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Pipe Ramming and Auger Boring provide Trenchless Solutions for Critical Crossings, Northwest Oregon

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1. ABSTRACT

The Cities of Lake Oswego and Tigard, Oregon, executed an Intergovernmental Agreement for the purpose of jointly planning, funding, constructing, owning, and operating expanded water supply facilities for their respective future water supply needs. Together, the Lake Oswego – Tigard Water Partnership has been expanding and upgrading Lake Oswego's conveyance capacity. This project has included a number of complex and interesting trenchless installations. In particular, the 7.5-mile finished water pipeline segment requires three trenchless crossings. The first is a crossing of Trillium Creek along Mapleton Drive in West Linn, Oregon. This creek has complex geotechnical conditions, is salmon bearing, and is in a very environmentally sensitive area. The design called for a 60-inch diameter steel casing beneath the creek. Another crossing was beneath Interstate-5, the major route for north-south traffic on the West Coast. This crossing was designed as a 42-inch steel casing beneath the highway. The final crossing was designed as a 48-inch steel casing installed under the Burlington Northern Santa Fe / Genesee and Wyoming railroad tracks in Tigard, Oregon.

This paper compares and contrasts two alternative trenchless technologies, pipe ramming and auger boring, for accomplishing these crossings and the basis for method selection during design and construction. The paper will highlight design and construction issues associated with each of the three crossings including geotechnical conditions, groundwater, traffic, work hours, noise, surrounding land uses, constrained work areas, private property impacts/easements, utilities, contractor competition and multi-agency coordination.

2. INTRODUCTION

In August 2008, the cities of Lake Oswego and Tigard (Program Sponsors) formally endorsed an intergovernmental agreement for sharing drinking water resources and costs. While the City of Lake Oswego undertook the management and construction of the infrastructure improvements, the financing of the project was shared by both entities, with an oversight committee consisting of representatives from both cities. The Lake Oswego-Tigard Partnership represents an important step forward for cooperative and regional, as opposed to purely local, water supply planning. This regional approach will help ensure that the more than 90,000 residents of both cities will continue to have a safe, affordable, and sustainable supply of drinking water.

Project Needs

Lake Oswego currently withdraws water from the Clackamas River in Gladstone as it has been for almost 50 years. The existing transmission, treatment, pumping and storage facilities are undersized to meet the current and anticipated future water supply needs of Lake Oswego in addition to being seismically vulnerable, and challenging to operate and maintain due to outdated, obsolete equipment. Tigard needs certainty of supply and the ability to control future water supply costs. The Partnership with Lake Oswego offers the best opportunity to achieve those objectives relative to Tigard's other supply options.

Project Components

The partnership project, estimated to cost $254 million, will replace and expand six existing facilities located in the cities of Gladstone, West Linn, Lake Oswego, and Tigard, Oregon. These new, state-of-the-art seismically resilient facilities include:

1) A new 38 million gallon per day (MGD) river intake pump station located on the Clackamas River in the City of Gladstone
2) Over 10 miles of new large diameter, mostly steel pipe, raw and finished water transmission mains ranging in diameters of 24-inch to 48-inch
3) A new 38 MGD water treatment plant located in City of West Linn
4) A new 3.5 million gallon (MG) reinforced concrete water storage reservoir located in Lake Oswego
5) A new, dual pressure zone, 20 MGD booster pump station located in Tigard

Figure 1 highlights the major components of this expansion project along with a construction timeline of each activity, as well as the three trenchless projects discussed in this paper.

