INTRODUCTION

As part of the Port Authority of New York and New Jersey’s (PANYNJ) Harbor Deepening Project, the Anchorage Channel within New York Harbor that serves the Port of New York and New Jersey, requires to be deepened to 50 feet below mean low water (MLW), for a length of 19,000 feet.

As part of the Harbor Deepening Project, the Anchorage Channel would be deepened to 50 feet below mean low water (MLW), for a length of 19,000 feet. The New York City Department of Environmental Protection (NYCDEP) owns, operates, and maintains two existing water siphons in the Harbor. Due to their shallow depth, both existing siphons must be relocated before dredging of the Anchorage Channel can be completed.

To replace the existing siphons, a new 9,440-linear-foot, 72-inch-diameter pipeline to be installed within a 12-foot diameter tunnel. The existing and proposed siphons are shown in Figure 1. The NYCDEP have previously crossed this reach of the harbor to the north with the construction of the Richmond Tunnel in the 1960s, although at depths of over 900-feet, the tunnel crossing of the harbor was excavated through rock.

A pressurized face tunnel boring machine will be used to excavate the tunnel through the predominantly soft ground soil conditions from a launch shaft in Staten Island to a receiving shaft in Brooklyn. The tunnel will be lined with gasketed, precast concrete segments. Following completion of the tunnel drive, a welded steel pipeline will be installed and the void between the steel pipeline and the tunnel will be backfilled with grout.

The harbor siphon tunnel is scheduled to be the first tunnel built under the Hudson River or the New York Harbor in many decades. The pressurized face tunneling methodology that will be used to construct the harbor siphon will be the first application of this technique for a sub-aqueous crossing in New York City.

On behalf of the New York City Department of Environmental Protection (NYCDEP) and the PANYNJ, the New York City Economic Development Corporation (NYCEDC) is managing a project. The CDM/Hatch Mott MacDonald Joint Venture (JV) is retained by the NYCEDC to perform engineering design services for this project.
1.1 Project Overview

The project comprises the following primary components:

- **Bored Tunnel (Siphon):** 12-foot nominal diameter bored tunnel to be constructed using a pressurized face tunnel boring machine and lined with a precast concrete, gasketted, segmental lining system. The tunnel drive will be approximately 9,440 feet in length. A 72-inch diameter steel transmission pipeline will be backfilled inside the tunnel.
- **Shafts:** The Staten Island launching shaft will be located near the intersection of Front Street and Murray Hulbert Avenue on Staten Island. The Brooklyn receiving shaft will be located in Shore Road Park near the intersection of Shore Road Land and Shore Road.
- **Trenchless Crossings:** Two micro-tunneled crossings, up to 84-inch in diameter and are approximately 325 and 120 feet in length, will be constructed beneath the Staten Island Railroad (SIR).
- **Staten Island and Brooklyn Land Piping:** Water transmission mains constructed in open cuts to connect the new infrastructure with the existing water distribution system.
- **New Chlorination Station:** A new chlorination station is required to boost the chlorine residual in the new siphon water supply.
- **Abandonment of Existing Siphons and Metering Chambers:** The existing siphons and metering chambers will be abandoned in place following successful commissioning of the new siphon.

1.2 Project Purpose

The two existing cast iron siphons provide a backup water supply to Staten Island in the event of an outage of the existing 10-foot diameter Richmond Tunnel, the primary transmission facility between Brooklyn and Staten Island. The siphons were constructed across the Anchorage Channel of the Upper New York Bay using the wet-trench excavation method and are 36-inch
diameter (Siphon No. 1) and 42-inch diameter (Siphon No. 2) constructed circa 1917 and 1925, respectively.

The purpose of this project is to replace the existing water siphons between Brooklyn and Staten Island, New York. The project involves the abandonment of the two existing water siphons and their replacement with a new water siphon across the New York Harbor and the Anchorage Channel, between Brooklyn and Staten Island. Figure 1 shows the general location of the existing and proposed siphons.

As part of this project, water mains on both the Brooklyn and Staten Island sides of the crossing will be installed to connect the new siphon to existing water transmission mains. In addition, a new chlorination station will be constructed on Staten Island to serve the new siphon. Various sewers will also need to be constructed or relocated to accommodate the project.

The proposed siphon would be located at a depth of at least 85 feet below MLW within the channel limits. This depth was selected in order to place the new siphon at a depth that would not be affected by the currently proposed dredging of the Anchorage Channel, as well as any reasonably anticipated future dredging within the channel.

