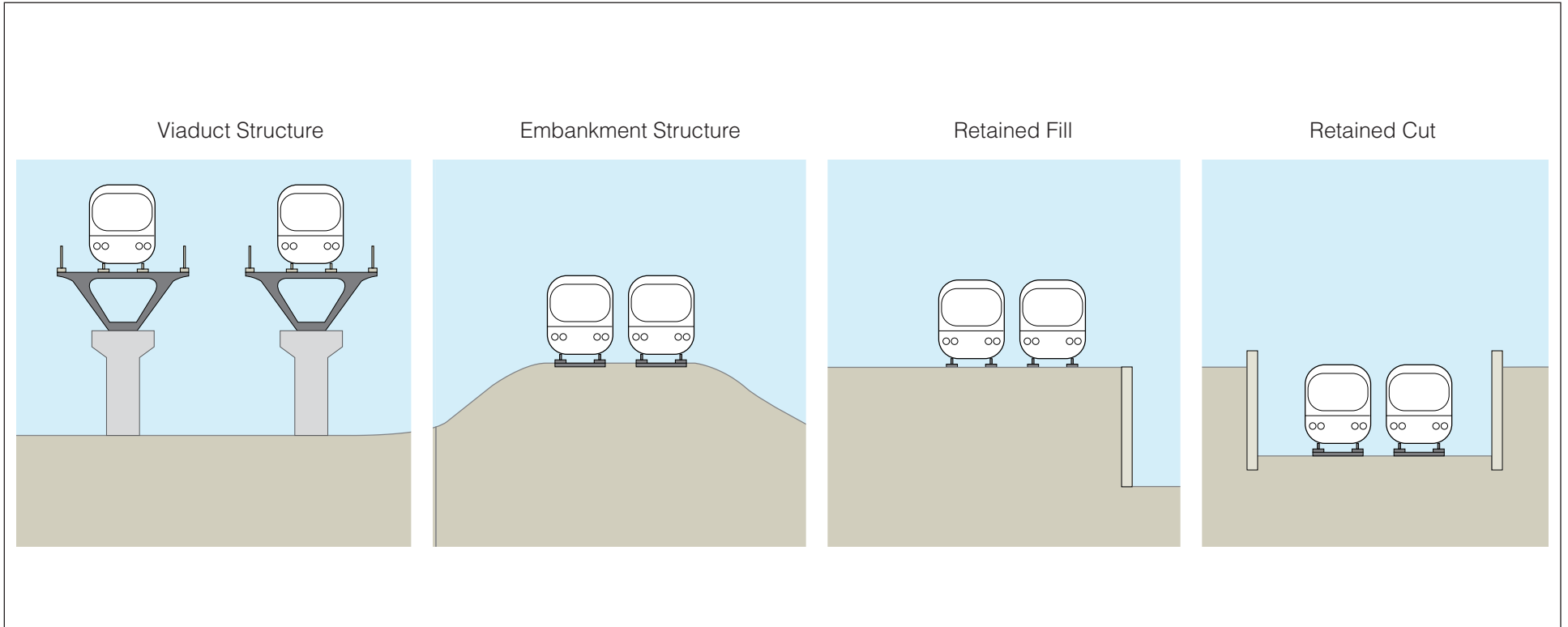
#### 3.3.1 NEW JERSEY SURFACE ALIGNMENT

The western portion of the new surface alignment would involve construction of two new tracks from Allied Interlocking in Secaucus (located east of Secaucus Junction Station) to the new tunnel portal in North Bergen. This would include construction of the new raised right-of-way (including segments of retained fill, sloped embankment, and viaducts); an adjacent access road in one segment; installation of new tracks and modification of existing tracks; installation of drainage systems; and installation of signals, power supply, and other related rail infrastructure. Construction of this segment of the Preferred Alternative would require temporary construction staging areas and temporary construction access roads. **Figure 3-5** shows the types of track support that would be used in this area.

##### 3.3.1.1 CONSTRUCTION OF SURFACE TRACK SUPPORT SYSTEMS

Between Allied Interlocking and approximately Tonnel Avenue, the existing NEC is on an embankment approximately 20 to 30 feet above the surrounding properties. With the Preferred Alternative, the existing embankment would be widened to the south to accommodate two new tracks. To support the new trackbed, retained fill structures consisting of reinforced concrete retaining walls on piles would be used where space constraints make an embankment with side slopes impractical, and to limit encroachment of the trackbed into wetlands, where practicable. East of Secaucus Road where the new alignment would begin to separate from the NEC, a new sloped embankment would be constructed. Viaduct structures would carry the new tracks across Secaucus Road and across the freight rail right-of-way used by Conrail and New York, Susquehanna & Western Railway (NYSW); a viaduct would also be used for a segment of the





NOT TO SCALE

right-of-way east of Secaucus Road. Construction access roads would be provided along the south side of the proposed new infrastructure.

A new roadway bridge would be built to carry Tonnelle Avenue over the track, which would descend in a cut to the tunnel portal. **Table 3-1** summarizes the track support elements for the Preferred Alternative.

**Table 3-1**  
**Track Support for Surface Tracks**

Track Support	Location
Retained fill (supported by retaining wall)	From the east side of County Road to a point approximately 550 feet east of Secaucus Road
Rail viaducts	<ul style="list-style-type: none"> <li>• Across Secaucus Road</li> <li>• Approximately 1,000-foot-long segment beginning approximately 550 feet east of Secaucus Road and extending to the embankment section</li> <li>• Across Conrail and NYSW freight tracks</li> </ul>
Sloped embankment	Curved section of new alignment, between viaduct segment and viaduct over freight tracks; east of freight tracks to Tonnelle Avenue
Roadway bridge	Tonnelle Avenue over new alignment
Retained cut / Open cut	Beneath Tonnelle Avenue to new portal

Construction of the embankment support structures would involve earthmoving and grading, bringing large quantities of engineered fill material to build the embankments, and additional material for surcharging the embankment areas to allow for compression and settling to adequately support the track system. For each area requiring surcharging, the surcharge would remain in place for approximately six months, after which excess soils would be removed. The amount of surcharge required and more precise durations will be developed during final design. In areas of retained fill and retained cut, the retaining walls would be installed on foundations supported by deep piles. In the area of sloped embankment, surcharging would be used to accelerate soil consolidation and reduce settlement time.

The bridges—one over Secaucus Road, and one over the Conrail and NYSW tracks—would involve the construction of the bridge abutments, supported by piles, with the bridge spans constructed last to support the new tracks. Construction activities at the Conrail-NYSW bridge would be scheduled in coordination with the freight rail companies to avoid impacts to their operations.

The viaduct structure that would carry a portion of the new track system would be constructed by installing support piles, then erecting the viaduct piers, and finally, constructing the spans of the viaduct to support the new tracks.

The new Tonnelle Avenue bridge would be constructed in a similar fashion. The existing four roadway lanes would be temporarily shifted in stages to allow the sequenced construction of a new bridge structure to carry the new roadway above the railroad alignment. Any required lane closures would be coordinated to limit impacts to off-peak periods. To provide adequate work-zone widths, it is possible that the travel lanes would be reduced from their current 12-foot widths and the roadway shoulders would be closed throughout the construction zone. Post-construction, lane and shoulder configurations would be restored. During construction of the new roadway, pedestrians would be diverted to the open sidewalk on the other side of the street at the upstream signalized intersections. Appropriate construction and staging plans would be incorporated into the Maintenance and Protection of Traffic (MPT) plans for this segment.



As the new tracks approach the new tunnel portal, an open cut area would be constructed and kept clear with retaining wall and engineered embankments.

Along this entire alignment, piles and/or drilled caissons would be installed to support the associated overhead catenary, signals, communications, and other rail systems.

#### 3.3.1.2 DRAINAGE

Construction activity in the surface tracks segment would also include construction of new drainage infrastructure, including culverts and storm sewers. Culverts that currently run underneath the existing surface tracks would be extended to include the area beneath the new tracks (in the vicinity of Penhorn Creek), and a new culvert would be built to direct water from the Project site east of Secaucus Road. In addition, a new 36-inch storm sewer would be installed beneath the parking areas of adjacent properties along the south side of the NEC west of Secaucus Road.

#### 3.3.1.3 TRACKWORK AND RAILROAD SYSTEMS

In the surface track segment, construction would also include installation of the various railroad systems, including tracks, signals and communication systems, and overhead contact system structures and wires. Foundations for the overhead contact system structures would be on drilled caissons reaching down to native soil or rock; on the viaduct structure, catenary poles would be attached to extended pier bents. Existing tracks and signals within Allied Interlocking east of Secaucus Junction Station would be modified to connect and control the new tracks connecting with the NEC. This work would involve the use of truck-mounted and rail-mounted equipment.

In addition, the Preferred Alternative includes modifications within the existing Amtrak substation (Substation 42) on the west side of Tonnelle Avenue on the south side of the NEC.

#### 3.3.1.4 UTILITY RELOCATION

Before the new rail bridge over Secaucus Road is built, utilities within the roadbed that could be disturbed by construction would be relocated. Utilities in and above Tonnelle Avenue would also need to be relocated to facilitate construction of the roadway bridge over the new alignment.

#### 3.3.1.5 CONSTRUCTION STAGING AREAS

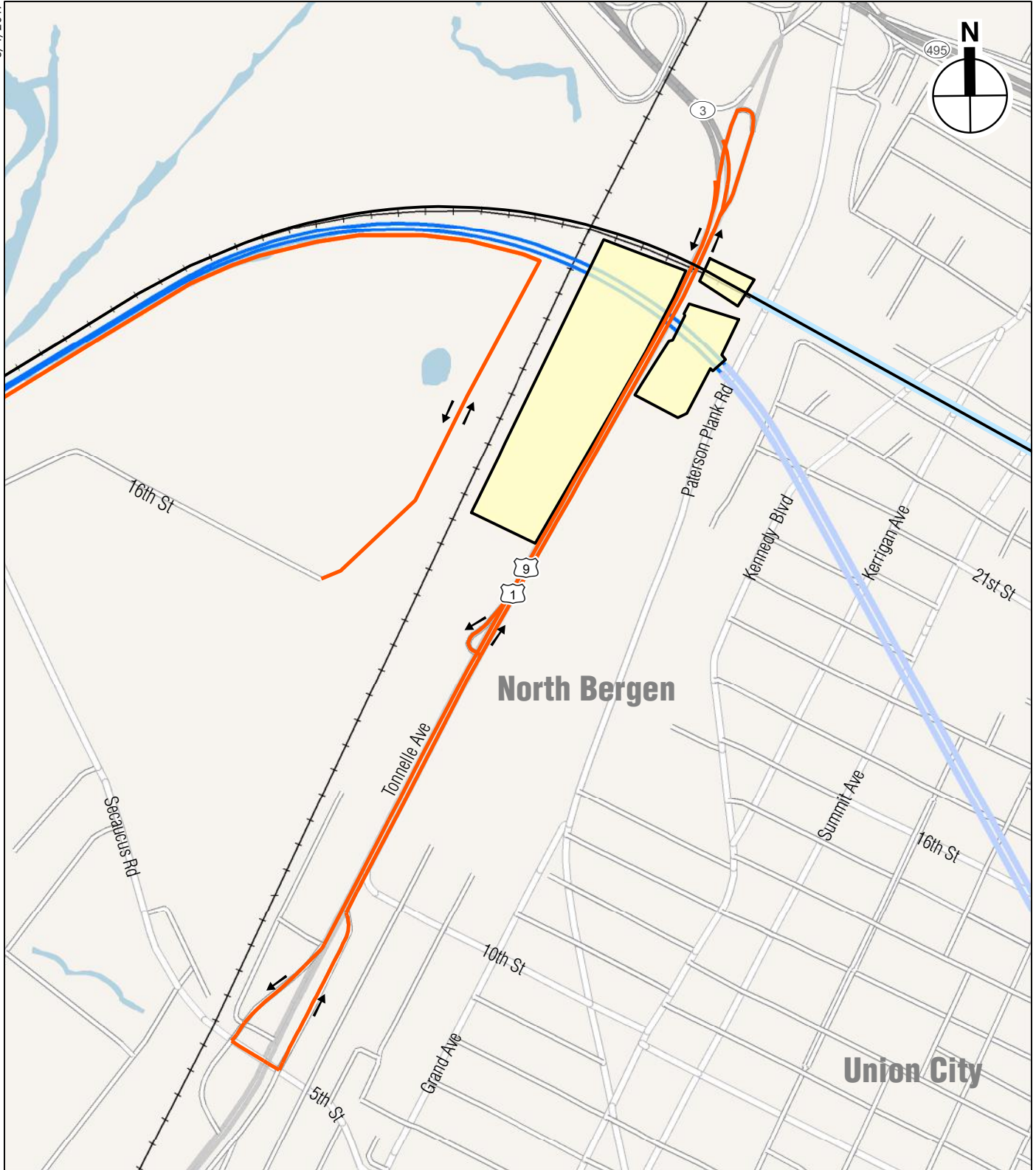
A construction staging site would be established on property owned by NJ TRANSIT, east and west of Tonnelle Avenue in North Bergen, where the alignment of the Preferred Alternative would cross beneath that roadway. The properties on either side of Tonnelle Avenue would eventually be connected via the underpass beneath Tonnelle Avenue created for the rail alignment. This staging area would be used for the construction of the surface tracks and for the tunnel beneath the Palisades (discussed in Section 3.3.2 below). It would accommodate storage and delivery of construction materials, truck deliveries of cement, steel, and fill materials, and removal of debris. **Figure 3-6** shows the location of this staging area.

#### 3.3.1.6 TRUCK ROUTES AND ACCESS ROADS

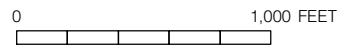
**Figure 3-6** shows the location and routes of the temporary access roads and truck haul routes to and from the Project site and staging areas for this stage of construction.

A new 20-foot-wide permanent vehicular access road (providing access to tracks with clearances required by local emergency responders) would be constructed along the south side of the new tracks in the sloped embankment section east of Secaucus Road. This road and the construction zone for the new viaduct above the freight railroad right-of-way would be accessed





- Construction Staging Area
- Proposed New Tunnel
- North River Tunnel to be Rehabilitated
- Proposed Surface Tracks
- Truck Routes and Access Roads
- Existing Northeast Corridor



Tonnelle Avenue Staging Area:  
Truck Routes and Access Roads  
**Figure 3-6**



through a NYSW lumber reload facility at the end of 16th Street in North Bergen, east of Secaucus Road.

In addition to this permanent road, temporary access to the construction site would be made via existing parking lots and driveways in the industrial and warehousing properties that adjoin the NEC. Trucks using these haul routes would be carrying construction materials to the site and hauling away construction debris, which may include hazardous materials encountered during construction.

Trucks would travel to and from the Tonnelle Avenue staging site using Tonnelle Avenue itself (U.S. Routes 1 and 9), which connects to I-495 (and from there to I-95/New Jersey Turnpike). On average, five to six trucks per hour would travel to and then from the staging site during construction of the surface alignment. Trucks using the haul routes for the Tonnelle Avenue staging site would be carrying construction materials to the site and hauling away construction debris and tunnel spoils, which may include hazardous materials encountered during construction. Truck routes would be coordinated with the New Jersey Department of Environmental Protection (NJDEP) and the local municipality, the Township of North Bergen.

Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

#### *3.3.1.7 SCHEDULE*

Construction activities for the portion of the alignment from Allied Interlocking to the tunnel portal would typically occur between 7 AM and 11 PM on weekdays. Work on the existing NEC would be conducted primarily during nights and weekends to avoid disruptions to daytime train service. This work would occur over approximately seven years, as follows:

- Surface tracks support, including utility relocation, embankment construction, viaduct construction, and bridge across freight tracks: 4.5 years (late 2019 – early 2024).
- Tonnelle Avenue bridge: 3 years (early 2020 – late 2022).
- Trackwork and railroad systems: 3 years (mid-2023 – mid-2026).

### **3.3.2 PALISADES TUNNEL**

The new Hudson River Tunnel would begin at the western face of the Palisades at a new tunnel portal excavated from the Palisades. The tunnel through the hard rock of the Palisades would consist of two approximately 5,130-foot-long tubes, each constructed by a TBM operating eastward from the Tonnelle Avenue staging site to the Hoboken staging site (discussed later in this chapter in Section 3.3.3). This section of the new Hudson River Tunnel through the rock of the Palisades is referred to as the Palisades tunnel.

#### *3.3.2.1 TUNNEL EXCAVATION*

The two tubes of the Palisades tunnel would be bored either by a single TBM that constructs one tube at a time or potentially by two TBMs working at the same time, to expedite the construction schedule. Construction worker and truck estimates for the analyses in this EIS have assumed that two TBMs would be operating in parallel. In this case, one TBM would be launched from Tonnelle Avenue and advanced into the tunnel before the second TBM would be launched, approximately two months after the first TBM. The separation of the two TBMs allows experience gained from the first TBM moving through the ground conditions along the Project alignment to be applied to the work of the second TBM.

If a single TBM were used, it could be disassembled at the Hoboken shaft after completion of the first tunnel bore and then transported by truck back to Tonnelle Avenue for reassembly and

construction of the second tunnel bore, or it could be pulled backward through the tunnel to Tonnelle Avenue. In this case, some TBM components would need to be removed for the machine to be pulled backward. Construction of the tunnel one tube at a time would take longer (potentially up to approximately a year longer), but would reduce the amount of daily activity at the staging site.

The initial approximately 50 feet of the tunnel would be constructed using controlled drilling and blasting, to excavate a starter tunnel in which the TBM could launch. After the starter tunnel has been excavated, the large components of the TBM would be brought to the Tonnelle Avenue staging site and the TBM would be assembled there.

