Proposed Construction Methods for the Harbor Island Desalination Facility Intake Tunnel

Introduction

This document describes methods of construction for a proposed intake tunnel extending from a proposed seawater desalination facility located on Harbor Island, outside of Aransas Pass, Texas, to a point in the Gulf of Mexico (GOM) approximately 3.1 miles east of the desalination facility. The proposed tunnel would be constructed via a tunnel boring machine (TBM) such that surface disturbance would occur in only two locations—the vertical work shafts at the intake point in the GOM and at the desalination facility on Harbor Island. The remainder of the construction would occur deep within the ground and under the sea bed, undetectable to marine life, flora, fauna or humans above ground.

Numeric measurements and values referenced in this document rely upon preliminary design considerations which are subject to confirmation or revision during the final engineering-design phase.

Preliminary Routing

The proposed intake tunnel measures approximately 3.1 miles long, shown in blue in Figure 1 below. A profile of the tunnel is provided in Figure 2.

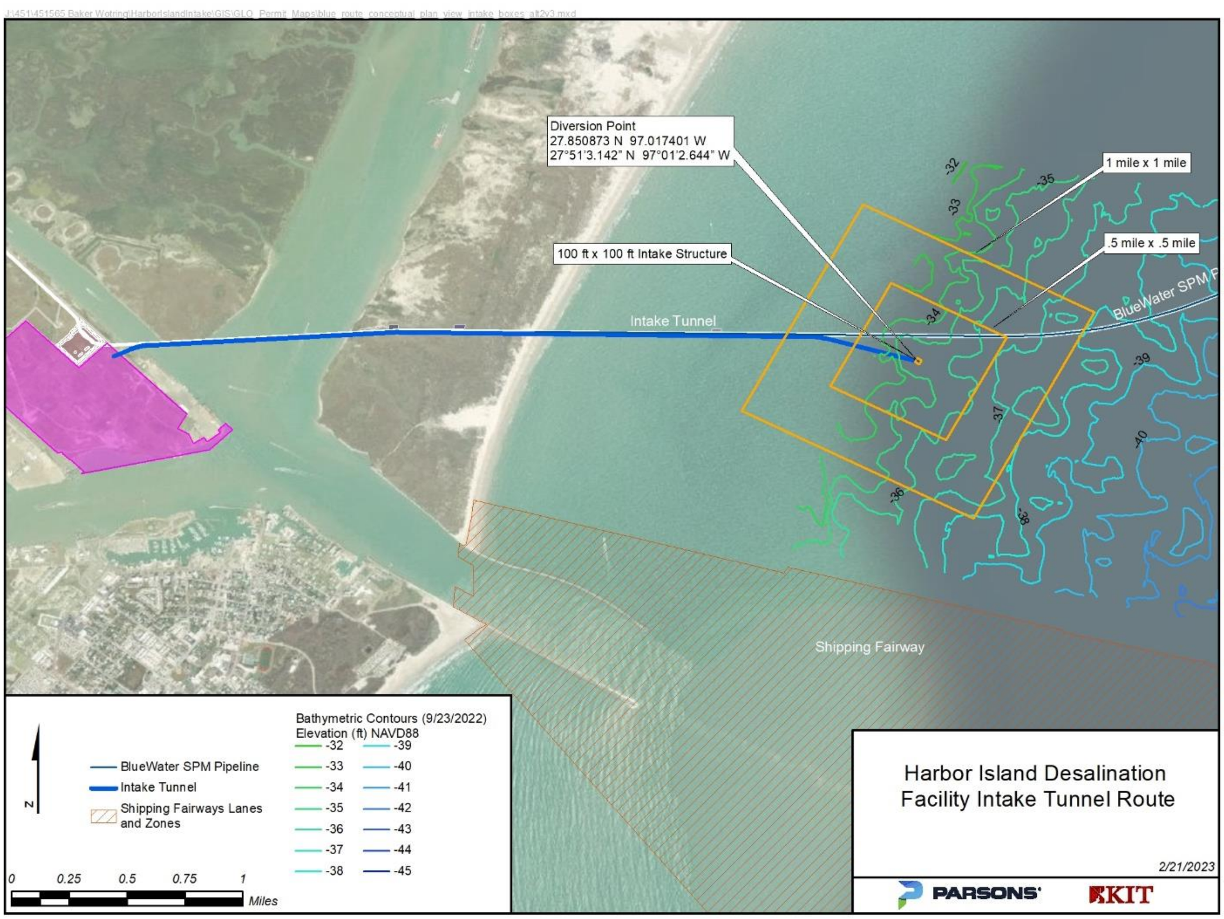

Figure 1. Alignment of Proposed Seawater Intake Tunnel

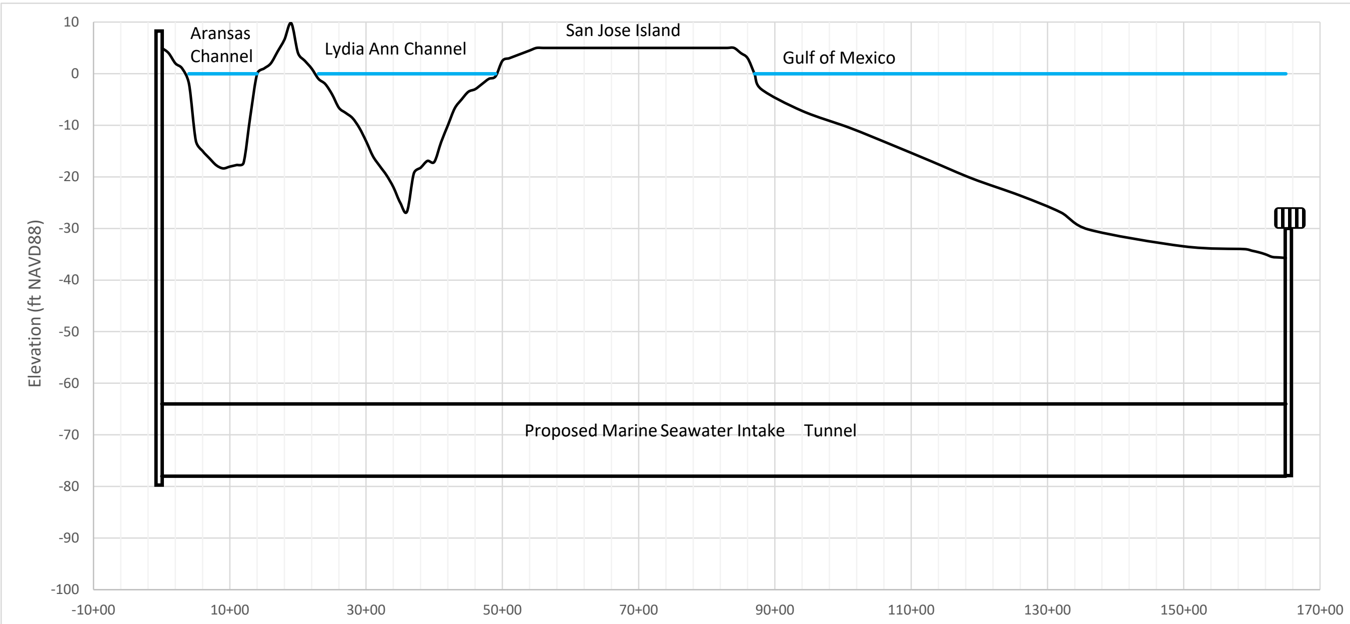

Figure 2. Profile of Proposed Seawater Intake Tunnel

