City of Napa Completes Challenging Hwy 221 Waterline Project
Utilizing HDD Instead of Open Cut

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ABSTRACT: The City of Napa Water Division was faced with completing a major waterline project along Highway 221 in the winter of 2012 to resolve a bottleneck that existed in its water distribution system. The project required replacement of 7,400-LF of an existing 16-inch water main with a new 24-inch water main from Napa Valley College south to Kaiser Road. The location of the new waterline replacement presented many challenges, including work along the CalTrans right-of-way associated with Highway 221, and working in and around Napa Valley College, Napa State Hospital, Napa Valley Memorial Park Cemetery, and the Municipal Golf Course at Kennedy Park. For this project, HDD was selected as the installation method due to narrow easements, utility conflicts, surface conflicts, varied topography, and other constraints that would have made traditional open-cut pipe installation difficult, time-consuming, and cost prohibitive. HDD overtook direct bury installation as the method choice due to the benefits of HDD methodology, but also it did not compromise the final installed asset in terms of construction practice and materials used. By the end, the pipe installation was completed with 6 drilled segments ranging between 100 and 1,700-LF, and only 100-LF of trench work.

This paper will focus on the planning and design of the project, specifically in the decisions made to utilize an alternate installation methodology due to the unique project constraints. It will also explore the construction phase of the successful installation, examining how engineering and planning decisions made on the front end materialized and were received through the course of the project’s completion.

1. INTRODUCTION

The City of Napa is located in Northern California, just an hour’s drive northeast of San Francisco. The city consists of Napa Valley College, numerous residential and industrial communities, and world famous wineries surrounded by beautiful landscapes. Over 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.

The CNWD operates three treatment plants on the outer edges of the system and maintains a transmission main system interconnecting all three treatment plants to convey treated water to system-wide distribution. This transmission main system consists of pipe diameters ranging from 14-inch to 42-inch nominal pipe sizes. It also is laid out with two primary corridors, the east and west side corridors, as it traverses the City from north to south.

A 36-inch transmission main provides the backbone for the west side corridor. This pipe is the primary interconnection between the Hennessey Treatment Plant to the north, and the Jamieson Treatment Plant to the south. A 24-inch transmission main provides the backbone for the east side corridor that connects to the 36-inch transmission main at the north and south ends of the City. However, along the east side corridor a pinch-point of 16-inch nominal pipe diameter transmission main was present within the 24-inch transmission main corridor. This
section of pipe limited the ability of the system to fully utilize the east side transmission main corridor, impacting water distribution capabilities of the system (see Figure 1).

Figure 1. Layout of the transmission mains within the CNWD water distribution system prior to the 2012 replacement project, showing the pinch point of the system that defined the need for the replacement project.

The effects of the pinch-point weren’t truly realized until operators had to manage the fill cycles of a new storage tank installed on the east side of the water system in 2005. During higher demands, the fill cycles were impacted such that two treatment plants needed to be put into operation before the system demands required it. During lower demands, the drain cycles were impacted such that the age of the water within the storage tanks became a concern. In addition, due to limited flow capacity through the 16-inch transmission main, leaks that occurred on the west side transmission main corridor greatly impacted the ability for water to reach the City from the Jamieson Canyon Water Treatment Plant.

Relieving the system of the pinch-point would allow the City to meet the flow and pressure requirements needed to supply water consistently throughout the entire system without depending on the operation of more than one treatment plant. Additionally, it would provide system redundancy to handle potential operational situations as they might occur with the ongoing use of the system, including emergency procedures. These concerns were a crucial part of the decision to proceed with the project. However, the priority of the project was intensified by the completion of the Jamieson Canyon Water Treatment Plant upgrades, such that in the summer of 2012, it was decided that the design of the project needed to commence for a winter 2012 construction period.
2. EVALUATING ALTERNATE INSTALLATION METHODS

When the existing 16-inch pipeline was originally installed in 1951, the area was undeveloped, used primarily for groves of fruit trees. The water main was only in place to serve a single water meter for the community to the south (now known as American Canyon). The only improvements in the vicinity were a paralleling small two-lane road and a state hospital on the opposite side of the road. The system was young, demands were limited, and the pipe was new. The Hennessey Treatment Plant was new and system demands could be met. But things can and do change over time, and the City of Napa was no exception.

