Project Clear: Efficient Hard Rock Tunneling below St. Louis, Missouri

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ABSTRACT

The Metropolitan St. Louis Water District's Project Clear is a 28-year program targeting water quality and wastewater capacity throughout St. Louis, MO. The extensive program involves multiple tunnels, including Deer Creek, a 6.3 km long tunnel being bored with the largest TBM ever used in the St. Louis area (6.5 m in diameter). Another tunnel, Jefferson Barracks, is using TBM components that have bored over 40 km of tunnel since 1981.

This paper will analyze the TBMs on this project as they bore in limestone and shale, and discuss the importance of the project for the St. Louis metropolitan area.

INTRODUCTION

Aging infrastructure is an issue of prime importance across the U.S., but one city is combating it with a plan for the ages. Over a generation, the scheme known as MSD Project Clear for the Metropolitan St. Louis Water District will target water quality and wastewater concerns in St. Louis, Missouri and surrounding areas. The USD $5 billion program was originally scheduled to take 23 years, but it is now a 28-year program with five more years to do additional work. The extensive program involves multiple tunnels, including Deer Creek, a 6.3 km (3.9 mi) long tunnel being bored with the largest TBM ever used in the St. Louis area (6.5 m/21.5 ft in diameter). Another tunnel, Jefferson Barracks, is using a TBM launched from one of the largest diameter shafts ever built in the U.S. (27 m/88 ft in diameter). Both projects, being constructed by SAK Construction (SAK), an O'Fallon, Missouri-based tunneling and pipeline rehabilitation contractor, are critical components of the area's wastewater system.

MSD Project Clear involves more than just underground works—the initiative includes planning, designing, and building community rainscaping, as well as system improvements and an ambitious program of maintenance and repair, all begun in 2012. Maline Creek, a drill-and-blasted storage facility on the Northern edge of St. Louis, is a big part of the underground plan scheduled for completion by late 2020. The underground structure consists of an 820 m (2,700 ft) long, 8.5 m (28 ft) diameter tunnel, also constructed by SAK. Maline Creek will help with wet weather conditions, serving as a storage facility when heavy rains occur. It will help store water so the system doesn't become overcharged, and hold that overflow until it can go to the Bissell Point Wastewater Treatment Plant. In doing so the facility will also reduce the volume of discharge into Maline Creek, a small tributary of the Mississippi (see Figure 1).

