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Extensive Small Diameter Pipe Jacking with Concurrent Methods Under I-15 CORE in Provo, UT

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ABSTRACT: The Interstate 15 (I-15) CORE Corridor Expansion Project, owned by the Utah Department of Transportation (UDOT), is home to one of the largest amounts of concentrated small diameter pipe jacking crossing in one location. Contractors simultaneously jacked 18 to 72-inch ID pipes with a guided boring machine (GBM) system and several tunnel boring machines (TBM) over the course of 17 months. Located in rapidly growing Provo City, UT, Utah County, the project spans a total of 24-miles along the I-15 CORE and will add to and restore the existing infrastructure to meet population demands through 2030. Minger Construction of Chanhassen, MN is a trenchless sub-contractor in a consortium of contractors and engineers for this project. The I-15 CORE Corridor Expansion, structured as a design build project, began in January 2010 and will continue through December 2012. With a minimal number of pipe jacking projects under their belt, the operators experienced a 95% up-time on their equipment and became highly proficient in maximizing their systems' performance through varying soil conditions and obstacles. A total of 14,587 lft. of RCP and steel casing pipe has been installed with GBM and traditional pipe jacking methods in 63 drives, all with an average of six-foot depth of cover. This total linear footage of 18 to 72-inch ID storm water pipelines was installed equally between the two methods upon completion of the project. Contractors averaged one drive every week in 50 blow count clay soil using one GBM system and five TBM configurations with additional ancillary equipment. All the pipe jacking equipment was acquired from the same manufacturer.

1. INTRODUCTION

Identified as the state's largest construction project, the Utah County Corridor Expansion or I-15 CORE, is owned by the Utah Department of Transportation (UDOT). Originally the I-15 was constructed from 1950-1974, with subsequent adaptations in the years leading up to this project. The I-15 CORE project encompasses 24-miles of reconstruction including the addition of lanes from Lehi Main to Spanish Fork Main Streets, extending an express lane from the towns of University Parkway in Orem to Spanish Fork, redesigning 10 freeway interchanges, and replacing 55 bridges while using low maintenance, 40-year concrete pavement. As one of the fastest growing counties in the nation and second most densely populated counties in Utah, the I-15 CORE project is essential to meet the needs of the aging infrastructure in Utah County and is projected to meet transportation demands through 2030.

Significant to this paper is the large scope of pipe jacking construction in a concentrated area.

2. PROJECT AREA/LOCATION

The 24-mile project expanse is located just south of Salt Lake City in the north-central region of Utah around Utah Lake (see Figure 1) and includes ten reconstructed or modified interchanges. A total of 202.8 miles in additional lanes were added in both directions with the central part receiving 42.45 miles of express lanes along with 20.37 miles of auxiliary lanes in various locations along the project area.