The TBM would proceed approximately 30 feet per day, so that each tube would take approximately nine months to bore, with the second TBM lagging behind the first by about two months. The two tubes would be supported with concrete liners, either precast segments that are installed as the TBM passes or cast-in-place concrete installed after the boring is complete.

The two tubes would be roughly 30 feet apart for the full length of the tunnel; this amount of separation would minimize the impact of the second TBM mining operation on the completed portions of the first tunnel.

### *3.3.2.2 CROSS PASSAGES*

The Palisades tunnel would have six cross passages connecting the two tubes of the rock tunnel at intervals of approximately 750 feet. Each cross passage would be approximately 30 feet long (i.e., the distance between the two tubes). The cross passages would be constructed using controlled drilling and blasting from within the tunnel. Construction of the cross-passages could commence after the completion of excavation of the first bore and be fully completed after completion of the second bore. Permanent lining of the cross passages would be with cast-in-place concrete with a waterproof membrane.

During blasting, geotechnical and structural monitoring would be used in coordination with the controlled blasting to ensure that vibration from blasting does not have the potential to damage the deteriorated concrete of the North River Tunnel, especially in the western Palisades where the new tunnel would be relatively close (approximately 400 feet) from the North River Tunnel.

### *3.3.2.3 TUNNEL VENTILATION DURING CONSTRUCTION*

Temporary fire-life safety systems would be installed within the new tunnel as it is excavated to protect workers during construction activities. This would include temporary tunnel ventilation, powered by large fans that would operate continuously during construction at the Tonnelle Avenue portal site. A standpipe system would be installed, and sufficient illumination levels would be maintained at the walking surface for worker safety. In addition, fire extinguishers and fire hoses would be provided in the tunnel during construction.

### *3.3.2.4 EXCAVATED MATERIAL AND DISPOSAL*

Excavated rock and soil (referred to as "spoils") would be removed from the tunnel at the rear of the TBM, and brought out of the tunnel at the Tonnelle Avenue staging site. In total, approximately 525,000 cubic yards of loose rock would be removed from the two tubes and cross passages as they are constructed. The tunnel contractor would be responsible for finding a suitable location for reuse or disposal of spoils from the tunnel mining. For rock to be reused, the use of a rock crusher would be required to meet the necessary rock size and grading.

Protocols developed during final design would be followed to identify spoils that may contain contaminated materials so that they can be handled appropriately and disposed of at a suitable location. Most of the excavated material would be clean, crushed rock, which can be reused



beneficially at other locations. The rock is not likely to be contaminated because of both its depth and impermeability—although there is a possibility that some of the rock could contain naturally occurring asbestos containing materials, which would limit the use of that portion of the spoils. Depending on the gradation (i.e., particle size) of the excavated material, and the timing of its removal, some of the spoils could be used to fill the embankment areas between Allied Interlocking and Tonnelle Avenue. Other reuse opportunities for uncontaminated rock could include filling abandoned mines, building artificial offshore reefs, reinforcing bulkheads, or use in road paving materials, depending on the consistency of the spoils materials. For example, crushed rock from the large water tunnel that New York City is constructing, Water Tunnel No. 3, is being transported by rail to Long Island, where it is being used as base material for road construction, and by truck to Staten Island, where it is being used as cover for the Fresh Kills Landfill.

Protocols for the transport of spoils from the construction sites would be developed to ensure the safe handling of these materials and would include procedures to secure the material from spilling off trucks, as well as for any inadvertent or accidental spills of materials falling from trucks removing this material from the staging sites.

For spoils that cannot be reused, commercial disposal sites may be appropriate. These facilities are required to meet all applicable regulations and typically process soils and dredge materials to recycle or beneficially reuse them.

#### *3.3.2.5 TRACKWORK AND RAILROAD SYSTEMS*

The various railroad systems, including tracks, signals and communications, and overhead contact system structures and wires, would be installed once the tunnel is complete. Construction and finishing of the various mechanical, electrical, and plumbing systems, including tunnel ventilation systems and tunnel lighting systems would also be installed once the tunnel is complete.

#### *3.3.2.6 CONSTRUCTION STAGING AREAS*

A construction staging site would be established on the east and west sides of Tonnelle Avenue in North Bergen where the alignment of the Preferred Alternative would cross beneath that roadway (see **Figure 3-6**). This staging site is the same as would be used for the surface tracks (discussed above in Section 3.3.1.5). The properties on either side of Tonnelle Avenue would eventually be connected via the underpass beneath Tonnelle Avenue created for the rail alignment. This staging area would be used for storage of construction equipment and material, parking and facilities for construction workers, construction office trailers, and related activities. Construction workers would access the rock tunnel from this site and deliveries would be for the tunnel construction would be brought here. The site would also be used for assembling and launching the TBM and removing spoils from the tunnel. The staging area would include locations for a construction crane, fuel, TBM water treatment facility, and an electrical substation to power the TBMs. There would also be an area for storing tunnel spoils until they can be trucked from the site for disposal. Note that the rehabilitation of the North River Tunnel (discussed in detail below in Section 3.3.10) would continue to use the Tonnelle Avenue staging area. To support the North River Tunnel rehabilitation, new construction access between the staging area and the tracks that are not in use (referred to as dead tracks) at the North River Tunnel portal would need to be constructed across the newly active tracks of the Hudson River Tunnel right-of-way. It may be possible to create such construction access in advance, during construction of the new Hudson River Tunnel.

### 3.3.2.7 TRUCK ROUTES

Trucks would travel to and from the Tonnelle Avenue staging site using Tonnelle Avenue itself (U.S. Routes 1 and 9), which connects to I-495 (and from there to I-95/New Jersey Turnpike). Trucks at the portion of the staging site on the west side of Tonnelle Avenue would travel south and make a U-turn just south of the site or farther south at Secaucus Road (see **Figure 3-6**). Removal of spoil materials by rail may be considered, but is unlikely considering the cost and additional handling involved to use this method of transport.

An average of approximately 15 to 19 trucks per hour would arrive at and depart from the Tonnelle Avenue construction zone during the most intensive construction activity. These trucks would be carrying construction materials to the site and hauling away construction debris and tunnel spoils, which may include hazardous materials encountered during construction. Truck routes would be coordinated with NJDEP and the local municipality, the Township of North Bergen.

Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

### 3.3.2.8 SCHEDULE

To achieve an expedited schedule, the two tubes of the Palisades tunnel would be constructed by two TBMs working in parallel, with the first TBM beginning operation approximately two months before the second TBM would begin boring the second tube. The tunneling operation would occur 16 to 24 hours a day on weekdays. Excavated rock would be stored at the staging areas at night and then removed during the day. While it is expected that much of the third (late-night, 11 PM-7 AM) shift would be devoted to maintenance of the TBMs and other equipment and systems to ensure they are in proper working order during the more active shifts, it is also possible that this shift could include additional TBM mining operations.

Controlled drill-and-blast construction for the starter tunnel and cross passages would be accomplished in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. Drilling and blasting would not be performed after 7 PM in sensitive areas (i.e., residential) unless permission from the appropriate regulatory agency (e.g., North Hudson Regional Fire and Rescue) is provided. Construction work for installation of trackwork and railroad systems would occur from 7 AM-11 PM on weekdays.

The construction activities for the Palisades tunnel would occur over approximately seven years, as follows:

- Site preparation and utility relocation: 1 year (mid-2019 – mid-2020).
- Starter tunnel, tunnel excavation, and cross passages: approximately 3 years (late 2019 – late 2022).
- Tunnel internal concrete: approximately 2 years (mid-2021 – mid-2023).
- Trackwork, railroad systems, and finishes: approximately 3 years (late 2023 – late 2026).

### 3.3.3 HOBOKEN SHAFT, STAGING, AND FAN PLANT SITE

The site of the New Jersey ventilation shaft and fan plant for the Hudson River Tunnel would be used as a tunnel access point and staging site during construction of both the Palisades tunnel and the tunnel beneath the Hudson River (referred to as the river tunnel). As discussed in Chapter 2, "Project Alternatives and Description of the Preferred Alternative," an approximately 130-foot-diameter ventilation shaft and associated fan plant would be constructed at a site on the south side of West 18th Street at the convergence of the municipal boundaries of Hoboken,

Weehawken, and Union City. The site is located in all three municipalities, but predominantly in Hoboken. It is bordered on the south by the tracks of the HBLR. **Figure 3-7** shows the location of the Hoboken shaft site and staging area.

A construction staging area would be established at the Hoboken shaft site, and once the ventilation shaft has been excavated, the shaft and adjacent site would be used for the removal of the Palisades tunnel TBMs and as the staging site to support tunneling operations for the excavation of the tunnel beneath the Hudson River to New York. The soft-ground TBMs that would excavate the river tunnel would be assembled and inserted through this shaft, tunnel spoils would be removed from this shaft, and deliveries and workers would enter the tunnel at this site. Once construction of the tunnel is complete, this site would be the location of the permanent fan plant for the ventilation of the new tunnel and to serve as an access and egress point during emergencies.

#### *3.3.3.1 SHAFT CONSTRUCTION*

At the Hoboken site, site preparation and set up activities would include relocation of a sanitary sewer that crosses the site. The approximately 130-foot-diameter vertical shaft would be excavated from the surface through earth and rock. Support walls would be installed within the earth portion of the shaft, potentially either slurry walls or secant piles, to support the sides of the excavation. The rock portion of the shaft would be excavated using controlled drill and blast.

In addition, at the bottom of the vertical shaft, starter tubes would be excavated using controlled drilling and blasting to create caverns from which the soft-soil TBMs could be launched for the river tunnel. Ground improvement through injection of grout into the soil and voids in the rock would also be used here to prepare the ground for the TBMs.

#### *3.3.3.2 STAGING SITE*

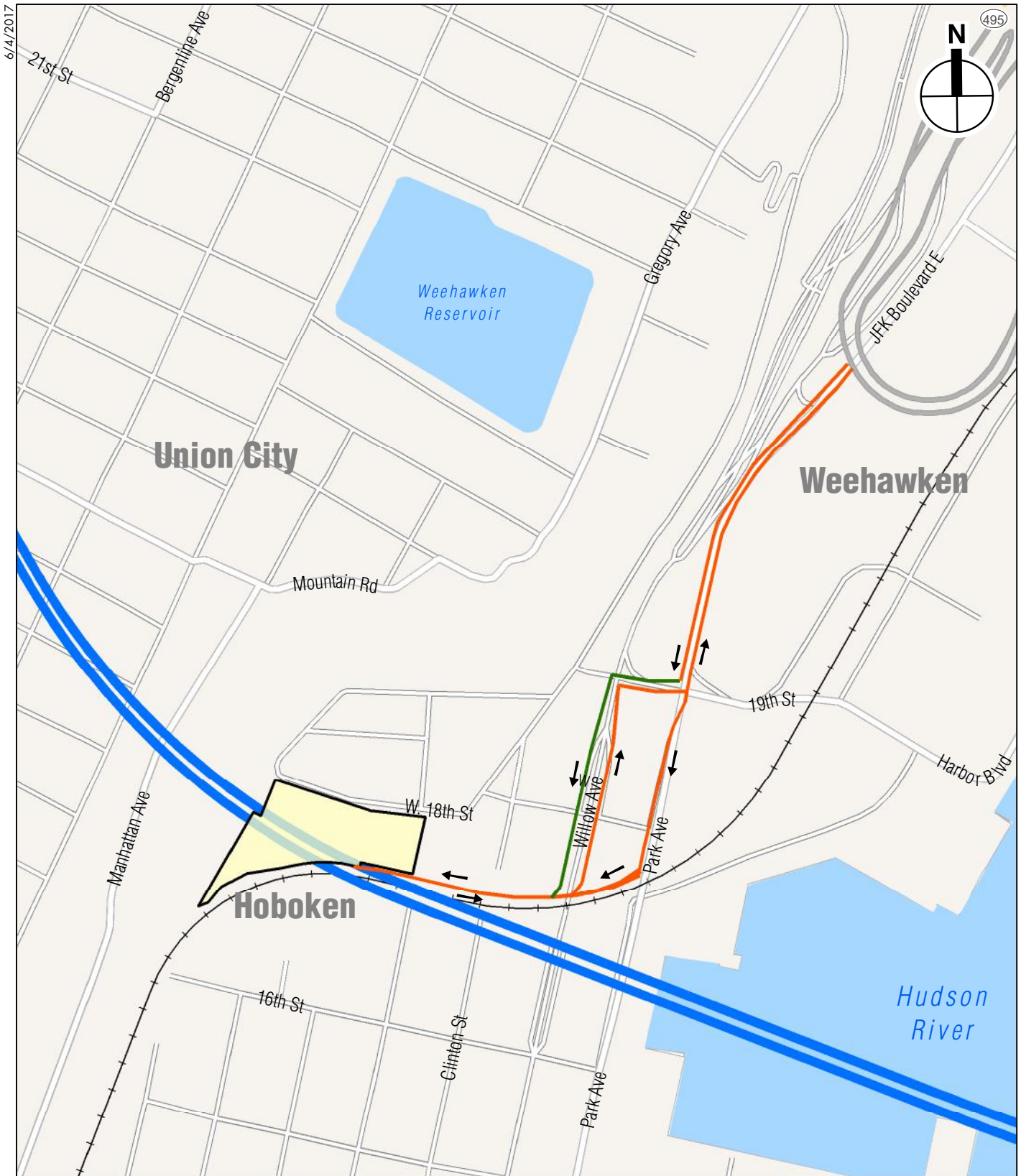
Once the Hoboken ventilation shaft is completed, it would be used as the terminus of the Palisades tunnel; the hard rock TBMs used to mine the Palisades tunnel would be removed from the tunnel via the shaft.

The Hoboken shaft would also be used as the access site for the soft-soil TBMs, with assembly and deployment of the TBMs occurring from this location. Construction activities associated with the river tunnel are described in Section 3.3.4 below. Similar to the site at Tonnel Avenue, the Hoboken staging site would be used for construction equipment and material storage, construction worker parking and facilities, construction office trailers, and related activities. Construction workers would access the river tunnel from this site and deliveries would be brought to the construction site here. The staging site would include locations for a construction crane, fuel, TBM water treatment facility, and an electrical substation to power the TBMs. There would also be an area for storing tunnel spoils until they can be trucked from the site for disposal.

Once the TBMs have completed mining the new river tunnel tubes, the shaft site would continue to be used as an access point for the completion of the river tunnel (described in more detail in Section 3.3.4 below), including installation trackwork and railroad systems, and other fit out.

#### *3.3.3.3 TRUCK ROUTES*

To reduce disruption to the residential neighborhood near the Hoboken shaft site, a temporary construction access road (also referred to as a haul route) would be constructed running along the north side of the HBLR right-of-way between the shaft site and Park Avenue. Use of this route would keep trucks away from smaller residential streets immediately north of the shaft site. Trucks and other construction vehicles would reach this access road using the local street system, as follows (see **Figure 3-7**):



Hoboken Staging Area:  
Truck Routes  
**Figure 3-7**



- Vehicles leaving the shaft site would travel eastward on the temporary road along the north side of the HBLR right-of-way, pass under the Willow Avenue viaduct, and turn left (i.e., north) onto the Willow Avenue service road, which runs adjacent to the Willow Avenue viaduct. At 19th Street, trucks would turn right (i.e., east) and then left (i.e., north) onto northbound Park Avenue/JFK Boulevard East, which leads to I-495 near the Lincoln Tunnel entrance. To shift trucks farther from the 10-story residential building on the east side of the Willow Avenue (the Gateway building at 1700 Park Avenue), the truck route could use a wider curve from the temporary construction road, which would require underpinning the Willow Avenue viaduct to allow a support pier to be moved.
- Trucks bound for the Hoboken shaft site would arrive via one of two access routes. In the first route, trucks would head south on JFK Boulevard East/Park Avenue and after 19th Street would continue on the Park Avenue service road adjacent to the Park Avenue viaduct. At the HBLR tracks, trucks would turn right (i.e., west) onto the temporary access road on the north side of the HBLR right-of-way. Between Park Avenue and Willow Avenue, this access road would be constructed on an existing surface easement owned by NJ TRANSIT, procured for the ARC Project, adjacent to the Gateway apartment building at 1700 Park Avenue (which has its entrance on West 18th Street between Park and Willow Avenues). The easement area is currently used by residents of this building as a dog run.
- An alternative truck route to the Hoboken shaft site is also being considered in this EIS to allow a comparison of routing options so that potential impacts from the trucking can be minimized. The alternative route would also start on JFK Boulevard East/Park Avenue north of 19th Street, but then rather than continuing south on the Park Avenue service road along the east side of the Gateway apartment building and passing through the building's dog run, this route would instead follow the reverse course of the outbound route, turning right onto 19th Street and then left onto the southbound Willow Avenue service road. This would shift trucks to the west side, rather than the east side, of the Gateway apartment building. At the HBLR right-of-way, trucks would turn right onto the temporary access road that would run alongside the HBLR tracks. To create an adequate turning radius for trucks, a narrow warehouse building at the southern end of the Willow Avenue service road (1714 Willow Avenue) would have to be demolished for this option.

Either truck access option could shift the outbound truck route away from the Gateway apartment building by underpinning of the Willow Avenue viaduct to create a wide enough turning radius for trucks leaving the staging area.

Because of the proximity of the temporary access road to the HBLR tracks, any required special safety protocols would be coordinated with NJ TRANSIT and the operators of the HBLR.

An average of approximately 8 to 16 trucks per hour would arrive at and depart from the Hoboken staging site during the most intensive construction activity. These trucks would be carrying construction materials to the site and hauling away construction debris and tunnel spoils, which may include hazardous materials encountered during construction. Truck routes would be coordinated with NJDEP and the two local municipalities, the Township of Weehawken and the City of Hoboken.

Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

#### 3.3.3.4 FAN PLANT CONSTRUCTION

Following completion of the river tunnel, construction of the emergency access and egress components of the shaft and the ventilation fan plant building would occur. This would involve typical construction methods for constructing the building frame, superstructure, core, shell, and

finishing work, including the installation of the fans and fire-life safety equipment. It would also involve driving piles to support the foundation for the fan plant at the site.

### 3.3.3.5 SCHEDULE

In general, work at the Hoboken shaft site related to site preparation, utility relocation, shaft construction, and tunnel fit-out would occur in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. Activities related to river tunnel excavation (see Section 3.3.4) would be conducted 24 hours a day on weekdays, with the late-night shift (11 PM-7 AM) used primarily for maintenance and preparation of the next day's tunneling. Construction work for installation of trackwork and railroad systems would occur from 7 AM-11 PM on weekdays.

Controlled drill-and-blast construction for the vertical shaft and starter tunnel would be accomplished in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. Drilling and blasting would not be performed after 7 PM in sensitive (i.e., residential) areas unless permission from the appropriate regulatory agency (e.g., North Hudson Regional Fire and Rescue) is provided.

Activities at the Hoboken shaft site and staging area would occur over an approximately seven-year period, as follows:

- Site preparation, utility relocations, construction of the shaft and starter tunnels: approximately 2 years (mid-2019 – mid-2021).
- Excavation of the river tunnel: approximately 1.5 years (early 2021 – late 2022).
- Excavation of tunnel cross passages: approximately 1 year (late 2022 – mid-2023).
- Construction of the fan plant structure and fit out: approximately 3.5 years (early 2022 – mid-2025).
- Tunnel internal concrete: approximately 3.5 years (early 2022 – mid-2025).
- Trackwork, railroad systems, and finishes: approximately 3 years (late 2023 – late 2026).

## 3.3.4 TUNNEL BENEATH HOBOKEN AND THE HUDSON RIVER

The tunnel beneath Hoboken and the Hudson River (i.e., the river tunnel) would consist of two approximately 7,200-foot-long tubes, each constructed by a TBM operating eastward. To achieve an expedited schedule, the two tubes of the tunnel beneath the Hudson River would be constructed by two TBMs from the Hoboken shaft site, working to the Manhattan shaft site near Twelfth Avenue (Section 3.3.7 below), where the TBMs would be removed. The TBMs would work in parallel, with start times staggered by approximately two months. The tunneling operation would occur 16 to 24 hours a day on weekdays. In advance of the tunneling, ground improvement and preparation activities would occur along the alignment in Hoboken. Construction of the river tunnel would also involve ground improvement within the Hudson River, discussed in Section 3.3.5 below.

### 3.3.4.1 GROUND IMPROVEMENT AND UNDERPINNING

The tunnel alignment east of the Hoboken shaft site would be located in a combination of soft soil, fragmented rock, and bedrock. In certain locations along the route, ground improvement or preparation work would be conducted in advance of the tunneling.

Prior to tunneling, ground improvement (such as injection of jet grout into the soil to harden the soil) would be conducted in the area of the new tunnel alignment close to and south of the HBLR right-of-way. This would include the area beneath PSE&G's substation and transmission lines, beneath Clinton Street, and along affected portions of the HBLR alignment. This would most likely be conducted from the ground surface. In addition, the alignment would pass beneath a



building between Clinton Street and Willow Avenue at 1622 Clinton Street/1622 Willow Avenue that is owned by PSE&G and houses electrical infrastructure and equipment, including a gas-insulated electrical substation. This building has a pile-supported foundation. Underpinning would require temporary relocation of activities within the building.

East of the PSE&G property, where the alignment would pass beneath the Willow Avenue viaduct, the pile-supported foundation of the viaduct would be underpinned. Piles would be drilled from the surface alongside the viaduct as part of this work. The roadway would remain open throughout this process, with only short-term, intermittent closures during off-peak hours or weekends.

The alignment of the new tunnel would also cross beneath a location where the Hoboken Rebuild By Design flood protection project is proposing to construct a flood wall. Coordination between the two projects is ongoing to ensure their mutual compatibility. It is possible that some sort of ground improvement, underpinning, or other measures could be needed at this location.

#### *3.3.4.2 TUNNEL EXCAVATION*

The two tubes of the river tunnel would be bored either by a single TBM that constructs one tube at a time or potentially by two TBMs working at the same time, to expedite the construction schedule. Construction worker and truck estimates for the analyses in this EIS have assumed that two TBMs would be operating in parallel. In this case, one TBM would be launched from Hoboken shaft and advanced into the river tunnel before the second TBM would be launched. If a single TBM were used, it could be disassembled at the Twelfth Avenue shaft in Manhattan after completion of the first tunnel bore and then transported by truck back to Hoboken for reassembly and construction of the second tunnel bore, or it could be pulled backward through the tunnel to the Hoboken shaft. Construction of the tunnel one tube at a time would take longer (potentially up to approximately a year longer), but would reduce the amount of daily activity at the staging site.

The TBMs for the river tunnel east of the Hoboken shaft site would be suitable for mixed-face conditions so that they are able to cut through both rock and soft soil. No dredging is proposed as part of the tunnel construction. Other than a segment of the alignment requiring ground improvement at the bottom of the river (Section 3.3.5 below), all river tunnel construction work would occur underground beneath the river bed.

The TBMs would proceed approximately 30 feet per day, so that each tube of the river tunnel would take approximately 10 months per tube to bore, with a lag between the start of the first and second TBM of approximately 2 months. The two tubes would be approximately 30 feet apart for the length of the tunnel and would be supported with concrete liners that are installed behind the TBM as it moves forward.

#### *3.3.4.3 CROSS PASSAGES*

This section of tunnel would have nine cross passages connecting the two tubes of the tunnel at intervals of approximately 750 feet. Each cross passage would be approximately 30 feet long (i.e., the distance between the two tubes). One cross passage would be within the land portion of the alignment and the rest would be beneath the Hudson River. The cross passages, located in mixed-soil and rock conditions, would be mined from within the tunnel tubes after the ground has been improved or stabilized where the excavation would occur. All activities associated with the construction of cross passages in Hoboken and beneath the Hudson River would be staged from the Hoboken staging site.

The cross passage in the land portion of the alignment would be approximately beneath Clinton Street at its northern terminus at the HBLR right-of-way. Ground improvement through injection

of grout from the surface (discussed above in Section 3.3.4.1) would protect the HBLR and PSE&G facilities from damage during construction.

The cross passages beneath the Hudson River would be excavated by mining, generally using SEM techniques. The cross passages would be excavated after the two tubes are completed and would require breaking through the tubes' concrete liner. Prior to the excavation, the ground would be improved. This may be done through the use of ground freezing, a technique where the ground is injected with a closed system of pipes in which a freezing liquid (calcium chloride brine) is circulated until the ground is frozen solid. To support the ground freezing operation, a freeze plant from which the brine is circulated would be located at the Hoboken staging site. The brine would be piped down the Hoboken construction shaft and along the river tunnel's two tubes for use at each cross passage location.

#### *3.3.4.4 OBSTRUCTIONS*

Obstructions may be encountered under the riverbed beneath the Hudson River during the underground boring for the river tunnel. These may include remnants of former waterfront structures close to the Manhattan shoreline, such as the former Pier 67, a possible former finger pier near West 28th Street, and a possible second former bulkhead line near Twelfth Avenue. Where these features were once located, timber piles may remain below ground that could be encountered by the TBM. If this occurs, the obstructions would be removed from the face of the TBM, either with compressed air pumped to maintain tunnel face stability or by applying ground treatment in advance so that work can be conducted under normal atmospheric pressure.

#### *3.3.4.5 EXCAVATED MATERIAL AND DISPOSAL*

Excavated material (i.e., spoils) from the river tunnel and cross passages would be removed at the rear of the TBM and brought out of the tunnel at the construction access shaft in Hoboken. In total, approximately 725,000 cubic yards of loose rock and soil would be removed from the two tubes and cross passages as they are constructed. The tunnel contractor would be responsible for finding a suitable location for reuse or disposal of spoils from the tunnel mining.

Protocols developed during final design would be followed to identify spoils that may contain contaminated materials, so that they can be handled appropriately and disposed of at a suitable location. Rock and clean fill may be suitable for beneficial reuse, as discussed above for the Palisades tunnel (Section 3.3.2.4).

Protocols for the transport of spoils from the construction sites would be developed to ensure the safe handling of these materials and would include procedures to secure the material from spilling off trucks, as well as for any inadvertent or accidental spills of materials falling from trucks removing this material from the staging sites.

For other spoils, commercial disposal sites may be appropriate. These facilities are required to meet all applicable regulations and typically process soils and dredge materials to recycle or beneficially reuse them.

#### *3.3.4.6 TRACKWORK AND RAILROAD SYSTEMS*

The various railroad systems, including tracks, signals and communications, and overhead contact system structures and wires, would be installed once the tunnel is complete. Construction and finishing of the various mechanical, electrical, and plumbing systems, including tunnel ventilation systems and tunnel lighting systems would also be installed once the tunnel is complete.



#### 3.3.4.7 CONSTRUCTION STAGING AREA AND TRUCK ROUTES

Construction of the river tunnel segment between the Hoboken shaft and the Manhattan shoreline would be staged from the Hoboken shaft site. This staging area and associated truck routes are described above in Section 3.3.3. Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

#### 3.3.4.8 SCHEDULE

Tunnel preparation work, including ground improvement and underpinning, would be conducted generally from 7 AM to 11 PM on weekdays.

To achieve an expedited schedule, the two tubes of the river tunnel would be constructed by two TBMs working at the same time. The tunneling operation would occur 16 to 24 hours a day on weekdays. Excavated material from the tunnel would be stored at the Hoboken staging area at night and then removed during the day. While it is expected that much of the third (late-night, 11 PM-7 AM) shift would be devoted to maintenance of the TBMs and other equipment and systems to ensure they are in proper working order during the more active shifts, it is also possible that this shift could include additional TBM mining operations.

Any controlled drill and blast required for portions of cross passages would be accomplished in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. Drilling and blasting would not be performed after 7 PM in sensitive (i.e., residential) areas unless permission from the appropriate regulatory agency (e.g., North Hudson Fire and Rescue) is provided.

Construction associated with the river tunnel would last approximately seven years, as follows:

- Ground improvement and underpinning: approximately 9 months (late 2019 – mid-2020).
- Excavation of the river tunnel: approximately 1.5 years (early 2021 – late 2022); with TBM activities occurring for approximately 11 months.
- Excavation of tunnel cross passages: approximately 1 year (mid- 2022 – mid-2023).
- Tunnel internal concrete: approximately 3.5 years (early 2022 – mid-2025).
- Trackwork, railroad systems, and finishes: approximately 3 years (late 2023 – late 2026).

### 3.3.5 RIVER TUNNEL IN-WATER WORK

As discussed above in Section 3.3.4, the two tubes of the new tunnel beneath the Hudson River would be constructed by TBM beneath the river bottom. With one exception, no dredging or other work in the Hudson River would occur.

As the tunnel approaches Manhattan, it would be relatively shallow beneath the river bottom, which could cause difficulties during tunnel boring. Generally, tunnels that are bored through soft soils should have soil above the tunnel equivalent to half the diameter of the tunnel or greater to avoid these challenges. The two tubes would each have an outer diameter of approximately 28 feet, so that at least 14 feet of cover should be above the top of the tunnel as the soft-soil TBM excavates the tunnel. For a 500-foot length of the alignment west of the New York pierhead line, the tunnel would have cover of less than 14 feet, with cover of approximately 10 feet at the shallowest point.

To address the construction risks associated with shallow cover, ground improvement would be conducted in this portion of the river bottom before the TBM excavation occurs. After the soil is hardened, the TBM could safely pass through the improved soils.

As shown in **Figure 3-8**, the low cover area would be approximately 550 feet long and 120 feet wide (wide enough to include both tubes of the tunnel) and would begin approximately 200 feet west of the New York pierhead line, extending westward. As discussed below, the ground improvement work proposed would be conducted in three sections, to minimize the area of navigable waterway that is disturbed at any one time.

#### *3.3.5.1 INSTALLATION OF COFFERDAM*

The work area within the river would first be enclosed by a cofferdam—a temporary, watertight structure that would isolate the water affected by construction from the surrounding river water. The cofferdam would consist of sheet pile walls driven into the river bottom from adjacent barges. Water within the cofferdam would be maintained at a few feet below the river level to maintain water pressure that flows inward to the cofferdam rather than outward. A Pollution Prevention Plan would be implemented for the in-water construction activities to minimize the potential for discharge of materials to the Hudson River during sheet pile installation and jet grouting activities conducted from construction barges.

#### *3.3.5.2 SOIL IMPROVEMENT THROUGH JET GROUTING*

Barges would be moored outside the cofferdam with construction equipment mounted on the barges. Working from the barges, the soils of the river bottom would be modified. The most likely technique for this is the use of jet grout, involving injection of a mix of cement grout, water, and compressed air at high pressure to mix with and partially replace the soil (see **Figure 3-9**).

The area of grouting would extend upward from the springline (i.e., vertical midpoint) of the tunnel alignment to the river bottom. This area of ground improvement also includes one cross passage location; in this location, the jet grouting would be deeper.

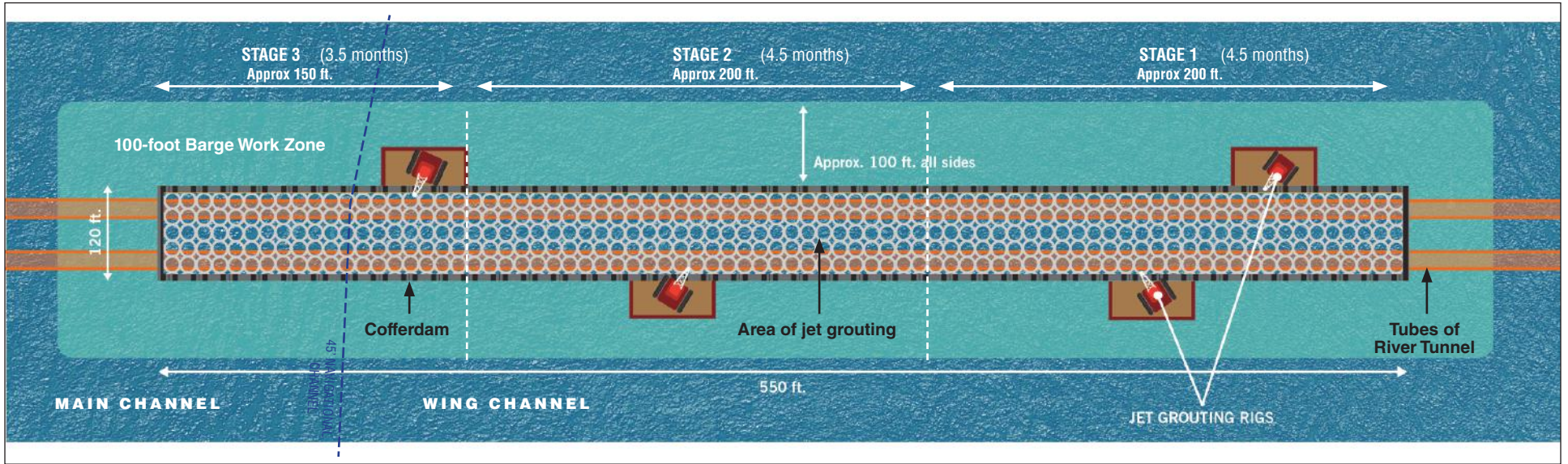
Jet grouting operations create columns of moderate strength “soilcrete” (i.e., soil mixed with cement and water) that are similar to a low strength rock. Jet grout columns can be placed adjacent to one another to form an overlapping mass of grouted soil. The material used would have a consistency equivalent to a hard clay with an anticipated uniaxial compressive strength (UCS) in the range of 200 pounds per square inch (psi) to 400 psi based on prior local experience. This is within the practical range of removal by both hydraulic and mechanical type dredging equipment.

Excess soil displaced by the jet grouting and the waste grout material would be contained within the cofferdam, removed by excavators on the barges, and then transported by barge for off-site transport to disposal sites.

