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**Billings Heights Uses HDD and Jack-and-Bore to Install New 24-inch
and 12-inch Lines**

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1. ABSTRACT

The County Water District of Billings Heights maintains more than 120 miles of pipe in Billings Heights, a suburb of Billings, the largest city in the state of Montana. Spurred by the energy boom, growth has been substantial through the last decade in Billings and the surrounding area.

To accommodate growth, the District decided to upgrade their existing water distribution system, previously at its maximum capacity, by adding new transmission lines and a reservoir. The new transmission line includes over one mile of 24-inch diameter pipe and nearly 1.5 miles of 12-inch diameter pipe. Once complete, the 24-inch pipeline will convey water from the new 4-million-gallon Ox Bow Reservoir and will allow the District to retire three existing booster pump stations that will then only be used in times of emergency. The presence of several obstacles along the alignment that needed to be crossed without being disturbed required installation by horizontal directional drilling (HDD) and jack-and-bore methods. Due to the sensitivity of the surface, some sections of the 12 and 24-inch transmission lines were required to be installed within a casing pipe.

The initiation of the watermain upgrade efforts, the decision process and procedures used to determine suitable materials and accommodate the sensitivity of the project location, and the various trenchless methods selected to lessen costs and environmental impacts will be discussed thoroughly in this paper. The main focus will be on the installation of water transmission mains at the highway, wetland and irrigation canal crossings.

2. INTRODUCTION

Billings is the largest city in the state of Montana. It is located in the southeastern part of the state and is the county seat of Yellowstone County. The city began growing rapidly when it surpassed Great Falls as Montana's largest city in 1970. Its strategic location positions Billings to be an important regional hub. Billings boasts a population of approximately 110,000, making it the only city in Montana to have over 100,000 people. The Bakken oil development in eastern Montana, one of the largest oil discoveries in U.S. history, and the Heath shale oil discovery north of Billings play an important role in Billings' growth. Paired with the energy boom and its associated tremendous workforce, and recent development in the healthcare sector, growth has been substantial in Billings and the surrounding area.

Billings Heights, a suburb of Billings, was annexed into the city of Billings in July 1984 and became the fastest growing region of Billings in the 1990s. Although geographically separated from the rest of Billings by the Rimrocks,

the Heights, like other areas in Billings, felt the impact of the rapid growth in the region. It is the home of roughly 20% of the population of Billings (see Figure 1).