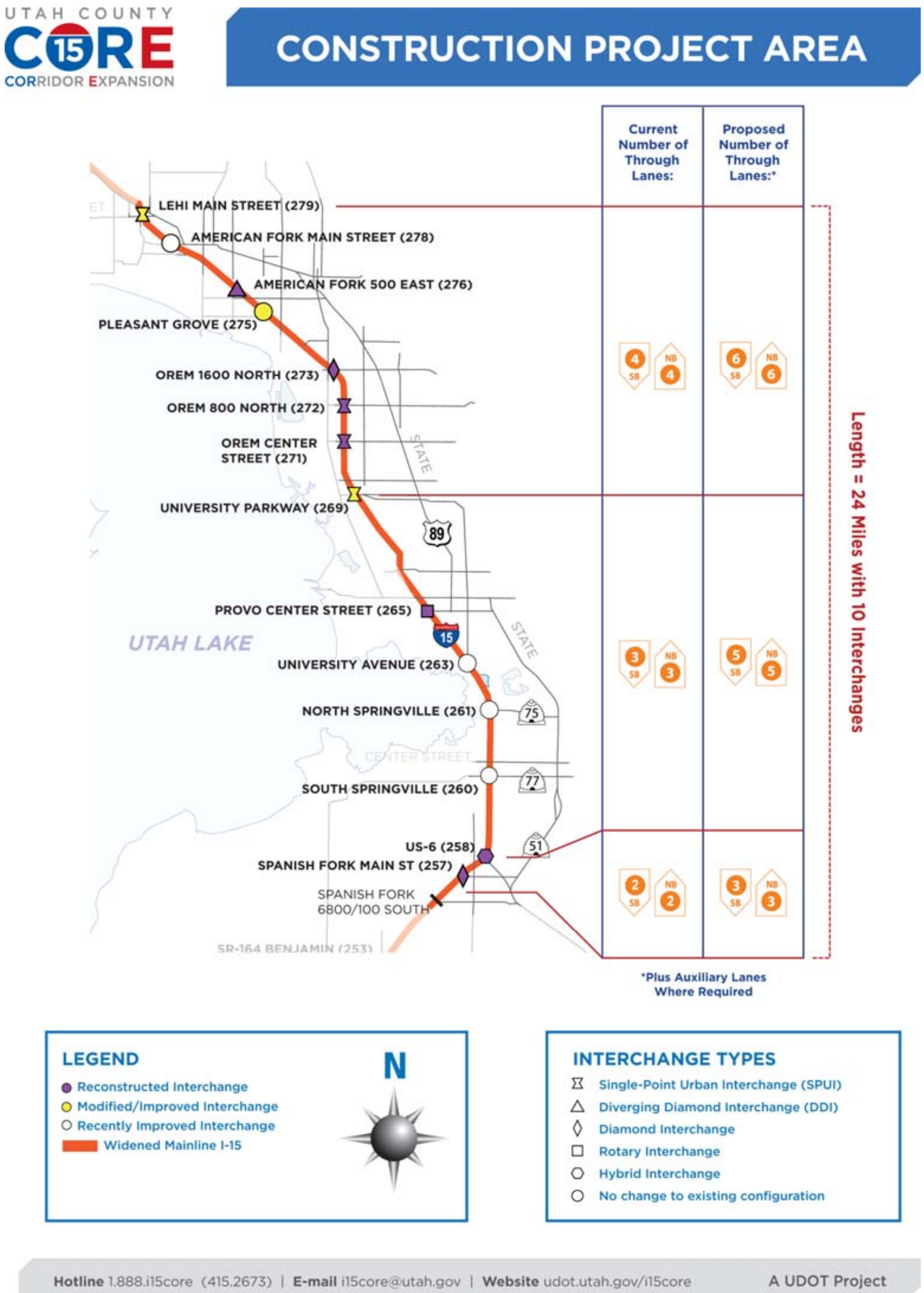

Figure 1. Utah County CORE 15 Corridor Expansion Construction Project Area

3. PROJECT TIMELINE

The full scope of the project, from design to completion is three years (see Figure 2). The majority of the pipe jacking linear footage was installed from June 2010 through May 2011. As of April 2011, the UDOT reported a total of 21.41 miles of drainage pipe was installed (Year One Construction Facts, 2011). Minger Construction did not install pipelines in the summer of 2011 due to traffic phasing and conflicts with other portions of the project. They resumed pipe jacking work in September of 2011 and finished in January of 2012.

Figure 2. I-15 CORE Timeline

4. CONSTRUCTION

The I-15 CORE is being constructed as a design-build project. After reviewing designs for a traditional construction processes versus the design-build plans, UDOT determined that design-build will “allow for a faster construction timeline and more efficiency, while fostering flexibility and innovation” (I-15 CORE Design-Build Fact Sheet, 2010). The UDOT had a history of successful design-build projects, with 34 completed since 1998, stating that they “saved millions in project costs by encouraging the use of innovative ideas and techniques and by completing projects ahead of schedule” (I-15 CORE Design-Build Fact Sheet, 2010). The I-15 CORE was bond funded and totaled 1.725 billion dollars.

The design-build consortium of contractors, Provo River Constructors (PRC) is comprised of many contractors in the local, state and national levels. Ames Construction Company Inc. of Salt Lake City, UT selected subcontractor, Minger Construction, Inc. of Chanhassen, MN to perform the storm sewer pipe jacking installation work. Minger was the main trenchless contractor. An auger boring contractor was brought in to perform two 36-inch steel casing drives when scheduling conflicts with their other systems prevented Minger Construction, Inc. from doing these two drives.

Minger Construction, Inc.’s primary construction portfolio included open trench, excavation, site grading and manhole construction utility work. Prior to approaching the I-15 CORE project, Minger’s previous pipe jacking experience was minimal and consisted of auger and hammer boring and a few GBM projects. Feeling confident in their operator’s ability and banking on the assistance from the manufacturer’s technicians, Minger bid on the I-15 CORE opportunity.

Several Minger crew members and their families relocated to the Provo area during the core construction period to ease the burden of travel and displacement. Minger employed a total of 15 people for this project, with ten crew members coming from Minnesota and the remaining five from the Utah area.