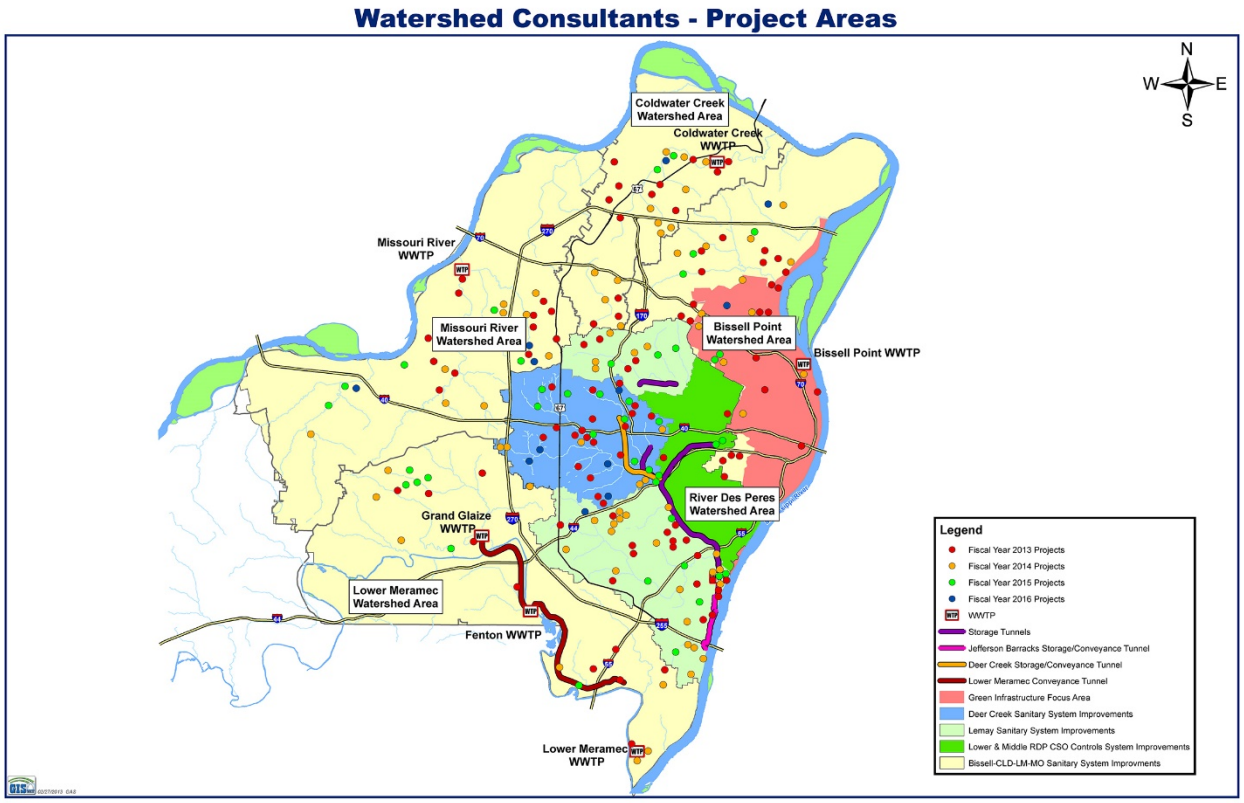

Figure 1. The extensive MSD Project Clear program. *Image credit: MSD (www.projectclearstl.org)*

The Deer Creek Tunnel, which extends from the City of Clayton along Interstate 44 to the City of Shrewsbury outside of St. Louis proper, has another function—to alleviate basement backups as well as sewer overflows. “The Deer Creek Sanitary Tunnel is a transmission tunnel that will add capacity to the overall system. The tunnel can also temporarily store water to keep the system from becoming overcharged,” said Hadley. The 45 to 76 m (150 to 250 ft) deep tunnel in the area’s limestone and shale bedrock has an inside diameter of approximately 5.8 m (19 ft). Construction of the tunnel and ancillary facilities is scheduled for completion in late 2022 (see Figure 2).

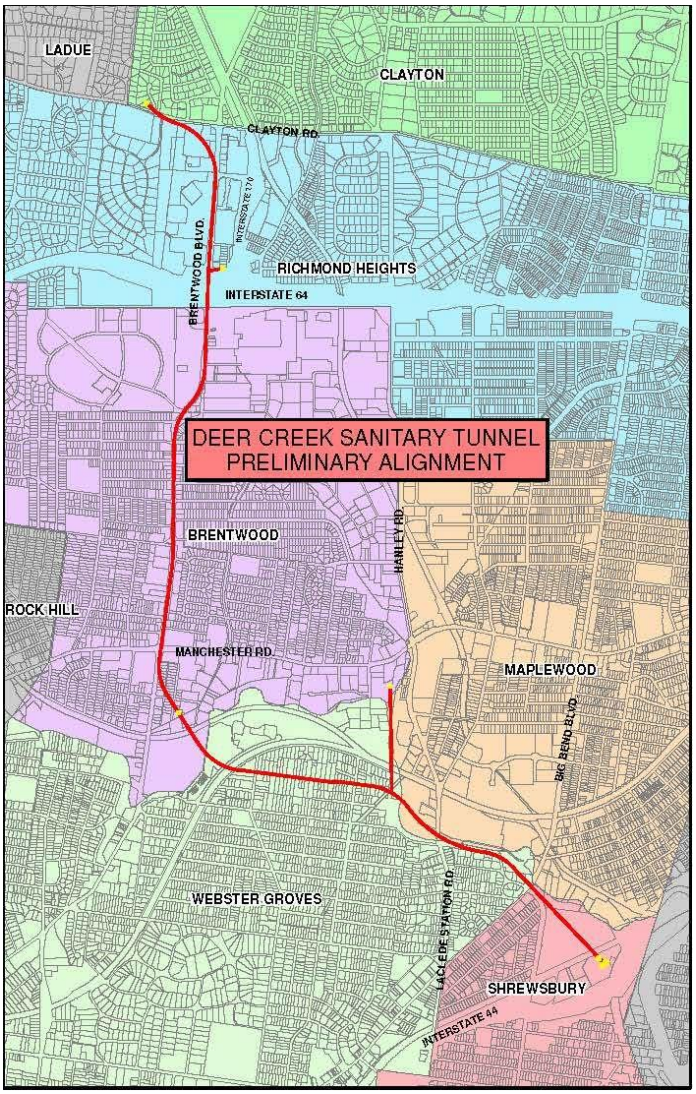

Figure 2. Detail of Deer Creek Tunnel Alignment. *Image credit: MSD (www.projectclearstl.org)*

Jefferson Barracks is another component of the plan. The 5,400 m (17,800 ft) long, 2 m (7 ft) i.d. tunnel runs parallel to the Mississippi River and extends to the Lemay Wastewater Treatment Plant located at the confluence of the River des Peres and the Mississippi. The Jefferson Barracks Tunnel service area currently conveys and collects wastewater through a series of pump stations, force mains, sanitary sewers, and combined sewers that are easily overtaxed during heavy rains. The 36 to 67 m (120 to 220 ft) deep tunnel, along with new combined sewers and a new pump station, will alleviate much of the problem. The deep tunnel will also allow the MSD to eliminate two intermediate pump stations and replace the existing trunk sewer. The tunnel is expected to be complete in late 2020 (see Figure 3).

