Chapter 1

CHATTAHOOCHEE TUNNEL

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ABSTRACT

This paper discusses the overall challenges to construct a 15,125.7 m (49,625 LF), wastewater drainage tunnel in Cobb County, Georgia by a joint venture of Gilbert Southern Corp. and S.A. Healy Co. and a construction manager Parsons, with Jacobs Associates as a subcontractor. The goal of the project is to provide wastewater retention during peak usage and is connected to a treatment facility near the Chattahoochee River. The primary component of the project is the TBM-driven hard rock tunnel. Additional works include drill and blast areas; four intake interceptors, two construction shafts and a 33.5 m (110 ft), diameter pump station shaft.

INTRODUCTION

For the last twenty years, the city of Atlanta, Georgia has resided near the top of the list of fastest-growing urban areas in the United States with Cobb County being a principle in this phenomenon. Bordering northwest Atlanta, the county is experiencing a tremendous population growth that is projected to continue well into the future. Cobb County Water System (CCWS), has acted to meet the demands for wastewater service. Currently handling approximately 70 mgd, CCWS engineers have foreseen the possibility that the quantity could double. The Chattahoochee Tunnel Project serves the dual purpose of increasing system capacity as well as preventing sanitary sewer overflows into the protected Chattahoochee River.

The heart of the project is the 15,125.7 m (49,625 ft), long, 5.58 m (18 ft 4 in), excavated diameter tunnel. It terminates at a pump station shaft that feeds the existing R.L. Sutton Water Reclamation Facility. Four intake sites collect both sewer flow and storm water runoff. During high usage times, the tunnel will serve as a storage reservoir for the wastewater, preventing the reclamation plant from becoming overwhelmed. The tunnel, as designed by the Georgia-based firm Jordan, Jones & Goulding, Inc., will have a capacity peak flow of 300 mgd. At the time the project was let at $113.6 million dollars, it represented the most expensive upgrade ever undertaken by Cobb County. It is worthwhile to note that through careful planning, CCWS had all of the funds available. No federal funding was required. It is also

Figure 1. Chattahoochee hard rock tunnel

important to note that CCWS has gone forward with this project solely with an eye to the future before federal mandates.

Notice To Proceed was given to Gilbert Southern and S.A. Healy Company team on June 28, 2000. Construction of the Chattahoochee Tunnel was accomplished in three sections. The first was a 387 m (1270 ft), drill and shoot tunnel between the R.L. Sutton Pump Station Shaft and the Elizabeth Lane Construction Shaft. The second and third portions were driven utilizing hard rock Tunnel Boring Machines. The South TBM Drive began at the Elizabeth Lane Construction Shaft and terminated at the Circle 75 Construction Shaft. The North Drive began at Circle 75 and terminated at the Indian Hills Intake. With a total length of 6703.7 m (21,994 ft), the South Drive featured eight right hand and three left hand curves while following the approved easement. The North Drive negotiated three right hand curves and seven left hand curves over the 7876.9 m (25,843 ft) length. The slope of the tunnel progressed upwards at a rate of 0.1%, insuring a fall of 15.24 m (50 ft), over the entire length of the Chattahoochee Tunnel. Cover for the tunnel averaged approximately 64 m (210 ft). The maximum and minimum conditions occurred on the South Drive with a minimum of 28.6 m (94 ft), and a maximum of 130 m (425 ft). Depth of the Elizabeth Lane Construction Shaft is 55 m (180 ft), while the depth of the Circle 75 Shaft is 70 m (230 ft).

In both of the construction shafts, a starter tunnel and a tail tunnel were driven by drill and shoot methods. At a length of 98.7 m (324 ft), the horseshoe shaped starter tunnels served two purposes. Initially they provided the room needed to assemble the TBMs underground. The tail tunnels also provided the needed for room for TBM assembly. The Elizabeth Lane shaft was completed before the primary drill and shoot tunnel holed through, necessitating the need for the extra space. The 27.7 m (91 ft), tail tunnel served an additional purpose at the Circle 75 Shaft. The South Drive was scheduled for completion several months before the North Drive would be finished. This TBM holed through into the end station of the tail tunnel. The space was then utilized to disassemble the machine, thus keeping the impact to the ongoing North Drive operations at a minimum.

GEOLOGY

The ground that lies along the tunnel alignment is a strong, metamorphic rock associated with the Piedmont region of the southeastern portion of North America.