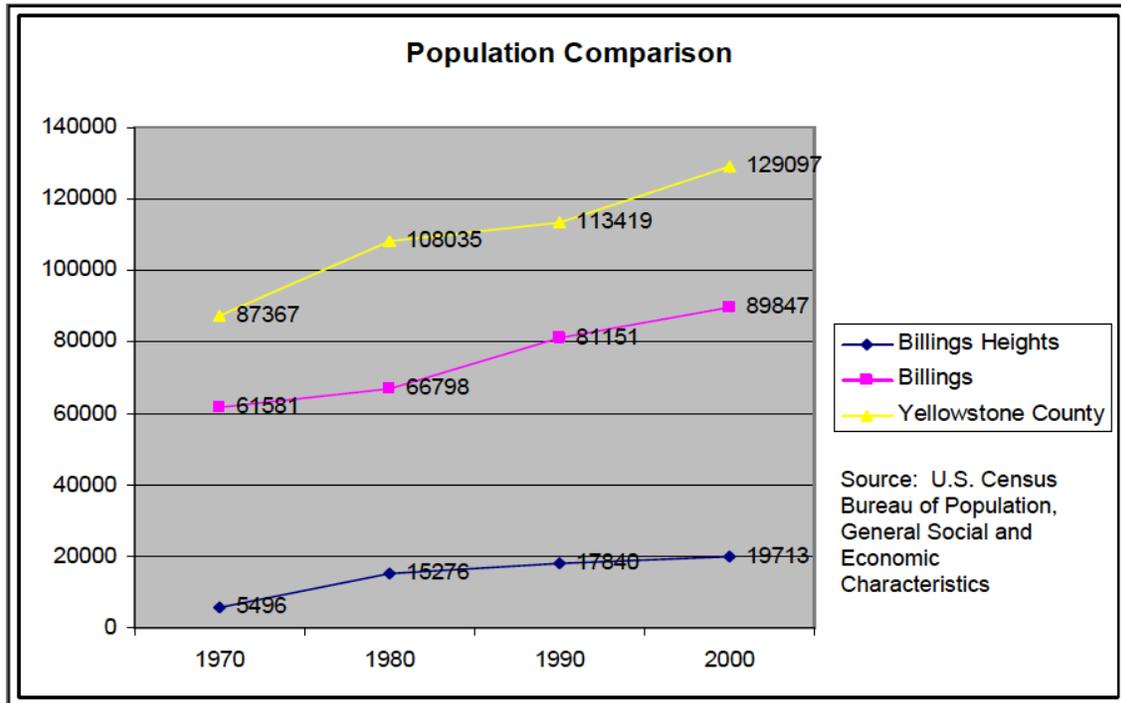


Figure 1. Population comparison data from the Billings Heights Neighborhood Plan.

Portions of Billings Heights’ existing water lines were undersized, and the distribution system was in need of additional storage. This represented a limitation for continued growth of the area. To alleviate these concerns, the District hired Interstate Engineering (Engineer) in 2008 to design the new transmission main and reservoir as a part of the District’s capital improvement plan.

The Ox Bow Transmission Main project aimed to provide additional storage and redundancy as well as open up additional areas in Billings Heights to provide growth to the northern part of the area and ultimately connect to the proposed Ox Bow Reservoir. The Ox Bow Transmission Main project is a two-phase project. Phase I included the installation of the necessary pipelines to connect the west side of the district to the new 4-million-gallon Ox Bow Reservoir, which will be installed as part of Phase II. Once completed and online, the new transmission main will convey water from Ox Bow Reservoir and Billings Heights will discontinue the use of the St. Andrews, Rolling Hills, and Inverness booster pump stations. These soon-to-be redundant booster pump stations will be maintained in an operable condition so they can be used during emergencies, if necessary. The new transmission lines will connect to Lanier Reservoir and serve the area in the Heights west of St. Andrews Drive before finally extending to the proposed Ox Bow Reservoir. The Ox Bow transmission line included over one mile of 24-inch diameter pipe and nearly a mile and a half of 12-inch diameter pipe, adding to the existing 120 miles of pipe maintained by the County Water District of Billings Heights (CWDBH).

3. DESIGN REVIEW

The Ox Bow Transmission Main project is a part of the District’s Long Range Plan, initiated in 2008. A preliminary engineering design report was submitted in May 2008. Then, in January 2009, the survey and preliminary analysis was completed. The Phase I design did not begin until April 13, 2015. The design was prepared in accordance with the Montana Department of Environmental Quality Circular DEQ – 1, Standards for Waterworks, February 24, 2006 Edition. The Engineer was in charge of the whole project design, management, and funding coordination. The District spearheaded the funding process and assisted with the project oversight. The District’s role was also critical in providing input and necessary information to the Engineer in the early design phase of the project.

As one of the early efforts of the design process, geotechnical investigations were completed in July 2015. The geotechnical investigation and engineering report concluded that the soil conditions were favorable for pipe installation along the proposed route. Twenty-one borings were drilled along the proposed pipeline route to depths ranging from 10 to 35 feet below the existing grade. The subsurface profile throughout the alignment included a varying depth of medium stiff to stiff lean clay soils over weathered shale bedrock. Layers of loose to medium dense silty and clayey sand soils were also encountered along the alignment. Groundwater was encountered near 5 Mile Creek and the box culvert irrigation crossing at depths ranging from 10 to 12 feet and 9 to 19 feet, respectively. The new transmission pipelines were anticipated to be at a depth of six feet. Thus, groundwater would most likely not be encountered along the alignment, and dewatering would not be required, with the exception of the 5 Mile Creek and box culvert irrigation crossing. The presence of groundwater at these crossings was one of the main reasons for choosing HDD installation methods at these points.



Figure 2. Field exploration map with boring locations along the pipe alignment.

Table 1. Soil corrosivity data from Geotechnical Engineering Report.

Boring	Depth (ft)	Material	Water Soluble Sulfate Content (%)	Resistivity (ohm-cm)	pH
B-2	9.5	Shale	<0.01	3,740	8.0
B-5	4.5	SM	0.02	375	7.6
B-6/8/11	4.5	CL	0.03	390	7.8
B-18	1.5	CL	0.08	361	7.7

Table 1 summarizes the testing results of the representative soil samples (locations are marked in red) collected along the proposed alignment. Resistivity values between 3,000 and 5,000 are considered to be aggressively corrosive to buried metals. Values below 1,000 are considered to be very strongly aggressive. Therefore, from a geotechnical perspective, corrosion protection of buried metal was critical to this project. The buried metal needed to be protected

via non-corrosive backfill, wrapping, coating, sacrificial anodes, or a combination of these methods. The importance of corrosion protection was even more dominant at the trenchless crossings, where restrained joint piping systems were required.