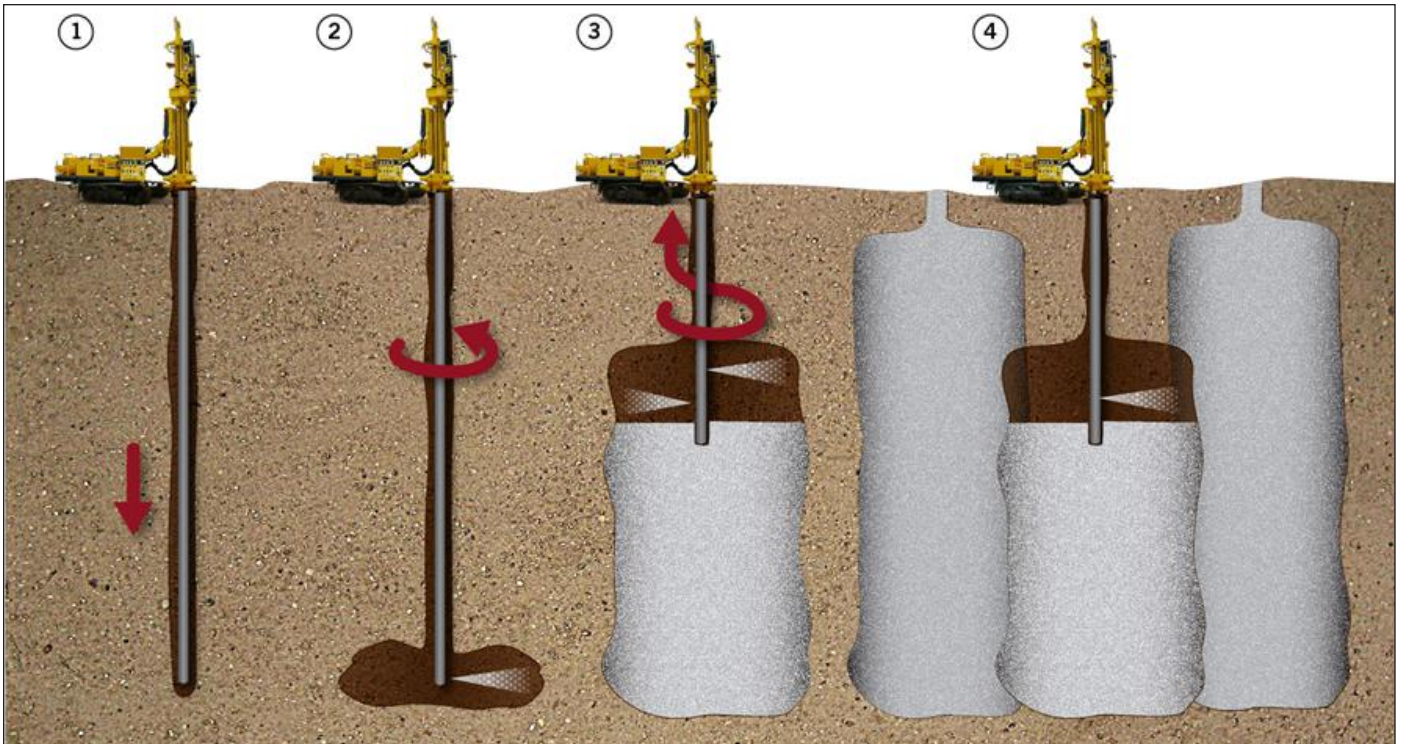
For a portion of the area treated with jet grout to form soilcrete, the jet grouting would extend up to 2 feet above the bottom of the river, to provide additional cover above the tunnel crown. However, this area would still be below the depth of the authorized navigation channel. In addition, as noted, the characteristics of the resulting soilcrete would be within the practical range of removal by both hydraulic and mechanical type dredging equipment. Therefore, the presence of the jet grout soilcrete would not impede future dredging to maintain the navigational channel.

#### *3.3.5.3 REMOVAL OF COFFERDAM*

As each stage of construction is complete, the sheet piles would be completely removed from the river bottom. Prior to sheet pile removal, all jet grout excess would be removed and any excess turbidity of pooled water would be reduced in accordance with the requirements of the Pollution Prevention Plan.

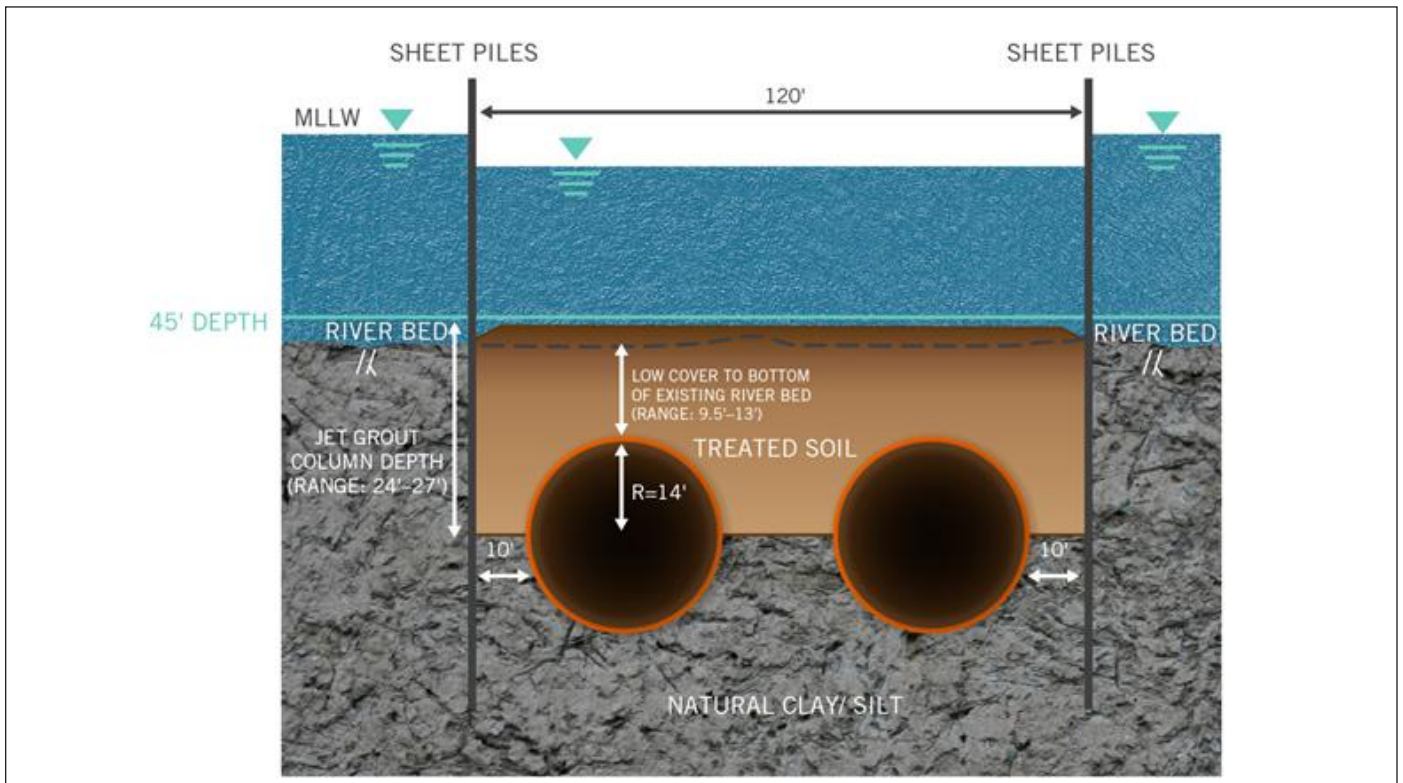






1. Steel drill rod inserted;
2. Jet grout activated under pressure;
3. Jet grout is forced into ground as rod is withdrawn;
4. Jet grout column is completed and more grout columns fill in spaces between them

Jet Grouting Process



Typical Cross-Section





#### 3.3.5.4 STAGING

The ground improvement work proposed would be conducted in three sections (of 150 to 200 feet each) to minimize the area of water that is disturbed at any one time. As each stage is completed, the sheet piles would be removed.

A work zone approximately 100 feet wide around the cofferdams would be established for barges and other equipment. (It is anticipated that typical barges that would be used here would be approximately 30 feet wide by 90 feet long.) Workers would travel to the construction zone on small boats (e.g., a tugboat or dinghy), from existing piers on the Hudson River shoreline. Two boats are likely to be needed, one for the crew and the other for material delivery. No new docking facilities are proposed. All equipment and construction material would be left on a barge at the work site in the river. The barges around the cofferdam would be permanently moored in place until the construction in the river is complete.

The in-water work would occur in three sections to limit the area of the river affected at any one time (see **Figure 3-8**). Including the buffer zone around the work for barges, the three work zones would be as follows:

- An eastern section approximately 400 feet long (200 feet of ground improvement and 200 feet for barges) by 320 feet wide (120 feet of ground improvement and 200 feet for barges). This section would be in the wing channel approximately 100 feet west of the New York pierhead line. Work here would last approximately 4.5 months.
- A middle section approximately 400 feet long (200 feet of ground improvement and 200 feet for barges) by 320 feet wide (120 feet of ground improvement and 200 feet for barges). This section would be in the wing channel approximately 300 feet west of the New York pierhead line. Work here would last approximately 4.5 months.
- A western section approximately 350 feet long (150 feet of ground improvement and 200 feet for barges) by 320 feet wide (120 feet of ground improvement and 200 feet for barges). This section would be in both the wing channel (50-foot-long ground improvement zone and 100-foot-long barge area) and the main channel (100-foot-long ground improvement zone and 100-foot-long barge area). Work here would last approximately 3.5 months.

#### 3.3.5.5 PROTECTION OF NAVIGATION

The whole width of the Hudson River is navigable and used by ships; small human-powered watercraft, including canoes and kayaks, also use the river, and there are several launches in the Project vicinity. The area from the New Jersey pierhead line to the New York pierhead line is part of the Federal navigation channel, with the wide central portion maintained to a depth of 45 feet by the U.S. Army Corps of Engineers (USACE) and the adjacent side channels (also referred to as “wing” channels) maintained to a depth of 40 feet. The area from the Manhattan bulkhead to the New York pierhead line is within the boundaries of Hudson River Park. The ground improvement zone for the river tunnel would include a segment 100 feet long in the 45-foot-deep navigation channel and a segment 450 feet long in the 40-foot-deep wing channel. Modifications to the river bottom would require a permit from the USACE and must meet conditions imposed by the USACE to protect the navigation channel and maritime safety.

As noted in the previous section, the in-water work would occur in three sections to limit the area of the river affected at any one time. During construction, safety measures would be followed to protect maritime commerce. Measures would include notifications to mariners via the United States Coast Guard (USCG), installation of lighting on barges and the cofferdam, and automatic identification system (AIS) transponders affixed to barges and cofferdams to enable electronic locating of the cofferdam and tracking of the barges. These measures will be developed in coordination with the USCG as the design advances.

### 3.3.5.6 SCHEDULE

Overall construction in the Hudson River would last 15 months, including the following:

- Mobilization: 1.5 months
- Stage 1: 4.5 months
- Stage 2: 4.5 months
- Stage 3: 3.5 months
- Demobilization: 1.5 months

The in-water work, including the installation of sheeting to protect the portion of the river and the jet grouting for riverbed stabilization, and the subsequent removal of the sheet piles or cofferdam would be accomplished in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. In-water construction work would occur from late 2019 through late 2020.

### 3.3.6 MANHATTAN WATERFRONT AREA

The TBMs excavating the two tubes of the river tunnel would continue below the Hudson River bottom, through the foundations of the Manhattan bulkhead, beneath Hudson River Park and Twelfth Avenue (also known as Route 9A) to the Manhattan shaft site at Twelfth Avenue, where the TBMs would be removed. In advance of the TBMs passing through, ground improvements would be made in the Manhattan bulkhead area to improve tunneling conditions as previously described in Section 3.2.2.2. This would allow the Preferred Alternative to avoid cut-and-cover construction (which would require extensive ground improvement including in the river) through this congested area, which includes a park, an active commercial heliport, highly used bikeway, and eight-lane state highway (New York State Route 9A).

#### 3.3.6.1 GROUND IMPROVEMENT BENEATH HUDSON RIVER PARK AND TWELFTH AVENUE

To allow tunneling beneath the surface rather than cut-and-cover excavation, the soft soils in the Manhattan waterfront zone would be treated through ground freezing, a technique that involves installation of a network of underground pipes and then circulation of a cold liquid (calcium chloride brine) through the pipe network until the ground around the pipes freezes solid. The piping used would be a closed, sealed system that would therefore not leak any brine into the surrounding ground. Some freeze pipes would be located inside the perimeter of TBM excavation; just prior to excavation, these pipes would be deactivated and isolated from the freeze system. Subsequently, the TBM would mine through the abandoned pipe. In addition to freezing, permeation (primarily cement with some additives) grouting would be used. The purpose of the permeation grout is described in Section 3.3.6.3 below.

The freeze and grout pipes would be installed in a grid pattern from the surface. Pipes can be installed vertically and also diagonally to minimize disturbance at the surface from pipe installation. Freeze pipes would be installed under portions of Twelfth Avenue from the median and from either side of Twelfth Avenue, and in Hudson River Park (including in the vicinity of the two southernmost helipads and fueling area of the West 30th Street Heliport), including into the landside portions of the bulkhead. Installation of the pipes would take about three months, with an additional two months for necessary grouting. Once installed, the freeze pipes would remain in place for up to four months while the brine is circulated through them and the ground gradually freezes; with the pipes in place for about another five months as both of the TBMs pass through the area (see Section 3.3.6.2, below). The pipe trench would be covered with steel plates or other temporary cover so the area above could be returned to use. Freeze plants, typically housed within one or two work trailers, would be located on the nearby Twelfth Avenue staging

site and/or within the West 30th Street Heliport (the staging site is discussed in Section 3.3.7). Pipes would connect the freeze plants to the underground pipes in the tunnel alignment. Finally, the freeze apparatus and remaining pipes would be removed and the areas would be restored, over approximately four months.

The installation of freeze pipes and related equipment within the southern portion of the heliport would affect heliport operations and would require the relocation of helicopter fueling facilities, as well as rendering one or more of the landing pads inaccessible during the duration of the ground freezing activities.

Similarly, the installation and operation of freeze pipes in the Twelfth Avenue northbound easternmost travel lane and parking lane would make the parking lane unusable during this process. In addition, some trenching across Twelfth Avenue may be required as part of the installation of the ground freezing system. It is anticipated that the effects to the northbound travel lane, as well as to all lanes affected by trenching across the avenue, could be minimized by doing necessary work during nights, weekends, and other off-peak hours so the lane could be decked and in use during peak hours. These construction activities would be closely coordinated with the New York State Department of Transportation (NYSDOT) to ensure uninterrupted use of the travel lane during peak hours.

The freeze pipe installation and freezing operation would be managed to avoid adverse effects to Hudson River Park and to the bikeway that runs parallel to Hudson River Park (which is within the jurisdiction of the highway but is maintained by the Hudson River Park Trust). During installation of the freeze pipes, a portion of the paved pedestrian walkway in Hudson River Park would be closed. A small area near the walkway could also be affected. The affected area is approximately 150 feet long. The walkway would remain open during this time, with a minimum width of approximately 8 feet through the construction zone. The bikeway would not be affected by installation of the freeze pipes, except for a potential short-term closure (up to several days) for trenching of freeze pipes across the bikeway; any trench would be immediately decked over and the bikeway reopened. The freeze pipes installed to treat this area would be installed from locations to the east or west of the bikeway at an angle to pass beneath the bikeway.

All of the areas disturbed by the freeze pipe installation would be restored after the freezing operation is completed and the tunnel segment has been excavated throughout this area.

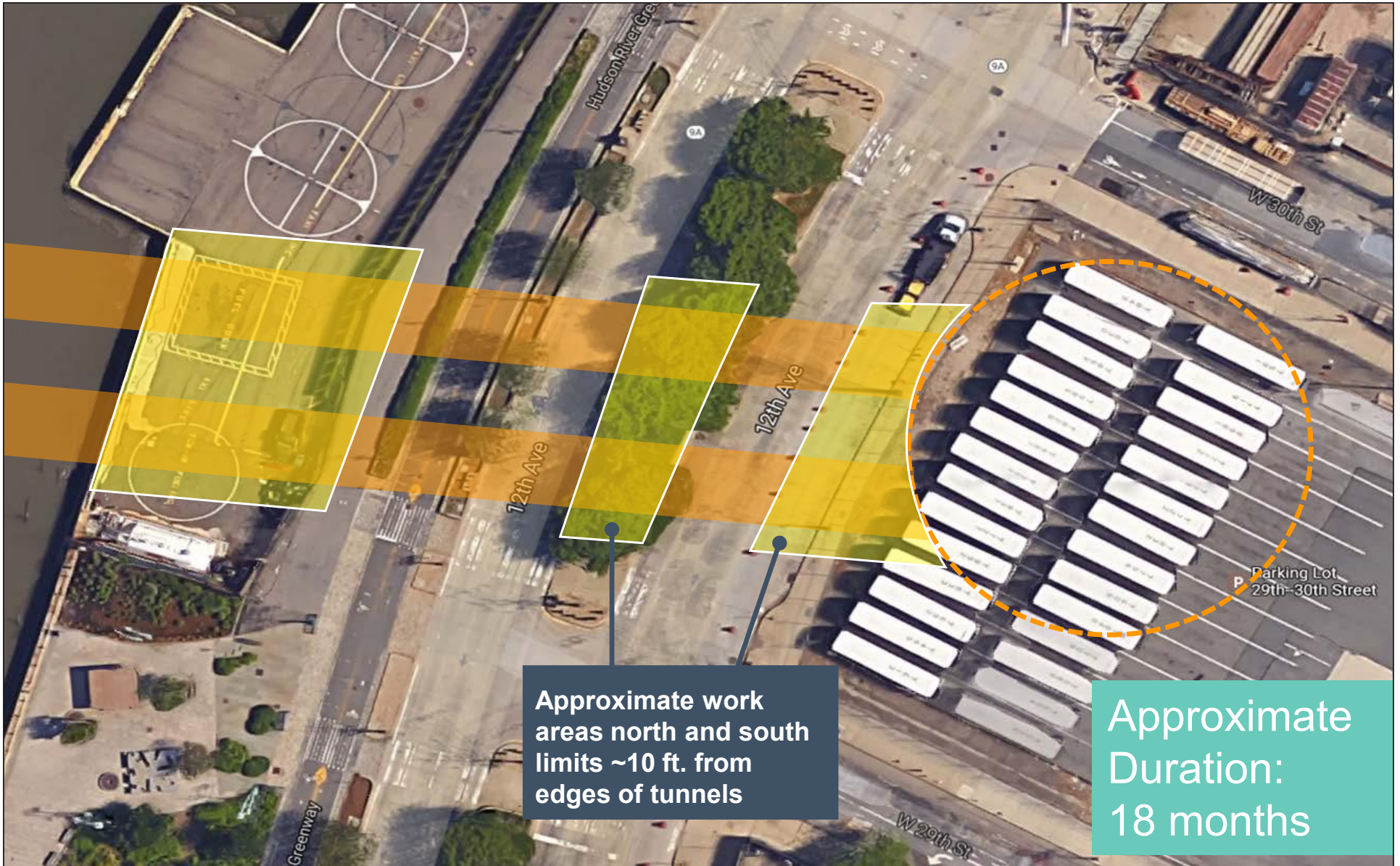
**Figure 3-10** shows the area where ground freezing would be implemented.