2 GEOLOGY & HYDROGEOLOGY

2.1 Regional Geology & Hydrogeology

The project site lies within the Hudson River Basin on the border between Staten Island and Brooklyn, near the confluence of the Manhattan Prong of the New England Uplift, the Newark Basin Physiographic Province, and the Atlantic Coastal Plain Physiographic Province. The region is generally characterized by thick glacial sediments overlying sedimentary and metamorphic rock. The bedrock at the project site is judged to be of the Hartland/Manhattan Schist Formations. Following the glacial retreat and subsequent sea level rise, sediments including poorly graded sand, silty sand, slightly organic silt, clay, and peat have been deposited in and adjacent to New York Harbor. The surficial geology of the land sides of the proposed tunnel alignment are dominated by glacial soils overlying bedrock.

2.2 Site Geology and Groundwater Conditions

The available subsurface data gathered during the multiphase geotechnical investigation program indicated high variability in the subsurface conditions along the proposed tunnel alignment, the shaft locations and water transmission mains. The subsurface stratigraphy in the project vicinity (land and marine), as encountered in the geotechnical borings, can be categorized into stratigraphic units as shown in Figure 2 and listed below:

- Fill
- Glacial Soils:
  - Silty Sand and Gravel (SSG)
  - Fine to Medium Sand (FMS)
- Recent Marine Sediments:
  - Plastic Silt and Clay (PSC)
  - Marine Sand with Silt (MSS)
  - Interlayered Clay, Silt and Sand (ICSS)
- Lower Deposits:
  - Lower Silt and Clay (LSC 1 and LSC 2)
  - Lower Sand and Silt (LSS)
  - Lower Sand and Gravel (LSG)
- Bedrock
At the tunnel horizon, the groundwater pressure will be primarily controlled by the water level within the harbor. Toward the land side portions of the alignment, the groundwater head at the tunnel horizon will be greater than the hydrostatic pressures from the harbor tide level, as indicated by observation well data.

3 SHAFT DESIGN

The locations of the two shafts were established based on establishing connections with the existing water distribution system, availability of suitable land, environmental impacts, and a suitable site for launching and servicing of a tunnel boring machine. The TBM launch shaft is located on a vacant lot in Staten Island, while the TBM receiving shaft will be located within a park at Shore Road in Brooklyn. Both shafts will be backfilled and contain 8 feet internal diameter riser pipes in the final configuration.

Two alternative methods of shaft construction were determined to be appropriate for shaft construction: ground freezing; or slurry walls. Although Slurry Walls were designed the contractor will be allowed to use either method as selected by the contractor.

The internal diameter of the Staten Island Launching Shaft is 28-feet with the base slab approximately 88-feet below existing ground level. The Brooklyn receiving shaft is 24-feet internal diameter and the base slab is approximately 140-feet below existing ground level. Shaft diameters were selected to accommodate water main piping and appurtenances, TBM launch at Staten Island, and TBM reception at Brooklyn.

The slurry wall panels were modeled and the slurry wall panels were reinforced to carry these forces. The reinforcement at the tunnel eyes for the break-out and break-in was specified using glass fiber reinforced polymer (GFRP) to allow the TBM to mine through the shaft wall without...
The slurry wall panels are to be excavated through predominantly granular soils with decomposed and weathered rock on the Staten Island side. The use of a hydromill (hydrofraise) was considered to be suitable for the anticipated ground conditions and to achieve the required verticality tolerance (1 in 200) for the construction of the slurry wall panels. The panel geometry was set out to accommodate a three-bite primary panel with a one-bite secondary panel. The secondary panel has an overlap of at least 6-inches with the adjacent primary panel concrete to form a robust joint between panels.

Watertightness of the shaft is defined in the contract specifications by allowable inflow criteria of 0.07 gallons per minute overall, and 0.0125 gallons per minute from any single source, with no running water from the wall permitted. The panel arrangement for the Staten Island Shaft is shown in Figure 3.

![Figure 3 – Staten Island Shaft Slurry Wall Panel Arrangement](image)

## 4 TUNNEL ALIGNMENT

The bored tunnel will consist of a nominal 12-foot excavated diameter, precast concrete, segmental lined tunnel, extending from the Staten Island shaft beneath New York Harbor to the Brooklyn shaft. A 72-inch welded steel pipeline will be installed in the tunnel to convey water between Brooklyn and Staten Island. The annular void between the steel pipeline and the bored tunnel lining will be backfilled with concrete. The alignment was established to meet a number of construction and operational considerations outlined below.
4.1 Staten Island Bulkhead and Demolished Piers

The tunnel vertical alignment near the Staten Island shaft has been located at a depth to provide clearance beneath the timber piles of both the existing bulkhead wall and the demolished Pier No. 8. The timber piles of the demolished pier were either pulled or cut at the mudline. The pile tip elevations have been assessed based on available historic drawings.