The bedrock consists of approximately 65% quartz-feldspar gneiss and 20% quartz-mica schist. The remainder consists of quartzite, granite, amphibolite and others. With significant amounts of quartz and garnet present, abrasive wear on TBM cutters was both anticipated and realized. The majority of the rock encountered ranged from good to very good and required only rock bolts for support. Numerous joint sets were encountered in the rock.

The South Drive was expected to present more of a challenge than the North portion. Traveling through a total of eight reaches, ground conditions were more varied on the South Drive. The potential for short areas of softer or extensively fractured ground existed, necessitating some ring steel ground support. As was anticipated, the North Drive, at 1.1 km (.67 mile) longer, but with only four reaches, did not have any areas that required the ring steel.

Six areas along the South Drive were designated by contract as Probe Zones. Surface topography such as low-lying areas with active streams or geological features such as fault zones created the potential for excessive ground water incursion into the deep tunnel. Prior to the bid, extensive core drilling samples were taken and analyzed to create a detailed geological mapping of the tunnel alignment, which proved to be very successful.

TUNNEL BORING MACHINES

The MB180HP TBMs used for this project were sister machines manufactured by The Robbins Company of Solon, Ohio. The TBM for the North Drive was originally built in 1990 and saw service in Hong Kong. The machine was returned to Ohio and underwent refurbishing in the Robbins' shop. The sister machine used for the South Drive was virtually new. Nearly identical with only a few minor exceptions, both of the TBMs are as described below. The 5.59 m (18´-4˝) cutterhead is driven by seven 422 Hp motors actuated by hydraulic clutches. The cutterhead speed was 10.8 rpm with a total torque of 1,536,257 ft.-lbs. The machine was equipped with a total of thirty-nine 475 mm (19 in) diameter cutters, each weighing in at 200 kg (440 pounds). The cutters consisted of both ¾ in. and ⅝ in. tip widths. The pressure per cutter was rated at 31,752 kg (70,000 pounds) for a total of 2,730,000 lb. of force against the face. Under a contractual arrangement with Gilbert/Healy, Robbins oversaw the rebuild of cutters on the main job site. Cutter usage was somewhat less than expected. Modifications to accommodate the ground conditions included the use of grizzlies and a false face in the cutterhead. The machines featured a dry scrubber system for dust control.

The successful completion of both of the tunnel drives is a decisive indication that given the geologic conditions encountered, the correct decision was made for both selection and design of the TBMs.

CONVEYOR SYSTEM

Gilbert/Healy opted to use a continuous conveyor belt system for each of the drives. The main belt system, reconditioned by Robbins, featured three boosters on the South Drive and four boosters on the North Drive with a return booster in both drives. The conveyor belt was a 0.6 m (24in) 550 PIW fire-resistant belt with 5/32 × 3/32 MSHA covers that ran at 182 m (600 ft) per minute. The boosters were positioned in the tunnel based on the number of curves and the tension in the belt. At the shafts, the material was transferred to a vertical belt, bringing the material up the shaft and transferring it to an overland conveyor. The vertical conveyor belt was a 1.21 m (48in) belt with a capacity of 450 tons per hour. A Roskie hopper was utilized at the bottom of the vertical belt to

Figure 2. Pump station shaft during drill and blast tunnel excavation

catch and reload any fallen debris from the vertical belt buckets. The tunnel belts culminate above ground through the main drive and into the belt storage unit.

GUIDANCE SYSTEM

Gilbert Healy opted to utilize a TBM guidance system manufactured by Precision Centerline Inc. PPS GmbH. The system is manufactured in Germany, and has had much more prevalent usage in Europe than in the USA. The primary difference between this system and the more traditional tunnel guidance set-ups is that a laser is not present. The major component is an unattended, remotely controlled theodolite that is capable of automatically locating and measuring target prisms. A two-axis, high accuracy inclinometer is also attached to the TBM. In operation, the theodolite is operated by a system computer that is mounted in an intrinsically safe cabinet in the operator's cab. Curves in the tunnel alignment are programmed into the computer. The guidance system performance proved to be excellent.

GROUND SUPPORT

Three types of ground support were required by contract for the entire length of the tunnel.

- TYPE A: (Four) 1.98 m (6.5 ft) rock bolts. Spaced at intervals of 1.21 m (4 ft) between bolts with each pattern of four on longitudinal 1.82 m (6 ft) centers (one pattern per TBM push).
- TYPE B: (Six), 2.44 m (8 ft), rock bolts. Spaced at intervals of 1.21 m (4 ft), between bolts with each pattern of six on longitudinal 1.21 m (4 ft), centers.
- TYPE C: Expanded steel ring. A three-piece arch of W6X20 steel segments with a rolled plate invert piece. Each ring was placed on 1.21m (4 ft), centers and supported welded wire fabric and/or steel lagging and when necessary, hardwood cribbing.