In addition to the ground freezing, below-ground obstructions present in the Twelfth Avenue roadbed and adjacent bikeway would be removed prior to tunneling. Specifically, piles that formerly supported the viaduct that carried the West Side Highway may remain buried in this area, primarily beneath the southbound lanes of Twelfth Avenue and beneath the Route 9A bikeway. The piles would be removed by a pile extractor working from the surface of Twelfth Avenue. This work could take approximately three months. An MPT plan would be followed to minimize disruption to traffic or the bikeway. Alternatively, the piles could be cut and removed manually from within the tunnel as it is excavated.

### 3.3.6.2 TUNNEL EXCAVATION

After the ground is frozen, the tunnel alignment from the Twelfth Avenue shaft to approximately the median in Twelfth Avenue would be excavated using SEM mining to permit direct underpinning of the steel pile-supported large-diameter sewer. The excavated tunnel would then be backfilled with flowcrete, a low-strength flowable concrete to allow the TBMs from the river tunnel to mine through the tunnel already created by SEM and eliminate the need for a cast-in-place waterproof lining. Instead, the TBMs would leave in place a permanent precast concrete tunnel lining.







#### 3.3.6.3 TUNNELING THROUGH THE MANHATTAN BULKHEAD

The tunnel alignment would pass through the foundation of the Hudson River bulkhead below the river bottom. In this area, the foundation of the bulkhead consists of riprap, cobbles, and timber support piles. The tunnel would be constructed through the bulkhead by the two staggered TBMs, after ground improvement of the tunnel alignment through a combination of grouting and ground freezing (see **Figure 3-11**).

Permeation (cement-based) grout would be installed from the land side of the bulkhead in both vertical and inclined orientations, to fill large voids in the bulkhead riprap prior to ground freezing. The grouting is most likely to be performed from the land side of the bulkhead (at ground level) in both vertical and inclined orientations. The grouting pressures would be as low as possible—high enough to travel horizontally through the riprap voids but low enough not to exceed the resistance of the overlying ground weight of 30 feet of overlying silt and clay—to limit the possibility of grout being released into the river. Instrumentation would be installed that continuously monitors changes of pressures in the ground during grouting. Safe limits of changes of pressures in the ground would be pre-established for specific locations as part of the monitoring plan.

Once the ground is frozen at the bulkhead, the river tunnel TBMs would both continue eastward (with a lag time of two months between them), tunneling through frozen ground and grouted ground at the bulkhead. The TBMs would be designed to be capable of cutting through timber piles and riprap under frozen ground conditions. If other obstacles are present, such as steel piles remaining from the former West Side Highway structure, the TBMs would pass through those as well. The TBMs would continue beneath Hudson River Park and Twelfth Avenue to the vertical shaft at Twelfth Avenue, where they would be removed.

Based on the conceptual design analyses performed to date, the Project team anticipates that tunneling through the bulkhead and part of its foundation with improved ground conditions (from ground treatment) would improve the stability of the bulkhead. The cement grouting would lock the riprap in place, improving ground stability. It would also help to spread the load of the bulkhead that would rest on the tunnel's tubes after tunneling is complete.

#### 3.3.6.4 UNDERPINNING

Prior to TBM tunneling, the steel pile-supported sewer line in the bed of Twelfth Avenue (Route 9A) would be underpinned. This would be done using an SEM tunnel constructed westward from the Manhattan shaft through the frozen ground. The sewer would be underpinned from within the SEM tunnel to avoid the need to excavate within Twelfth Avenue. **Figure 3-12** illustrates the underpinning of the sewer. As shown in the figure, the supports for the sewers would rest on top of the new Hudson River Tunnel.

#### 3.3.6.5 CONSTRUCTION STAGING AREA AND TRUCK ROUTES

Construction activities in the Manhattan waterfront portion of the alignment would be staged from the Twelfth Avenue staging site, discussed below in Section 3.3.7. Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

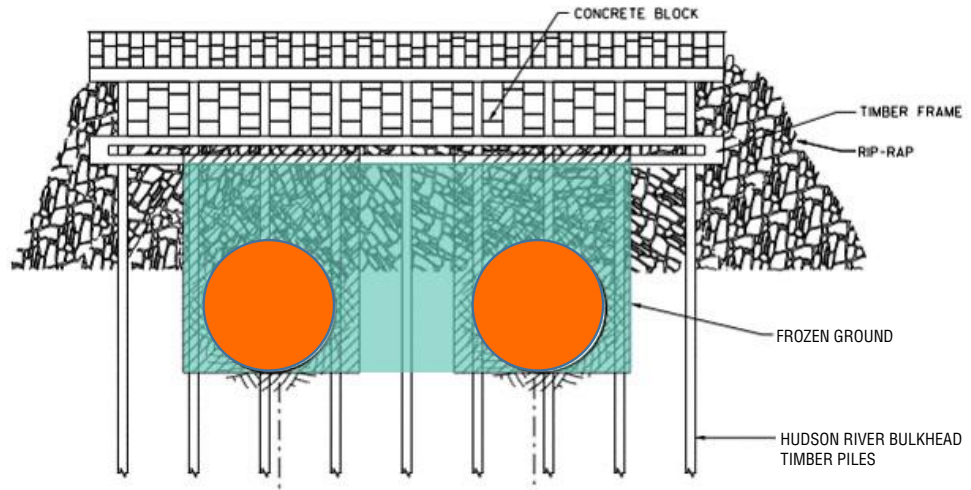
#### 3.3.6.6 SCHEDULE

The ground improvement in the Manhattan waterfront area would be performed in one eight-hour shift per day (7 AM-3 PM) on weekdays. Subsequently, the SEM construction of the tunnel from the shaft site west to the Hudson River bulkhead would be accomplished in two eight-hour



Historic cross section of the Manhattan bulkhead showing the alignment of the new tunnel

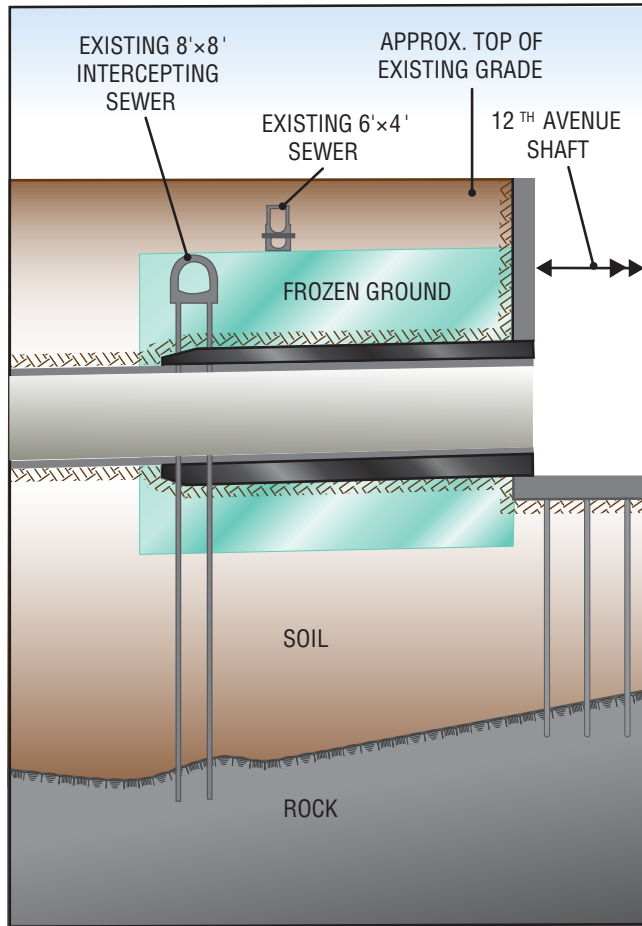
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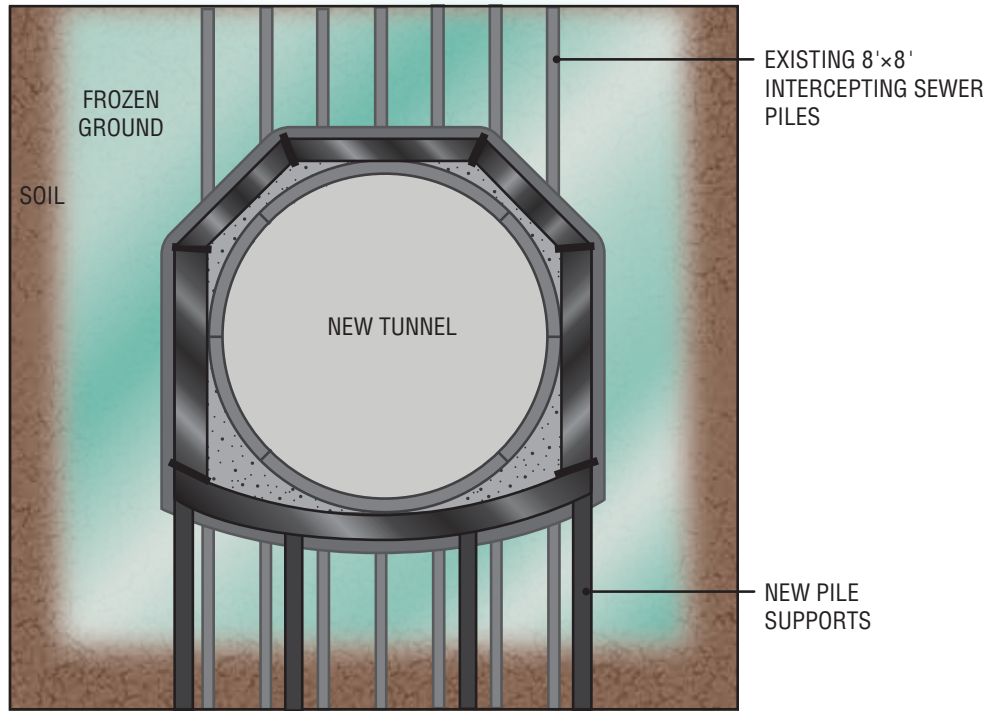
### Section View

Cross section of the new tunnel as it passes through the Manhattan bulkhead

B



A. Illustration of the new tunnel where it passes beneath the existing intercepting sewer at Twelfth Avenue, requiring underpinning of the sewer.



B. Detail showing the new tunnel with existing and proposed support piles for the intercepting sewer at Twelfth Avenue.



shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays. This work would last approximately two years (from mid-2019 through mid-2021).

### **3.3.7 TWELFTH AVENUE SHAFT, STAGING, AND FAN PLANT SITE**

Construction of the river tunnel would be staged from New Jersey, as discussed above, so that tunnel spoils—up to the point of SEM tunneling described in Section 3.3.7.2 below—are removed from the New Jersey shaft site and deliveries are made through that site. The site of the Manhattan ventilation shaft and fan plant for the Hudson River Tunnel would be used as a tunnel access point for retrieval of the river TBMs. It would also be used as a staging site and laydown area for other Manhattan construction activities and would be the permanent location of an approximately 130-foot-diameter ventilation shaft and associated fan plant for the Preferred Alternative.

#### **3.3.7.1 SHAFT CONSTRUCTION**

The Manhattan shaft site is located on the east side of Twelfth Avenue between West 29th and West 30th Streets, close to the corner of Twelfth Avenue and West 30th Street. At this site, a vertical shaft would be excavated from the surface to a depth below the new tunnel. The site is soft ground, which would be supported through the use of slurry walls. A slurry plant would be located on the site temporarily to prepare bentonite slurry required for the installation of slurry walls.

#### **3.3.7.2 STAGING SITE**

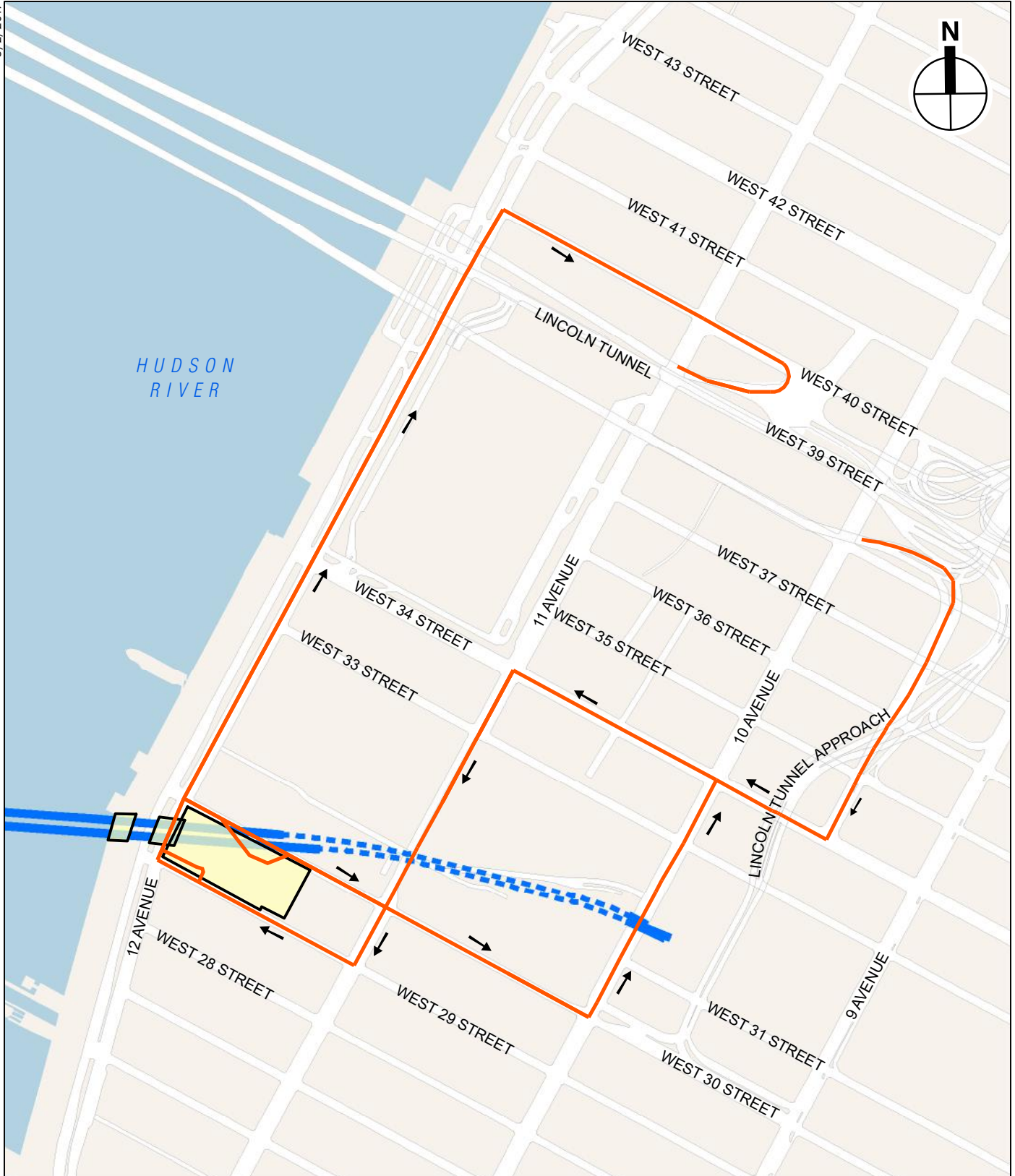
The staging and laydown site would be established on the western end of the block between West 29th and 30th Streets from Eleventh to Twelfth Avenue (Manhattan Block 675). The Twelfth Avenue staging site would include the full lot where the ventilation shaft and fan plant would be located (Block 675, Lot 1). In addition, the Project would also require the use of a portion of the adjacent property on West 29th Street (Block 675 Lot 12). **Figure 3-13** shows the location of the Twelfth Avenue staging site. (A more detailed illustration of the lot boundaries on Block 675 is provided in Figure 4-4 in Chapter 4, “Analysis Framework.”)

This site would be used to stage all of the Manhattan construction activities for the Hudson River Tunnel, including removal of the TBMs after they have completed the two tubes of the river tunnel, ground freezing activities between the Manhattan bulkhead and the median in Twelfth Avenue, construction of the tunnel segment between Twelfth Avenue and the north side of West 30th Street, and construction of the tunnel segment that crosses Tenth Avenue. As outlined below in Section 3.3.7.5, construction on Block 675 would begin in 2019 and last approximately seven years, with completion at the end of 2026.

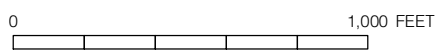
The staging area would fully occupy all of Lot 1 on Block 675 for the duration of the Hudson River Tunnel’s Manhattan construction. Most of the western portion of the block would be occupied by the 130-foot-diameter ventilation shaft itself, which would be used for access to the Manhattan tunnels. In addition, the staging site would house a variety of construction equipment and materials, including a freeze plant to support ground freezing operations west of the shaft, a slurry plant for installation of slurry walls (a type of excavation support), and laydown and storage for construction materials, including large rebar cages for the concrete support walls, as well as worker support facilities. Once the TBMs have been removed through the construction shaft, the shaft site would continue to be used as an access point for the internal concrete finishing for the tunnel.



