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MULTIPLE HDD WATER MAIN INSTALLTIONS ACROSS HIGHWAY 29, NAPA, CA

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ABSTRACT: In the summer of 2013, the City of Napa Public Works, Water Division, undertook a project to greatly improve their water circulation between the east and west sides of their system. The existing system contained a number of undersized, aged, and leaking water mains across Highway 29, which severely limited the amount of water that could be moved through the system. With this project, the City was able to replace eight of the old crossings with only three new freeway crossings. With the new crossings, along with the ancillary piping improvements in the vicinity, the system can now better serve the water demands in the area.

Due to the complexity of the crossings, horizontal directional drilling (HDD) was chosen as the method for pipeline installation. Each crossing required negotiation around a very congested existing utility corridor, work with CalTrans for Highway 29, work with Napa Valley Wine Train for their railroad, in addition to the usual pipeline construction considerations.

This paper will review the design needs for the project, detail how the project objectives were met with construction practices specific to the challenges of these site locations and discuss how the City of Napa is addressing new infrastructure projects to deliver satisfactory design life expectations.

1. INTRODUCTION

The City of Napa (City) is located in Northern California, an hour's drive northeast of San Francisco and the Bay Area. The city is comprised of numerous residential and industrial communities, and of course, many famous wineries and signature landscapes. More than 78,000 people depend on the City of Napa Water Division (CNWD) for providing safe and reliable drinking water on a daily basis, as well as several neighboring cities including Calistoga and St. Helena (Thomas, 2013).

The northern portion of the City's potable water distribution system is divided into two major sections by the Highway 29 (Hwy 29) corridor, which runs north and south through the City. This viaduct not only contains Hwy 29, which is a California Department of Transportation (CalTrans) highway, but also houses the Wine Train right of way, in addition to frontage roads on either or both sides. Crossing this viaduct with utilities was necessary, but involved undertaking.

Over years of distribution system expansion and development, the City has maintained fourteen waterline crossings of this corridor. However, of these fourteen crossings, approximately one third of them have been capped off and abandoned. Due to the location of the crossings and the difficulty and expense of maintaining or replacing them, when there was a leak or a major issue, the City simply removed them

from service. In addition to the water lines that have been removed from service, another third of them are undersized and to do not effectively function to move water across the viaduct (Lovell, May 2013). As such, the Hwy 29 corridor in effect becomes a roadblock for moving water effectively from west to east in the northern portion of the City's distribution system.

2. PROJECT SOLUTION AND DESIGN

Despite the need for improved system interconnection, the hurdles of construction and maintenance through the Hwy 29 corridor remained firmly in place. The City Engineering team attacked the problem from two angles: minimize the number of crossings required to improve the system flow across the highway and use alternate methods of construction in order to get the crossings installed.

To the first point, the City evaluated the required size, number, and locations of crossings required. They were able to solve the majority of the flow issues with only three new strategically placed crossings: one located at Salvador Avenue (the northern most crossing within the City), one at Sierra Avenue (the south crossing of the primary pressure zone), and the final one at F Street (a central crossing for one of pressure impacted zones in the system). The crossings at Salvador and Sierra would each be installed with a 24-inch nominal casing to support a 16-inch nominal carrier pipe. The third location at F Street would only require a 16-inch nominal casing to support a 12-inch nominal carrier pipe. Along with boring the pipelines across the highway, all three installations required ancillary piping beyond the highway in order to complete the flow improvements intended for each area.

To the second point, the City evaluated using alternate forms of construction installation methodology to install these critical crossings of the CalTrans Hwy 29, and the Wine Train right of ways. Due to the utility conflicts located on each side of the freeway, in addition to the curved alignment required, they decided to refer to a trenchless method that worked well for them on several other projects, namely horizontal directional drilling (HDD).