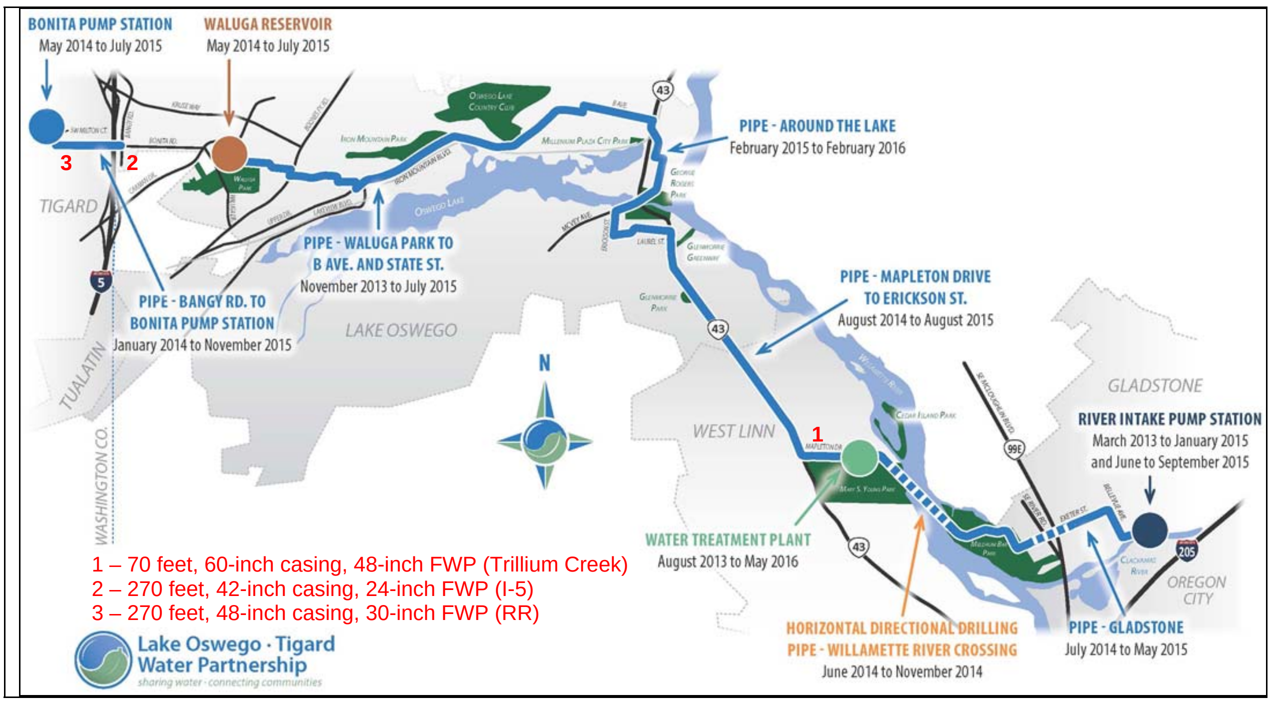

Figure 1: Major Project Features and Construction Timeline, Projects Discussed in Paper

As Managing Partner, Lake Oswego is responsible for securing all regulatory permits and approvals from local, state and federal agencies necessary to construct the new facilities and contracting for design, and construction. The terms of the partnership agreement also obligate Lake Oswego to deliver water from the new facilities to Tigard no later than July 1, 2016.

Project Challenges

Major challenges to the program include the following:

- A project completion span of eight-years from concept development.
- Legal challenges from local project opponents and conservation groups
- Construction of a new water treatment facility located within a residential neighborhood
- Construction within, across, and under a major river – home to endangered salmon and steelhead.
- Project financing amidst the Great Recession and global economic instability
- Maintaining full time operation of the existing WTP while the new WTP is constructed

- Property Acquisition
- Transitioning from existing system to the new system
- Construction of large diameter pipelines within and along narrow local roads in residential neighborhoods and across two major highways and railroads

Mitigating Risk with Trenchless Pipeline Construction Methods

Traditional cut and cover methods of pipe installation across sensitive streams, highways and railroads were not allowed by federal and state agencies, and railroads, as there were feasible trenchless methods with less impact. Therefore, the Program Sponsors turned to the use of pipe ramming and auger boring to secure permitting agency approvals and mitigate against potential environmental impacts. This paper focuses on three trenchless segments of the pipeline construction, and provides discussions on the factors important for design and construction decision making.