Two ATLAS COPCO 1238 hydraulic drills were mounted on platforms on either side of the TBM main beam. Holes for the rock bolts were drilled approximately 5.2 m

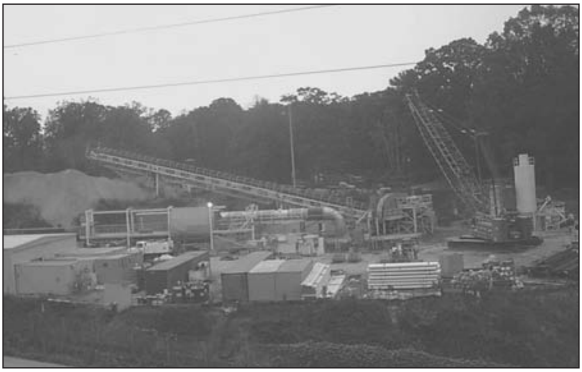

Figure 3. Top of shaft conveyor belt system

(17 ft), behind the excavated face. Specified rock bolts used in this project were a Norwegian design by Orsta Stall Industries, distributed by Ingersoll Rand, under the product name of CT-BOLT tm. The bolt is a mechanical bolt with a grouted jacket. A ChemGrout CG-570 mixer and pump unit was mounted on the upper platform of the bridge conveyor. On a typical production day, a two-man crew would grout rock bolts once a shift, averaging forty bolts completed per application.

The majority of the tunnel was supported with the Type A rock bolt design pattern. This was augmented with the installation of extra ‘spot bolts’ where ground conditions dictated. As expected, several areas of highly weathered Gneiss were encountered on the South Drive. This ground, when disturbed would act as a clayey-sandy silt, requiring Type C steel sets. The zones varied from 7.3 m (24 ft), to 122 m (400 ft). Throughout the drive, the TBM would occasionally enter short areas where weathered or blocky rock conditions were not severe enough to require the steel sets. Originally these areas were to be supported with Type B bolting. Gilbert/Healy instead opted to support these areas with Welded Wire Fabric mesh (4×4 W2×W2), attached with a combination of design bolts, spot bolts or five-hole mine straps. Additional materials occasionally used included 3.35 m (11 ft), long by four-inch channel caps, rolled to the correct radius. The determining factor for the choice of type of ground support was the competence of the ground for the installation of rock bolts.

DEWATERING

In both starter tunnels, Gilbert/Healy blasted out a sump chamber 4.8 m by 4.5 m by 12 m deep (16 ft by 15 ft high with a depth of 40 ft). Collected groundwater and water used by the TBM was pumped from a reservoir at the sump chamber, up the shaft to ground level, then into a mixing tank. Chemicals were added to control the pH. A coagulant, hydro chloride, was added to facilitate the removal of sediment. The water then passed through three settlement ponds before entering existing streams. Monitoring was ongoing for nephelometric turbidity with a maximum allowed of 25 NTU. The specifications for pH stated that water leaving the site must fall within in the 6 to 9 range. Groundwater occurrence throughout the tunnel was primarily seen as seeps and drips from exposed rock joints and rock bolts. Random areas exceeded 3.78 l/min (1 gpm). With both drives completed, groundwater flow from the South drive was 2,082 l/min (550 gpm), and 3,216 l/min (850 gpm) from the North.

Figure 4. Installing Type C steel sets

THE PUMP STATION AND CONSTRUCTION SHAFTS

The initial portion of the project undertaken was the 33.5 m (110 ft), diameter by 52 m (170 ft), deep Pump Station Shaft that would eventually become the terminus for the tunnel. The work plan for this shaft and both of the 9.75 m (32 ft), construction shafts were similar. The possibility of groundwater incursion necessitated a reinforced concrete diaphragm wall around each. Subcontractor Bencor Corp., a slurry wall specialist based in Dallas, Texas, performed the work. Bencor used their clamshell to excavate down to bedrock. From that point, they used a Hydra-Mill to complete the individual panels.

Gilbert/Healy excavated to bedrock inside the completed walls, then initiated a drill and shoot operation to take them to depth. The Pump Station shaft used two Tamrock 550 Tiger hydraulic track drills and a CAT 322BL excavator to sink the shaft. A Manitowoc 777 crane with a 10 CY muck box was used to hoist the material. The Elizabeth Lane and Circle 75 construction shafts used two Tamrock Commando 300 drills with a CAT 313B-CR excavator to achieve the respective depths, 54.9 m (180 ft) and 70.1 m (230 ft). A Manitowoc 888 crane with a 10 CY muck box was used to hoist the material from the shaft.