HDD, a widely accepted trenchless technology accepted for the installation of both dry and wet utilities for more than 20 years, utilizes a steerable drilling rig to create a curvilinear bore hole under a given obstruction. With drilling rods available in multiple lengths, installation possibilities are usually only limited by the deflection capabilities of the pipe material being installed. After a pilot hole is completed, the bore hole can then be enlarged with a series of passes with larger reamers, eventually up to a size slightly larger than the outer diameter of the product pipe such that the product pipe can then be pulled back through it. The final step in the process involves pulling the product pipe through the excavated bore hole, eventually connecting each end to the utility system. As a result, this type of construction makes it feasible to install a pipeline under an obstruction such as a river or, in this case, the Hwy 29 corridor, without having to excavate through the obstruction.

In order to assure that any future issues with these casings would be maintainable, as well as to comply with right-of-way requirements, the City installed casing pipes around the required carrier pipes. This meant that if there was ever an issue with the carrier pipe, any water leak would migrate to either side of the corridor to the water easement areas, and would not adversely impact the use or stability of the transportation infrastructure located in the corridor. In addition, since the crossings were cased, the carrier pipes could theoretically be removed and reinstalled if there was ever an issue, without the need to install a new crossing.

Pipe materials used with HDD installations need to be flexible enough to maneuver through curvilinear alignments of the bore path as well as strong enough to handle the tensile forces that occur during installation. For these three highway crossings, the City elected to use the same pipe material that they had success with on their previous HDD projects: fusible polyvinylchloride pipe (FPVCP). FPVCP is produced to AWWA C900 and C905 standards, but utilizes a thermal butt-fusion process to join lengths of the pipe together. This creates a joint that has the same capabilities as the pipe itself, including tensile capacity, making it a valuable option for HDD applications where good tensile force capacity is required.

In order to complete the crossings, the City first needed to coordinate and receive approval from both CalTrans and the Napa Valley Wine Train for the installation method, depths, and materials used for each crossing, for both the casing and the carrier pipe. In this case, the City was interested in using FPVCP as both the carrier pipe as well as the casing pipe. Using similar materials reduced the total material cost price, but more importantly, use of the non-metallic material addressed the City's concern regarding the corrosive nature of the soils in the area which have generally been defined as "highly corrosive" to metallic infrastructure. Although using FPVCP was a non-standard casing material for both groups, both CalTrans and the Wine Train approved the use of FPVCP as both the casing and carrier pipe.

In 2012, the project was originally limited to the crossings at Salvador Avenue and F Street, with the intension of installing Sierra Avenue the following year due to budget constraints. However, due to a restriction on the construction of the Salvador Avenue crossing, which required that portion of the project to be completed within a two month period, available and qualified drillers were limited and the resulting bids were few and costly. The City decided to reject the bids at that time and repackage the project with the addition of Sierra Avenue the following year when the additional budget would be available. The project was competitively bid and awarded for $3.3 million to Mountain Cascade, Inc. of Livermore, CA, who selected Advanced Boring Systems as their subcontractor for the directional drilling services. Underground Solutions, Inc. provided the FPVCP and fusion services for the project.

3. SALVADOR AVENUE INSTALLATION

The first crossing that was completed was the Salvador Avenue crossing which included work through a four-way signalized intersection in Caltrans right-of-way. Due to the proximity of an elementary school to the work area, the contractor's schedule was limited to start and finish within a two-month window during the summer of 2013 to maximize safety of the public and minimize traffic concerns during the active part of the school year calendar. The Salvador Avenue installation was broken into four phases of construction, as illustrated in Figure 1.

Completing the HDD installation across Hwy 29 was the first phase of construction at Salvador Avenue. The installation was approximately 600-feet long, requiring a horizontal offset in order to align properly with the 60-foot horizontal shift of the roadway. For constructability purposes, reducing the offset would have created other challenges such as the requirement of night work by CalTrans, closing access to the highway from the public streets, and reduced equipment laydown area. To complete the crossing, the contractor needed to install the 24-inch casing pipe then pull the 16-inch carrier pipe into the installed casing.

