Large-Diameter Microtunneling and MTBM Wet Retrieval at the Gilboa Dam Reconstruction Project

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Abstract

Gilboa Dam, located in upstate New York, impounds Schoharie Creek and forms the Schoharie Reservoir, the northernmost reservoir in the Catskill System of the New York City water supply. To ensure the dam's continued long-term performance and reliability, the New York City Department of Environmental Protection (NYCDEP) embarked on a reconstruction program to extend the dam's service life under the current New York State Department of Environment Conservation (NYSDEC) dam safety guidelines. NYCDEP will construct a Low-Level Outlet (LLO) to facilitate the ability to drain the reservoir and meet proposed conservation releases. The LLO consists of two 9-foot diameter tunnels (a water leg and a land leg), ultimately terminating at a new chamber that will release water to the Schoharie Creek downstream. The two tunnels are approximately 2,160 linear feet combined, and will be completed using trenchless microtunneling construction methods, with microtunnel boring machine (MTBM) wet retrieval when the water leg is mined into the receiving site at the reservoir's bottom. This paper reviews the overall project and then focuses on selected trenchless construction methods for large-diameter microtunneling, MTBM wet retrieval, and underwater construction.

INTRODUCTION

The Gilboa Dam, located in Schoharie County in upstate New York, was constructed between 1919 and 1927 to create the Schoharie Reservoir impoundment as a key component of New York's water supply system. The original dam was a classic NYCDEP gravity dam design, consisting of a 160-foot-high by 1,326-foot long spillway overflow structure constructed of mass Cyclopean concrete with a 3- to 5-foot-thick Ashlar masonry façade of mortared quarried stone on the entire downstream face, and a portion of the upstream face (Figure 1). The dam was abutted on the west by a 160-foot-high by 700-foot-long earth filled embankment section consisting of homogenously rolled earth fill with a concrete core wall. The stepped overflow structure, also constructed of Cyclopean concrete with stone veneer facing, cascades water from the Spillway into the Side Channel, which varies from 80 to 270 feet in width. The stepped façade is intended to dissipate energy as water overflows the Spillway.

Based on the age of the dam and as part of NYSDEC's forward looking program, an evaluation of the dam and appurtenances after being in service for over eight decades revealed evidence of deterioration and the need for reconstruction and upgrading to extend the dam's service life in line with current NYSDEC dam safety guidelines and operational standards (Gannett Fleming/Hazen and Sawyer Joint Venture July 2008).

Figure 1. Current Rehabilitated Spillway Control Section at Gilboa Dam

To extend and ensure continued reliable operation of the dam over the next 100 years of service, the NYCDEP embarked on a series of construction projects scheduled to be completed in phases, as summarized below. Although the focus for this paper is the trenchless microtunneling installation of the LLO tunnels and appurtenances, it is necessary to identify some of the work planned and completed through various phasing and sequences from 2008 through 2015 for the dam reconstruction and upgrade program.

DAM RECONSTRUCTION PHASING PLAN

To expedite initiation of construction work at the Dam Reconstruction project site, NYCDEP elected to complete the work with multiple construction contracts and phases. The contracts and construction phases were staged to allow some construction to be initiated while other design activities continue to progress. The components of work completed as part of the reconstruction and upgrade activities include:

- Installation of crest gates and notch (2009 to 2011)
- Clearing and preparation of project site for heavy construction (2009 to 2011)
- Reconstruction to improve dam stability—spillway façade and side channels (2011 to 2015)

The LLO Construction Contract, the subject of this paper, was awarded in 2015 with Notice to Proceed in June 2015, and is currently under construction. It involves the installation of an LLO and other appurtenances. The LLO requires the construction of a jacking shaft, two tunnels (108 inches in diameter) and two receiving sites. The tunnels will be constructed using microtunneling techniques to tap into the reservoir for the LLO water intake, a method not common for tunnels of this size, making the installation unique for today's standards. The objective of this paper is to present a detailed description of the Low Level Outlet, the associated features, and the construction methods to be used.

TRENCHLESS MICROTUNNELING CONSTRUCTION FOR LOW LEVEL OUTLET

This section focuses on the major components of the trenchless construction features associated with the LLO construction activities, construction methods to be employed, construction sequencing, and challenges that must be overcome to successfully complete the project and achieve the project objective(s). Descriptions of the associated trenchless structures and anticipated construction methods are also discussed.