3. OVERVIEW OF AUGER BORING AND PIPE RAMMING

Auger Boring

Auger boring involves simultaneously jacking steel casing segments forward while removing the spoils via a rotating auger flight. Rotation of the auger removes soil at the face while carrying the spoils back to the jacking pit where they can be removed using a clam shell or excavator. Since the auger is not capable of providing continuous face support, groundwater is problematic as it can cause the soils to flow and flood the steel casing causing catastrophic settlement at the face of the excavation. As a result, auger boring is typically limited to stable soils located above the water table or in those soils that can be dewatered along the entire alignment. Dense soil is ideal for auger boring as it retains stability at depth, mitigating the risk of surface subsidence. The maximum drives length for auger boring is dictated by the torque available to turn the auger flights, and is typically on the order of 350 to 400 feet. The method provides only minor grade control with limited steering techniques, resulting in accuracies not better than 0.5 percent of drive length. The ideal geotechnical conditions for auger boring are medium dense to dense clays, silts and sands above the water table. For soils below the water table, dewatering or other methods of soil stabilization must be utilized in order to successfully complete the installation without surface settlement.

Pipe Ramming

Pipe ramming consists of ramming an open-ended steel pipe through the soil using repeated percussive blows from a pneumatic or hydraulic hammer. Spoils enter the open end of the pipe throughout the ramming process, forming a soil plug which provides face support by counterbalancing soil overburden and groundwater pressures. Establishment of an adequate soil plug is therefore essential when groundwater is expected along the alignment. After the pipe is in place, spoils can be removed using an auger flight, compressed air, or water jetting. The maximum drive length for pipe ramming is between 350 and 400 feet and is limited by the capacity of the pipe to withstand induced ramming loads. Because the pipe is not fitted with a steering head, the line and grade are dictated by the initial set up of the pipe and the response of the pipe to native soil conditions. Depending on the precision of the initial pipe alignment, vertical grade accuracy of 1 percent of drive length can be achieved. Pipe ramming is suitable for a wide variety of soils, provided that there is sufficient material to form an adequate soil plug before installation beneath sensitive structures or below the groundwater table. Alternatively, sand bags or control density fill (CDF) may be used to form an effective plug within the first pipe section prior to the start of the ram. As this plug effectively prevents soil and groundwater flow into the casing, pipe ramming has an extremely low risk of surface settlement with sufficient ground cover which is why it is a preferred trenchless method by many railroads.

Table 1. Comparison of Auger Boring and Pipe Ramming

Comparison Factor	Preferred Method
Accuracy	Auger Boring
Achievable Length	Comparable
Construction Noise	Auger Boring
Need for Dewatering	Pipe Ramming
Settlement Risk	Pipe Ramming
Schedule	Pipe Ramming
Cost	Comparable

4. TRENCHLESS CROSSINGS

This section describes relevant parameters for design and construction considerations for each of the subject trenchless crossings, including casing and product pipe, soil conditions, groundwater, land uses, traffic and noise.

Trillium Creek

Casing and Product Pipe: 70 feet of 60-inch steel casing, with 48-inch welded steel finished water pipeline.

Soil Conditions: COARSE GRAINED ALLUVIUM ranging from very loose, light brown silty SAND; non-plastic; fine sand, wet, to medium dense to dense gray silty GRAVEL with sand; non-plastic; fine to coarse sand; subrounded, fine to coarse gravel; wet.

Groundwater: Groundwater was measured at 4.82 feet below ground surface on April 25, 2013, and 9.95 feet below ground surface on August 6, 2013, at piezometer TCB-02. Therefore, groundwater varies approximately from 1 to 6 feet above casing crown.

Land Use: Single family residential housing. Nearest home is approximately 120 feet from launch shaft.

Traffic: 18-foot wide collector road (Two 9-foot travel lanes typical). Single lane closure with flagging required.

Noise: Work conducted during daytime work hours with noise mitigation as required by land use conditions of approval from City of West Linn, Oregon. Nighttime work may be allowed by exception, when approved by City of West Linn City Manager.