The complications of this particular crossing existed on both sides of the highway. To the east, where the drilling equipment was stationed, the contractor was limited to approximately 100-ft long parking strip along the curbline to layout all equipment and provide the bore pit for the driller. The site was limited in this way in order to avoid closure of the driveways to the school which had to remain open due to summer school classes. To the west, the receiving pit was located on the north half of a four-way intersection to maintain Caltrans requirement for an unobstructed exit "ramp" for traffic coming from Hwy 29, otherwise the project would require night work. The drill equipment side and pipe insertion side could not be reversed due to the lack of laydown area for the 600-feet of casing and carrier pipe on the east side of the highway.

This crossing posed difficulties for the driller, who needed to complete the drill with two horizontal alignment shifts while maintaining a minimum depth profile as required by CalTrans and the Wine Train, without exceeding the bending limits of the FPVCP. To make things even more complicated, in order to reach the design depth of 8-feet at the receiving pit, the drill head had to be maneuvered under the railroad tracks, under Salvador Creek and an associated concrete box culvert, under a 36" water transmission main and 8" high pressure gas line, but at the same time, come up shallow enough to avoid a 6" high pressure gas main, and a 14" sewer main. Besides the drill head needing to avoid utilities, it also had to be within a 1-ft vertical tolerance in order to successfully complete the pull back of the new casing and carrier pipe. There was limited knowledge about the existing culvert and the material

underneath, which increased the risk if the driller came in too shallow. If the driller came in too deep, the gas and sewer would have been hit.

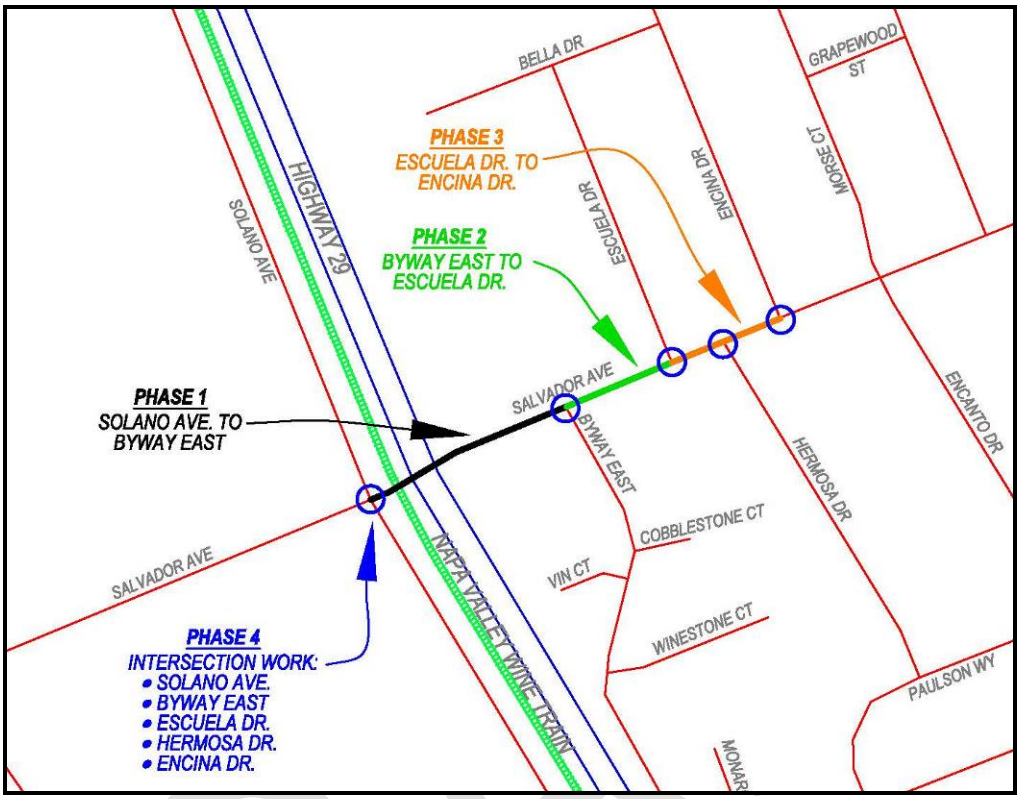

Figure 1. Schematic of the construction phasing associated with the Salvador Avenue waterline installation. Phase 1, Solano Ave. to Byway East was completed with HDD installation methodology, while Phases 2 through 4 were completed with traditional trench construction methods (City of Napa, 2014).