5/2/2017



- Construction Staging Areas
- Truck Routes
- Proposed New Tunnel
- Hudson Yards R.O.W. Preservation



Twelfth Avenue Staging Area:  
Truck Routes  
**Figure 3-13**



In addition to Lot 1, the Twelfth Avenue staging site would include the western portion of Lot 12, extending 205 feet along West 29th Street from Lot 1.<sup>2</sup> As discussed in Chapter 6A, “Land Use, Zoning, and Public Policy,” Section 6A.4.3.2, the New York City Department of City Planning (NYCDCP) is evaluating a zoning change for the eastern end of Block 675, a proposal referred to as Block 675 East. The Block 675 East rezoning would affect all of Block 675 except Lot 1. Within the rezoning area, two private developers are proposing new high-rise residential developments close to Eleventh Avenue. The rezoning proposal and the two private developments are a separate undertaking from the Hudson Tunnel Project and are not subject to review under the National Environmental Policy Act (NEPA). Lot 12 is part of a site on which a private developer is proposing a high-rise residential project planned for completion by 2021. The development would include a high-rise component on Eleventh Avenue, a mid-rise (approximately five-story) component on West 29th Street near Eleventh Avenue, and a one-story component stretching approximately 225 feet along West 29th Street to fill the site. In the mid-rise and one-story section, the ground floor along West 29th Street would house an accessory parking garage. The garage would potentially incorporate a one-story station for Emergency Medical Services (EMS) ambulances at the western end of the lot that would also be built as part of the development project.

The Hudson Tunnel Project team has been coordinating and will continue to coordinate with the developer for the adjacent project about use of Lot 12. Based on current conceptual design, the Project team anticipates that the western 205 feet of Lot 12 would be required for construction staging for the Hudson Tunnel Project for the duration of the tunnel construction, until the end of 2026. The Project team will continue to evaluate the space needs for Manhattan construction staging to determine whether construction activities on Lot 12 can use less space or have a shorter duration than the full Hudson River Tunnel construction period, which could allow completion of the development’s one-story parking shell and EMS facility prior to completion of the Hudson River Tunnel construction. Based on coordination to date and the conceptual design information for the Hudson Tunnel Project, this timing is not likely; thus, this EIS assumes that the Hudson Tunnel Project’s space needs during construction may not allow completion of the shell of the parking garage and EMS facility by 2021. Instead, tunnel construction staging would occur on the western 205 feet of Lot 12 until the end of 2026. In that case, the Hudson Tunnel Project may complete the shell of the one-story portion of the parking garage and potential EMS facility for incorporation into the development project, if agreed to by the developer.

If the Hudson Tunnel Project’s construction needs can be accommodated, it is also possible that the private developer could build the shell of its one-story parking garage and the adjacent EMS facility within the previously anticipated timeframe for that project, with completion of the shell by 2021. In that case, the Hudson Tunnel Project would use the space within that shell for construction staging. After the Hudson Tunnel Project’s construction is complete—by 2026—the developer would complete the garage and EMS facility.

### 3.3.7.3 *FAN PLANT CONSTRUCTION ON LOT 1*

Following completion of the other Manhattan components of the Preferred Alternative, construction of the emergency access/egress components of the shaft and the ventilation fan plant would be undertaken. This would involve typical construction methods for constructing the building frame, superstructure, core, shell, and finishing work, including the installation of the fans and fire-life safety equipment.

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<sup>2</sup> As shown in Figure 4-4, Lot 12 is 425 feet long and is located along West 29th Street. It extends from a point 100 feet west of Eleventh Avenue to a point 259 feet east of Twelfth Avenue.

Lot 1 may also be developed in the future with a separate development. As described in Chapter 6A, “Land Use, Zoning, and Public Policy,” Section 6A.4.3.1.1, the site’s current zoning would allow a commercial office or hotel building of approximately 940,000 square feet. Such a building is not proposed as part of the Hudson Tunnel Project, but could be undertaken in coordination with the Hudson Tunnel Project. In this case, it could be constructed together with the Twelfth Avenue fan plant.

#### 3.3.7.4 TRUCK ROUTES

Trucks carrying materials to and from the Twelfth Avenue staging area would use local streets on the West Side of Manhattan to reach the site (see **Figure 3-13**). Access and egress to the site may be provided from West 29th Street, Twelfth Avenue, and/or West 30th Street depending on the final staging layout at the site. The route to the staging area proceeds south from the Lincoln Tunnel on Dyer Avenue to West 34th Street, then west to Eleventh Avenue, south to West 29th Street, and west to Twelfth Avenue. Trucks leaving the site would proceed north on Twelfth Avenue to West 40th Street, then east to the Lincoln Tunnel access road at Galvin Avenue, located between Tenth and Eleventh Avenues.

Hauling materials and debris by rail was not considered due to the nature and capacity of the NEC, particularly the rail system in the vicinity of PSNY. The NEC in this area and PSNY are used exclusively by passenger rail, with the very limited exception of use by work trains for minor maintenance in the immediate vicinity of PSNY; it is not appropriate to haul materials and debris in this area. Use of barging for hauling away demolition debris may be considered, but is unlikely considering the cost and additional handling involved to use this method of transport and the difficulty of mitigating impacts to Hudson River Park resulting from operation of conveyors that would need to be erected through the park from the Twelfth Avenue staging site.

An average of approximately 12 to 18 trucks per hour would arrive at and depart from the Manhattan staging site during the construction period. Peak trucking activity would range from approximately 32 to 42 trucks per hour during peak construction periods, anticipated to occur in 2020 and 2021. Trucking would occur Monday through Friday from 7 AM to 10 PM. These trucks would be carrying construction materials to the site and hauling away construction debris and spoils from the tunnel excavation sites in Manhattan, which may include hazardous materials encountered during construction. Truck routes would be coordinated with the New York City Department of Transportation’s (NYCDOT) Office of Construction Mitigation and Coordination (OCMC), NYCDOT, and NYSDOT, as necessary.

Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

#### 3.3.7.5 SCHEDULE

In general, work at the Twelfth Avenue staging site would occur in two eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM) on weekdays, five days a week. Construction activities at the site would last approximately seven years, as follows:

- Site preparation, Twelfth Avenue shaft, and SEM mining construction: approximately 2 years (mid-2019 – mid-2021).
- Fan plant construction, finishing, and fit out: approximately 4 years (late 2021 through mid-2025).
- Trackwork, rail systems, and MEP finishes: approximately 4 years (late 2023 – late 2026).

3.3.7.6 *POTENTIAL BUILD-OUT OF PARKING GARAGE ON ADJACENT PROPERTY (LOT 12)*

As described above in Section 3.3.7.2, this EIS assumes that the Hudson Tunnel Project's space needs during construction may not allow completion of the shell of the parking garage and potential EMS facility by 2021 and that the parking garage and potential EMS facility could be delayed until after the Hudson River Tunnel is complete in 2026. In that case, it is possible that after completion of construction on the Twelfth Avenue shaft site, the Project Sponsor for the Hudson Tunnel Project would construct the western 205 feet of the parking garage and potential EMS facility on Block 675 Lot 12 for incorporation into a private development project being planned at the eastern end of the block, if agreed to by the developer.

In connection with the potential rezoning and related actions, NYCDCP is currently preparing an EIS in accordance with New York City's City Environmental Quality Review (CEQR) regulations that evaluates the potential effects of the proposed rezoning for the Block 675 East project.<sup>3</sup> The Draft Scope of Work for the EIS for the Block 675 East project, dated April 12, 2017, describes that the EIS for Block 675 East will evaluate the temporary impacts related to construction and the permanent impacts associated with the development that would occur in the rezoning area as a result of the rezoning and related actions. The Block 675 East EIS will assume that new developments would be built at the east end of the block by 2021 as a result of the rezoning.

This EIS for the Hudson Tunnel Project assumes that the Hudson Tunnel Project's space needs during construction may not allow completion of the shell of the one-story parking garage and EMS facility on Lot 12 by 2021. Instead, tunnel construction staging would occur on the western 205 feet of Lot 12 until the end of 2026 and the one-story parking garage would be constructed after that. Therefore, this EIS analyzes the impacts associated with this potential delay in the schedule for construction and completion of the one-story parking garage and potential EMS facility that could result because of the Hudson Tunnel Project.

The parking garage and potential EMS station would occupy the full 205-foot length of the west end of Lot 12, and the full 99-foot depth. It would be approximately 23 feet tall, with a slab foundation (no cellar below). Construction of the Block 675 Lot 12 parking garage and EMS facility is anticipated to take approximately 18 months, including approximately three months for pre-construction remediation of hazardous materials on the site, if required. Construction activities are expected to include:

- Hazardous materials remediation: up to three months (early 2027);
- Mobilization, excavation, and foundation: five months (early 2027 – mid-2027);
- Superstructure: three months (late 2027);
- Building envelope: four to five months (late 2027 – early 2028); and
- Mechanical systems: one to two months (mid- 2028).

There would be an average of 62 construction workers per day in the peak month of construction for the Block 675 Lot 12 facility (month 13, during which the building envelope would be constructed). Truck trips would peak at 94 per month, or 5 per day (month 8, during construction of the foundation, when concrete trucks would arrive and depart the site). This EIS analyzes the impacts associated with a potential delay to the construction of the one-story parking garage and potential EMS facility until after 2026. The total delay would be approximately seven years—from a completion date of 2021 to a completion date of 2028.

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<sup>3</sup> <https://www1.nyc.gov/site/planning/applicants/scoping-documents.page>.





### **3.3.8 TUNNEL FROM 30TH STREET TO PSNY**

East of the Twelfth Avenue shaft site and staging area, several tunnel segments would be constructed. In addition, the Hudson Yards Right-of-Way Preservation Project would be fitted out with track and rail systems. These segments of the Preferred Alternative are discussed below.

#### **3.3.8.1 WEST 30TH STREET CUT-AND-COVER CONSTRUCTION**

The segment of tunnel extending from the Twelfth Avenue shaft across West 30th Street would be constructed using cut-and-cover techniques. Prior to excavation, utilities in the roadway would be supported or relocated out of the construction zone. Following utility relocation, the tunnel alignment in West 30th Street would be excavated. Slurry walls would be used to support the excavation area.

The western half of West 30th Street would be closed for the duration of the cut-and-cover excavation process, estimated at about three years (from early 2020 through mid-2023). There would be traffic and pedestrian diversions in this area during this activity (described in more detail in Chapter 5A, "Traffic and Pedestrians").

#### **3.3.8.2 CONSTRUCTION IN THE HUDSON YARDS RIGHT-OF-WAY PRESERVATION PROJECT SEGMENT**

Separately from the Hudson Tunnel Project, Amtrak has been constructing the Hudson Yards Right-of-Way Preservation Project to preserve a railroad right-of-way beneath the Hudson Yards overbuild north of West 30th Street between Tenth and Twelfth Avenues. This project consists of a concrete casing that extends from the north side of West 30th Street to the west side of Tenth Avenue. The project is being constructed in phases and, once completed, will be available for use as the alignment for the Preferred Alternative.

The alignment for the Preferred Alternative would make use of the concrete casing, and would finish the casing with tracks, communications, signals, and other railroad systems.

#### **3.3.8.3 TENTH AVENUE CUT-AND-COVER CONSTRUCTION**

At the eastern end of the Hudson Yards Right-of-Way Preservation Project, the tunnel alignment would extend beneath Tenth Avenue via cut-and-cover construction. Cut-and-cover excavation is most suitable for this segment because of its short distance (about 100 feet) and its relatively shallow depth (about 20 feet below the surface). This portion of the alignment is in mixed rock and soil conditions. The soil segment would be excavated using support of excavation such as secant piles or soldier pile and lagging, and the rock portion would likely be excavated using controlled drilling and blasting. The Tenth Avenue roadway would remain open throughout this process, although temporary lane closures would occur.

#### **3.3.8.4 NEW CONNECTIONS TO PSNY**

East of Tenth Avenue, a new tunnel portal would be constructed, which would require demolition of a portion of the A Yard retaining wall and selective underpinning and/or relocation of support columns for the Lerner Building, which are currently supported by the retaining wall.

Constructing new track connections for the Preferred Alternative would involve modifications to the existing track system at PSNY. This work would require trackwork and minor excavation to lower the profile of several tracks so they can meet the grade of the new tunnel tracks at the new portal within A Yard. An existing track that runs diagonal to the existing track network to provide connections to the PSNY platform tracks, known as the I Ladder, would be extended to connect to the new tunnel's tracks, so that connections are available from the new tunnel to PSNY Tracks 1 through 18. In addition, certain tracks within A Yard would be modified. The new

tunnel's tracks would connect to two of the A Yard tracks, which would be connected to the station platform tracks via the extended I Ladder and a shorter connection referred to as the J Ladder. Other switches in A Yard would be modified to support the new tunnel operations.

Track profiles beneath the Lerner Building would be modified to accommodate the new tracks. Specifically, certain tracks in A Yard must be lowered to meet the alignment of the Hudson River Tunnel tracks. During the approximately six-month period when this is occurring, storage tracks at D Yard and A Yard would not be available. NJ TRANSIT would relocate the three trains it currently stores in A Yard and D Yard to other storage locations either at Sunnyside Yard in Queens or in New Jersey (for more information, see Chapter 5B, "Transportation Services," Section 5B.6.2.3).

The new extension to the I Ladder would require removal of approximately 10 columns of the existing Lerner Building. New spread footings and columns would be constructed adjacent to the existing columns outside the track clearance zone. A new permanent structural connection would be made at the top of the columns and underside of existing building girders. Once the load is transferred to the new columns at each location, the existing columns and footings would be removed.

In addition, approximately 100 linear feet of the single-track Empire Line tunnel beneath Tenth Avenue would have to be lowered so that the Empire Line track would connect to the lower track profile in the A Yard area created to connect to the new tunnel. This would be accomplished through mechanical rock excavation. If possible, the work would be conducted during weekends over an approximately 20-month period so that train service would be maintained on weekdays. If this is not practicable, full closure of the Empire Line tunnel connection to PSNY may be required for two to three months, with trains diverted to Grand Central Terminal.

Tie-in to existing railroad facilities would be accomplished during night and weekend outages to the extent practicable. However, as this is a constricted area, there may be some disruptions to train service or schedules as a result of construction activities and the corresponding safety measures that would be in place during construction (see Chapter 5B, "Transportation Services," Section 5B.6.2.3).

#### *3.3.8.5 FAN PLANT AT TENTH AVENUE/LERNER BUILDING*

A fan plant to provide ventilation for the new tunnel segment from the Twelfth Avenue shaft to the new Manhattan portal at Tenth Avenue would be constructed near Tenth Avenue. The fan plant would be constructed within an existing Amtrak easement area above the tracks of the A Yard. Based on conceptual design, this fan plant would be located beneath the Lerner Building, which spans the A Yard tracks on the east side of Tenth Avenue from West 31st to 33rd Street. The work would require reconfiguration of the area above the tracks to include ventilation fans, power supply for the fans, and equipment rooms for the control of the fans. This area already serves as ventilation for the A Yard area and exhaust for the new fan plant would be through the existing louvers on the west face (Tenth Avenue façade) of the Lerner Building.

#### *3.3.8.6 TRACKWORK, RAILROAD SYSTEMS, AND MEP FINISHING*

The various railroad systems, including tracks, signals and communications; and overhead contact systems structures and wires, would be installed once the tunnel is complete. Construction and finishing of the various mechanical, electrical, and plumbing systems, including tunnel ventilation systems and tunnel lighting systems would also be installed once the tunnel is complete.

### 3.3.8.7 SCHEDULE

Construction activities for Manhattan components of the Preferred Alternative would generally occur on weekdays in eight-hour shifts per day (7 AM-3 PM and 3 PM-11 PM). The overall duration would be seven years, as follows:

- West 30th Street cut-and-cover, including associated utility relocation: approximately 2 years (early 2020 – early 2022).
- Tenth Avenue cut-and-cover and fan plant, including associated utility relocations: approximately 1.5 years (mid-2021 – late 2022).
- Lerner Building underpinning, approximately 15 months (late 2023 – late 2024)
- New connections to PSNY, including track modifications, regrading of A Yard, and lowering existing track profiles including Empire Line: approximately 21 months (late 2024 – mid-2026).
- Fit-out of Hudson Yards Right-of-Way Preservation Project: approximately 3.5 years (late 2021 – mid-2025).
- Trackwork, railroad systems and MEP finishing, approximately 2.5 years (early 2024 – mid-2026).

### 3.3.9 COORDINATION WITH OTHER CONSTRUCTION PROJECTS

The Project Sponsor would coordinate with entities responsible for construction activities on sites near the proposed construction site for the Preferred Alternative. In Hoboken, Project construction would be coordinated with adjacent construction work on the Hoboken Rebuild By Design project, which would intersect the alignment of the river tunnel just west of the Hudson River shoreline.

In New York, the Project Sponsor would coordinate Project construction with adjacent construction work on several large-scale projects, including the Hudson Yards Project, which is creating a new development on a platform over the Long Island Rail Road's (LIRR) John D. Caemmerer West Side Yard between West 30th and West 33rd Streets, Twelfth Avenue and Eleventh Avenue); the West Side Yard Perimeter Protection Project being constructed by LIRR around the West Side Yard; and construction of residential buildings proposed at the eastern end of the block between West 29th and West 30th Streets, Twelfth Avenue, and Eleventh Avenue. As discussed above in Section 3.3.7.2, this includes close coordination with the developer proposing a new residential project on West 29th Street near Eleventh Avenue.

### 3.3.10 REHABILITATION OF NORTH RIVER TUNNEL

Once construction of both tubes of the new tunnel is complete and Amtrak and NJ TRANSIT service is shifted to the new tunnel, rehabilitation of the North River Tunnel would begin. Rehabilitation work would be accomplished by taking one tube out of service at a time for reconstruction while the other tube remains in service. Once rehabilitation of the first tube is complete, that tube would be recommissioned (i.e., put back in service) and the second tube would be taken out service for rehabilitation.