Low Level Outlet Microtunneling Alignment

The microtunneling alignment originates at the intake structure location at the bottom of Schoharie Reservoir, upstream side of the Dam, and under approximately 130 feet of water. The water leg of the microtunneling alignment projects in the northeasterly direction outside of the Dam footprint to the Gate Shaft, at the right abutment, which also serves as the Jacking Shaft for the microtunneling operations. From the Jacking Shaft, the land leg of the LLO Tunnel projects in the northwesterly direction towards Schoharie Creek downstream of the dam, and terminates at the face of the proposed portal where the MTBM will be received (Figure 2).

Gate Shaft (Microtunneling Jacking Shaft)

The Gate Shaft, which is designated as the Jacking Shaft for both the water and land leg microtunneling operations for the LLO construction, is 43 feet in excavated diameter and extends from the ground surface at approximately El. 1,156± feet to the top of bedrock at El. 1,127± feet (Figure 3). The shaft then proceeds from top of the bedrock at 40.5 feet in excavated diameter down to the bottom of the shaft to approximately El. 969.5 feet. The geologic profile at the Gate Shaft is includes a 29.3-foot overburden stratum atop the bedrock, with a total shaft excavation depth of approximately 186.8 feet. The anticipated shaft excavation sequence and construction method involves perimeter pregrouting to control groundwater inflow during shaft excavation and launch of the MTBM for microtunneling operations. The shaft is planned to be pregrouted in a series of 10-foot zones, as shown in Figure 4.

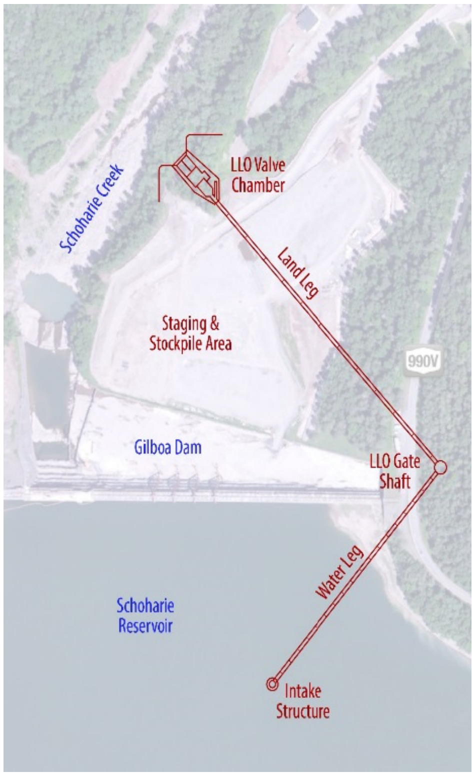

Figure 2. Low Level Outlet Tunnel Alignment

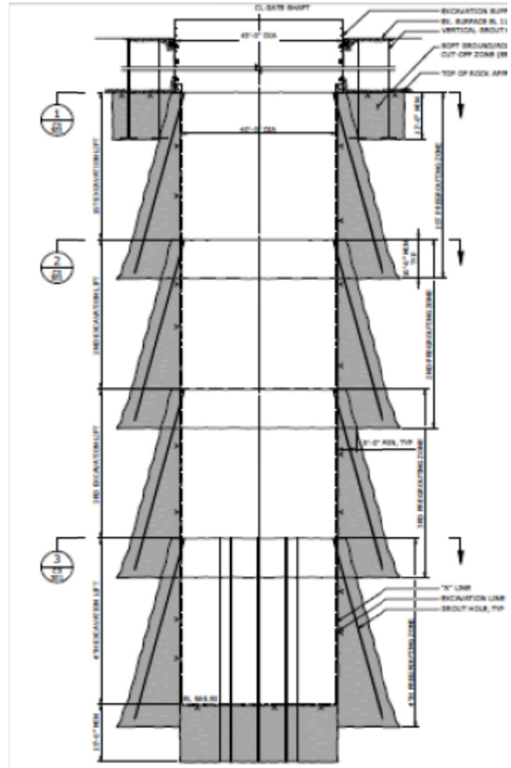

Figure 3. Gate Shaft Vertical Section

Prior to excavation of each grouted zone, four 3-inch probe holes will be drilled to verify the effectiveness of the grouting. If the groundwater inflow exceeds 5 gallons per minute (GPM) per hole drilled, the zone in question would receive additional grout treatment until excavation is advanced to the bottom of the shaft. The face of the excavated shaft is expected to be treated with 3-inch-thick shotcrete with welded wire fabric.