As if that wasn't difficult enough, to avoid nightwork, the driller had to use a crosswalk to monitor the location and elevation of the drill head. If the contractor wanted to close even one lane for the project, CalTrans would have enforced nightwork. With residences so close to the drilling equipment, neither the City nor the Contractor wanted to perform work at night. Night hours meant working exclusively between 9 pm to 3 am, including the set-up of traffic control, thus reducing a normal 8 to 10 hour working day to 4 hours.

Although geotechnical reports for each side of the highway indicated dense clays for the majority of the crossing, they missed a cobblestone layer that the driller had to work through. The new soils condition luckily only slowed the driller down for a small section of the entire length. Groundwater was pretty light allowing the mud to mix smoothly and easily. The driller had some difficulty completing the final horizontal alignment due to issues with the signal monitoring of the drill head that occurred halfway through the pilot bore. Since the drill section was so short, there was no room to correct the alignment, and no guarantees that the signal issue wouldn't return. However, even though the drill was off of the planned alignment, a 2-ft shift of the receiving pit was sufficient to correct the alignment and install the first reamer for the reaming phase. After the pilot hole was completed, the rest of the drill proceeded without incident. The driller understood the risks of the area and maintained a steady slow pace to avoid complications.

When it was time to complete the pullback of the 24-inch casing, the contractor needed to lift the pipe with two excavators and a backhoe in order to snake the pipe into the receiving pit. For pullback, those who were supporting the pipe had to be cautious of overhead wires within the intersection as they approached the pit (see Figure 2). As this was the first pullback of the project, it was quickly determined that in order

for a smooth pullback operation, there needed to be a minimum of 3 vactor trucks clearing the pits: one dropping off spoils, one returning from the drop-off of spoils, and one stationed at the site. However, 100-ft into the start of the pull back, the vactor trucks became the delay. Heavy traffic slowed their progress to and from the disposal site, the size of the bore pit was relatively small so the storage capacity for when the vactor trucks were transitioning preventing continuous progress of the pull back, and as the pullback was on the last 100-ft of completing, one of the larger vactor trucks broke down, thus slowing the installation further. Although the pullback was completed that day, due to the delays, the pullback extended 4 hours longer than initially anticipated.

Figure 2. Installation at Salvador Avenue avoiding the overhead utilities during pullback from the exit pit on the west side of Hwy 29 (left) to the restricted receiving pit on the east side of Hwy 29 (right).

The following day, pull-back of the 16-inch carrier pipe still required support of the excavators and backhoe, but since the hole was then supported by the casing pipe, vactor trucks were not needed. The contractor had a couple teams of workers strapping on casing spacers as the driller pulled the pipe. Each changing of a rod provided just enough time for the spacer installations and the pullback was relatively continuous.

After the drilling portion was completed and the new casing and carrier pipes were installed, Mountain Cascade was able to complete the final three phases of the freeway crossing, including 700 feet of traditional open trench construction methods.

4. SIERRA AVENUE INSTALLATION

The second crossing completed was the Sierra Avenue crossing. This crossing and subsequent piping work covered the longest length of any of the crossings for the project and included two sections of HDD installation. The HDD portions included the installation of approximately 600-ft of 24-inch casing and 16-inch carrier pipe across Hwy 29, followed by an additional 1,100-ft of 12-inch carrier pipe to be drilled through a recently paved section of Sierra Avenue from Jeffeson Street to Garfield Park (see Figure 3).