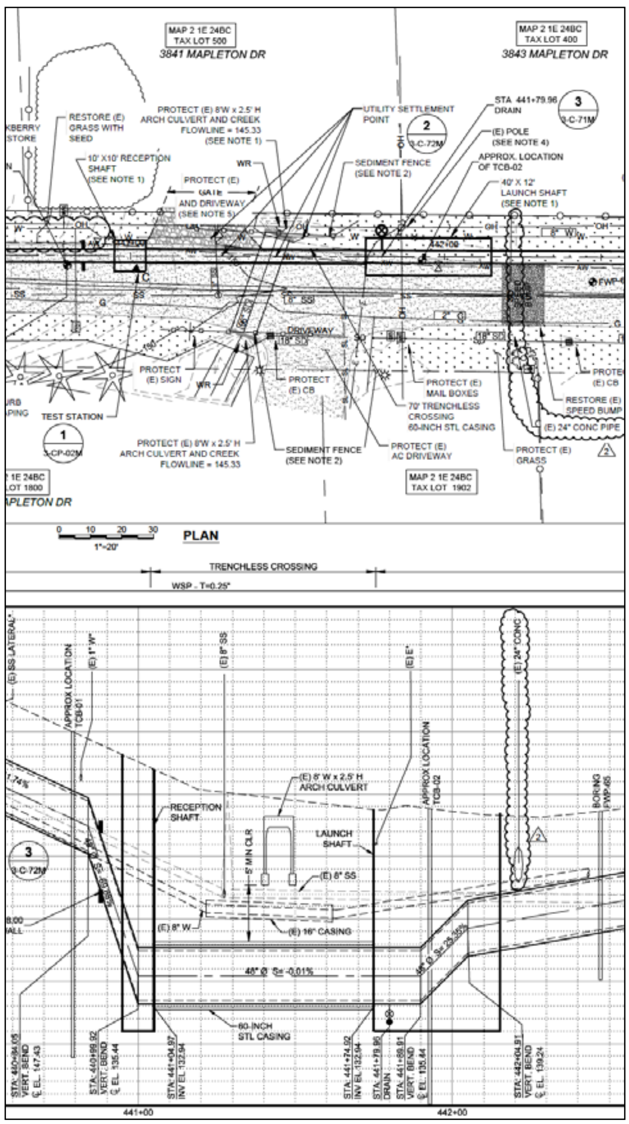

Figure 2: Finished Water Pipeline undercrossing of Trillium Creek (West Linn, Oregon)

Interstate 5

Casing and Product Pipe: 270 feet of 42-inch steel casing, with 24-inch ductile iron finished water pipeline.
Soil Conditions: ALLUVIUM, loose to medium dense light brown SAND to Silty SAND, low plasticity to non-plastic; moist/wet.
Groundwater: Groundwater was estimated at 8.0 feet below ground surface during drilling of KFWP-55 on January 15, 2014. Groundwater was measured at 10.3 feet below ground surface on January 21, 2014, and 12.3 feet below ground surface on May 13, 2014, at piezometer KFWP-46. Therefore, groundwater varies approximately from 1 to 7 feet above the casing crown.
Land Use: Commercial land use at launch shaft site and commercial/multi-family residential at reception shaft site.
Traffic: Shaft sites are located outside of roadway traveled areas. Construction ingress and egress coordinated with private properties, City of Tigard and Oregon Department of Transportation.
Noise: Work conducted during daytime and nighttime work hours with noise mitigation as required by City of Tigard, Oregon.