The project is divided into five areas from north to south (see Figure 1): Lehi Main Street (exit 279) though south of Pleasant Grove (exit 275) as area **A**, north of Orem 1600 North (exit 273) though south of Orem Center Street (271) as area **B**, north of University Parkway (exit 269) through just south of Provo Center Street (exit 265) as area **C**, north of University Avenue (exit 263) through just north of South Springville (260) as area **D**, north of South Springville (exit 260) through north of US-6 (exit 258) as area **E** and north of US-6 (exit 258) through Spanish Fork 6800/100 South as area **Z**.

Initial project discussions and design plans estimated that 100+ trenchless borings would be necessary. After further design revisions, that number was brought down to 60+ and has manifested into a final quantity of 63 drives. Due to shallow depth of cover and in order to keep costs low, the residual bores were redesigned as open cut pipelines. The majority of the 63 bores consist of highway cross culverts and storm drainage tunnels, with about 5% of the bores for utilities. Old culverts and storm drainage tunnels were abandoned and PRC filled the retired lines with grout. About 85% of the new installations were parallel to the abandoned tunnels.

The project owner did not specify that trenchless methods must be used in the original bid package. Due to the design-build nature, emphasis was placed on innovation, optimized costs and adhering to the timeline. All pipe jacking work had to be completed while other highway, express way, interchange and bridge work was conducted and live freeway traffic was moving. Minger had to be willing to revise and re-work the shafts according to changing traffic patterns (see Figure 3).

Figure 3. GBM construction work along I-15 CORE project with moving traffic.

The reinforced concrete pipe (RCP) used was specially manufactured by Old Castle Precast in sizes 18, 24, 30, 36, 48, 60 and 72-inch ID. The smallest diameter pipe was 18-inches ID with a mere 2.5-inch wall thickness yet responded well under 150-tons of jacking pressure. The RCP sizes 18 through 28-inch ID were 8-foot segments. The RCP in the 60 and 72-inch ID sizes were 12-foot sections. The combined length of RCP installed with both pipe jacking systems was 12,599 lft. with an additional 1,730 lft. in extension lengths[1]. The longest drive of RCP, with 24-inch ID RCP was 456 lft. and completed with the GBM system. There were 10 drives where steel casing pipe, acquired from various manufacturers, was used in 24, 30, 36 and 48-inch ID sizes. The steel casing pipe installed with a TBM, was in 20-foot lengths. The steel casing pipe installed with the GBM method was cut into 10-foot lengths and welded at each joint. The total length of steel casing pipe installed on this project was 1,988 lft. with an additional 690 lft. in extension lengths on these bores. The longest drive of steel casing, with 24-inch ID RCP was 250 lft. and completed with the GBM system.

Minger Construction completed all pipe jacking drives with a GBM system and several sized TBMs. Additional equipment used with the GBM system included a cutter head with integral swivel, three sizes of power cutter heads (PCH) upsizing tools, along with a power pack and dirt bucket. The TBMs were launched with an all-in-one pump unit, yoke, skid, haul unit configuration and intermediate jacking stations (IJSs) to distribute the thrust load on longer drives with harder ground conditions. Most of the pipe jacking equipment was purchased or leased by the contractor from manufacturer, Akkeman Inc.

[1] Extension lengths were pipelines installed on many of the drives via open-cut methods to meet utility tie-ins.

The GBM method is typically a three-step process (see Figure 4). First, pilot tubes, with a soil appropriate steering head mounted on the front, establish line and grade. Next, the bore diameter is increased as the casings and augers perform excavation of the spoils. The third step is where the final product pipe is installed directly behind the casings and augers. As pilot tubes, casings and augers, then final product pipe is installed and advanced, a section is removed from the reception shaft. This three-step method continues until the final product pipe is in place. If a PCH or powered reaming head (PRH) is used, it is placed behind the casings and augers and before the final product pipe. The auger spoil flow is reversed toward the reception shaft for removal. The PRH or PCH's rotating cutter bits excavate the soil to the final pipe diameter while minimizing jacking force and accelerating the speed of the drive.