Unlike Salvador Avenue, there wasn't a time constraint for construction along Sierra Avenue, even though the project was only a block from several schools. The location also was not a full CalTrans intersection, but served as an entry and exit ramp to Sierra Avenue on the east side of the highway. The street on the west side that the pipe was to align with was Devonshire Drive, a residential street, at the Solano Avenue intersection, which is a major collector street.

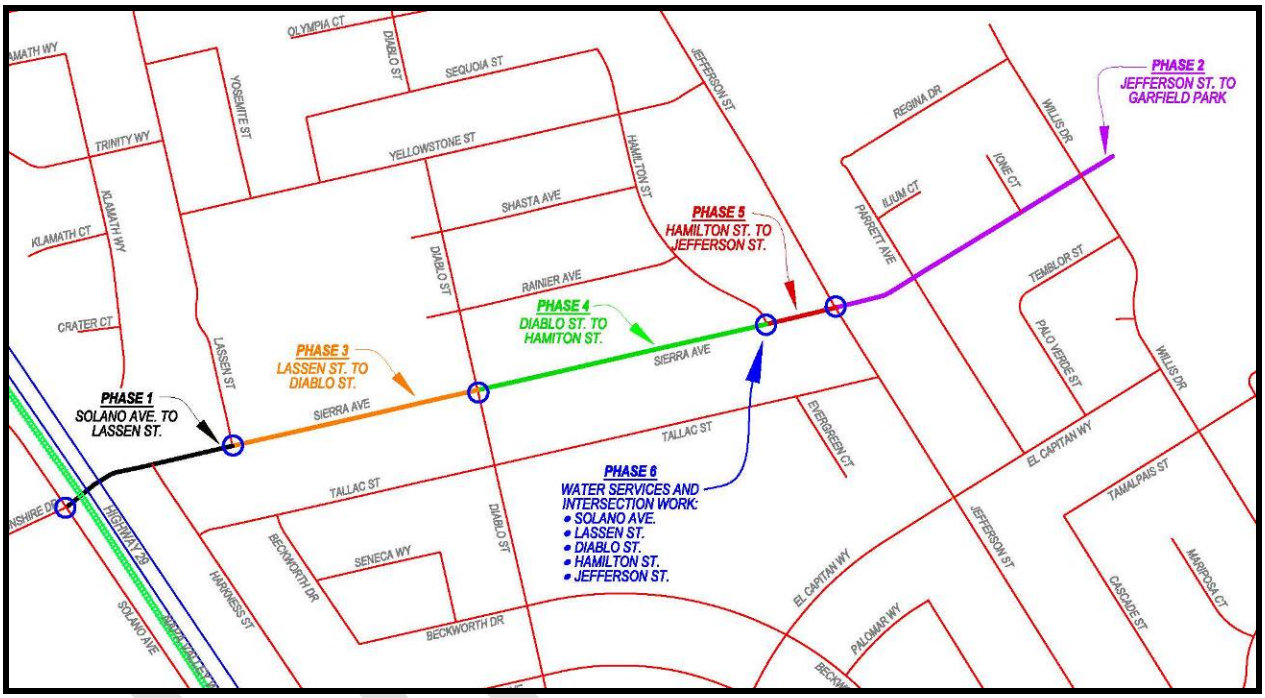

Figure 3. Schematic of the construction phasing associated with the Sierra Avenue waterline installation. Phase 1, Solano Ave. to Lassen St. and Phase 2, Jefferson St. to Garfield Park were completed with HDD installation methodology. Phases 3 through 6 were completed with traditional methods (City of Napa, 2014).

Although the Hwy 29 crossing at Sierra Avenue included only a single horizontal offset to achieve, the complexity was high due to the utility clusters at the receiving pit. Even though the driller did not have to maneuver the drill head under a drainage channel, a similar tolerance of 1-ft was still necessary as the drill exited the alignment. The facilities the driller had to maneuver under included an 8-inch high pressure gas main, a 36-inch water transmission main, and a 12-inch water distribution main. Although the drilling equipment did not continue farther west to conflict with additional utilities, the driller could not be deeper than the design, otherwise the new pipeline could not be maneuvered into the bore pit because of existing 4-inch and 6-inch high pressure gas mains, a 30-inch storm drain, and a fiber optic cable conduit.