#### 3.3.10.1 STAGING

Before rehabilitation of the North River Tunnel can begin, staging areas would be established. Because hauling demolition debris and construction materials through PSNY is not feasible, the contractor would need to transport construction materials and debris via the tunnel portal in North Bergen, New Jersey. The track outside the decommissioned tube would temporarily be "dead" track (i.e., not in service for passenger rail operations) and thus suitable for use by

construction work trains. All core rehabilitation activities would take place within the North River Tunnel, with activities in the staging areas outside the portal consisting largely of material conveyance.

Rehabilitation of the North River Tunnel would continue to use the Tonnelle Avenue staging area previously established for construction of the new Hudson River Tunnel. New construction access between the staging area and the “dead” tracks at the North River Tunnel portal would need to be constructed across the newly active tracks of the new Hudson River Tunnel right-of-way. It may be possible to create such construction access in advance, during construction of the new Hudson River Tunnel.

Two staging access options have been developed for accessing the North River Tunnel tracks from the portion of the staging site on the west side of Tonnelle Avenue (see **Figures 3-14 and 3-15**):

- **Deck and crane trestle system at portal.** The Project contractor could build a deck and crane trestle system over the tracks of the NEC at the tunnel portal, where the tracks are located in an open cut. This system would take advantage of the approximately 45-foot vertical clearance above the tracks. The deck area would be at the same elevation as the Tonnelle Avenue bridge over the NEC so the deck could be accessed at grade from Tonnelle Avenue. A vertical partitioning wall would be constructed between the two North River Tunnel tracks in this area to isolate and protect the operational track from the one under construction. The contractor would use a large crawler crane on the deck over the dead track to service its work train or conveyance vehicles into the decommissioned tube. Access to the crane would be via the deck over the live track. The use of a deck system would allow the Project contractor to lower construction material onto the construction track and lift debris from the track, and while shielding the active track from debris and protecting the overhead contact system (i.e., catenary).

To move between the crane and the Tonnelle Avenue staging site on the west side of Tonnelle Avenue as well as any available land left on the portion of the Tonnelle Avenue staging site on the east side of Tonnelle Avenue once the new tunnel is in operation, trucks would use Tonnelle Avenue’s U-turn loops.

- **Extended deck and crane system at portal crossing new tracks.** Another option would be to include a deck and crane trestle system as described above, but with a larger deck that extends across the new active tracks leading into and out of the new Hudson River Tunnel. With this extended deck, construction equipment could move easily between the North River Tunnel and the remaining staging area on the east side of Tonnelle Avenue. Cranes would be placed at either end of the decking system to transfer materials. To move between the crane and the Tonnelle Avenue staging site on the west side of Tonnelle Avenue, trucks would use Tonnelle Avenue’s U-turn loops.

In addition, the Project team considered several other access options that used staging areas on the west side of Tonnelle Avenue. These included an option with a 350-foot-long conveyor to move materials from the NEC over Amtrak’s active substation (Substation 42) and adjacent historic substation building (Substation 3) to the staging area on the west side of Tonnelle Avenue from the NEC; an option in which a decking and crane system is employed on the west side of Tonnelle Avenue, over the active substation and adjacent historic substation building; and an option with a similar deck and crane system on the west side of Tonnelle Avenue west of the substations but adjacent to the freight rail right-of-way. These alternative access options had significant disadvantages compared with the two options described above, including placing cranes in close proximity to an active electrical substation, introducing conveyer systems that are not universally useful for transporting all types of materials necessary at the site, very tight fit of the conveyor system that may require modifications to the substation, need to build the





North River Tunnel Rehabilitation:  
Staging Area Option with Platform over North River Tunnel Tracks  
**Figure 3-14**





North River Tunnel Rehabilitation:  
Staging Area Option with Platforms over  
North River Tunnel Tracks and Hudson River Tunnel Tracks  
**Figure 3-15**





decking system 20 feet higher to clear the substation, and/or bringing the decking and cranes very close to the adjacent freight railroad right-of-way. Therefore, these options are not being advanced.

### *3.3.10.2 PROVISION OF REDUNDANT FIRE-LIFE SAFETY INFRASTRUCTURE AND DECOMMISSIONING*

Before work begins in the first tube, redundant fire-life safety infrastructure must be established in the tube that would remain active so the active tube can be operationally independent of the tube to be reconstructed. Redundant fire-life safety infrastructure to be established includes fire standpipes and emergency means of egress. This infrastructure would be installed during temporary weeknight and weekend service outages. The tube that requires the least redundant life-safety infrastructure, as determined by further investigation during the final design stage, would be the first tube to remain active.

Decommissioning of the first tube to be reconstructed would follow and would include the termination of track crossover (i.e., disabling switches to ensure that trains cannot accidentally switch to track entering the decommissioned tube), termination of third rail traction power and the overhead catenary system, and relocating third-party cables in the existing duct bank. This work would initially be performed during temporary service outages and then under a complete service closure, which would occur when the active tube is operationally independent of the tube to be decommissioned.

### *3.3.10.3 REHABILITATION WORK*

Rehabilitation work would include reconstruction of the bench walls and track system; cabling work in the duct banks, along the tunnel crown, and above the bench walls; and any necessary work to address cracking and spalling on the interior face of the tunnel liner (i.e., tunnel wall). The work would be conducted in a linear sequence with work beginning at the Manhattan end of the tunnel and moving westward toward the portal in North Bergen. This would give the contractor the option to use the existing track bed within the decommissioned tube for conveyance of personnel, construction debris, and construction materials before being demolished and reconstructed. Virtually all of this work would occur underground, with only the materials delivery and debris removal being visible at the Tonnelle Avenue staging site in North Bergen. Materials conveyance via a conveyor belt or other temporary system is also an option. The work would be conducted on a schedule of six days per week, with two 10-hour shifts per day. Work elements include the following:

- **Tunnel ventilation.** During demolition of the existing concrete within the tunnel, temporary ventilation would be necessary to ensure worker safety and compliance with Occupational Safety and Health Administration (OSHA) regulations. The tunnel environment and air quality can differ greatly between demolition and construction, which would result in different amounts of ventilation being required for different activities. The existing ventilation fans as well as temporary infrastructure for dust suppression methods (e.g., water) and supplemental ventilation (e.g., in-line fans/ducts, potentially with use of an enclosure around the construction/demolition zone to contain airborne dust) would be installed. The system would capture silica dust from ventilated air and would be designed so as to not impact air quality outside the tunnel.
- **Bench wall demolition and reconstruction.** The most time-consuming and critical work activity involves the demolition, removal, and reinstallation of the bench walls, the embedded duct banks, and associated duct bank cabling and wiring. Bench walls would be completely demolished down to the tunnel liner. Demolition work would be staggered with one side leading the other by approximately 500 feet to give work crews sufficient clearance. Bench

walls would be demolished, with materials bagged for removal. During demolition, the attachment hardware for the new bench walls would be installed.

Because concrete from this century-old tunnel may contain asbestos, protocols developed during final design would be followed to identify spoils that may contain contaminated materials so that they can be handled appropriately and disposed of at a suitable location. Protocols for the transport of spoils from the construction sites would be developed to ensure the safe handling of these materials and would include procedures to secure the material from spilling off trucks, as well as for any inadvertent or accidental spills of materials falling from trucks removing this material from the staging sites.

Concrete work for new bench walls and duct banks would begin once demolition has advanced 3,000 to 5,000 feet, with one side leading the other by approximately 500 feet. The new cable and wire in the new bench wall ducts would be pulled when bench wall construction is approximately 80 percent complete.

Any work to address cracking and spalling on the interior face of the concrete tunnel liner would be undertaken concurrently with construction of the bench walls.

- **Track system demolition and reconstruction.** Track removal and replacement would start after the bench wall is advanced far enough that the track construction does not interfere with to the bench wall construction. Track system demolition and ballast removal would be performed sequentially in 2,000-foot sections; then halted until that section is reconstructed. The track system would be assembled and built using the top down method in which the track system is supported and set to grade; the concrete is then placed, encasing the ties, and the concrete surface finished by hand.

Concrete would either be delivered using a portable concrete mixer on a work train, or pumped from the staging area through a slick line laid in the track bed.

Environmental characterization of the ballast to be removed has not yet been conducted; however, the ballast has the potential for Polychlorinated Biphenyl (PCB) contamination due to the oil-infused equipment and rolling stock used in the tunnel. If this contamination is verified, the ballast removed from the tunnel would be stored and treated at the staging area prior to being hauled for permanent disposal at an appropriate facility. Special containment would be provided around the perimeter of the contaminated ballast muck pile.

- **Cabling.** Cabling and replacement of cable attachments in the tunnel crown and above the existing bench wall, including catenary, signals, and communications would be performed after the completion of bench wall and track construction.

#### 3.3.10.4 RECOMMISSIONING

Upon completion of all rehabilitation activities, the rehabilitated tube would be recommissioned. Recommissioning activities would include the activation of track crossover (i.e., re-enabling switches that allow trains to enter the tracks approaching the rehabilitated tube), activation of third rail traction power and the overhead catenary system in the tube, testing the signal system, and testing the operation of the reconstructed tunnel. Upon completion of the recommissioning activities, the tube would be returned to active rail service. At that point, the second tube could be decommissioned and the work described above would be undertaken in the second tube.

#### 3.3.10.5 TRUCK ROUTES

All construction materials would be delivered and all debris would be removed from the primary staging area by truck. Trucks would travel to and from the Tonnelle Avenue staging area using Tonnelle Avenue itself (U.S. Routes 1 and 9), which connects to I-495 and from there to I-95/the New Jersey Turnpike. Trucks at the staging site on the west side of Tonnelle Avenue would have to head south and make a U-turn just south of the site or farther south at Secaucus Road.



During peak construction (i.e., when bench wall construction, track demolition, and track construction are happening simultaneously), there would be a maximum of 32 truck trips (in- and outbound combined) per hour during peak construction activities, which would occur during the last six months of the rehabilitation for each tube, with less intensive periods of construction falling in the range of 8 to 18 hourly truck trips. Truck routes would be coordinated with NJDEP and the local municipality, the Township of North Bergen.

Removal of demolition materials would generally be undertaken by truck, with debris going to several facilities, depending on whether it is disposed of, has potential contamination, or is to be recycled. Locations for the disposal/recycling of demolition materials have been identified in Secaucus, Newark, and in Keasbey, New Jersey. In general, hauling construction materials to the site and removal of debris by rail was not considered due to the nature and capacity of the adjacent railways. Protocols for the transport of spoils from the construction sites would be developed to ensure the safe handling of these materials and would include procedures to secure the material from spilling off trucks, as well as for any inadvertent or accidental spills of materials falling from trucks removing this material from the staging sites. The NEC is used exclusively by passenger rail in this segment and use by work trains outside the temporary dead track in the immediate vicinity of the tunnel portal is not appropriate. Use of the adjacent freight railroads for hauling away demolition debris may be considered, but is unlikely considering the cost and additional handling involved to use this method of transport.

Potential impacts on traffic conditions, noise levels, air quality, and the surrounding community from the construction-related truck traffic are evaluated in subsequent chapters of this EIS.

### *3.3.10.6 SCHEDULE*

Construction for the rehabilitation of the North River Tunnel would be completed in two 10-hour shifts per day (7 AM-5:30 PM and 5 PM-3:30 AM), six days a week (Monday through Saturday). Other than the construction of the staging area and access point at Tonnelle Avenue, the rehabilitation effort would be undertaken for one tube of the North River Tunnel at a time. Overall construction would have a duration of approximately four years, or approximately 22 months for each tube, as follows:

- Construction of the access to existing tunnel portal, decking, conveyor and/or trestle system to access temporary dead track at North River Tunnel portal from Tonnelle Avenue staging area: 3 months (late 2026 – early 2027).
- First tube, decommissioning, installation of redundant life-safety infrastructure and tunnel ventilation, and installation of dust collection/suppression and ventilation systems: 3 months (late 2026 – early 2027).
- First tube, demolition and reconstruction of bench walls and duct banks: 9 months (early 2027 – late 2027).
- First tube, installation of new conduit and cabling, including catenary wiring: 7 months (mid-2027 – early 2028).
- First tube, demolition and reconstruction of the track system: 6 months (late 2027 – mid-2028).
- First tube, commissioning activities to place the reconstructed tube back into service: 2.5 months (mid-2028).
- Second tube, set up of construction staging and access: 3 months (mid-2028).
- Second tube, decommissioning, installation of redundant life-safety infrastructure and tunnel ventilation, and installation of dust collection/suppression and ventilation systems: 3 months (mid-2028 – late 2028).

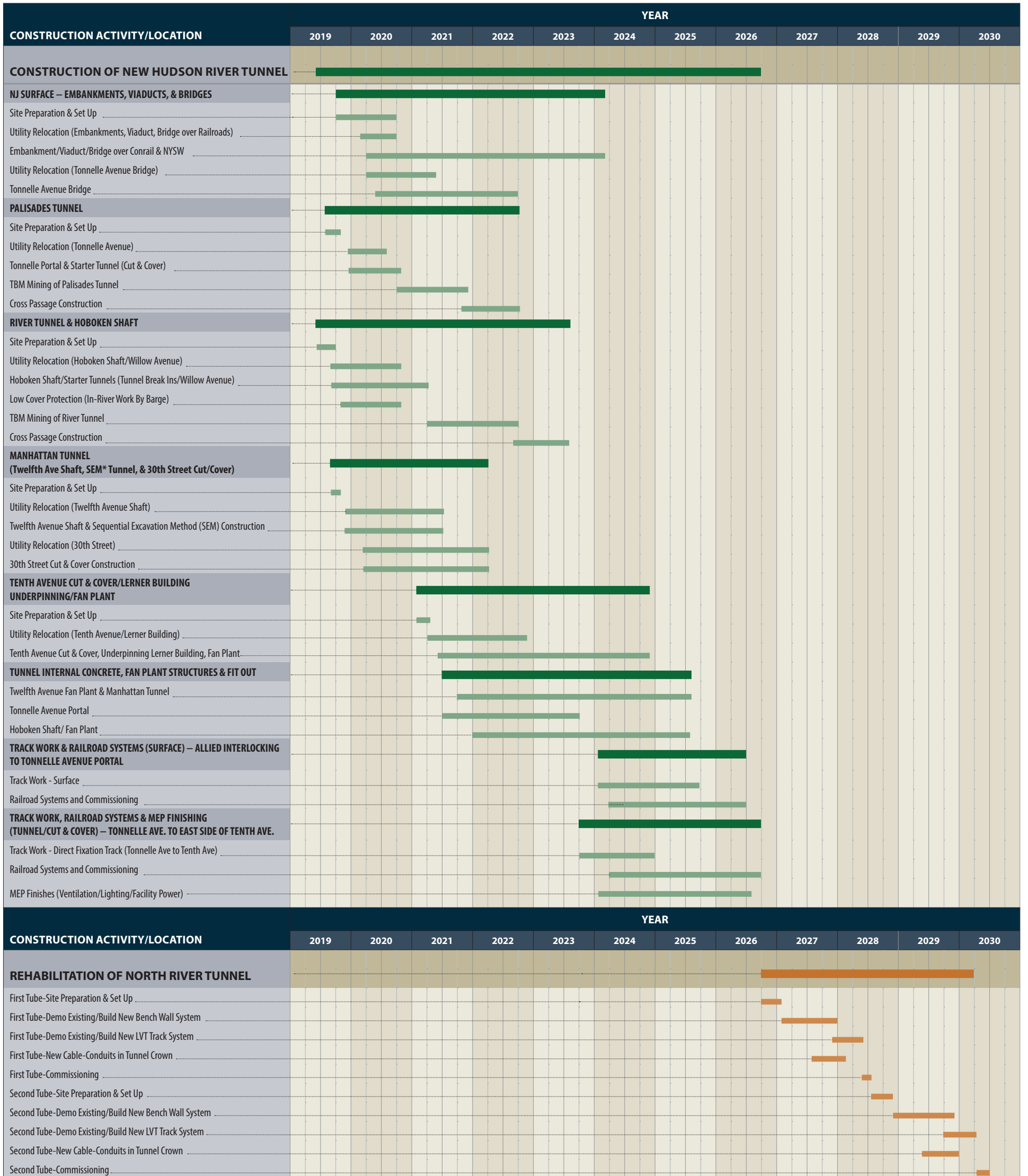
- Second tube, demolition and reconstruction of bench walls and duct banks: 9 months (late 2028 – late 2029).
- Second tube, installation of new conduit and cabling, including catenary wiring: 7 months (mid-2029 – late 2029).
- Second tube, demolition and reconstruction of the track system: 6 months (late 2029 – early 2030).
- Second tube, commissioning activities to place the reconstructed tube back into service: 2.5 months (mid-2030).

### 3.4 OVERALL CONSTRUCTION SCHEDULE

Construction activities for the Preferred Alternative would begin in 2019 with construction of the new Hudson River Tunnel. Once the new tunnel is completed in 2026 and placed into service, the rehabilitation of the existing North River Tunnel would commence, with both tubes of the North River Tunnel back in service for passenger rail operations in 2030. **Figure 3-16** provides a summary of the overall construction schedule by major construction activity. A summary of the anticipated major construction activities for the Preferred Alternative is provided below in **Table 3-2**.

As noted earlier, information presented in this chapter and analyzed throughout this EIS is based on conceptual engineering (10 percent design) and is likely to evolve as the engineering and design advances. Accordingly, the preliminary sequencing plan and overall construction schedule developed for the proposed construction activities represents a reasonable estimate of how the Preferred Alternative could be constructed; this plan is likely to change as engineering evolves.