The project consisted of new 12-inch and 24-inch water pipelines for the CWDBH (see Figure 3). The new 12-inch water main began near the intersection of Lake Elmo Drive and Rolling Hills Drive. This pipeline extended north along Lake Elmo Drive for approximately 0.9 miles, crossing 5 Mile Creek and a tree grove along the alignment. The pipeline then made a turn on Alexander Road and transitioned to 24-inch water main. The alignment further extended east along Alexander Road, crossing under a Phillips 66 crude oil line, an existing box culvert, and Highway 87. Then, the water main extended northeast to cross the Billing Bench Water Association (BBWA) canal, continued to the northeast under an open field up to Independent Lane. From there, it extended north to approximately 1,000 feet past the Lanier Reservoir. The project location was on the north edge of the city in an area featuring wide open fields with minimal housing, lessening any traffic control challenges.

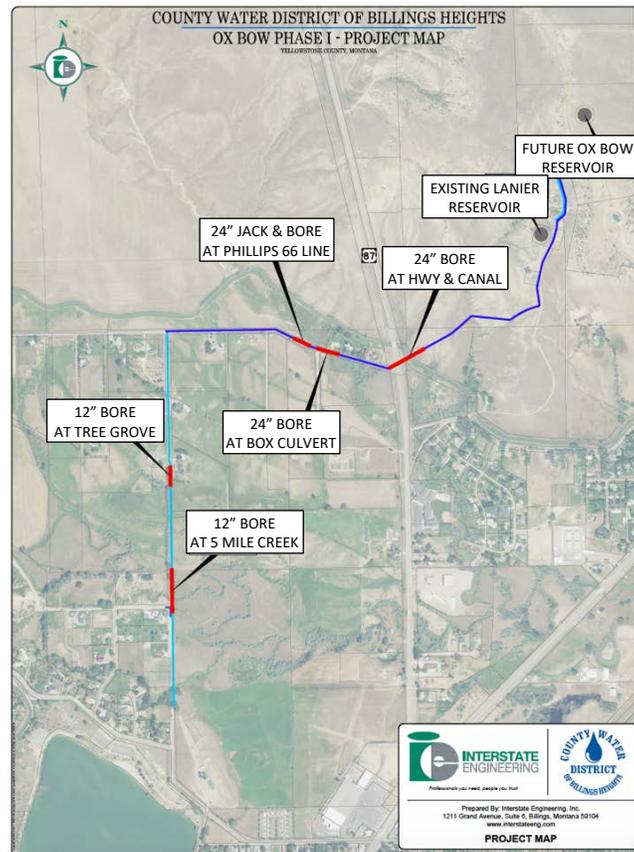


Figure 3. Project vicinity map for Ox Bow Transmission Main Phase I.

While most of the pipeline was installed by open cut methods, trenchless methods were required to install approximately 1,700 feet of the pipeline due to the number of areas with settlement-sensitive features at the ground surface. The proposed pipe route crossed 5 Mile Creek, a tree grove, the Phillips 66 crude oil line, a box culvert, and a combined crossing of Highway 87 and the BBWA canal. For 5 Mile Creek, the existing creek bed and adjacent wetlands could not be disturbed. Meanwhile, the existing cottonwood grove had one of the largest and oldest trees in the area and was to be left undisturbed if possible. The additional work to clear these large diameter trees was also not desirable as it would significantly affect the total project duration and cost. A 12-inch steel high-pressure crude oil pipeline, owned and operated by Phillips 66, was also discovered during the initial survey, and caused a potential conflict with the new 24-inch water main. Similar to the 5 Mile Creek crossing, the District and Engineer did not want to disturb the existing box culvert and adjacent wetlands. Finally, open cutting through the existing Highway 87 and the BBWA canal was simply not an option due to the sensitivity of the surface and the potential disruption of traffic.

Time was also one of the limiting constraints for this project; the BBWA canal crossing needed to be completed by April 1, 2016 to ensure that the construction would not interrupt the beginning of irrigation season.