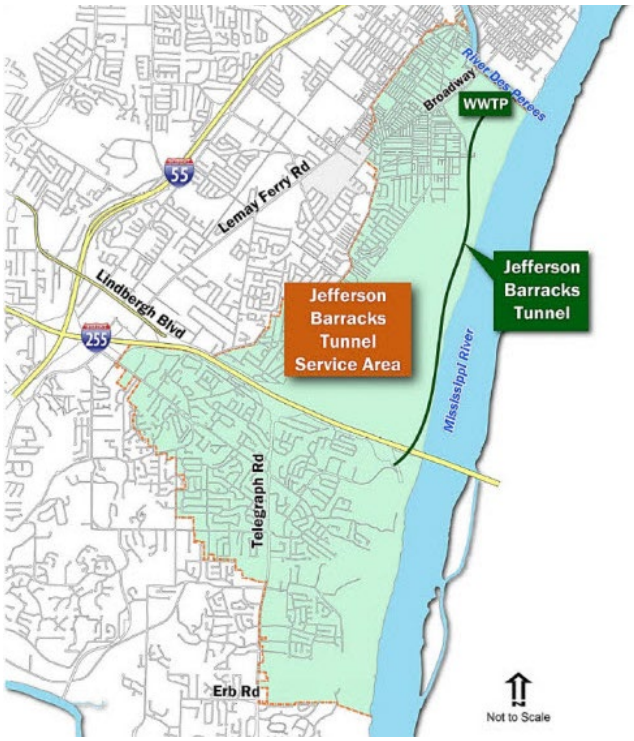

Figure 3. Detail of Jefferson Barracks Tunnel Alignment. *Image credit: MSD (www.projectclearstl.org)*

MACHINE DESIGN

Deer Creek

The machine for the Deer Creek Tunnel is a rebuilt 6.5 m (21.3 ft) Main Beam TBM originally built in 2002 for the Parramatta Rail Link in Sydney, Australia. On that project, the machine achieved a then-world record of 92 m in one day while boring in sandstone. For the Deer Creek project the diameter was changed from 7.2 m to 6.5 m, and the overall machine was refurbished after years of storage (see Table 1 and Figure 4).

Table 1. Deer Creek TBM Specifications

Machine Diameter	6,553.2 mm
Main Bearing	High capacity, 3-axis
Cutters	19” front and back-loading; 17” center twin
Number of Disc Cutters	33 (face/gauge); 8 (center)
Recommended Cutter Load	311 kN
Maximum Operating Cutterhead Thrust	13,571 kN
Cutterhead Power	7 x 330 kW = 2,310 kW
Cutterhead Speed	0-10 RPM
Cutterhead Torque	2,549 kNm @8.6 RPM
Breakout Torque	3,824 kNm
TBM & Back-Up Assembly Weight	715, 536 kg