Strict noise requirements restricted the initial efforts. The Construction Management team of Parsons/Jacobs monitored blast vibrations and air over pressure readings throughout the duration of the blasting.

On December 28, 2001, Gilbert/Healy had completed the excavation of the Pump Station Shaft, the drill and shoot tunnel had holed through, and work on the Chattahoochee Interceptor had been completed. The Shaft was then turned over to Archer Western. Concrete lining of the shaft by Archer was included in a separate $128 million contract for upgrades to the R.L. Sutton Treatment Plant.

THE DRILL AND SHOOT TUNNEL

Construction of the 387 m (1,270 ft), drill and shoot tunnel between the R.L. Sutton Pump Station Shaft and the Elizabeth Lane Shaft included pre-excavation grouting a potentially contaminated 91 m (300 ft), zone. A paint manufacturing plant had once existed adjacent to the site, and the possibilities of VOC’s existed. The grouting was

Figure 5. Robbins 261 TBM at their Solon, Ohio, facility

performed with the goal of preventing the contaminated plume from migrating into the completed tunnel. When the area was reached, contaminated groundwater was discovered, however, contaminated tunnel muck was not encountered. Gilbert/Healy used a Tamrock T08-290 drill jumbo and a Tamrock Toro 007 7 CY scoop tram to excavate the main tunnel. As with sinking shaft, the Manitowoc 777 crane with a 10 CY muck box was used to hoist the material.

Upon completion of the starter and tail tunnels at the Elizabeth Lane Shaft, Gilbert/Healy began using the smaller equipment to extend the tail tunnel along the Drill and Shoot alignment. Hole through occurred 32.9 m (108 ft) from the end station of the tail tunnel.

THE SOUTH DRIVE

The Robbins TBM was launched on August 1, 2001. Initial hydraulic problems slowed progress, and all the cutterhead clutches had to be replaced early in the drive. Production was slowed whenever the TBM encountered one of the clayey-sandy silt areas. The soft material quickly plugged the cutterhead buckets unless forward progress was slowed, allowing injected water the time to continually flush the buckets.

Three months into the drive, Gilbert/Healy discovered three broken cutterhead studs during a routine cutter check. This began a pattern where broken studs were occasionally found. When the studs were removed, it was found that the threaded holes were partially misaligned. With a slight misalignment of the head, the studs encountered excess stress. For the duration of the drive, fifty-four cutterhead studs broke and had to be replaced. The full compliment of studs for the TBM was seventy-two.

Dust control while mining in the quartz bearing rock was a concern. Gilbert/Healy attempted various engineering controls including additives. Dust tests revealed an ongoing problem. Eventually, the Construction Manager, Parsons/Jacobs Associates, required that all inspectors wear dust masks while the TBM was mining. The Gilbert/Healy followed with the same requirements for its personnel.

At the arrival of each probe zone, Gilbert/Healy utilized both of the rock bolt drills mounted on the TBM, to perform the probing and inspect the conditions that lay ahead. Originally it was planned to drill through ports in the cutterhead, into the tunnel alignment area. Unfortunately, the TBM portholes were too small for the allowed bits. A compromise had the probe holes originating behind the cutterhead, angled outward between four and seven degrees. The probing was done in sixty to one hundred foot increments. Two, 2¼ in diameter probe holes, opposite of each other at either 2:00 and

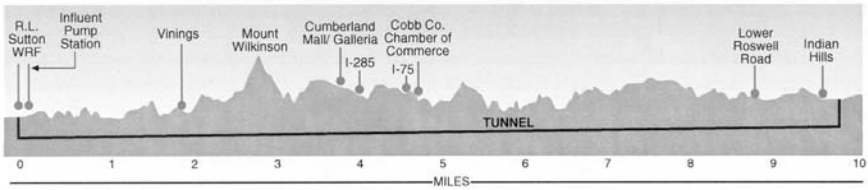

Figure 6. Tunnel profile

8:00 o'clock positions or 10:00 and 4:00 o'clock positions were required. If the holes were dry, mining would commence to a station twenty feet behind the end station of the holes. Additional probes were performed, and the procedure was duplicated until the face station reached the end of the zone. The average zone extended 91 m (300 ft). When the tunnel crossed under Interstate I-285, a zone of 213 m (700 ft), was required.