To ensure the safety of the workers and the utilities in the area, the receiving pit was purposely larger and deeper than usual in order to expose the existing gas and water mains to visually confirm that the drill head avoided the utilities.

Similar to Salvador Avenue, the laydown area for the drilling equipment was about the same with only about 100-ft available along the curbline. Instead of being a straight laydown area, it was partially on Sierra Avenue and then continued around the corner of the adjacent intersection. Although it was the same available length, the angle of the equipment made it easier for the driller to monitor the mixing of the drilling fluid.

Unfortunately, similar to issues witnessed in Salvador Avenue, an unknown electrical interference during the drilling activities occurred where the driller lost track of the drill head location. The driller's team spent hours with the equipment manufacturer and replacement equipment trying to determine what the cause was. Although the signal floor was 3 times below where the drill head design depth was, even at a depth of 10-feet, the signal kept getting lost. The City placed faith in the driller that the issue would resolve itself once they reached the freeway, knowing that there would be sufficient length remaining in the drill to complete minor corrections. Luckily, past experience proved to work in the City's favor, and the signal did return steadily as it approached CalTrans right-of-way.

In another location, the option to make adjustments after half of the drilling was complete may not have been feasible, but with the stiff clays the driller was working in, the drill head followed direction well and was able to be corrected. When the pilot hole reached the receiving pit on the east side of the freeway, there was concern that when the final reamer (36-inch diameter) was installed, that the drill was going to come up too shallow and conflict with the existing utilities. When the 16-inch reamer was installed, the concern was confirmed. However, instead of trying to attempt the drill again, the driller used the open excavation to his benefit and worked the drill head down by reaming several back and forth passes, so that the weight of the drill head was able to cut out more earth underneath the utilities to allow the larger reamer to pass by. The effort had to be repeated with each reamer pass, and extra caution was employed, including additional vactoring of the hole, as the drill head passed by. In the end, the pipe was able to be successfully installed, meeting the minimum separation requirements for each of the utilities.

Unlike Salvador, the laydown area for the casing and carrier pipes was not available down Devonshire Drive, which had residential driveways along each side. Perpendicular to the new pipe alignment, Solano Avenue had sufficient laydown area for the pipeline, however, due to the tight radius of the intersection and the proximity of structures and trees, the pipe was fused into three 200-ft sections. The day of the pullback, the pipe was lifted by backhoes and excavators and carried around the corner and down Devonshire Drive to be assembled with two intermediate fusion joints (see Figure 4). For the 24-inch diameter pipe, this operation was completed in about 4 hours and pullback commenced immediately after it was completed.

Figure 4. Installation procedure shown for the Sierra Avenue crossing required moving sections of fused pipe,

Figure 5. Challenging components of the Sierra Avenue crossing included working within close proximity of high pressure gas and water transmission mains (left), and underneath the Napa Valley Wine Train (right).

Luckily, during pullback, the bore pits on both sides of the highway were large enough to support the mud coming out of the hole, giving the vactor trucks time to leave and return without impacting the rate of the pullback. Just an hour past the estimated time of completing, the casing was installed. The following day, the fusing operation for the carrier pipe was completed in a similar manner with the movement of the pipe around the corner and completing two fuses in order to pull the pipe into position.

The second drill on Sierra Avenue was much simplier in some ways than the freeway crossings, but also had its own complications. Due to the traffic loads, the drilling equipment had to be stationed on the east end of the site at Garfield Park. Since this 1,100-ft section was only a 12-inch water main, the design limited the permitted drill depth to not exceed 8-feet in order to allow for reasonable construction of future service connections. Shallow installations increase the risk of frac-out, especially when the installation is parallel to other existing utilities. In addition, instead of the stiff clay at deeper depths, there was a higher chance of modified soils conditions with backfilling and other trench work.