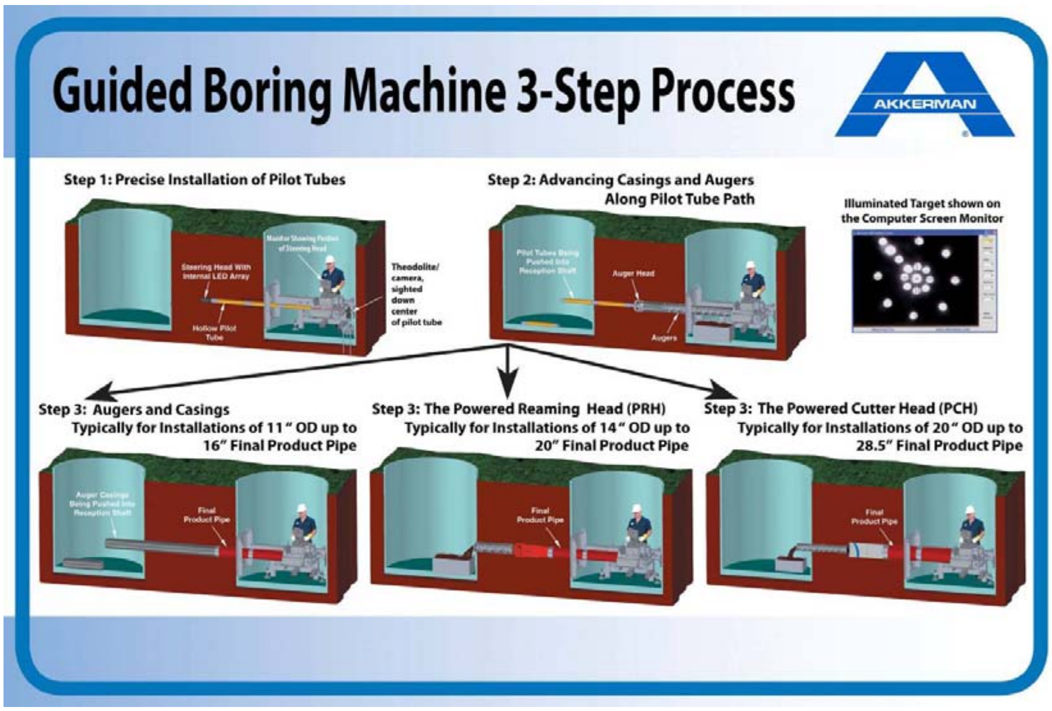

Figure 4. Guided Boring Machine 3-Step Process

A GBM jacking frame with a 200-ton thrust capacity was used for diameters ranging from 18 to 36-inches ID and totaled 6,542 lft. in 29 drives. A PCH upsizing tool, in three sizes was used in conjunction with the GBM jacking frame to increase the final bore diameter to match the final product pipe. The longest GBM drive on this project was 456 lft. of 24-inch ID RCP.

The all-in-one Akkerman 5000 Series pipe jacking system matches pipe to a skid and thrust yoke while hydraulic cylinders from the pump unit advance the pipe on line and grade. Five sizes of TBMs were used to complete 34 drives ranging in size from 36 to 72-inches ID and totaled 8,045 lft. The longest TBM drive on this project was completed with the TBM 360 and installed 432 lft. of 36-inch ID RCP.

Paramount to the performance of the equipment was the need for accurate line and grade due to a shallow depth of cover (see Figure 5). Ideally contractors like to have at least two full pipe diameters of cover above the drive. The shallow cover on most of the drives on this project made the need for bore accuracy even more critical. Since most of the bores were replacement culverts and storm drainage tunnels, contractors had to work within the existing infrastructure. The drive with the shallowest cover rested six-inches below the roadway and averaged six feet for the whole project. The deepest drive was 30-feet below ground surface and Minger crew members immediately pressure grouted it upon its completion.

Figure 5. This TBM has emerged with little depth of cover.

Minger's drive logs were divided into GBM and TBM installed pipelines (Appendix A and B). The shortest drive, 99 lft., was conducted with a GBM system in construction area C. The longest drive, 456 lft., was achieved with the GBM system in area B where the soil was mostly sandy. Three drives, originally slated as GBM drives, had to be converted to TBM drives due to unsuccessful attempts at getting the pilot tubes through the ground because of large amounts of unknown obstacles that the pilot tubes could not penetrate.

Minger reported a 95% up-time on all pipe jacking equipment. When faced with the simultaneous demands, one GBM and one TBM crew would average two to three GBM bores and two TBM bores per month. When necessary, the crew would work a double shift or all day. Minger reported their best installation with the GBM system was 18, 8-foot sections of 24-inch ID RCP in 10 hours or144-feet. Their best production rate with a TBM 480 was 13, 8-foot sections of 48-inch RCP in 10 hours or 104-feet.