The schedule and estimates of daily truck trips and workers at each site are based on the assumption that both tubes of the new Hudson River Tunnel would be bored at the same time, using two TBMs. The Project's contract documents will likely require that the tunneling be completed in a specified amount of time, leaving the means and methods for that completion to the Project contractor. Therefore it is possible that the Project contractor would conduct the tunneling differently than outlined in this chapter and evaluated in this EIS, but to meet the aggressive schedule presented in this EIS, similar tunneling progress, and therefore similar numbers of workers and trucks, would be required.



Note: \* = Sequential Excavation Method



**Table 3-2  
Major Construction Elements for the Preferred Alternative**

<b>Construction Activity</b>	<b>Notes</b>	<b>Duration</b>
<b>NEW HUDSON RIVER TUNNEL</b>		
<b>NEW JERSEY SURFACE ALIGNMENT</b>		
Embankment with retaining wall	<ul style="list-style-type: none"> <li>From County Rd to approximately 500 feet east of Secaucus Rd, with a bridge over Secaucus Rd</li> <li>Relocation of utilities</li> </ul>	late 2019 to early 2024 (4.5 years)
Meadowlands viaducts	<ul style="list-style-type: none"> <li>From approximately 500 feet east of Secaucus Rd to approximately 1,500 feet east of Secaucus Rd</li> <li>New drainage features installed</li> </ul>	late 2019 to early 2024 (4.5 years)
Sloped embankments	<ul style="list-style-type: none"> <li>From the eastern end of the viaduct to the west side of Tonnelle Ave, with a bridge over the freight tracks</li> </ul>	late 2019 to early 2024 (4.5 years)
Bridges	<ul style="list-style-type: none"> <li>At Secaucus Rd and the freight tracks</li> <li>Relocation of utilities</li> </ul>	late 2019 to early 2024 (4.5 years)
Tonnelle Ave bridge	<ul style="list-style-type: none"> <li>New bridge carrying Tonnelle Ave over the new rail right-of-way</li> <li>Relocation of utilities at this location</li> </ul>	early 2020 to late 2022 (3 years)
Modifications to Allied Interlocking	<ul style="list-style-type: none"> <li>Tie-in to the existing NEC tracks just east of County Rd</li> </ul>	mid-2023 to mid-2026 (3 years)
<b>PALISADES TUNNEL</b>		
Cut-and-cover support of Tonnelle portal and start of tunnel	<ul style="list-style-type: none"> <li>New portal location is east of Tonnelle Ave in the western face of the Palisades, directly beneath Paterson Plank Rd</li> </ul>	mid-2019 to mid- 2020 (1 year)
TBM mining of Palisades tunnel	<ul style="list-style-type: none"> <li>Rock TBM mining using two staggered, parallel TBMs from the tunnel portal to the Hoboken shaft site</li> </ul>	late 2019 to late 2022 (3 years)
Cross passage construction	<ul style="list-style-type: none"> <li>Cross passages at approximately 750-foot intervals along the length of the Palisades tunnel using drill-and-blast mining techniques and jet grouting</li> </ul>	late 2021 to late 2022 (1 year)
<b>HOBOKEN AND RIVER TUNNEL</b>		
Hoboken shaft and starter tunnel	<ul style="list-style-type: none"> <li>Access/ventilation shaft constructed from ground surface using conventional excavation methods</li> <li>Starter tunnels excavated using conventional methods with the use of grouting to stabilize the area</li> <li>Relocation of utilities at this location</li> </ul>	mid-2019 to mid-2021 (2 years)
Underpinning and ground improvement	<ul style="list-style-type: none"> <li>Underpinning required at Clinton St and Willow Ave</li> </ul>	late 2019 to early 2021 (1.5 years)
TBM mining of river tunnel	<ul style="list-style-type: none"> <li>Soft-soil TBM mining using two staggered, parallel TBMs from Hoboken shaft under the Hudson River to Twelfth Ave shaft</li> </ul>	early 2021 to late 2022 (2 years)
Cross passage construction	<ul style="list-style-type: none"> <li>Cross passages at approximately 750-foot intervals along the length of the river tunnel using drill-and-blast mining techniques, jet grouting, and ground freezing</li> </ul>	late 2022 to mid-2023 (1 year)
<b>RIVER TUNNEL IN-WATER WORK</b>		
Ground improvement of low-cover area in river	<ul style="list-style-type: none"> <li>Low cover above the river tunnel stabilized via jet grouting</li> </ul>	late 2019 to late 2020 (15 months)



**Table 3-2 (Cont'd)**  
**Major Construction Elements for the Preferred Alternative**

Construction Activity	Notes	Duration
<b>MANHATTAN ALIGNMENT</b>		
Ground freezing and SEM construction	<ul style="list-style-type: none"> <li>Ground freezing techniques stabilize ground</li> <li>SEM mining to construct tunnel opening beneath northbound Twelfth Ave</li> </ul>	mid-2019 to mid-2021 (2 years)
Twelfth Ave shaft	<ul style="list-style-type: none"> <li>Access/ventilation shaft constructed from ground surface</li> <li>Relocation of utilities at this location</li> </ul>	mid- 2019 to mid-2021 (2 years)
West 30th St cut-and-cover tunnel	<ul style="list-style-type: none"> <li>Relocation of utilities between Eleventh and Twelfth Aves</li> </ul>	early 2020 to early 2022 (2 years)
Tenth Ave cut-and-cover tunnel	<ul style="list-style-type: none"> <li>Excavation of Tenth Ave between West 30th and West 31st Sts</li> <li>Relocation of utilities at this location in</li> </ul>	early 2021 to late 2024 (4 years)
Underpinning of Lerner Building	<ul style="list-style-type: none"> <li>Underpinning required at the Lerner Building (450 West 33rd St)</li> <li>Relocation of utilities at this location</li> </ul>	early 2021 to late 2024 (4 years)
Track connections to PSNY	<ul style="list-style-type: none"> <li>Track work and modifications to the I Ladder and A Yard tracks below grade between Ninth and Tenth Aves</li> <li>Lowering of track profile and grade of Empire Tunnel</li> </ul>	mid-2026 (6 months)  late 2024 to mid-2026 (2 years)
<b>TUNNEL INTERNAL CONCRETE, FAN PLANT STRUCTURES AND FIT-OUT</b>		
Twelfth Ave shaft and fan plant, Manhattan tunnel	<ul style="list-style-type: none"> <li>Construct internal concrete finishes for Twelfth Ave shaft and Manhattan tunnel</li> <li>Construct Twelfth Ave fan plant</li> </ul>	late 2021 to mid-2025 (4 years)
Tonnelle Ave portal, Palisades tunnel	<ul style="list-style-type: none"> <li>Construct internal concrete finishes for Tonnelle Ave portal and Palisades tunnel</li> </ul>	mid-2021 to mid-2023 (2 years)
Hoboken shaft and fan plant, river tunnel	<ul style="list-style-type: none"> <li>Construct internal concrete finishes for Hoboken shaft and river tunnel</li> <li>Construct Hoboken fan plant</li> </ul>	early 2022 to mid-2025 (3.5 years)
<b>SYSTEM WORK</b>		
Track work	<ul style="list-style-type: none"> <li>Surface alignment: conventional ballast system installed</li> <li>Tunnel: direct fixation track system installed</li> </ul>	late 2023 to late 2026 (3 years)
Signals and communications	<ul style="list-style-type: none"> <li>Signaling and communication systems installed along full length of new rail alignment</li> </ul>	mid-2024 to mid-2026 (2.25 years)
Overhead catenary	<ul style="list-style-type: none"> <li>Overhead catenary supports and catenary wire installed along full length of new rail alignment</li> </ul>	mid-2024 to mid-2026 (2.25 years)
Traction power substations	<ul style="list-style-type: none"> <li>Upgrades/modifications made to existing substations in Hackensack and at PSNY</li> </ul>	mid-2024 to mid-2026 (2.25 years)
Mechanical, electrical, and plumbing finishes	<ul style="list-style-type: none"> <li>MEP finishes (tunnel ventilation, lighting, facility power substations, and controllers) installed along new tunnel alignment and at shaft sites, fan plants, tunnel portals</li> </ul>	early 2024 to mid-2026 (2.5 years)
<b>Total for New Hudson River Tunnel</b>		<b>88 months (approximately 7 years)</b>
<b>NORTH RIVER TUNNEL REHABILITATION</b>		
<b>RECONSTRUCTION OF FIRST NORTH RIVER TUNNEL TUBE</b>		
Construct access to existing tunnel portal and site set up	<ul style="list-style-type: none"> <li>Construct decking system to access tunnel portal from Tonnelle Avenue staging area</li> </ul>	late 2026 to early 2027 (3 months)
Installation of redundant life-safety infrastructure and tunnel ventilation; decommissioning of tube to be reconstructed	<ul style="list-style-type: none"> <li>Install redundant life-safety infrastructure (fire standpipes and emergency means of egress) in tube to remain open</li> <li>Install dust collection/suppression and ventilation systems in tube to be reconstructed</li> <li>Decommissioning activities to take tube to be reconstructed out of service</li> </ul>	late 2026 to early 2027 (3 months)



**Table 3-2 (Cont'd)  
Major Construction Elements for the Preferred Alternative**

<b>Construction Activity</b>	<b>Notes</b>	<b>Duration</b>
Demolition and reconstruction of existing bench walls and duct banks	<ul style="list-style-type: none"> <li>Demolish existing bench walls along full length of tube; remove existing piping/cablings from embedded duct banks.</li> <li>Construct new bench walls with embedded duct banks; pull new piping and cabling</li> </ul>	early 2027 to late 2027 (9 months)
Installation of new conduit and cabling	<ul style="list-style-type: none"> <li>Remove existing conduit/cabling including catenary, signals and communication wiring from tunnel ceiling and walls along full length of tube</li> <li>Construct new conduit/cabling</li> </ul>	mid-2027 to early 2028 (7 months)
Demolition and reconstruction of track system	<ul style="list-style-type: none"> <li>Demolish existing ballast-supported track system along full length of tube</li> <li>Construct new direct fixation track system</li> </ul>	late 2027 to mid-2028 (6 months)
Commission reconstructed tube	<ul style="list-style-type: none"> <li>Commissioning activities to place reconstructed tube back into service</li> </ul>	mid-2028 (2.5 months)
<b>RECONSTRUCTION OF SECOND NORTH RIVER TUNNEL TUBE</b>		
Construct access and site set up	<ul style="list-style-type: none"> <li>Site set up for second tube construction area</li> </ul>	mid-2028 (3 months)
Installation of redundant life-safety infrastructure and tunnel ventilation; decommissioning of tube to be reconstructed	<ul style="list-style-type: none"> <li>Install redundant life-safety infrastructure (fire standpipes and emergency means of egress) in tube to remain open</li> <li>Install dust collection/suppression and ventilation systems in tube to be reconstructed</li> <li>Decommissioning activities to take tube to be reconstructed out of service</li> </ul>	mid-2028 to late 2028 (3 months)
Demolition and reconstruction of existing bench walls and duct banks	<ul style="list-style-type: none"> <li>Demolish existing bench walls along full length of tube; remove existing piping/cablings from embedded duct banks.</li> <li>Construct new bench walls with embedded duct banks; pull new piping and cabling</li> </ul>	late 2028 to late 2029 (9 months)
Installation of new conduit and cabling	<ul style="list-style-type: none"> <li>Remove existing conduit/cabling including catenary, signals and communication wiring from tunnel ceiling and walls along full length of tube</li> <li>Construct new conduit/cabling</li> </ul>	mid-2029 to late 2029 (7 months)
Demolition and reconstruction of track system	<ul style="list-style-type: none"> <li>Demolish existing ballast-supported track system along full length of tube</li> <li>Construct new direct fixation track system</li> </ul>	late 2029 to early 2030 (6 months)
Commission reconstructed tube	<ul style="list-style-type: none"> <li>Commissioning activities to place reconstructed tube back into service</li> </ul>	mid-2030 (2.5 months)
<b>Total for North River Tunnel Reconstruction</b>		<b>44 months (approximately 4years)</b>

### 3.5 SUMMARY OF CONSTRUCTION ACTIVITIES BY SITE

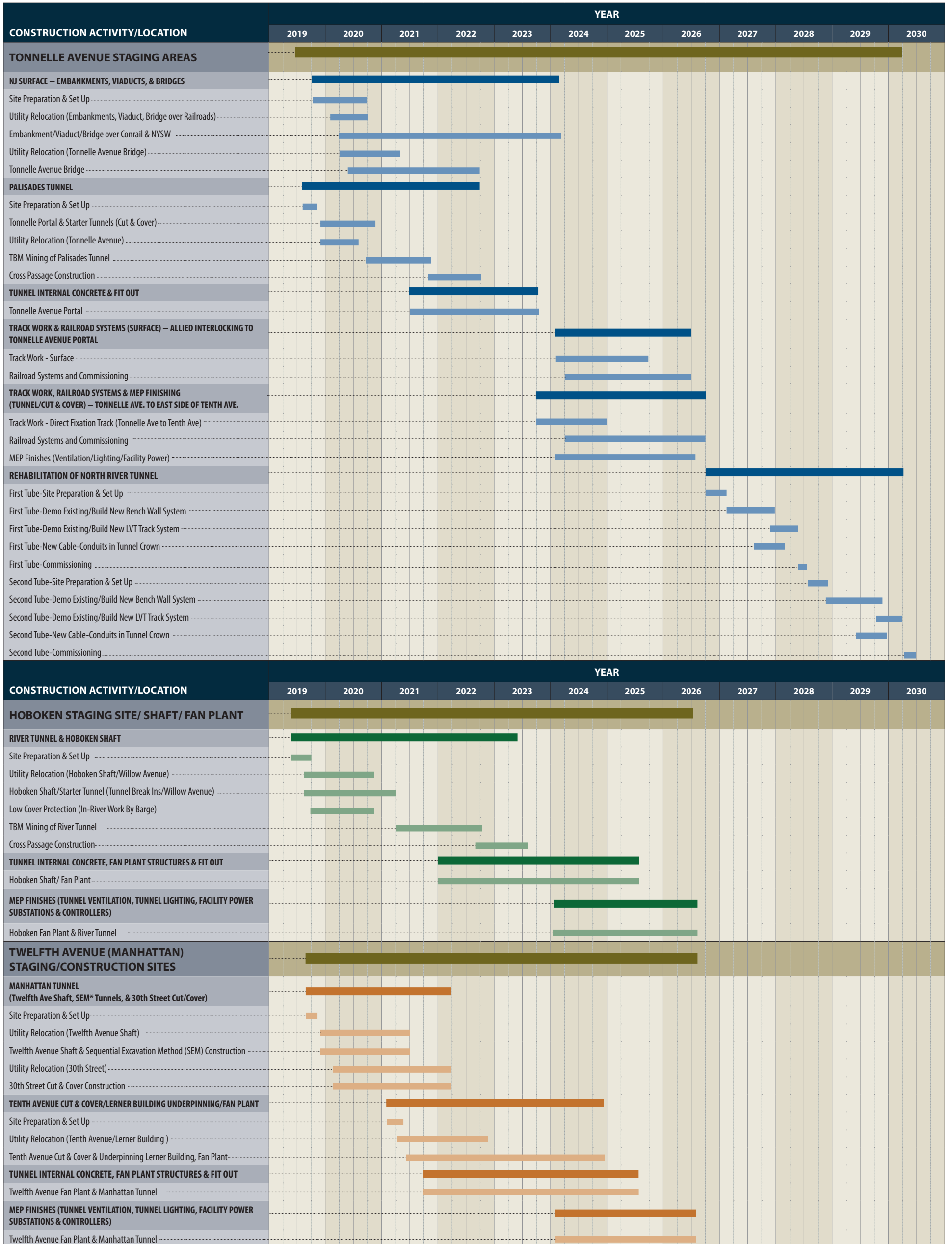
The majority of the construction activities would be staged from the three main construction staging areas: (1) the new and existing tunnel portal locations, with staging areas on either side of Tonelle Avenue (U.S. Routes 1 and 9) in North Bergen, New Jersey; (2) the Hoboken shaft site and staging area in Hoboken, New Jersey; and (3) the Twelfth Avenue shaft site and staging area in New York. Based on the overall construction schedule for the various construction activities, the peak construction activities (most intensive numbers of workers and truck movements) for the Preferred Alternative would occur in 2021 at the Tonelle Avenue and Twelfth Avenue sites for the Hudson River Tunnel, while the peak construction activities at the Hoboken site for Hudson River Tunnel would occur in 2022. The rehabilitation of the North River Tunnel is scheduled to begin in 2026 after the opening of the new tunnel, with peak construction activity for this aspect of the Preferred Alternative occurring in 2029 at the Tonelle Avenue site.

At the Tonnelle Avenue staging site, construction activities would commence in mid-2019 for the new tunnel construction (with new construction for the surface embankments, viaduct, and bridges, as well as the mining of the Palisades tunnel. Construction activity at this staging site would extend to mid-2026, when the new tunnel would be completed. Immediately following completion of the new tunnel, construction activities associated with the rehabilitation of the existing North River Tunnel would begin, starting in late 2026 and extending to early 2030 when the rehabilitation would be complete, and service using the North River Tunnel would be fully restored.

At the Hoboken shaft site and staging area, construction activities would commence in mid-2019 with the construction of the shaft, and would extend until mid-2026 as the Hudson River segment of the new Hudson River Tunnel from the shaft site to the Manhattan bulkhead is completed.

At the Twelfth Avenue shaft site and staging area, construction would also begin in mid-2019 with shaft construction. Construction activities at this site and in Manhattan would continue until mid-2026, as the trackwork, railroad systems, and MEP finishing work is completed for the portion of the new tunnel in Manhattan and connecting to PSNY.

**Figure 3-17** provides a summary of the duration of major construction at each of the three staging sites. \*



Note: \* = Sequential Excavation Method