As anticipated, almost immediately, frac-outs started to pop-up 15-feet away from the drill alignment, following the alignment of an existing 4-inch water main. To reduce the pressure of the mud, the driller arranged for a series of cores to be cut out of the street section (the only permitted cut in a recently paved street that didn't trigger overlaying the entire length of work) to relieve the pressure, then he stationed vactor trucks at each hole to monitor the mud as it tried to exit the pit. This complication slowed the pace of the drill but allowed the driller to stay at the design depth.

When the driller was ready for the pipe pullback operations, the contractor had to complete another series of difficult maneuvers with the pipe. Similar to Devonshire Drive, Sierra Avenue had residential driveways along both sides of the street. As a result, the pipe had to be fused into three 400-ft sections and carried down Sierra almost ½-mile in order to complete the two final fuses for pullback. With the smaller diameter

pipe, the flexibility of the pipe made it more difficult to maneuver than the larger pipe when adjusting it to Devonshire Drive, but the pipe was also lighter, allowing smaller equipment to be used to move it.
As the pullback operations began, there was a question of how much mud was still in the drilled hole after the frac-out monitoring that was required during drilling. The driller pushed in more drilling fluid to account for any voids that might exist and kept vactor trucks stationed at each hole. Within 2-hours, the entire length of 12-inch pipe was installed with almost no mud exiting the relief holes.

5. F STREET INSTALLATION

The Hwy 29 crossing along F Street was smaller and shorter than the ones at Sierra Avenue and Solano Avenue. The contractor was anything but relieved to move equipment to this area. Unlike Salvador and Sierra which were heavily used roadways where one could see across the highway, there was no visibility across the 300-ft drill length. Besides the fences and foliage located on each side of the highway, Caltrans had a planted median with 10-ft high bushes screening each direction of travel.