The soil conditions on the drives ranged from a variety of wet clay, silt, cobble, and gravel. Slag was also a prominent soil type which was transported as fill into the area from a nearby steel mill in the 1950s when the highway was originally constructed. Minger discovered that the TBM performance was optimized in stiff sand while the GBM performs best in clay and mud. Minger found that each construction area had distinctive soil properties. Area A was laden with slag rock, iron deposits. Area B was sandy. Area C was the most difficult with large cobblestone, undocumented obstacles including concrete, asphalt and concrete slag along with pipe, storm and irrigation lines, iron, and galvanized steel culverts in sandy soil. There was not any trenchless work performed in area D. Area E and Z was very wet and the water table was encountered just one foot below the ground.

The majority of the work, 48 drives, were completed between June 2010 and May 2011 with the remaining 15 bores completed between September 2011 and January 2012. At the conclusion of this project, Minger Construction performed 63 connecting storm sewer and one sanitary sewer drive on this project in quick succession.

5. CHALLENGES

Typically, most projects are faced with a litany of challenges, wherein operators must adapt to efficiently persevere. One of the contractor's largest hurdles was refiguring shaft locations due to traffic pattern or project construction changes. Often the exact footages of the bore were not available until a few days prior to its expected start date. This presented many dilemmas in terms of obtaining pipe, moving equipment, maintaining crew safety, optimizing distance from other concurrent I-15 CORE construction and contending with live traffic. The trench boxes needed to be large enough to accommodate the equipment, 8 to 20-foot length pipe[1] sections, and enough above ground surface space for the pipe jacking ancillary equipment. Changes to drive lengths and sizes had to be relayed to the pipe manufacturer so that the appropriate amount of pipe was delivered in time for the bore launch. Minger became a resource in helping the other utility contractors with tie-ins, manhole and catch basins and other wet utility work. This assistance sped up the process for Minger to come in to complete their work.

The pipe manufacturer worked with Minger to fine tune the small diameter concrete jacking pipe to better serve their needs. During the first 24-inch drive, the pipe cracked after installation of five segments. The manufacturer re-engineered the pipe, finding that the spigots needed to be reinforced and the revised the curing process. They reimbursed Minger for the associated setbacks. This process, although it presented delays, resulted in a high quality jacking RCP which was able to endure at least 150-tons of jacking pressures. Minger reported excellent service with Old Castle during project changes and subsequent delivery changes.

Minger experienced a few instances of equipment malfunction. These issues included a TBM haul unit gear box replacement, problems with the hydraulic controls of the TBM conveyor lift and steering and cabling connections on their guidance system.

The composition of area C was undocumented and chock-full of obstacles and large, naturally occurring cobbles in sandy soil. When the highway was originally constructed in the 1950s, pipelines and surface material was buried along with transported slag from a nearby steel mill. The obstacles included stumps, iron ore deposits 12+-inches in diameter, concrete bases from former light posts, storm and irrigation lines, concrete pipe, asphalt chunks, steel culverts and concreted slag. Minger found that the GBM could not be used in this area because the pilot tubes could not penetrate or displace these objects. Three small diameter drives, originally intended for the GBM system, had to be changed to TBM system drives. Minger had to hand mine at the front of the cutter head to remove the obstacles from the face of the bore. In addition, this area contained pockets of loosely compacted gravel, which would funnel down into the cutter face. In these cases, Minger pressure grouted the outside of the pipe string to reduce the potential of forming voids.

Another occasion of difficulty was when a pump unit power cord, made of highly desirable copper, was stolen from the job site. Following this, Minger disconnected the cable from the generator and pump unit and placed it inside a locked storage container after each use.

During the winter months, colder temperatures would cause the high pressure jetting water and bentonite lubrication fluid to freeze. To overcome this, Minger placed frost blankets over the jetting and lubrication pumps. They also created a tarped frame and ran a propane heater inside the shaft to keep fluids warm. At night they either ran the propane heater or removed the pump unit from the launch shaft and stored it in the job-site trailer.

6. CONCLUSION

On the I-15 Corridor Expansion Project, Minger Construction, Inc. installed an unprecedented amount of trenchless construction linear footage in one concentrated area. Although several of the original crossings were eliminated due to value engineering and shallow cover, Minger was able to install a sizeable number of new highway culverts, storm drainage and utility crossings with pipe jacking methods. While faced with challenging soil conditions, concurrent construction strains, shallow depth of cover and other stressors, Minger gained a vast amount of expertise on their equipment's capabilities and is now able to tackle similar prospects with a high level of assurance. The UDOT and Provo citizens can also enjoy the benefits of the quality of its infrastructure for many years to come.