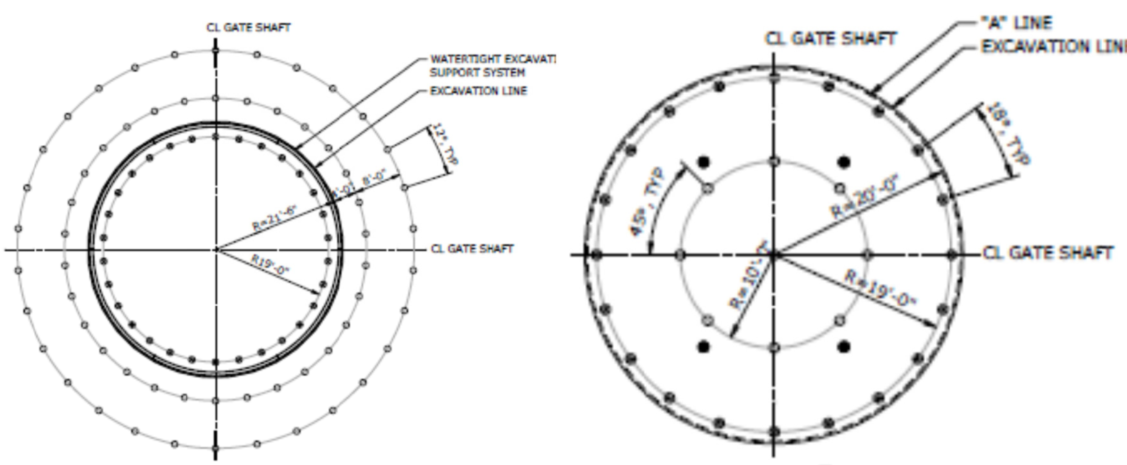

Figure 4. Perimeter Pregrouting (left) and Probe Drill Pattern (right)

After tunnel construction is complete, two roller gates will be installed within the lower part of the gate shaft. These will be situated at the outlet of the upstream tunnel and the inlet of the downstream tunnel. The roller gates will provide a means for dewatering the tunnel as well as the Gate Shaft for future inspection and maintenance. The roller gates will also provide a means for additional security and a source of redundancy to control reservoir levels if there are problems with the downstream control valves. The shaft will be concrete lined to an approximate finished inside diameter of 40 feet.

Receiving Site at Intake Structure Location

The initial phase of construction for the intake structure will be to prepare a suitable receiving pit for the wet retrieval of the MTBM. This portion of the work involves dredging and underwater grading, predominantly accomplished from the reservoir surface from a working barge platform. The finished grades will be verified by sonar. The normal reservoir water level reading is approximately at El. 1,130 feet, while the top of the bottom reservoir sediment layer at the location of the intake and MTBM receiving site is recorded at approximately El. 996 feet. As part of the receiving site and intake structure foundation preparation, it is required that the limits of the receiving site be dredged with pneumatic and hydraulic dredging techniques with some of the dredged material cast within the bottom of the reservoir (see Figure 5a for receiving site dredging plan; Figure 5b for receive site profile).