The main work shaft (also known as the TBM launch shaft) is the vertical shaft planned for the Harbor Island site on the left side of Figure 2. A second shaft will be excavated in the Gulf of Mexico at the terminus of the tunnel, where the intake structure will be installed on the right side of Figure 2.

Assumed Geotechnical Conditions

A project-specific geotechnical investigation has not yet been performed along the alignment; however, some geotechnical data for inshore portions of the alignment have been reported in Appendix J to the license application for the Bluewater Texas Terminal Deepwater Port project to the Army Corps of Engineers (available at regulations.gov/docket/MARAD-2019-0094). The data available indicate soils at the elevation of the proposed tunnel include medium dense to very dense silty sands, and soft to very stiff lean and fat clays. Available boring logs and a generalized understanding of the geology in the Corpus Christi area suggest that only sands and clays are present at the elevations at which the tunnel will be constructed. These conditions are characterized as “soft ground”, that is, in laymen’s terms, soils and not rock. All tunneling will occur at elevations well below sea level. The top of the tunnel is proposed to be at an elevation of approximately -64 feet NAVD88.

A geotechnical investigation will be performed prior to final design that will influence many aspects of the design. The ultimate configuration and methods will be determined during final design after the geotechnical investigation is completed. Presented below is a generalized version of typical construction methods for a tunnel.