[1] The typical pipe size used for the Akkerman 4812A GBM jacking frame is two meters to fit in a 12-foot minimum shaft.

7. REFERENCES

I-15 CORE Design-Build Fact Sheet. (2010). Utah Department of Transportation. Available: http://www.udot.utah.gov/i15core [2010, May].

Year One Construction Facts. (2011). Utah Department of Transportation. Available: http://www.udot.utah.gov/i15core [2011, April].

Appendix A

I-15 Core Project

Utah County, Utah

Project Start Date: June 1st, 2010

Guided Boring Machine Work

Bore	Name	Size	Type	Pits (EA)	Boring Length (LF)
1	P (B3) 06-14	24"	RCP	1	256
2	P A10-1	24"	RCP	1	184
3	P A 14-7	24"	RCP	1	232
4	P A17-7	24"	RCP	1	176
5	P A14-4	24"	RCP	1	240
6*	P (B2)03-22	24"	RCP	1.5	456
7	P (B2)04-3	30"	RCP	1	224
8	B-U2B	24"	STEEL	1	250
9	B-U1B	24"	STEEL	1	170
10	P C14-1B	24"	RCP	1	232
11	C-U1B (36")	36"	STEEL	1	220
12	C-U1B (24")	24"	STEEL	1	210
13	P D11-2	24"	RCP	1	208
14	P C15-1	30"	RCP	1	256
15*	A-U52 (24")	24"	STEEL	1.5	234
16*	A-U52 (30")	30"	STEEL	1.5	246
17	C 21-1	30"	RCP	1	208
18	Z 12-1	30"	RCP	1	304
19	Z 12-17	18"	RCP	1	264
20	E 1-1	24"	RCP	1	208
21	P (B1) 08-6	18"	RCP	1	200
22	Z 03-1	18"	RCP	1	216
23	C 10-1B	24"	RCP	1	240
24	C 08-16	24"	STEEL	1	99
25	Z 26-1	36"	STEEL	1	157
26	C 16-1A	24"	RCP	1	176
27	C 17-5	24"	RCP	1	248
28	Z 22-1	18"	RCP	1	248
29	C 29-8	36"	STEEL	2	180

Total Bores Completed: 29

Total Linear Feet: 6,542

Tunnel Boring Machine Work

TBM	Name	Size	Type	Pits (EA)	Boring Length (LF)
1	TSSD	48"	Steel	1	222
2	P A3-1	48"	RCP	1	208
3	P A2-19	48"	RCP	1	240
4	P (B3)08-18	60"	RCP	1	195
5	P A6-32	54"	RCP	1	264
6	P (B3) 07-19	36"	RCP	1	184
7	P A14-10	36"	RCP	1	200
8	P (B3) 04-39	36"	RCP	1	200
9	P A2-17	36"	RCP	1	224
10	P A8-2	36"	RCP	1	296
11	P A25-13	36"	RCP	1	296
12	P A12-19	36"	RCP	1.5	256
13	P A12-24	36"	RCP	1	144
14	P (B1) 02-36	48"	RCP	1	208
15	P (B3)01-6	48"	RCP	1	208
16	P (B3)01-9	36"	RCP	1	208
17	P (B3)02-5	36"	RCP	1	304
18	P D11-1	36"	RCP	0.5	0
19	P D12-1	36"	RCP	1	168
20*	P A10-2	36"	RCP	1.5	240
21	P A31-5	36"	RCP	1	248
22	P C22-9&6	48"	RCP	1	184
23	C 1-1B	36"	RCP	1	336
24	A 12-3	36"	RCP	1	280
25	A 12-5	36"	RCP	1	248
26	A 11-10	48"	RCP	1	240
27	A 43-8	36"	RCP	1	248
28	(B3) 05-10	72"	RCP	1	260
29	C 03-7	48"	RCP	1	224
30	C 17-1	48"	RCP	1	248
31	C 08-1B	36"	RCP	1	432
32	C 09-1C	36"	RCP	1	320
33	A 8-24	48"	RCP	1	280
34	C 06-2	48"	RCP	1	232

Total Bores Completed: 34
Total Linear Feet: 8,045