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TRENCHLESS REHABILITATION OF A TRENCHLESS INSTALLATION

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ABSTRACT: The Saratoga Road Culvert Replacement Project was intended to replace a damaged 18-inch diameter concrete culvert that crosses underneath Saratoga Road on Whidbey Island, Washington. The replacement culvert was originally planned as a 54-inch diameter steel casing with a 48-inch HDPE liner. The proposed crossing was roughly 170 feet long, and ranged in depth from approximately 35 to 45 feet below ground surface.

Auger bore pipe jacking was recommended by others to install the 54-inch steel casing. However, the contractor elected to install the casing using pipe jacking combined with hand excavation at the pipe face. After roughly 100 linear feet had been installed, soil and groundwater began to flow into the casing, resulting in the formation of a significant sinkhole above the culvert. Following formation of the sinkhole, the casing was subsequently abandoned in place and the project as designed was terminated.

Staheli Trenchless Consultants (STC) was contacted to evaluate feasible alternatives to complete the culvert installation which would both address the current site conditions (including the partially installed 54-inch casing) and pose minimal risk to Saratoga Road during construction. After visiting the site and reviewing the existing geotechnical report, STC recommended open-ended pipe ramming as a feasible method for completion of the culvert installation. The new design rams a 30-inch steel casing through 100 feet of the existing 54-inch casing, and through 70 feet of native soils to daylight. This paper describes the project history in light of the multiple installation attempts and details lessons learned throughout the entire process of pipeline installation.

1. INTRODUCTION

Saratoga Road is located on Whidbey Island, which lies within Puget Sound about 30 miles north of Seattle, Washington (Figure 1). The island is between 36 and 62 miles in length and 1.5 to 12 miles in width, and has an approximate population of 60,000 people. At the project location, Saratoga Road crosses a steep ravine containing a small creek which runs from south to north. The creek is diverted through an 18-inch concrete culvert, which was found to be damaged and was slated for replacement by Island County Public Works in 2005.

2. FIRST INSTALLATION ATTEMPT

The replacement culvert was originally intended to be a 54-inch diameter steel casing with a 48-inch HDPE liner, which would allow fish passage under Saratoga Road. The proposed crossing was roughly 170 feet long, and ranged in depth from approximately 35 to 45 feet below ground surface (bgs). The replacement culvert alignment ran parallel to the existing culvert.

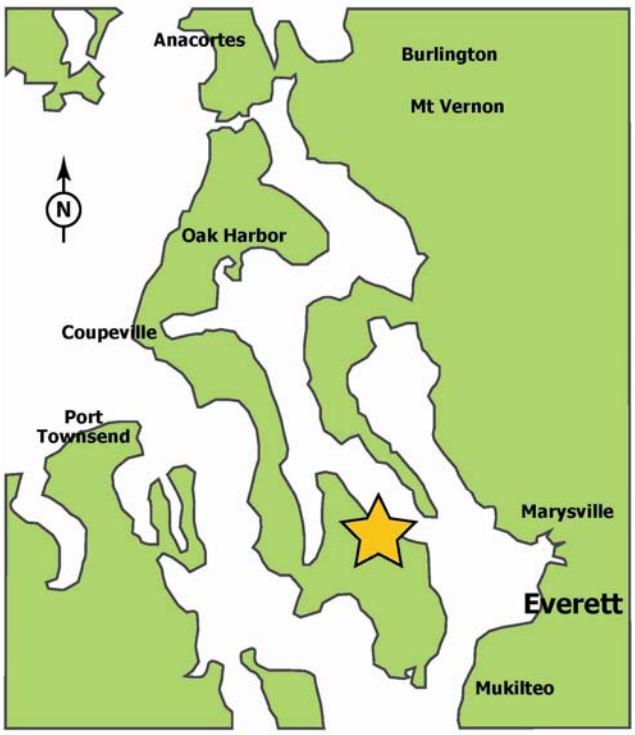

Figure 1: Location Map - Saratoga Road

Geotechnical investigations conducted in the project area encountered 35 feet of fill, consisting of 25 feet of loose sand underlain by 10 feet of medium dense silty fine sand. The native soils encountered below the fill consisted of 9 feet of very stiff, rusty laminated silt underlain by very dense sand. Perched groundwater was detected at the contact between the silty sand and laminated silt layers, and noted that the elevation of the static water table in the vicinity of the project area was liable to vary as a function of season, precipitation, and other factors.

Auger bore pipe jacking was recommended to install the 54-inch steel casing. The construction contract was awarded to C Johnson Construction with Northwest Boring as the pipe jacking sub-contractor, who proceeded to install the casing using pipe jacking combined with hand excavation at the pipe face. The pipe was jacked from the upstream side of Saratoga Road downhill at a shallow grade.