Proposed Tunnel Method

Because it is anticipated that soft soils will be encountered for the entirety of the tunnel profile, the proposed method for tunnel construction is an earth pressure balance TBM (Figure 3). TBMs for soft ground have a cylindrical shield to support the soil strata being mined through, and a bi-rotational cutterhead equipped with cutting tools to remove the intact ground and draw the loosened material into the cutterhead. The excavated soils are captured and removed from a chamber behind the cutter wheel.

Pressurization of the face of the excavation is required in permeable soil under unbalanced hydrostatic pressure, given the expected tunnel condition under the sea. If the face of the excavation were not pressurized, the unbalanced water pressure could allow soils to flow through the gaps in the cutter head and into the TBM and resulting excavation, filling the tunnel with soil. Such conditions may cause sinkholes and excessive settlement at the ground or sea bed and may cause damage to existing infrastructure (e.g., adjacent oil pipelines).

Earth pressure balance TBMs function by maintaining a pressurized environment in a void just behind the cutter head and excavation face called a “muck chamber.” The face pressure is continuously monitored by operators in the TBM. The muck is a mixture of fragmented excavated spoils and soil conditioning additives (if any) to improve the material handling properties of the excavated material. The muck chamber is created by a bulkhead separating the construction crew from the pressurized environment at the face. Soil is removed from this pressurized environment by removing it through a helicoidal screw contained in a long steel cylinder. The helicoidal screw turns to slowly remove soil from behind the pressurized bulkhead while maintaining the appropriate face pressure. At the rear of the screw auger is a slide gate, where excavated soils are discharged onto a conveyor belt and then into muck cars near the end of the TBM shield. The muck cars/belt conveyor transport the muck to the primary work shaft, where they are hoisted to the surface by muck boxes or a vertical conveyor and into a temporary stockpile area/surge pile.

The TBM shield is a cylindrical steel shell that is pushed forward along the tunnel, while the ground is excavated inside the shield. The main shield and tail shield support the ground as the tunnel lining is installed and fully protects workers within the tunnel. The shields fully encapsulate the excavation, never exposing the ground or leaving any area unsupported. The shield is propelled using hydraulic jacks that thrust against the tunnel lining system installed within tail shield. The shield is designed to withstand the pressure of the surrounding ground and hydrostatic pressure.

To support the excavated bore in the soft soils at depths below sea level, a precast concrete segmented liner is proposed. This lining type has become the industry standard lining for large diameter soft ground TBM mined tunnels and is designed to meet project requirements for durability and watertightness. The liner helps to maintain the pressure the machine is exerting on the ground and provides a solid base against which the thrust jacks in the TBM propulsion system can push the cutterhead forward. For this reason, the TBM is used in conjunction with a prefabricated ground support system, which most commonly consists of pre-cast concrete segments that are bolted and gasketed to form a watertight lining, like that shown in Figure 4. This watertight lining must be designed to withstand construction, ground, seismic and hydrostatic loads.

The concrete segments are erected in the tail shield of the TBM (Figure 5), bolted and gasketed together to form a continuous ring. Thus, a TBM advance cycle consists of excavation and then ring erection and grouting during the next TBM excavation cycle so that a continuous lining is built behind the TBM. The faces of the segments are usually tapered, so that when assembled they can be rotated to accommodate horizontal and vertical curvature of the alignment.

For corrosion protection, handling strength, and production needs, precast concrete tunnel segments are cast with a dense high strength concrete. Dense concrete is accomplished by using fine filler materials to fill the microscopic pores and voids between the cement particles. Concrete segments are usually reinforced by either steel reinforcing bars or steel fibers.

Precast concrete linings are fully capable of providing a structurally adequate and long-lasting tunnel lining in the presumed soil materials to depths beyond those of the proposed tunnel.

It should be noted however, that if geologic faults exist, the faults can create active shear zones which, when severe enough, could distort and shear a typical precast concrete lining. Accordingly, these fault zones must be given special design consideration details. Future geotechnical investigations will verify whether fault movement is a potential concern along the tunnel alignment.