Grouting was performed if the probe holes produced water at a rate of 0.2 gpm per linear foot drilled. When ground water was discovered, Type III Portland Cement was pumped at pressures equaling the amount of potential ground-water head. Secondary, and if necessary tertiary holes, were drilled and pumped with grout. In several instances, the G/H opted to perform additional probing. This was done to examine future conditions when the TBM was mining through soft ground, or in areas where they felt that there was a potential of encountering additional ground water. Three hundred and eighty-eight hours were spent drilling the probe holes. Two hundred and twenty-eight hours were then spent on the grouting operations.

Gilbert/Healy proposed that tunnel alignment be altered in the Little Nancy Creek Intake area. By altering planned curves slightly, it was determined that the tunnel could come closer to the shaft, shortening the length of the adit, and also consolidating the surface structures required near an existing dam. The resulting change took 4.8 m (16 ft), off of the total length of the South Drive and required minimal changes to the easements. It also resulted in shallower excavations needed for the surface structures.

Average monthly production for the South drive was 186 m (610 LF) to 629 m (2,065 LF), per month. The best day of mining produced a world record of 84.4 m (277 LF).

On Monday, Oct. 7th, 2002, an audience of dignitaries and media were present at 10:40 AM when the cutterhead holed through into the tail tunnel at the Circle 75 Shaft.

THE NORTH DRIVE

The start-up operations for the North Drive mirrored the efforts that had already been accomplished on the South. Launching took place on November 25, 2001. Initial production rates progressed upward daily, with a total of over 30 m (100 LF), mined on December 3rd, only the fifth actual day of mining. As expected, the mining was easier with the average daily production beating the sister drive by 6.7 m (22 LF).

The first significant event happened when the TBM encountered a large groundwater flow at approximately 2,682 m (8,800 LF), into the drive. Two additional zones with substantial water ingress followed. Initial estimates of the amounts involved were impossible to ascertain, but the flows eventually leveled out to approximately 568 l/min (150 gpm). This water hampered mining with crews having to concentrate on hand mucking the areas around the TBM and shaft. Gilbert/Healy brought in sub-contractor Foundation Engineering Contractors (FEC), to grout this area after the machine had passed, and the inflow was reduced to approximately 132 l/min (35 gpm).

There were no contract probe zones scheduled for the North Drive. Following the influx of groundwater at the earlier stations, the decision was made by all the parties to probe in three zones. No significant water was found in these areas

The second event of note began on the graveyard shift on July 14, 2002 when ratcheting noise and severe vibration from the machine bearing area indicated a major problem. Subsequent investigation found broken teeth on the bull gear. The TBM had mined a total of 4,775 m (15,667 LF). Gilbert/Healy crews were able to replace the unit underground. The entire effort took only fifteen calendar days to complete.

The TBM reached the final station at Indian Hills on December 20, 2001. Gilbert/Healy then mined an additional 31.7 m (104 LF) to provide access and muck storage for the Indian Hills Intake Chamber and shafts. With no exit shaft, the TBM components were pulled back to the Circle 75 Shaft for removal. Before this could be accomplished, the vent and drop shafts for the Indian Hills Intake Station had to be completed to provide ventilation in the tunnel.

INTAKE STRUCTURES

Four intake structures provide the tie-in with the existing wastewater system. Each features a jack leg driven drill and blast chamber and an adit of various lengths. Subcontractor, RaiseBor drove the drop and vent shafts for each location. Ductile iron piping was installed in each shaft, connecting the concrete vaults at the surface with the concrete lined chamber. A stainless steel splatter plate is embedded in the slab for each chamber. The Chattahoochee Interceptor tunnel, connected to the Main Tunnel, has a 244 m (800 LF), adit that was lined with Reinforced Concrete Pipe. This intake was on the grounds of the R. L. Sutton Water Reclamation Facility. The other three represented difficult logistics in tight areas with adjacent streams and at Little Nancy, a reservoir and dam. Sheet pile was driven at each site to act as a coffer dam for excavation of the vaults. Indian Hills is located on the grounds of a golf course between a green and a tee-box.

CONCLUSION

The original contract specified that fifty percent of the tunnel would be concrete lined to a finished diameter of 4.8 m (16 ft). Concerns by the public over impact to the water table have generated extra work. At this time 92% of the South Drive will now be lined. Panning and contact grouting are in utilized wherever significant groundwater is entering the tunnel through the rock joints. Progress continues towards a completion date of November 2004.

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