After World War II, the City population exploded and the needs of the City changed. Today, this same 1.4 mile stretch of pipeline now fronts and supplies water to major land users including Napa Valley College, Napa State Hospital, a public golf course, an industrial park, and a cemetery. The two-lane road became a CalTrans thoroughfare, Hwy 221, into the heart of the City with four lanes of through-traffic and signalized intersections.

Because of the new land uses surrounding the water main, many project constraints needed to be considered for the replacement project. Some of the known obstacles included:

- Staying within the existing 20-ft wide easement
- Protecting and keeping the existing transmission main in service
- Avoiding other utilities adjacent to and within the existing water easement (including power poles, reclaimed water, gas, and private irrigation)
- Protecting ordinance identified “Significant Trees” and limiting established tree removal
- Creeks and drainage crossings
- Minimizing impacts to private facilities (including structural walls, signage, fences, and landscaping)
- Highway traffic and signalized intersection crossings, including an underpass
- Avoiding cemetery burial plots
- Varying topography (including limited access points)
- Soils corrosive to buried metallic infrastructure

Figure 2. Various locations along the alignment that posed challenges for the construction process. These included (from top left, clockwise), one of the signalized CalTrans intersections at Napa Valley College, the cemetery frontage, an existing valve location, and the private drive ramp to the underpass.
Although many of the physical obstacles were within the existing easement, removing or destroying many of them would have had environmental and/or political backlash that would have delayed the project (see Figure 2). Some of the obstacles could be avoided with the acquisition of additional easements or relocation, but this would have resulted in additional upfront costs for impact reports, permits, and legal documentation, plus increased construction costs for the additional fittings. Some obstacles, such as signalized intersections and creeks, couldn’t be avoided, but complications with local and state authorities would have added expenses and could impact the project with undetermined delays.

Buried obstacles were also a challenge for designing the project. The existing transmission main was centered within the existing easement, leaving little room for construction and protection of the existing main. Other utilities also complicated the design due to their proximity to the easement, some of which are intertwined within the same easement. Due to the agricultural uses of the region in the past, and past uses, buried abandoned infrastructure was a concern because each would have to be assessed and addressed by removal, avoidance, or possibly relocation. It was also not uncommon to find archaeological artifacts in the project area due to previous Native American settlements in the area.

Along with the obstructions and construction difficulties, the window of time available for construction was limited. Due to increased risk of working close to the existing transmission main, the City needed to limit construction to the winter when demand was less and potential damage to the exiting main during construction would be less likely to trigger an emergency need to activate a secondary treatment plant. In addition, the upgrade was needed before the following high demand period, which pushed the construction period to the immediate winter (2012), giving little advance time for bidding or for contractors to prep the construction area. The shutdown time permitted for the contractor was also limited to low demand periods, which forced a completion deadline of early spring.

With all of these considerations, three different installation methods where considered for the replacement project. The first was to perform traditional direct bury trenching, which would include trenching within 3-feet of the existing transmission main (while active) and placing the new pipe in the trench. The second was to pipe burst the existing main, simultaneously splitting the existing steel line, expanding it, and pulling in the new pipeline behind this operation. The third was horizontal directional drilling (HDD), which included boring a guided path underground and pulling in a new pipe into this bored excavation.

Direct bury trenching has been the traditional method of water main installation for the City of Napa. Many local contractors can complete trench installations with existing equipment available in the area. However, most of the project obstacles would remain an issue with trench construction. With the limitation of staying within the existing easement, every structure, tree, intersection, creek, and burial ground would have to be addressed and/or mitigated. A large number of change orders would have to be accounted for in the cost of avoiding buried infrastructure such as existing water and gas lines and potential Native American artifacts. Special permits and handling would be required for each creek crossing and access points to CalTrans right-of-way. Spoils removal would be a heightened issue due to the reduced intake of spoils at local sites during the winter season. Due to the proximity of Napa River, stormwater protection controls and monitoring would increase. Trench construction also needs to stop during inclement weather, which can frequently occur during the winter season. Due to the ranging topography, equipment would not be able to reach the entire extent of the easement without other permissions, rights-of-entry, and grading from the adjacent property owners, plus would increase the number of bends and fittings required to address the topography. Trees conflicting with construction would have to be removed, including “Significant Trees”, thus requiring mitigation. Finally, the burial grounds would have to be relocated or another easement would have to be obtained to relocate the water main alignment.