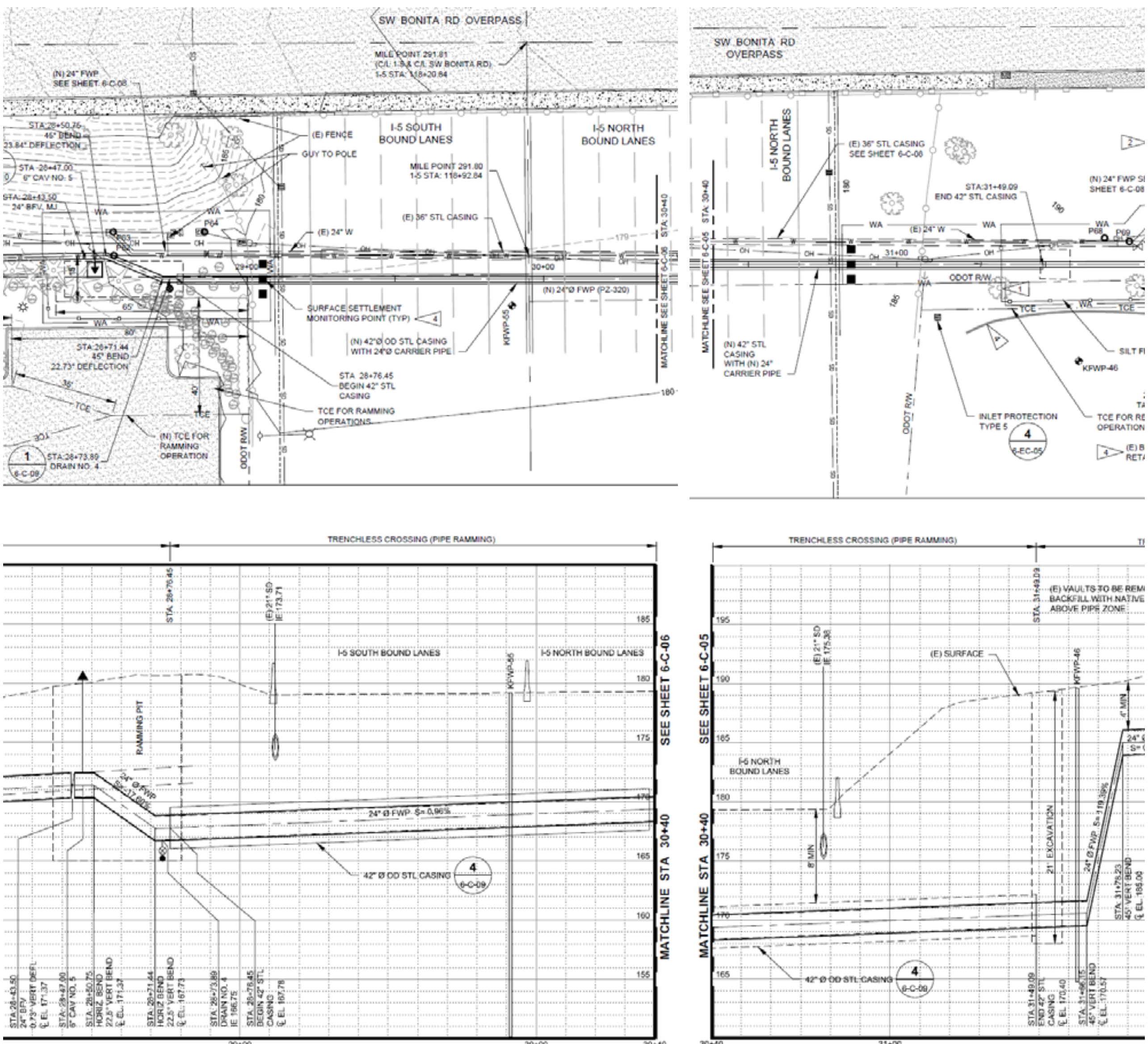

Figure 3: Finished Water Pipeline undercrossing of Interstate 5 (Tigard, Oregon)

Railroad Crossing (Genesee and Wyoming/Portland and Western and Union Pacific Railroads)
Casing and Product Pipe: 270 feet of 48-inch steel casing, with 30-inch ductile iron finished water pipeline.
Soil Conditions: ALLUVIUM, medium dense to firm, mottled SILT to Silty SAND; low to medium plasticity; moist/wet.
Groundwater: Groundwater was measured at 13.6 feet below ground surface on January 21, 2014, and 12.3 feet below ground surface on May 13, 2014, at piezometer KFWP-51. Therefore, groundwater varies approximately from 2 to 5 feet above the casing crown.
Land Use: Commercial and industrial land uses.
Traffic: Bonita Road is a major arterial for City of Tigard traffic to and from Interstate 5. Peak traffic volumes equal or exceed single lane capacity. Night work from 8:00pm to 6:00am is used for construction. Center turn lane used for shaft construction with single lanes open eastbound and westbound on either side of the launch shaft. Flagging used as needed for casing placement in shaft.
Noise: Work conducted during nighttime work hours with noise mitigation as required by City of Tigard, Oregon.