To minimize disturbance to these areas, the Engineer elected to use trenchless installation methods for the crossings, and open cut methods for the rest of the pipeline. The crossings at 5 Mile Creek, cottonwood grove, the box culvert, and the adjacent Highway 87 and BBWA Canal would be installed by HDD. The Phillips 66 high pressure crude oil pipeline crossing would be installed inside a 30-inch steel casing pipe which would be installed by the jack-and-bore method. The Engineer originally planned to install this section using HDD, like the other crossings; however, the Phillips 66 engineers were more comfortable with jack-and-bore installation of the casing. The pipe alignment could be more accurately controlled in a jack-and-bore installation with a straight rather than curved alignment and a smaller annulus between the casing and the excavation, assuring the Phillips 66 engineers that the new transmission line would not impact the existing oil line. The rest of the pipeline would be installed by open cut method since most of the alignment was located in open areas with very light traffic.

Determining the pipe profile of the trenchless section was pretty straight forward. There were no tight bend radii or compound curvilinear profiles required along the alignment. Furthermore, the alignment could be easily altered if necessary since there was ample open area to work with as long as the minimum 6.5-foot vertical clearance was met. These were ideal components for HDD installation.

Pipe sizes were determined in the initial design phase. The Engineer performed hydraulic modeling of the area considering the forecasted demand and future expansion. The completed hydraulic modeling indicated that 12-inch and 24-inch diameter pipes were sufficient and best suited for this application. The operating pressures within the proposed water main would be below 150 psi. However, the District generally requires 235 psi (DR 18) polyvinyl chloride (PVC) pipe as an added safety factor. Ultimately, 12-inch DR 14 and 24-inch DR 18 PVC pipes were chosen for the Ox Bow transmission main. The 12-inch DR 14 PVC pipe is 305 psi pressure rated. The increase in pipe thickness for the 12-inch water main was the District's decision. The District wanted a thicker wall pipe to increase the safety factor of the pipeline operation. In general, the District was willing to trade the thicker walls and higher costs on its transmission and major distribution pipelines in order to attain a greater safety factor.

Fusible polyvinyl chloride pipe (FPVCP) was used on all the bored crossings. However, other materials were also considered during the design process. Other restrained joint bell-and-spigot PVC pipe systems, such as Certa-Lok and Eagle-Loc, were allowed during the bidding process as an equal to FPVCP as the trenchless water main carrier pipe. Due to concerns that the restrained joint bell-and-spigot PVC pipes would not be able to handle the bore lengths, could potentially leak at gasketed joints, and the potential of corrosion on any metallic joint components, encasements were required if these types of systems were selected. For the 12-inch water main, FPVCP was chosen over the other restrained joint PVC systems because it could be installed as a stand-alone carrier on the 12-inch HDD, lowering boring costs. Similarly, the main consideration of choosing FPVCP for the 24-inch water main was its maximum bore length capability. FPVCP could withstand longer pulls compared to other restrained joint PVC systems. Moreover, FPVCP's fused joint system allowed the whole pipe section to join seamlessly as if it was a single monolithic pipe. This reduced the risk of leaks in the future operation of the pipe.

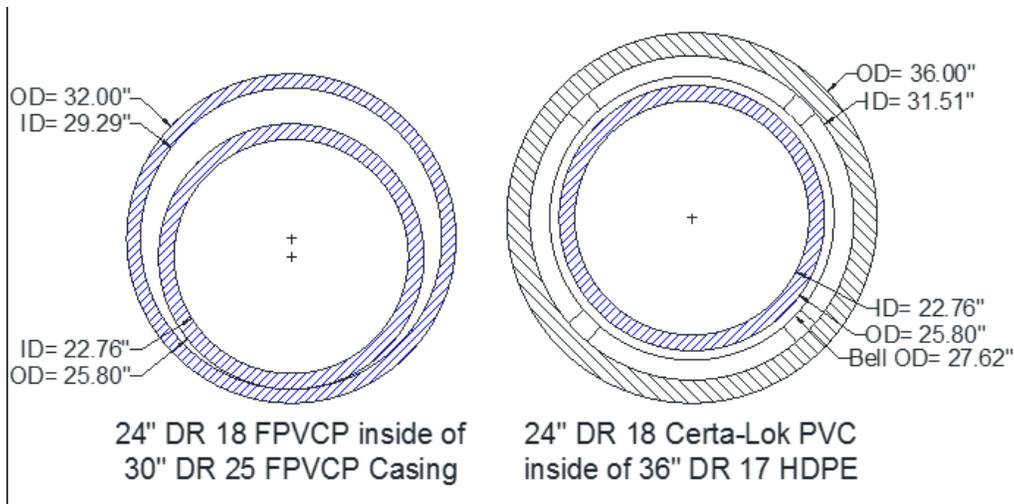


Figure 4. Comparison of specified pipe materials.