Pipe bursting technology would resolve several obstacle issues associated with the limitations of the existing easement such as tree protection and limiting damage to private facilities. However, pipe bursting was determined to be infeasible for the project for multiple reasons. Primarily, the technology would have eliminated use of the existing transmission main for the duration of the project. The existing transmission main was the sole source of water to Napa Valley College, the State Hospital, the golf course, and the cemetery, and it could not be shut down for more than a few hours. The nearest location where a temporary main could be installed was approximately 1,500-ft away from the north end of the project, and it would have to extend almost the full length of the project to reach all of the sites. In addition, increasing the risk of the water system and eliminating a key transmission main
for several months was not acceptable. Other conflicts with pipe bursting included the shallowness of the pipe (concerns with soil uplift as the bursting process upsizes the existing line to the new pipe diameter), proximity of other utilities, unknown location of fittings and bends in the existing transmission main (requiring trenching in areas where the pipe bursting can’t work), and the close proximity of other utilities.

Horizontal directional drilling installation method would be able to address the majority of the concerns for the project. The project could be designed with focused equipment areas and tie-in points, avoiding aboveground and belowground obstacles. Spoils would be reduced by 75% from that of trenching. Reduced trenching also reduced the stormwater protection requirement for the project and the amount of rutting damage caused by vehicular movement along the length of the project. Fittings and bends could be limited to tie-ins, and the new transmission main could be installed within the existing easement and in close proximity of the existing main with minimal risk to the existing facilities. Drilling also allows for fewer rain impacted delays allowing the City to set a “complete by” date for the project. Finally, with equipment focused at particular tie-in locations, access constraints and disturbance of local traffic, public uses, and surrounding lands could be greatly reduced. Fewer vehicle trips from the site would also mean less risk of incidents and a safer work environment for the contractor.

3. DESIGN PHASE OF THE PROJECT

Horizontal directional drilling was selected for the replacement water main due to its flexibility in meeting the project constraints. The next step was to select the pipe and appurtenance materials for the project. With known corrosive soils in the area and the depths required to directional drill a 24-inch diameter main, it was important for the CNWD to select something that could be cathodically protected (if metallic) or was non-corrosive. The pipe material also needed to exceed the system pressures and potential water hammer in the project area as well as exceed the safe pull force needed for the installation. For safe installation, the pipe needed to be flexible enough to bend as the pipe was pulled through the curvilinear bore alignments. A fully restrained system, without the use of additional fittings was needed to ensure maximum pipeline performance.

With HDD installations, it is essential to minimize the size of the bore hole in order to reduce the cost of the project, the time needed to complete the drill, and the cost of drilling fluid and spoils removal. To minimize the drilling and fitting cost, the exterior diameter needed to be as small as possible while maintaining the 24-inch internal diameter, and be able to connect to ductile iron size fittings, which is the standard fitting size used within the CNWD water system.

After considering all of the factors, 24-inch DIPS DR18 Fusible C-905® pipe (FPVCP) was chosen to replace the 16” Water Main (see Figure 3). The selected pipe material, including its fully restrained fusion joints, met the requirements of the project and was a pipe technology that the City had worked with successfully in the past. The use of FPVCP ensured a capable pipe material for use in HDD and also limited the amount of metallic fittings that would be required to maintain the required restraint on the pipeline thus limiting the cathodic protection needed for the system.

By the time the City of Napa elected to proceed with the project, staff only had one month to complete the design of the project in order to construct the project in the winter of 2011/2012. With the limited amount of time, and the existing CNWD knowledge of HDD projects, CNWD elected to design the pipeline project ‘in-house’ so that it could be completed within the allotted time period, all aspects of the design could be controlled, and project costs could be kept to a minimum. The particular focus of the design was at the tie-in points. These locations were a key component to limiting the construction work areas, connecting to existing water services, the installation of new in-line valves, and avoiding known conflicts. Although the intent was to minimize the number of tie-in points along the length of the project, the occurrence of inadvertent drilling fluid returns or frac-outs was a concern. Due to the topography changes in some areas, longer pulls would have required higher working pressures with the drilling fluid thus increasing the risk of an inadvertent return. Due to the environmental sensitivity of the project, including construction through the cemetery property, reducing the potential number of frac-outs and being prepared for those that did occur was a high priority in the project design. As a result, the project was designed with seven HDD segments ranging from 600-ft to 1,700-ft.