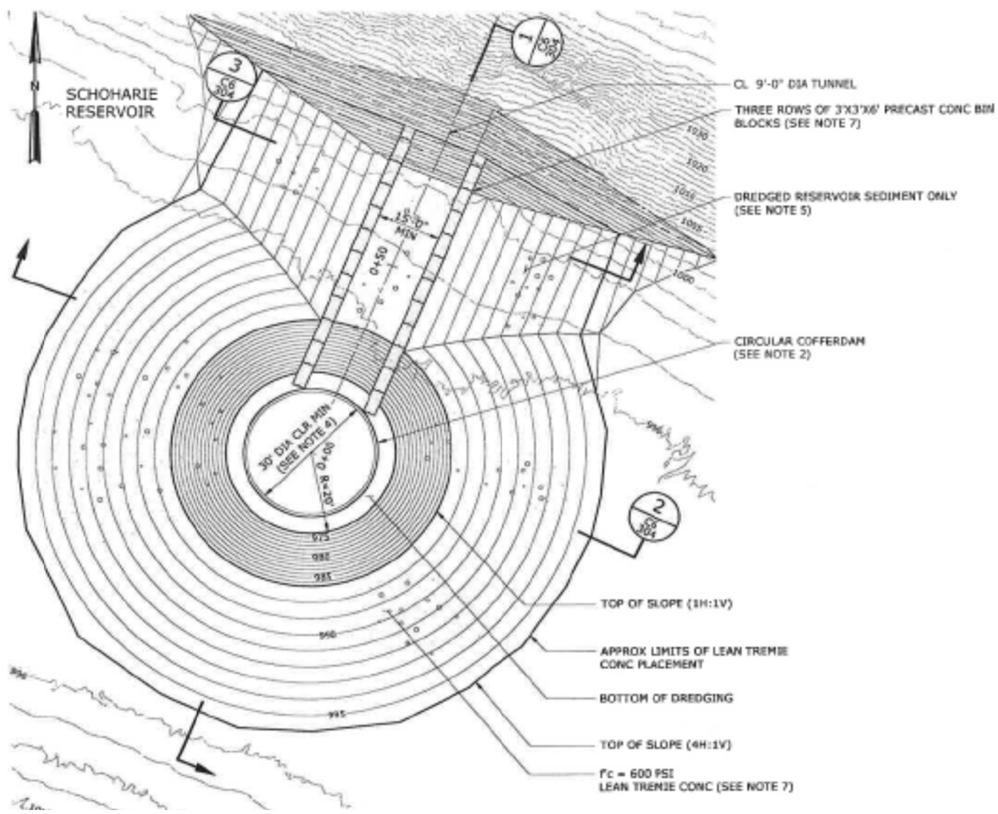

Figure 5a. LLO Intake Receiving Site Dredging Plan

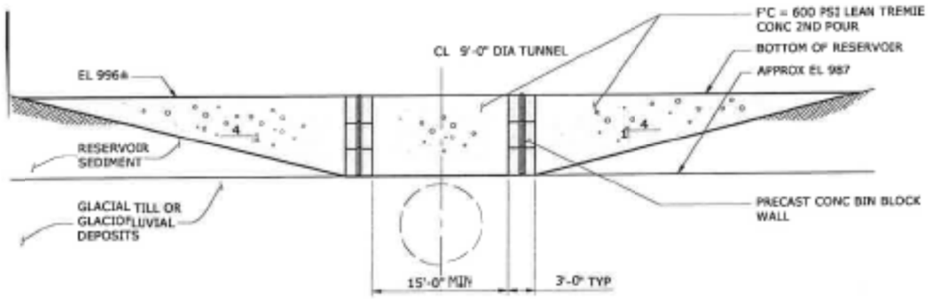

Figure 5b. LLO Intake Receiving Profile

The dredged limits of the receiving site are required to be replaced with tremie concrete with a 30-foot-diameter, 26-foot-tall cofferdam at the center line of the water leg tunnel to the Jacking Shaft. The cofferdam will be fitted with a prefabricated breakout eye for the MTBM reception and filled with sand pending the arrival of the MTBM at the completion of the water leg tunnel mining.

After the tunnel construction is complete, a specialty underwater diving team will be engaged to install the intake elbow that will be secured with tremie concrete within the cofferdam, install the bulkhead atop the elbow, and install the intake structure. The bulkhead atop the elbow will remain in the closed position until the tunnel is ready to be flooded.

Receiving Site at Portal / Valve Chamber Location

The receiving site for the land leg tunnel excavation is located downstream of the Gilboa Dam where microtunneling terminates at the portal, along the bank of Schoharie Creek. This portal will remain as the eastern wall for the open-cut excavation portal that will house the bifurcation piping connection between the tunnel and the valve chamber to control drawdown of the reservoir. As part of the preparation required to receive the MTBM, a 10-foot cube grout plug is required to be installed at the portal face to stabilize the ground for MTBM break-out at completion of the land leg tunnel.

After the land leg tunnel construction is complete, the contractor will continue with other work necessary for installation of the valve chamber structure, connection with the tunnel, and finishing for the LLO water release into Schoharie Creek.

Microtunneling Construction for Low Level Outlet Tunnels

The two tunnel segments as described above are scheduled to be constructed utilizing a 108-inch-diameter MTBM with slurry pressurized face (AVN2200AB) manufactured by Herrenknecht. Per contract requirements, the new MTBM is specifically designed and fabricated for use at the Gilboa Reconstruction Project (Figure 6a). The MTBM design requirements include the ability to mine mixed ground conditions containing cobbles and boulders in sizes up to 30% of the MTBM outside diameter, as presented by the Geotechnical Baseline Report (Gannett Fleming / Hazen and Sawyer 2014). The MTBM is designed to operate under an external hydrostatic pressure equivalent to 153 feet of water head and allow for underwater retrieval. The MTBM is required to be equipped with an air lock hyperbaric chamber to allow for safe personnel access to the tunnel face in the event of obstruction intervention or cutter maintenance (Figure 6b). An extensive list of additional functionalities for the MTBM is also included in the design.