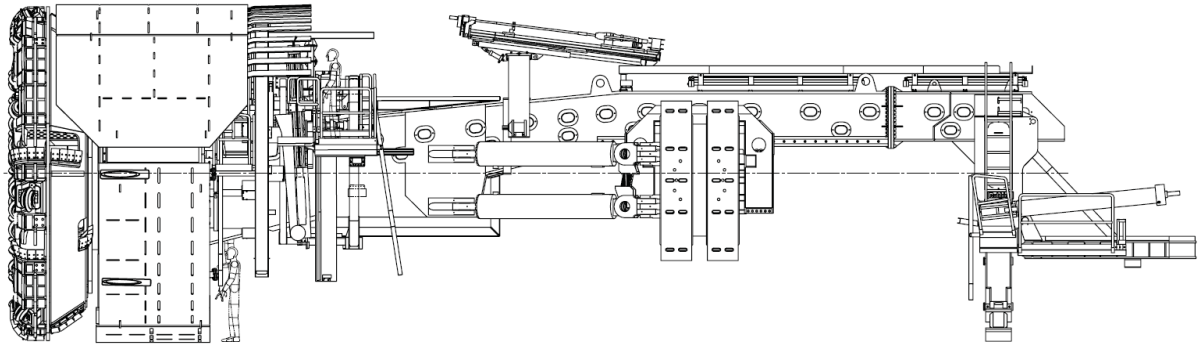

Figure 4. Deer Creek TBM profile

Jefferson Barracks

The Jefferson Barracks TBM, while small in diameter, has a rich history. The TBM, owned by SAK, was refurbished from 3.43 m (11.25 ft) diameter to 3.35 m (11.0 ft) diameter, and fitted with 27, 17-inch diameter cutters and 900 kW (1200 HP) electric drive motors. The SAK team also built customized drill platforms for the small machine. Components of the TBM are made up of two veteran machines—one of those is "Chelsea the Chomper", the Robbins TBM used at the Lemay Redundant Force Main in 2014, also part of MSD Project Clear in St. Louis. That project was the machine's 12th tunnel, bringing it to over 40 km (25 mi) of tunnel bored in its long career.

Originally built by Robbins in 1981 for a hydroelectric tunnel in Austria, the TBM excavated multiple tunnels in Europe and Central America. The machine spent some years in Costa Rica, boring more than 8 km (5 mi) at the El Encanto hydroelectric tunnel, before being purchased and shipped to the U.S. It was also used on a short storm sewer tunnel in St. Louis prior to the Lemay Redundant Force Main. The TBM was then refurbished and launched in February 2014 to bore the 945 m (3,100 ft) long Lemay tunnel and successfully holed through in May 2014.

Components of another Robbins Main Beam TBM were also used on the machine—that of the machine known as "Miss Colleen", most recently used at Baltimore's Bi-County Water Tunnel. The 3.0 m (9.8 ft) diameter machine was one of the world's longest running TBMs in operation. It had been used on at least ten different projects between 1973 and 2011, totaling at least 50 km (31 mi) of hard rock tunnels (see Figures 5-7).

Figure 5. “Miss Colleen”, the Main Beam TBM for the Bi-County Water Tunnel
Figure 6. “Chelsea the Chomper” breaks through at the Lemay Redundant Force Main in 2014

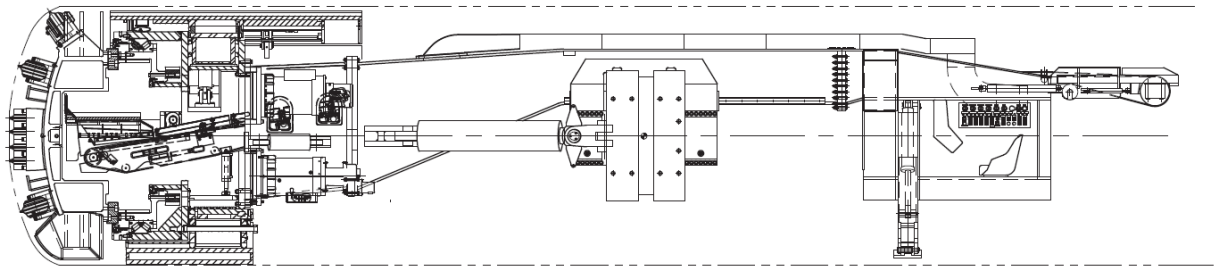

Figure 7. Jefferson Barracks TBM profile

EXCAVATION PROCESS

Deer Creek

The 6.5 m (21.3 ft) diameter Robbins Main Beam TBM at the Deer Creek Tunnel began its journey from a 52 m (170 ft) deep, 13 m (42 ft) diameter launch shaft built using drill & blast techniques. Contractor SAK utilized a 117 m (385 ft) starter tunnel and 15 m (50 ft) tail tunnel, also conventionally mined, for machine launch at the bottom of the shaft. The machine was launched in February 2019, and has since excavated more than 4,600 m (ft) of limestone and shale rock at 103 MPa (15,000 psi) UCS (see Figure 8).