The project benefitted from the local dense clayey soils because it would be able to maintain borehole stability and reduce the risk of collapse of the borehole. However, the clay was also considered to be “hard” in several locations.
where the blow counts were more than 50 per foot with a 140-lb hammer, which would incline drillers to use different types of equipment. In order to avoid risk to the City by identifying the correct material or drilling equipment, the project bidders received a copy of the geotechnical bores located along the length of the project, as well as cone penetration tests in between the bores, to provide as much information up front in hopes of avoiding delays and change orders during construction. The specifications identified the minimum size of drill equipment required for the project to avoid contractors attempting to utilize undersized equipment in order to save costs.

![Figure 3. Fused 24-inch FPVCP, staged and ready for installation via HDD.](image)

Defined drilling areas with starting and ending points within 20 feet coupled with a provided “do not exceed depth” and a minimum drill equipment size gave the driller flexibility while still meeting proper installation requirements for the project. The flexibility allowed the contractor to avoid conflicts (real or anticipated) before construction commenced, while the “do not exceed depth” (ranging between 25-ft to 40-ft) kept the new pipeline at a reasonable maintenance depth and prevented the interior working pressure of the pipeline from exceeding 150-psi.

To ensure that the lowest bidding contractor was proficient with large diameter drilling projects for pressurized pipe, the City used its pre-qualified driller list created for other large diameter projects planned for the system. Having this list in hand avoided delays that would have occurred after bidding the project just to confirm a driller has the necessary experience to complete the work.

Finally, to give the contractor the chance to control which sites were used for the drill equipment and which were used for pullback of the pipeline, the specifications included a “return to pre-construction conditions” clause. This clause allowed for the contractor to remove fences or landscaping necessary to complete the work, but helped limit how much was impacted with the cost to be borne by the contractor.

With all of the flexibility designed in the project, there was one extremely limiting point in the specifications that was designed to not move, regardless of “non-working” days. The water main had to be fully activated by a set
date. This included passing the bacteriological and pressure tests, as well as tying in the new water main and existing services. By the time the contract was awarded and the pre-construction meeting had taken place, the contractor had less than four months to have the new water main in service.

4. CONSTRUCTION PHASE OF THE PROJECT

The project started in January, 2012 with The HDD Company, Inc. as the primary contractor. Immediately, the contractor planned for the tight timeline and teamed up with a secondary drilling company, Kinnan Engineering, Inc. to be drilling at the same time. The contractor also teamed up with K.J. Woods Construction, Inc. to complete all of the tie-ins. With this organization, three different teams were able to work at the same time at various locations along the length of the project without interfering with one another.

Having the two drilling teams on the project created no challenges for the CNWD. The HDD Company, Inc. was the general contractor, so the second driller was no different than having another sub-contractor for the project, but in this case, the City benefitted from the two firms having worked together before. The two teams were stationed at the north and south ends of the project area, so they were able to work in unison without interfering with each other’s progress. Each team also conducted their work with very different approaches. One team would drill at a faster pace than the other team, making more progress each day with the distance which helped the project remain on schedule. The slower team was able to create a cleaner hole (almost zero resistance during pullback) with fewer inadvertent returns, ideal for drilling under the cemetery property.

The project had an original design of seven drilled segments for the entire project, ranging from 100-ft to 1,700-ft. The first pilot hole for the project started within the frontage of Napa Valley College. This section was the longest drill length of the entire project at 1,700 feet. Due to the soft surface soils in the area, the contractor placed steel plates under the equipment stationed over the transmission main to avoid damage to the existing pipe. The inlet point was a difficult location for the contractor due to the slopes the equipment had to be arranged on and the vertical difference between the entry and the exit point. However, even with the challenges, within three weeks of mobilization of the project, the first length of pipe of 1,700-ft FPVCP was pulled through.

Figure 4: Complicated arrangement of drilling equipment fronting the golf course. The green grass of the golf course can be seen behind the orange construction fence.
At the same time, the second contractor was working on the bore under the cemetery, a length of 1,500-ft. Besides working around an active cemetery, the contractor had to account for inadvertent returns around the established trees and at the shallow point of the drill length which went from a 40-ft depth to 20-ft in a short distance. However, the difficulties of the drill showed up halfway in the bore and the soil changed to a harder material, making it more difficult to drill. Instead of increasing the pressure to continue pushing through and increasing the risk of an inadvertent return in the cemetery property, the contractor decided to switch from a push-ream process to a pull-ream process. With this method, progress was slightly reduced, but the contractor was able to successfully reduce fluid annular pressures and safely pull the length of pipe under the cemetery property.