Figure 6a. Microtunnel Boring Machine

Figure 6b. Hyperbaric Chamber

The jacking pipe scheduled for use as the initial and final ground support is a 108-inch-diameter, 1.375-inch-thick Permalok steel pipe with T-7 gasketed joints for both the land and water leg tunnels. Per the contract, two intermediate jacking stations are required for each of the tunnel legs. Utilization of butt welded steel jacking pipe joints are not allowed for this project.

SUBSURFACE CONDITIONS

The subsurface conditions along the tunnel alignment are summarized herein. The summary is limited to the horizon of the tunnel from the intake location at the reservoir to the tunnel portal at the downstream end of the alignment.

The LLO Tunnel is expected to be mined in bedrock on either side of the jacking shaft for approximately 1,725 linear feet, about 80% of the entire alignment. As such, the discussion regarding the subsurface, for the scope of this paper, is limited to the area from the location of the jacking shaft to the receiving sites at the intake and portal locations (that is, the reaches of the interface/mixed ground conditions and the bedrock). This information is extracted from the Conformed Contract Documents and is summarized below.

Gate Shaft (Microtunneling Jacking Shaft))

Subsurface conditions at the jacking shaft location consist of a 27- to 29-foot-thick overburden that is predominantly glaciofluvial deposits consisting of stiff to hard silty/clay with traces of sand and gravel. These soil materials have low permeability, with the groundwater level varying between 6 and 10 feet below the ground level. The bedrock lies directly below the overburden strata and consists of fine grained sandstone with occasional layers of siltstone and clay seams. The rock is generally moderately fractured to massive with generally high recovery and Rock Quality Designation (RQD) percentages ranging from 88 to 100 percent with an average recovery of 99 percent. The bedrock that will be encountered during excavation of the gate shaft is expected to be strong and abrasive. Laboratory test results indicate that the Unconfined Compressive Strength varies from 17,870 psi to 28,990 psi, with an average of strength of 23,200 psi. The Cerchar Abrasivity index ranges from 4.4 to 5.1.

Land Leg Tunnel

The subsurface condition in the tunnel horizon for both the land and water leg alignments is similar to the rock condition described for the gate shaft rock, except for the short reach of mixed ground conditions at the terminal ends of the tunnels. The profile of the bedrock along the tunnel alignment varies, with the high point located at the Gate Shaft where top of bedrock is recorded at 29 feet below grade. From the Gate Shaft, the top of bedrock dips downward on both sides of the tunnel alignment.

On the land leg side, the top of bedrock slopes towards the portal wall of the Valve Chamber, where it appears to strike the crown of the tunnel towards the end of the tunnel drive, which presents as overburden fill with cobbles and boulders, as the topography slopes down toward Schoharie Creek downstream of the Dam.

Water Leg Tunnel

Similarly, the top of bedrock dips downward from the Gate Shaft towards the Intake location in the reservoir and appears to strike the crown of the tunnel, where it appears to transition from bedrock to soft ground (Figure 7). This soft ground is characterized as very fractured and weathered rock with an RQD varying between 0 and 37 percent. The soft ground anticipated in the tunnel horizon consists of very compact granular glacial till soil materials predominantly consisting of coarse to fine sand with moderate amounts of silt and varying amounts of gravel. Occasional cobbles and boulders are anticipated from the rock interface to the location of the receiving site. The bottom of the reservoir consists of silt and miscellaneous debris deposited over the years.

Groundwater

The maximum water level within the Schoharie Reservoir is approximately el. 1,130 feet. Groundwater appears to follow the land topography, varying from 6 to 10 feet in the overburden. In situ parker permeability test results conducted at the Gate Shaft location indicate permeability ranging from 1.75E-05 cm/sec to a high of 3.62E-04 cm/sec. Groundwater inflow is likely to occur during Gate Shaft excavation.