After roughly 100 linear feet (LF) of the casing had been installed, soil and groundwater began to flow into the casing presumably at the contact between the lower fill unit and the native soil. Soil and groundwater ran into the casing, resulting in the formation of a significant sinkhole on the shoulder of Saratoga Road above the culvert. Following formation of the sinkhole, the casing was subsequently abandoned in place and the project as designed was terminated (Figure 2). A dewatering well was placed near the opening of the partially installed casing to prevent surface water from entering the pipe or flowing within the soil backfill around the existing culvert.

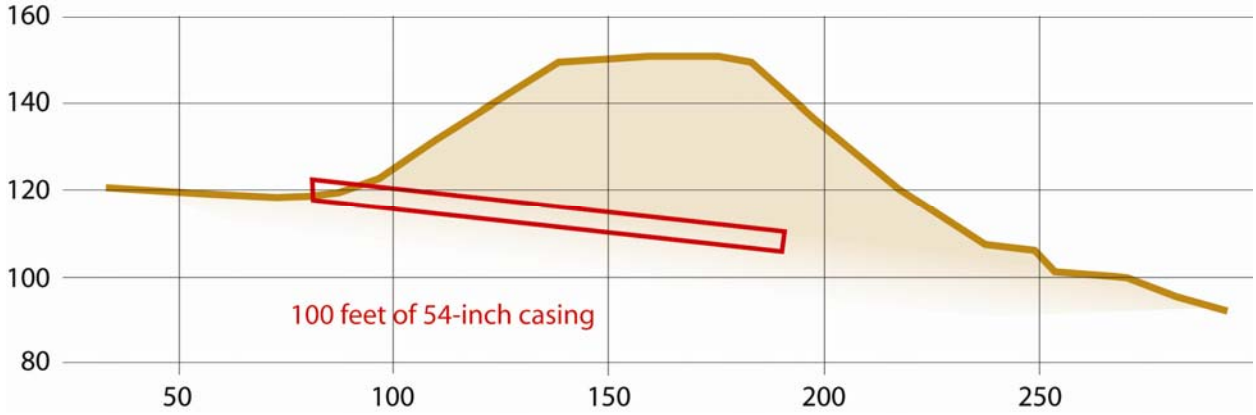

Figure 2: Profile view after the first installation attempt

3. SUBSEQUENT DESIGN MODIFICATIONS

Staheli Trenchless Consultants (STC) was contacted in October of 2007 to evaluate feasible alternatives to complete the culvert installation which would both address the current site conditions (including the partially installed 54-inch casing) and pose minimal risk to Saratoga Road during construction. Open-cut installation was not considered to be viable due to both the prohibitively high cost and the need for the road to remain open throughout construction. Upon visiting the site and reviewing the existing geotechnical report, STC considered the feasibility of two trenchless alternatives, both incorporating the method of open-ended pipe ramming. These options consisted of 1) ramming the existing 54-inch casing the remaining 70 feet; and 2) using the existing 54-inch casing to conduct a smaller steel casing up to the soil face, then ramming the smaller casing the remaining distance.

Ramming the existing 54-inch casing would have taken advantage of the pipe which had already been installed and in which the soil plug had already reached equilibrium. However, the existing casing was found to have a ½ inch wall thickness, which was not considered sufficient to withstand the ramming forces that would be required to move a large diameter casing which had been stationary for several months. Using the 54-inch casing to conduct a smaller casing would negate this risk, as a smaller casing would not require an increased wall thickness, and would utilize a new cutting shoe. Additionally, the smaller casing was expected to displace less soil than the 54-inch casing at the exit location, where the steep slope of the ravine is at high risk of land-sliding.