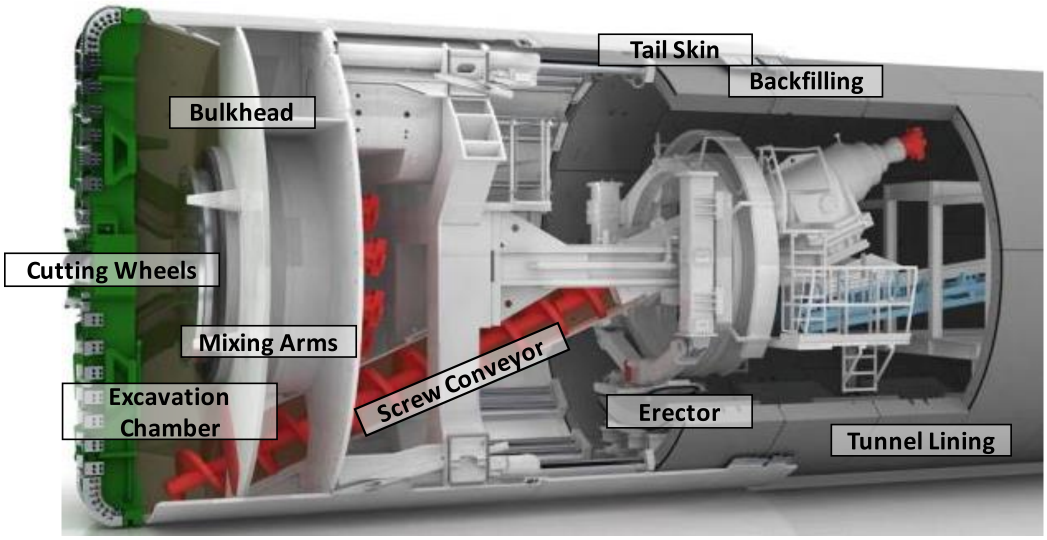

Figure 3. Earth Pressure Balanced (EPB) TBM
(Modified from https://www.herrenknecht.com/en/products/core-products/tunnelling/epb-shield.html)

Figure 4. Example Pre-cast Concrete Segmental Lining

Figure 5. EPB TBM Erecting a Pre-cast Concrete Segment

Shaft Construction

Shafts are the most important component of most water-conveying tunnel projects because these are the only locations of construction activities notable at the ground surface. The shafts contemplated for the intake tunnel system include two very distinct types of shafts. The main work shaft is where the TBM is launched and serves as the main access point for tunneling activities. This shaft will be located on the Harbor Island site, with a diameter large enough for optimal tunnel activities, and nearly all the at-grade construction activities will occur here.

The second shaft will be located offshore in the GOM and is where the TBM may be retrieved and will serve to install the pipe connection between the tunnel and the intake structure above the sea bed. The configuration of this shaft and the methods required to construct it are far different from the primary shaft. Both shafts are discussed further below.

Main Shaft Support System

The shaft excavation support system currently considered most feasible for the proposed main tunnel shaft based on the assumed soil conditions is secant piles (Figure 6). Secant piles provide a water-tight, rigid excavation support system. Secant piles are installed by drilling a series of overlapping circular shafts that form a concrete cylinder. A secant pile shaft support system is also designed to act as a compression ring, accounting for installation tolerances and the irregularities of the individual round columns.

The individual drilled shafts are constructed using typical drilled shaft foundation techniques. The shaft excavation walls are supported using drilling slurry, drilled temporary steel casing, or both. The use of temporary steel casing helps maintain a tighter vertical tolerance and helps when biting into adjacent primary concrete shafts. Each secant pile shaft will be 80 to 100 feet deep. The final diameter of the main shaft at Harbor Island will be approximately 35 feet.

A secant pile support system can be constructed in very challenging ground and groundwater conditions to cut off groundwater flow so that only a sump in the excavation bottom is required for groundwater control.

For shafts where the TBM break-in location is beneath the groundwater table in unstable/flowing ground, ground improvement may be performed to create a zone of modified ground (e.g., jet grouting) around the planned penetration location. This zone acts as a seal and has several advantages, including: 1) the zone allows the contractor to pressurize the TBM face to the required full pressure upon leaving the shaft, and 2) it reduces the risk of overmining, which could lead to settlement or sinkholes to the ground surface. In addition, special seals surrounding the TBM shield are designed for ingress of the TBM into the shaft wall.