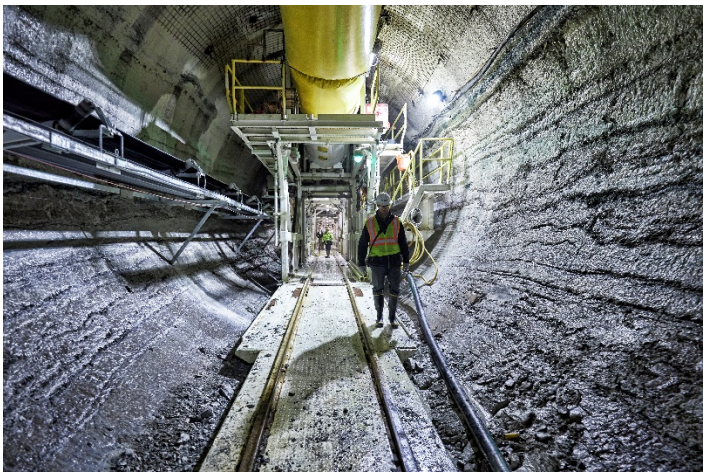

Figure 8. TBM excavation in limestone and shale rock

Crews probe drill 60 m (200 ft) ahead of the TBM during each of the two daily 10-hour shifts to check for groundwater. Very little groundwater has been encountered, though the GBR shows that groundwater is a possibility. Much of the tunnel has been in Type I rock, and the competent ground requires minimal support consisting of five, 2.4 m (8 ft) long rock bolts and wire mesh. As of October 2019, the tunnel is more than 60 percent complete.

Traveling behind the TBM is a Robbins continuous conveyor system—a good way of minimizing downtime as compared with muck cars, particularly as the tunnel gets longer. The system consists of a side-mounted in-tunnel conveyor, along with a vertical conveyor to bring muck to the surface and a stacker conveyor for temporary onsite muck storage (see Figure 9).

Figure 9. The Deer Creek shaft and continuous conveyor system

Once excavation is complete, the tunnel will be lined with a 5.8 m (19 ft) i.d. concrete liner. Crews will then work to connect up a series of 10 shafts located 30 to 550 m (100 to 1,800 ft) off of tunnel alignment with drill & blasted adits. The shafts will eventually draw wastewater from existing sewers in the area.

Jefferson Barracks

Work at Jefferson Barracks began with the large diameter launch shaft in April 2018, site of a future pump station, and constructed in karstic limestone conditions with groundwater. Pre-excavation grouting was performed to limit the potential for large groundwater flows into the shaft.

Shaft construction involved a secant pile wall extended into the bedrock, while an excavator removed overburden material. Excavation of the overburden began in late April 2018 using a tracked excavator. Drill and blast methods were used to break the underlying bedrock into pieces small enough to be removed by the excavator, as well as buckets and a crane. The 27 m (88 ft) diameter by 50 m (166 ft) deep shaft was completed in October 2018, and was followed by a starter tunnel, also excavated by drill and blast, for the Robbin Main Beam TBM that would bore the Jefferson Barracks tunnel. Tunneling began on October 31, 2018 (see Figure 10).

Figure 10. The 27 m diameter Jefferson Barracks shaft

The Robbins TBM bored through limestone and dolomite with layers of shale similar to that encountered at Deer Creek, but with more groundwater. Crews achieved rates of up to 24 m (80 ft) per shift, working in two 9-hour shifts per day while installing rock bolts between 60 and 120 cm (2 to 4 ft) long and wire mesh. Groundwater was a challenge for the crew, with water flowing into the tunnel at rates of 300 l (80 gal) per minute that had to be pumped out.

Once complete, the tunnel will be lined with a 2.1 m (84 in) diameter fiberglass pipe liner in an operation that will take three to five months, followed by new intake structures that will connect up with six tunnel adits to intercept surface flow, diverting it from gravity sewer systems.

CONCLUSIONS

With many of its major projects underway, MSD is set to keep on track with its 28-year goal to improve water quality. TBMs are an important component of those underground works, and rebuilt TBMs have proved to be a cost-effective solution. The use of tried and tested machine components in a rebuild is nothing new—at least 50% of Robbins projects in a given year utilize rebuilt machines—but the storied pedigree of the components in St. Louis is worthy of note. It is for these reasons that a robust steel structure and a large bearing to diameter ratio are key, as they are associated with longer equipment life. With good maintenance TBMs have been known to bore 50 km (31 mi) or more, and some TBMs are still in use worldwide that have been in operation for nearly six decades.

As MSD Project Clear progresses, public outreach remains critical to ensure support in the community. MSD's Project Clear staff conduct regular public meetings where they give quarterly tunneling updates and the latest project timelines. Whenever drill & blast work is required, the community and local officials are notified. Other types of outreach include stakeholder engagement meetings with other local utilities, transportation agencies, environmental groups, and any other organizations that might be impacted or have interest in Project Clear.

Project Clear has gotten positive support using their communication model, with the overall goal that the public is minimally impacted by the construction work but are secure in the knowledge that the water system is being maintained and aging infrastructure is being improved. With the implementation of Project Clear the community will see no ill effects during heavy rains such as flooding and backups onto streets.