The results of the site investigation indicated that the Pier No. 8 and Pier No. 9 piles toward the harbor end of the piers were likely driven deeper than indicated on the historic drawings. As part of the risk management approach adopted on the project, the horizontal alignment was amended to avoid the plan location of the harbor end of the demolished piers.

4.2 Harbor Dredging

The proposed siphon must be constructed at a depth sufficiently below the proposed channel depth of El. -50.0. The NYCDEP has also expressed an objective of constructing the proposed siphon deep enough to accommodate possible future harbor deepening programs. Based on the constraints defined for the project, the proposed siphon will be installed with the top of pipe at or below El. -75.9. This depth will be maintained across the Anchorage Channel, the Bay Ridge Channel, and the Stapleton Anchorage.

4.3 Brooklyn Seawall

The Belt Parkway, a six lane highway, and the adjacent Promenade at Brooklyn are protected from the harbor by a seawall. Historic design drawings and bathymetric data show that the seawall is founded on a relatively shallow riprap foundation placed on the previously existing mudline. The tunnel vertical alignment was set to provide sufficient cover below this structure.

4.4 Gravity Drainage of the Tunnel

The vertical alignment of the siphon tunnel has been subject to a number of changes. The final alignment is based on the requirement to provide gravity drainage of the tunnel to one of the shafts and to position the vertical alignment with due consideration of the ground conditions. The final vertical alignment provides a slope from the Staten Island Shaft toward the Brooklyn Shaft.

5 TUNNEL LINING DESIGN

The lining rings have an internal diameter of 10'-4" and an outer diameter of 11'-8". The rings consist of four 67.5° parallelogram segments and two 45° trapezoidal segments. The nominal width and thickness of the lining rings are 56.0 inch and 8.0 inch, respectively. The rings are tapered 0.5 inch, with a minimum width of 55.5 inch and a maximum width of 56.5 inch.

Several different cross sections were analyzed to study the effect of rock and the various soil strata along the project alignment on the tunnel lining. The effect of dredging in reducing the load on the lining after construction was also investigated.

Each segment is fitted with ethylene-propylene-diene monomer (EPDM) gaskets to resist water ingress into the completed tunnel. Dowels are provided at the circumferential joints, with a typical pitch of 22.5°, and two bolts are provided at each radial joint.

The gaskets are designed for a maximum hydrostatic pressure of 9.0 bars, including gap and offset, providing a factor of safety of two in relation to the actual hydrostatic pressure. The material properties for the segments are:

Compressive strength of concrete, fc' = 7,500 psi
Yield strength of reinforcement, fy = 75,000 psi
6 STEEL WATER MAIN

The required internal diameter of the steel water main through the siphon tunnel is 72-inches. The wall thickness required to meet to NYCDJ standards is 0.625-inch. The pipes will be joined by a single internal field welded lap joint and verified by magnetic particle and dye penetrant testing.

Following a corrosion control study recommendations were made for controlling corrosion of the steel pipe in the shafts and tunnel, these included:

- The steel piping should be electrically isolated from all tunnels and casings through the use of plastic or plastic coated spacers.
- The high pH cement grout backfill will passivate the external surface of the steel piping which will result in an extremely low rate of external corrosion.
- The steel piping in the tunnel and shafts may be installed without an external coating since the high pH grout will protect the pipe.

7 ACCESS

A number of options were considered for access to the water main in the tunnel through the shafts. These options were assessed in relation to constructability, durability, access, and maintenance. It was considered beneficial to provide additional space for access to the water main by providing a 96-inch diameter riser pipe in the shafts. Full shaft backfill around the riser pipe was preferred by the NYCDJ for durability and long term maintenance considerations.

8 CURRENT STATUS OF THE PROJECT

In October 2009, the NYCDJ issued a Negative Declaration determining that the proposed project will not have a significant effect on the environment. An Environmental Assessment Statement was prepared by the JV to provide supporting evidence to the determination.

The NYCDJ issued a Request for Qualifications (RFQ) for the provision of tunnel construction services on August 19, 2009. Contract Award and Notice to Proceed are anticipated to be in the second quarter of 2010.