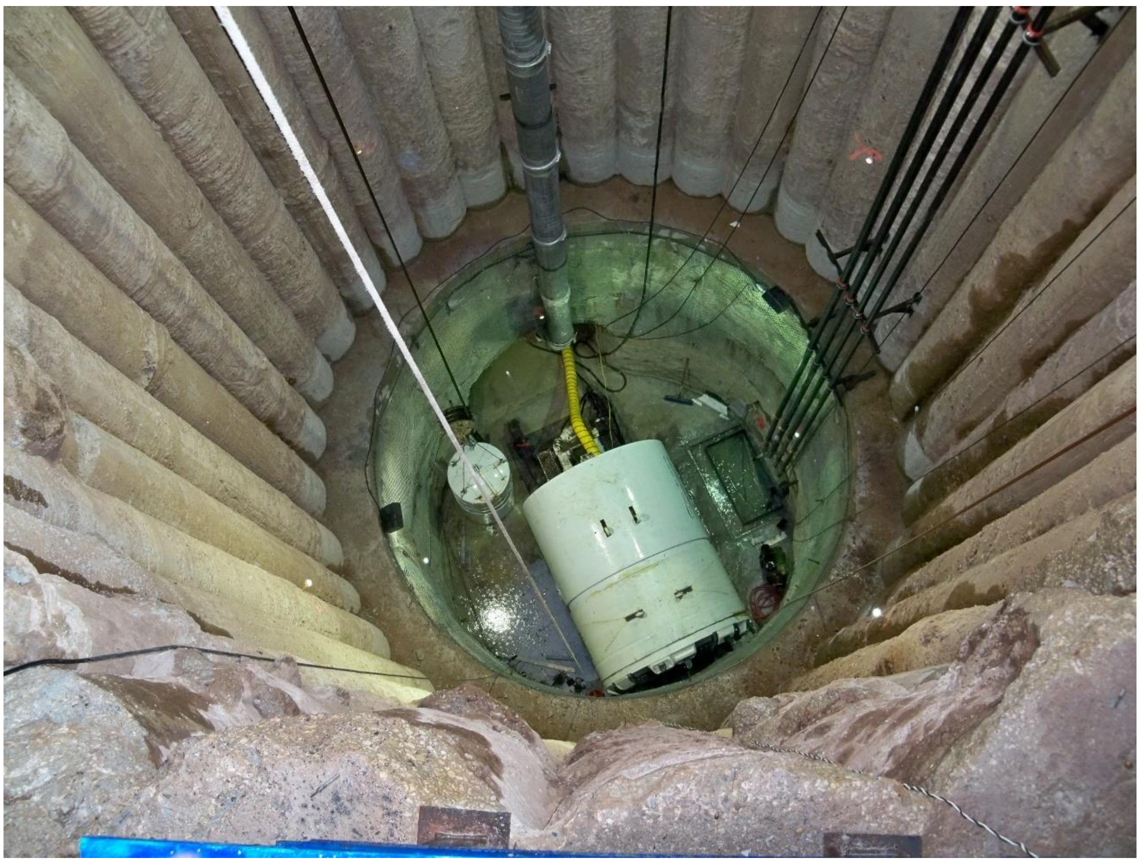

Figure 6. Example of Secant Pile Shaft with 10 ft diameter TBM

Offshore Intake Shaft

The proposed tunnel will terminate approximately 1.3 miles offshore, in the open waters of the Gulf of Mexico, at a sea bed elevation of approximately -35 feet NAVD88. The top of the proposed tunnel is at an elevation of approximately -64 feet NAVD88, so there is approximately 29 feet of separation between the top of the tunnel and the sea bed. The precise construction methods and details of an offshore shaft can be very complicated and subject to the Contractor’s means and methods. We again note that the ultimate configuration and methods will be determined during final design after the geotechnical investigation is completed.

The offshore shaft connection will be constructed from platforms mounted above the offshore shaft location. Well before the TBM arrives to the offshore shaft location, a large caisson is lowered to the sea bed, anchored into the sea bed, and dewatered. Ground improvements may be performed on sea bed sediments in the space between the tunnel and the sea bed. These may include jet grouting or excavation via tremie concrete. A shaft will be constructed down to the level of the tunnel inside the caisson, excavating vertically down through the grouted/concreted plug. The TBM bores horizontally through the same grouted/concreted material to arrive at the shaft site.

After the spaces are safely excavated, a vertical conveyance pipe, or riser, is installed between the top of the tunnel up to an elevation near the sea bed, where the prefabricated intake system manifold is installed on the riser, and velocity caps connected to the manifold. Eventually, the portion of the caisson above the sea bed is removed, and the connection between the manifold and tunnel is completed. Connection of the intake riser to the intake tunnel is completed by remotely operated vehicles and robotic "sea horses". Some operations may be performed by divers.