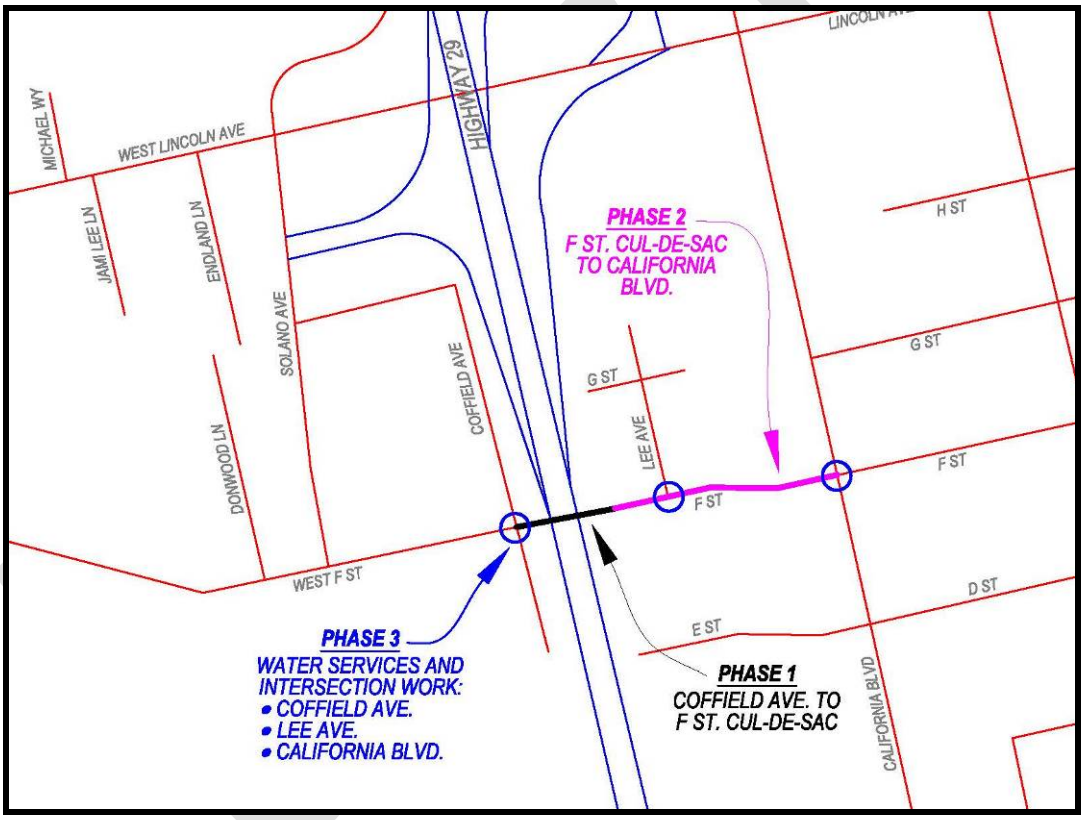

Figure 6. Schematic of the construction phasing associated with the F Street waterline installation. Phase 1, Coffield Ave. to F St. Cul-De-Sac was completed with HDD installation methodology, while phases 2 and 3 were completed with traditional methods (City of Napa, 2014).

This last portion of the project was completed with the drill equipment placed on the west side of the freeway to avoid blocking driveways and access to homes. In order to avoid both a 6-inch and a 10-inch high pressure gas line, 12-inch distribution main, 6-inch sewer main, and a 60-inch storm drain, the equipment had to be set up close to the highway, blocking a lane of access to a cul-de-sac. To maintain access to homes, the driller had to maintain steel plates over the bore pit during drilling activities which made clearing the hole of drilling fluid a challenge. But the realization of why access had to be

maintained was quickly realized when a fire started south of the project area and a fire truck had to go through the project site.

Unfortunately, due to the location of the high pressure gas mains in the vicinity, although the drill could be stationed to start past them, the driller was not able to install his equipment stabilizers as he normal would. With the short distance and soils conditions of the area, if he needed assistance stabilizing the drill rig, he would use the weight of an excavator to assist.

To make matters more interesting on the last drill, there was another previous drill of fiber optic cables along a similar alignment that the contractor had to parallel, along with a 6-inch water main and a sewer main. The location of the fiber optic drill was not certain, due to the lack of a tracer wire. The best option available was utilizing the location of old trench cut lines from the previous work located on the east side of the highway to indicate where the alignment might be. Instead of a straight line that was intended, to give the driller a little more space away from the unlocatable utility where the pilot head might shift into, the driller adjusted his angle slightly to the south to complete a curved drill alignment.

Figure 7. Maintaining access across a cul-de-sac while avoiding high pressure gas mains and significant trees for the F Street crossing.

The significant size and amount of trees in the area, which were to be protected during construction, ended up being a help instead of a hindrance. The driller was able to use them as a target, since other visual options were not available, and they helped to successfully steer the pilot bore.

However, all was not as simple as desired. The pilot hole had to be re-drilled with the last 15-feet of the alignment in order to avoid a sewer crossing that was missed during design, but the driller only had to go back a few rods (~50-ft) before he was able to make the small adjustment and make it into the receiving pit.

6. SUMMARY

In the summer of 2013, the City of Napa Public Works, Water Division, undertook a project to greatly improve the water circulation between the east and west sides of the northern part of their potable water distribution system. The City was able to replace eight of the old crossings with three new Hwy 29 corridor crossings utilizing HDD installation methodology. These three new crossings, along with the ancillary piping improvements in the vicinity, better serve the water system demands in the area.

Each crossing required negotiation around a very congested existing utility corridor, work with CalTrans for Highway 29, work with Napa Valley Wine Train for their railroad, in addition to the usual pipeline construction considerations. Due to the diligent planning effort and the experience of the general and specialized contractors on the project, each crossing was completed without critically impacting the Hwy 29 viaduct.

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