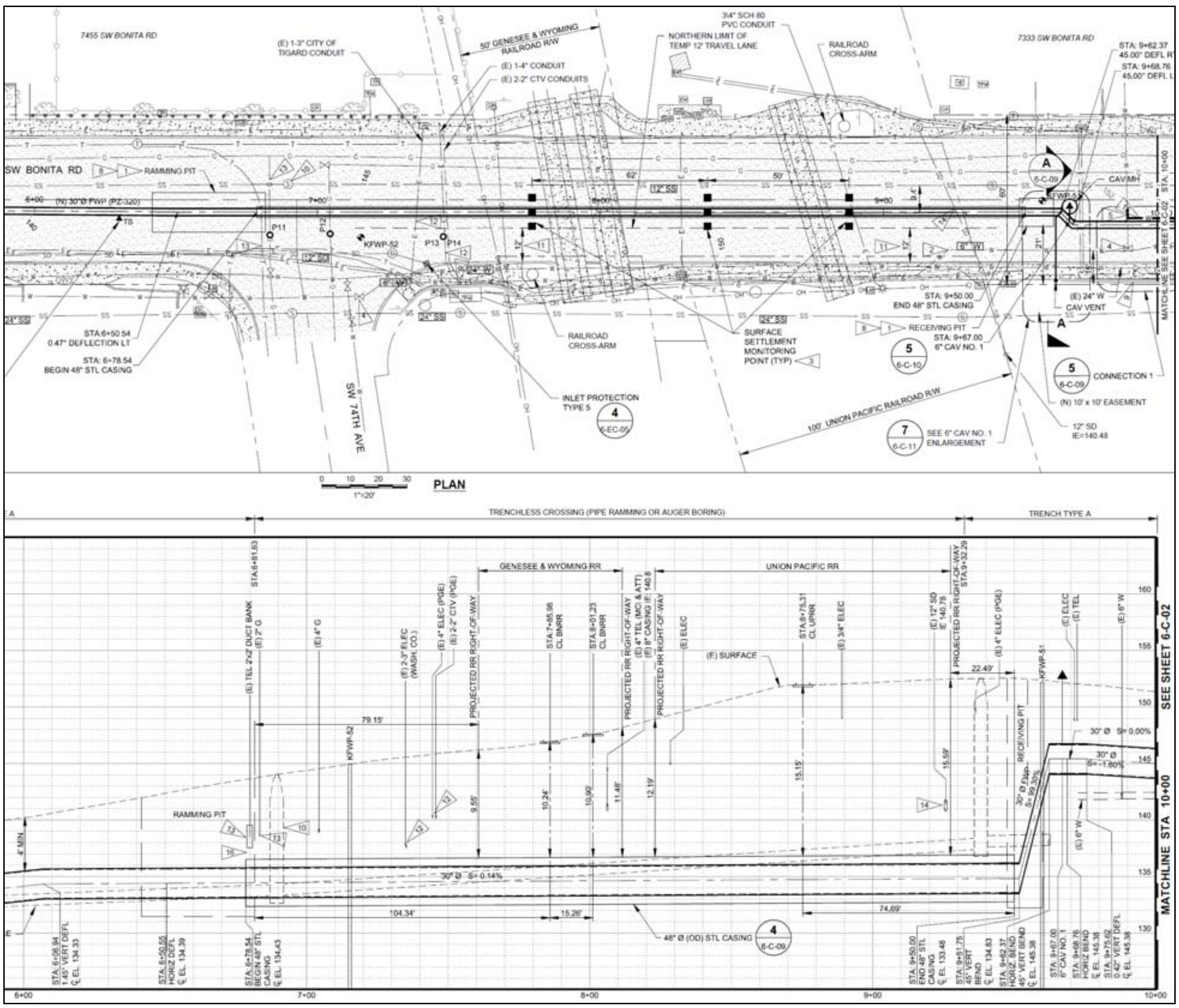

Figure 4: Finished Water Pipeline undercrossing of railroads (Bonita Road, Tigard, Oregon)

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5. SUMMARY

To summarize, three projects were designed and advertised for bids as pipe rams. The design decision for pipe ramming was based on settlement concerns and risks related to groundwater above the crown of the casing. One project, the railroad undercrossing, was changed during the bid period to allow either pipe ramming or auger boring. Two projects, Trillium Creek and Interstate 5 undercrossings, were changed during construction from pipe ram to auger boring. Therefore, all three projects were constructed as auger bores and no pipe rams were constructed, as summarized in Table 1.