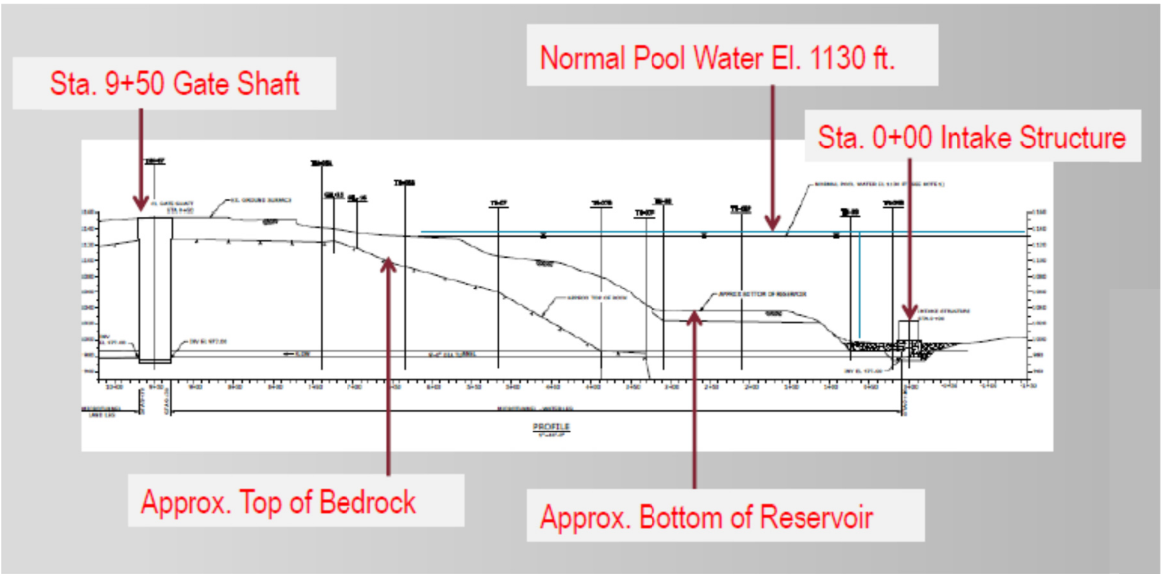

Figure 7. Water Leg Tunnel Cross Section

PROJECT-SPECIFIC FEATURES AND REQUIREMENTS FOR LLO TUNNELS

Groundwater Control

Because of relatively high rock permeability and the close proximity of the Schoharie Reservoir with a water elevation at 1,130 feet, a pre-excavation grouting program is required around the Gate Shaft's perimeter. The pregrouting will extend the full depth of the shaft to seal off the potential pathways of the groundwater inflows during shaft construction and launch of the MTBM.

Intake Structure and MTBM Receiving Site

Because of the soft silt/clay deposits at the bottom of the reservoir, dredging will occur to remove the soft sediments to competent depth for the intake structure foundation. Also, ground modification will be performed to replace the dredged area with tremie concrete to stabilize the cofferdam. This will improve the soils for microtunneling operation. When the MTBM breaks into the cofferdam, it will be rigged and hoisted to the surface via the wet retrieval method with assistance from the specialty diving operation.

Fish and Wild Life Permit Requirement

Because of eagle (endangered species) nesting at the site, blasting to excavate the Gate Shaft and any other construction activities within 500 feet of the eagle nest are prohibited between January 1 and July 31, leaving a limited window to commence and complete the shaft construction.

Tunnel Construction Requirements

It is stipulated that the land leg tunnel will be constructed first so that lessons learned with MTBM performance and ground behavior can be carried into the water leg operation. Also, as a requirement for the water leg construction, three bulkheads are to be installed as follows:

- Bulkhead No. 1: On the inside face of the land leg in the Gate Shaft.
- Bulkhead No. 2: Directly behind the MTBM to provide a seal at the front of the lead pipe.
- Bulkhead No. 3: At the rear of the lead pipe.

The two lead bulkheads are to be fabricated watertight with power cables, slurry lines, and access hatch to the face of the MTBM in the event of obstruction intervention and disk cutter maintenance. In addition, the contract stipulates an air lock compatible with the MTBM.

PROJECT CONSTRUCTION STATUS

The construction contract was awarded to the low cost responsive bidder, Southland Renda Joint Venture, with a construction bid price of $142 million with a Notice to Proceed (NTP) date of June 29, 2015. The contractor has mobilized to the site, working with the construction manager in providing critical submittals for long lead equipment, materials, and permits. Preparatory work has begun, and includes site clearing, temporary access road construction, and geotechnical borings in the valve chamber area for wing wall foundations.

REFERENCES

Gannett Fleming / Hazen and Sawyer. 2014. *CAT-212C Schoharie Reservoir Low Level Outlet Conformed Contract Documents.* Gilboa: NYCDEP.

Gannett Fleming / Hazen and Sawyer - Joint venture. July 2008. *Gilboa Dam Reconstruction Environmental Assessment and Project Description.* New York: New York City Department of Environmental Protection.