The 24-inch water main under the box culvert and under Highway 87 and BBWA canal required the use of a 30-inch FPVCP casing pipe, installed by HDD. The casing pipe was needed to further protect the pipe from the external load imposed by the surface features, especially under Highway 87. The casing pipe would be installed by HDD and then the carrier pipe would sliplined through the casing. The Engineer considered 30-inch DR 25 FPVCP and 36-inch DR 17 high density polyethylene (HDPE) pipe for this application. The larger HDPE casing pipe was required to provide the same internal diameter of the specified FPVCP casing while assuring the same structural capacity of the pipe wall. The difference in material tensile strength required HDPE pipe to have almost twice the thickness of FPVCP. Therefore, using HDPE pipe as the casing would yield higher installation costs due to the resultant larger bore diameter. Also, a larger casing pipe would still be required if restrained joint bell-and-spigot PVC was chosen due to the differences in overall outside diameter of the pipe (See Figure 4). The decision to use FPVCP on the casing pipe was also part of the District's effort to keep the project's HDD materials as consistent as possible. Ultimately, costs, time frame, and meeting site constraints were the primary drivers for the contractor ultimately selecting FPVCP for the trenchless portions of the project.

Phase I of the Ox Bow Transmission Main project was advertised in December 2015 with an estimated project cost of approximately \$3 million. Eight sealed bids were received on January 19, 2016. After the review process, Western Municipal Construction (Contractor) was awarded the contract as the lowest responsible bidder on the project (see Table 2). Their bid of \$2,160,000 came in under the engineer's estimate. Western would act as the general contractor for the project, and Denny's Electric was subcontracted to complete the HDD sections of the transmission main.

Table 2. Project bid tabulation.

Bidder	Total Bid
Western Municipal	\$ 2,160,000.00
Central Excavation	\$ 2,358,784.00
Kinkaid Civil Construction	\$ 2,361,334.00
Dick Anderson Construction, Inc.	\$ 2,440,560.00
COP Construction LLC	\$ 2,446,690.00
Mountain View Building of Montana, Inc.	\$ 2,471,726.00
EDK Engineering and Construction, Inc.	\$ 2,729,973.00
Wilson Bros. Construction, Inc.	\$ 2,845,179.00

4. PERMITTING

Before the beginning of construction, the District had to obtain necessary permits to perform the work in the designated location. A permit from the U.S. Army Corps of Engineers was required for the 5 Mile Creek flood plain. A separate Flood Plain Development Permit was also needed from Yellowstone County. BBWA also issued a permit for construction under the canal. This permit specified that the crossing had to be completed by April 1, 2016 to prepare

for irrigation season. While the entirety of the work west of Highway 87 was within the dedicated public right-of-way, the work located east of Highway 87 was on private property. The District successfully obtained the necessary easements for the construction, operation, and maintenance of the transmission main.

Additionally, a cultural resource investigation was conducted on a portion of project site. The State Historic Preservation Office called for a cultural investigation on the area from the BBWA canal to the Lanier Reservoir. The investigation was performed by a reputable local resource firm and no significant resources were found.

5. CONSTRUCTION

Construction began on February 22, 2016. The initial construction efforts started with standard clearing and grubbing, saw cutting pavement and digging trenches for the open cut installation, and lining the canal bottom with concrete. The concrete lining of the canal bottom was required by the BBWA according to their issued permit. Traffic control was very minimal since the construction took place in a scarcely populated area with a lot of open spaces and little to no housing (see Figure 5). Reduced speed limits were required in areas where HDD was performed, namely on Lake Elmo Road, Alexander Road, and Highway 87, due to proximity of workers to the roadway.