The most complicated equipment set-up during the project was on the second to last drill fronting the public golf course. In order to complete the drill, the contractor needed to arrange the equipment between a line of trees, fences, and powerlines. Although a very tight space, with just the removal of only a few tree branches, the contractor was able to squeeze everything into the space required (see Figure 4). However, once the equipment was in place, drilling proceeded more smoothly than the other six drilled sections, with no inadvertent returns or unexpected conditions.

The final and most difficult section of the project was fronting the industrial park where, based on the drilling arrangement decided by the driller, the pipe needed to cross a major intersection and be manipulated over an existing meter station and under overhead wires before entering the ground 30-ft away (see Figures 5 & 6). The contractor’s other option was not permitted as it would have required the pipe to be fused within the cemetery and block access to the cemetery driveway. With the selected orientation and to avoid local traffic concerns, the pipe was pulled on a Saturday when commercial traffic was the lightest and could be easily re-routed through other streets.

While the drillers were completing their pilot holes for each drill, fusion technicians from Underground Solutions, Inc. (UGSI) fused each section of pipe on the pullback side of the drill length. Varying topography made some areas more difficult to support the pipe, but the fusion technicians were able to come up with creatively safe options which allowed for some of the longer lengths.
Due to the little time needed for each tie-in to be completed, KJ Woods didn’t come in until most of the drilling lengths were completed (see Figure 7). When they did, tie-ins ranged from 2 to 3 days to complete, including the installation of a protective wax tape around all metallic fittings for corrosion protection. Although the team consisted of only 3 to 4 crewmen at any time, they were fast and efficient at completing each section.

Only one drilling complication occurred on the very last bore (the shortest length of only 100-ft) that required the City to change the installation method. Near the CalTrans intersection, at the meter station, the contractor found an unmarked buried pipeline more than 12-inches in diameter buried under a 2-foot section of asphalt more than 10-feet deep, and only 10-feet from the end of the pilot hole. The option was to open up the intersection and trench down to a bottom pit of 13-feet to put in enough fittings to bring the pipe to the proper grade, or attempt to drill again and avoid the conflict. The City elected to attempt the bore again since the total length of the bore was just 100-feet, enough to get past the meter station. The second pilot hole attempt was successful. However, when the contractor pulled in the 30” reamer, there was an unexpected change in the existing backfill. The soil turned from clay into a lightly compacted sand material and collapsed on the reamer.

The collapse removed the possibility of inserting the pipe via directional drilling, so the area known to contain a large number of buried active and inactive infrastructure from multiple utilities needed to be trenched. Completing this section proved the cost benefit of selecting directional drilling as opposed to trenching the entire project. With a 100-ft section, the contractor had to spend 3 days jack hammering through a buried concrete vault, hand digging a 40-ft section to get around existing water mains, fences, electrical signal wiring, a gas main, and private water lines. The cost of this section of pipeline alone cost 300% more than the original line item for pipe installation with HDD. Even with the complications, the contractor successfully activated the new pipeline and brought it into service one month before the fixed deadline.

Figure 7: Completion of one of the tie-ins including an air-release valve, an in-line 24” valve, and a 6” bypass around the valve. Note the use of the wax tape for corrosion protection on all metallic appurtenances.
In the end, the project was completed early and within the planned budget, with only 6% of the contingencies used.

5. RESULTS OF THE PROGRAM

There were many positive actions taken during the project to ensure project success that are recommended for future projects. Giving the driller strong direction but with a level of flexibility helped decrease risks to the system while providing installation options to the contractor to make conflict avoidance easier. This also leveraged the strength of the driller, whose job is to be an expert in dealing with all things involved with HDD installations. Using the driller as a resource, and not just a contractor, can improve how well a project is constructed and result in an overall better product.

With the short design period, an HDD project was ideal. Different aspects of the design could be sent out so that in-house staff could be focused on the project plans. One firm completed the topography survey of the site while another completed soils investigations for the project. Tie-ins were designable without 100% information available, where any changes would be minor. Also, outside resources were used to help assess feasibility of the project, including the pipe manufacturer (UGSI) and two local drillers, which helped fine-tune the design and specifications for the work.

Due to other local drilling projects requiring large diameter pipe, the City already had a pre-qualified list of drillers that could be used for the project. The list of drillers had already passed the background check for experience with the size and scope of similar projects, which eliminated the delay that would have occurred if completed after the project bids were received.

6. REFERENCES