Table 2. Summary of Trenchless Crossings

Project Schedule	Crossing Name	Designed as	Low Bid	High Bid	Constructed as
Schedule 3	Trillium Creek	Pipe Ram	$162,700	$320,000	Auger Bore
Schedule 6	Interstate 5	Pipe Ram	$350,000	$530,000	Auger Bore
Schedule 6	Railroad Crossing	Pipe Ram	$275,000	$601,000	Auger Bore

During the bid period for Schedule 6, a question was received requesting use of auger boring for Interstate 5 and the Railroad Crossing. Based on review by the Design/Construction Management Team, a guided auger boring specification was provided for use on the railroad crossing. It was further clarified that the Interstate 5 crossing was to be bid as a pipe ram and the Railroad Crossing was to be bid as either a pipe ram or a guided auger bore.

During construction, RFIs were submitted by the Contractors requesting change from pipe ramming to auger boring for the Interstate 5 undercrossing, and similarly for Trillium Creek. Review of the pipe ramming versus auger boring included considerations of traffic impacts (shaft size and location, night or day construction, and duration of construction) and impact on adjacent neighbors (noise – night or day construction, and duration of construction). Based on review by the Design/Construction Management Team and Oregon Department of Transportation, the following response was issued qualifying the approval for Interstate 5 undercrossing, and similarly for Trillium Creek:

> *"No exceptions taken to proposal to auger bore the crossing of Interstate 5 with the following conditions:*
>
> 1. *Risks for this modified approach are solely borne by the CONTRACTOR*
> 2. *Surface WORK related to I-5 such as surveying, setting settlement monitoring points, other above-ground WORK is to be accomplished 9pm to 5am*
>   *-If single lane closure is necessary, then work hours are to be 10pm to 5am*
>   *-If two lane closure is necessary, then work hours are to be 11pm to 5am (with mobility notice)*
> 3. *Trenchless WORK is to be accomplished during daytime work hours (7:00am to 6:00pm Monday through Friday, and 8:00am to 6:00pm on Saturdays, upon approval of the ENGINEER for Saturday WORK.)*
> 4. *Maximum settlement of 0.5 inches is allowable*
> 5. *Settlement monitors are to be placed as shown on the drawings plus additional monitors set 50 feet north and south of casing centerline on each side of I-5 (total of 10 monitors)"*

6. CONCLUSIONS

1) Within the context of technical feasibility, agency acceptance, and manageable risk, market forces may drive decision to use auger boring rather than pipe ramming

2) Even when pipe ramming is mobilized, pipe ramming contractors still need to find efficient, cost effective methods for spoil removal.

3) Contractor assessment of risk may deviate from designer assessment of risk. This is a consequence of contractor equipment and staff availability when viewed by the contractor in conjunction with existing soil/groundwater conditions and other related construction conditions and risks.

7. REFERENCES

Staheli, K., Moore, B., Eder, A., Holland, J., Komarek, J., and Koellermeier D., (2014). "Large Water Distribution Pipeline Calls for Challenging Trenchless Installation in Lake Oswego, Oregon." ASCE Pipelines 2014: From Underground to the Forefront of Innovation and Sustainability, S. Rahman and D. McPherson, eds., American Society of Civil Engineers, Reston, VA.

Komarek, J., Rahman, S. Staheli, K., Austell, B., Staheli, J., and Smith, G., (2015). "Trenchless Installations on the Lake Oswego-Tigard Partnership Project: Use of Steel Water Pipe and Steel Casing Pipe for HDD and Microtunneling." North American Society of Trenchless Technology.

Stuedlein, A., and Meskele, T., (2013). "Analysis and Design of Pipe Ramming Installations, Final Report SPR 710." Geotechnical Engineering Group, School of Civil and Construction Engineering, Oregon State University for Oregon Department of Transportation Research Section and Federal Highway Administration.