Figure 7. Example of a Vertical Conveyance Shaft Being Lowered Toward a Tunnel at Sea

Main Work Shaft Site Considerations

Main Shaft Site Characteristics

The main work shaft site on Harbor Island is the primary construction site for the tunneling project. The proposed shaft site location is in a currently undeveloped coastal zone, officially an island, that was historically used for industrial oil and gas operations. The developed properties near the site are industrial or dedicated to commercial shipping. The nearest residences are more than 1.2 miles from the site. The site is served by Harbor Island Road and then Texas State Highway 361.

Activities at the main work shaft site may include:

- Site lighting at night
- Lifting of tunnel muck from tunnel to ground surface with heavy cranes
- Lowering of supplies from ground surface to tunnel
- Compressor for ventilation system
- Heavy earth moving equipment to remove and dispose of excavated muck
- Other large construction equipment (cranes, front end loaders, etc.)
- Concrete plant to produce concrete segments for tunnel lining segments
- Batch plant for grout
- Precast concrete lining segment storage areas
- Temporary laydown for TBM components and other major equipment

- Other laydown space for materials and supplies
- Storage facilities
- Workshops
- Power substation or generators
- Project offices and employee facilities, including employee parking
- Arrival of supply trucks
- Storage of stripped topsoil for future site reclamation

The existing property provides enough space to store the entire inventory of the pre-cast tunnel lining segments. The TBM major components will be delivered to the Harbor Island TBM launch shaft site with very large truck-trailers. The disposal location for the tunnel spoils and truck haul routes will be developed during design.

Shaft Size

The main work shaft will be large enough so the TBM components can be lowered into the shaft, and muck cars can be lifted out, while also allowing room for additional construction equipment, ventilation, laborers, and other project and construction needs. Figure 8 shows an example of the main head of a TBM system being lowered into the main work shaft and shows typical cranes that would be utilized for tunneling operations, albeit the machine shown is significantly larger than required for the Harbor Island project.

The top of the shaft will include personnel safety measures that meet OSHA requirements. Often, the excavation support system (secant piles) is constructed so it simply extends above the ground surface a sufficient distance to create a wall or barrier to act as fall protection. Shaft flood protection from storm surges during construction will be a project requirement, and the safety barrier will be constructed so that it can support the design flood event.

Figure 8. Example of a Large-diameter TBM Cutterhead and Shield Being Lowered into a Main Work Shaft

Muck Handling and Disposal

Excavated material (i.e., muck) produced from tunneling excavation must be removed from the tunnel, temporarily stored outside the main work shaft, dewatered, and placed on site as fill material.

The main work shaft site will accommodate a temporary muck pile (surge pile) and allow for seamless removal of muck to upland areas needing fill. Tunnel muck will be removed from the tunnel using a rail muck wagon that is raised and lowered using a crane through the shaft site

It is anticipated that the tunnel will be excavated at a rate of 60 to 120 feet per day, including a multi-shift, 24-hr workday. This equates to 350 to 700 cubic yards (CY) per day of material. At this rate, the 3.1mile tunnel would be completed in approximately 190 days. The entire 3.1-mile tunnel is expected to produce approximately 100,000 CY of muck.

The main work shaft site will accommodate a muck pile that results from at least two days of mining. This would allow for an entire weekend of tunneling without requiring fill material management over the weekend.

All site entry and exit at the site will follow all required state, local, and federal rules for surface water protection and avoidance of construction nuisances.

Power Requirements

For a tunnel diameter up to 25 feet, the power required to run the TBM may be around 6 to 10 MW. Additional power is required for other project activities, such as: muck conveyor system and boosters, shaft and tunnel ventilation systems, lighting, and other ancillary equipment. For a large tunnel project such as this proposed seawater intake tunnel, a power substation may be required.

Site Restoration

After completion of tunneling construction activities at the site, the main work shaft will be converted into the exit well for the desalination facility intake tunnel. A marine life screening structure and pump station will be constructed at an intake bay adjacent to the exit well. Much of the remainder of the Harbor Island property will be used for the construction of the desalination facility and a future shipping terminal.

Geotechnical Instrumentation and Control of Ground Movements

Prior to actual construction, an extensive preconstruction survey is conducted of the area within the potential influence of the tunnel alignment and surface works. This is done over the entire alignment with a typical width of hundreds of feet. The condition of all structures and facilities, including surface features like roadways, and buried utilities are examined and documented. Given the location and alignment of this project, the instrumentation and control will be minimal. The tunnel will pass beneath an on-site road and possibly some utilities near the main work shaft before crossing beneath channels and the GOM. Instrumentation may be required if there are any crossings beneath petroleum pipelines.