There were four HDD sections in this project. Ideally, the whole pipe section would be fused to form a single length and pulled in at one time. Consequently, the Contractor had to locate and obtain the necessary permissions for staging and pipe layout areas. The contractor coordinated with local property owners to secure an area for FPVCP's fusion and layout. Fortunately, obtaining access to fusion and layout areas was not a problem for this project. The first pull was for the HDD section under Highway 87 and BBWA canal. The 468-foot borehole was constructed from March 1 to March 9, 2016. The 30-inch FPVCP casing was pulled on the same day that the borehole was completed. During the first pull, one of the joints of the 30-inch casing pipe broke prior to insertion into the borehole due to contamination. This can happen when foreign material gets inadvertently trapped in a fusion joint, which will weaken the joint. This type of joint defect rarely happens since fusion technicians are required to clean and inspect pipe ends prior to fusing. On March 14, 2016, the pipe supplier responded quickly to resolve the issue. A small portion of the pipe around the broken joint was cut off, and the two pipe lengths were fused back together. The 30-inch casing pipe pull-in was completed on the same day within three hours. Afterward, the 24-inch water main was installed within the 30-inch casing pipe in place.



Figure 5. Project location had ample open area for staging and pipe layout [fusion (left); layout (right)].

The second HDD installation was for the 5 Mile Creek crossing. The Contractor constructed a 515-foot borehole along Lake Elmo Road from March 15 to March 16, 2016. A 12-inch water main was immediately pulled in after the bore was complete. The following day, the Contractor had already begun boring under the tree grove, approximately 900 feet north of the 5 Mile Creek crossing. This was a 220-foot 12-inch water main bore. The boring and pipe pull-in for this section was completed on the same day. The pipe pull-in for both 5 Mile Creek and tree grove (Figure 6) crossings took only an hour.



Figure 6. HDD pull-in under tree grove. The bore was installed in cold and inclement weather.

The final HDD section was the box culvert crossing on Alexander Rd. This included 280 feet of 24-inch water main inside a 30-inch casing pipe. The crossing was bored from March 21 to March 23, 2016. One lane of traffic was closed during boring and pull-in. Traffic was very light and the lane closure had only minimal impact (Figure 7). Like the first HDD, the 30-inch casing pipe pull-in was done immediately after the borehole was completed. The pull-in was three hours in duration. The 24-inch water main was then pulled into place inside of the casing.



Figure 7. Staging and installation of crossing under box culvert [existing culvert (left); pull-in (right)].

The jack-and-bore section under the Phillips 66 pressurized crude oil pipeline followed a similar procedure as the HDD sections in regard to the carrier pipe installation. The pipe was fused and laid on the ground along an existing ditch (Figure 8). The Contractor started by jacking and boring 200 feet of 30-inch steel casing. The process occurred from March 1 to April 11, 2016. The 24-inch water main was put in place on April 22, 2016. The water main insertion only took five hours. HDD would have been completed in a shorter time frame. However, the Phillips 66's engineers' preference for jack-and-bore was based on the added protection for the critical crude oil pipeline.



Figure 8. Jack-and-bore installation under Phillips 66 oil pipeline. A steel casing was bored and jacked into place (left); FPVCP with casing spacers was then placed inside the casing (right).

The proposed transmission main was completed on June 1, 2016. The line was pressure tested at 200 psi for 2 hours. The transmission main was connected to the existing system and fully operational on September 15, 2016.

6. CHALLENGES AND LESSONS LEARNED

Overall, the project went smoothly. There was the minor setback from the failed fusion joint on the 30-inch casing pipe for Highway 87 and BBWA canal crossing due to contamination; however, the pipe supplier's quick response made this only a minor hiccup in the scheme of the project. The Engineer maintained that one of the biggest challenges on this project was the crossing under Highway 87 and the BBWA canal. Extensive effort was made to avoid disrupting current traffic flows on the highway and meet the BBWA's critical date of April 1, 2016. HDD technology provided an efficient and fast turnaround for installation.

7. CONCLUSION

The project was successfully completed on time and proved to be a good application of trenchless installation methodologies. The suitable soil conditions and availability of sufficient working area contributed to the successful outcome of the HDD installations. The Engineer was very impressed with the short time frame required to fuse and install FPVCP by HDD. The four HDD crossings were actually completed before the single bored-and-jacked crossing was finished even though both methods were started on the same day. The District was very satisfied by the project result. The installed transmission main opened up a new service area in the northeast part of the district. The transmission main now connects the west side of the district to Lanier Reservoir while the Ox Bow Reservoir is being constructed. When the Ox Bow Reservoir is completed, the transmission main will be extended to the new reservoir, and the District's two-phase water storage system upgrade will be complete.

8. REFERENCES

City of Billings (2015) – Project Manual: Water System Improvements Ox Bow Transmission Main for The County Water District of Billings Heights I.E. #Y15-00-059, Bid Documents, December 2015.

Planning and Community Services Department, City of Billings (2005) – The Billings Heights Neighborhood Plan, September 2005.