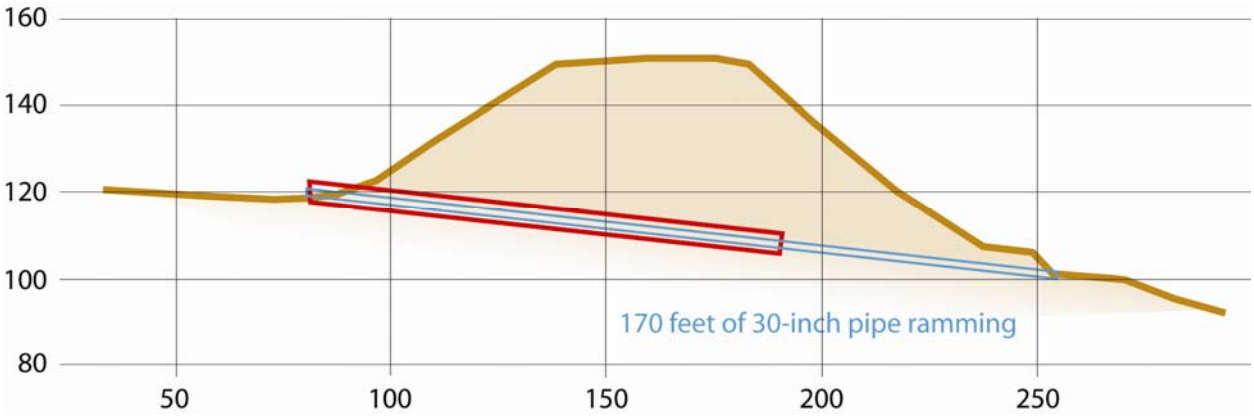

Figure 3: Profile view of design modifications

Subsequent hydraulic investigations by Island County Public Works selected a final culvert diameter of 24 inches, performed after the creek classification had been downgraded from fish-bearing. The final design consisted of the 24-inch diameter HDPE liner conducted by a 30-inch steel casing installed via open-ended pipe ramming (Figure 3).

4. SECOND INSTALLATION ATTEMPT

The project was divided into two contracts, with the first consisting of ramming the 30-inch casing through the 54-inch casing to daylight and cleaning out the resulting spoils. This contract was awarded to Trenchless Construction Services with Ground Piercing as the ramming sub-contractor. The second contract consisted of installing the 24-inch HDPE liner and grouting between the product and casing, and was awarded to Gary Harper Construction.

Construction on the first contract commenced in August of 2008. The proposed ramming tool was a Grundoram Koloss, manufactured by TT Technologies, and capable of providing an impact force of 966,640 lbs. This was considered to be more than adequate for the anticipated loads, as the engineer predicted total required ramming force was 332,188 lbs. As the proposed casing pipe had a minimum

yield strength of 60,000 PSI and a wall thickness of 0.563 inches, pipe bearing capacity was considered sufficient to protect against failure during ramming, with a factor of safety of 7.

Figure 4: The Grundoram hammer ready to ram

Upon mobilization for pipe ramming it was determined that despite the installation of the dewatering well, static water within the pipe had risen to the level of the 54-inch casing opening. The water was removed using an on-site vacuum truck, an operation that was repeated several times over the course of the installation as the level of static water within the pipe continued to refill.

After dewatering, the cutting shoe was attached and the first 120 feet of the 30-inch casing was welded and installed within the 54-inch casing, reaching the face of the soil plug generated after the initial trenchless failure. The crew was able to install approximately 5 feet of the 30-inch casing through the soil plug using horizontal impacts by the excavator bucket, leaving approximately 20 feet of casing exposed at the entry point. After checking line and grade, the ramming tool was attached to the end of the 30-inch casing using an adapter, and ramming commenced (Figure 4).

For the first several feet of the ram, the casing was advanced at an average rate of less than ½ inch per minute. During this time it was observed that the 30-inch casing appeared to be reverberating off of the 54-inch casing, presumably along the 100 or so feet of open-air casing. Discussions with the pipe ramming contractor concluded that the 30-inch casing was not getting appropriate resistance along the first 100 feet of the ram, which in a typical pipe ram is entirely encased in soil. To combat this, the excavator bucket was moved to provide downward pressure on the pipe crown, increasing the resistance of the ram. After this change the casing advancement noticeably increased in speed, reaching an average rate of approximately one inch per minute. This rate was maintained until ramming ceased in order to weld on an additional 40-foot section of pipe, bringing the total pipe length to 160 LF.

5. PROBLEMS ENCOUNTERED

After completing the weld, the ramming tool was attached to the new end of the 30-inch casing and ramming commenced. Advancement rates were constant at about one inch per minute for the first 5 feet, with the excavator bucket positioned on the pipe crown as before to increase resistance. However, after the first 5 feet, advancement rates slowed noticeably and forward progress appeared to stop. Ramming continued for approximately 60 minutes, during which the pipe did not visibly advance.

A meeting between the contractor and owner was held, during which the possibility of soil coming into the void space between the 54-inch and 30-inch casings was discussed. This was seen as a substantial concern due to the potential of another sinkhole forming along Saratoga Road above the culvert alignment. Also discussed was the possibility of encountering an obstruction. As noted in the geotechnical report, wood pilings from a historic bridge were known to be present within the fill of the road embankment, and possibly within the proposed alignment of the pipe ram. However, it was established in the meeting that failure to complete the culvert installation, now on its second attempt, was a greater risk

than development of a new sinkhole along Saratoga Road. Subsequently, it was decided that ramming would continue until further notice.

Ramming continued without visible pipe advancement for approximately 15 minutes. Suddenly, the pipe was observed to rotate about 1/8 of a turn, at which time the pipe started to slowly advance again at a rate of one inch in 20 minutes. This rate increased to one inch in 5 minutes, during which time the pipe rotated another 1/8 to reach a full quarter turn from the start of the ram. While it is not uncommon for pipes to rotate slightly during ramming, it is unusual for them to do so in such an abrupt manner. However, since pipe advancement had gradually increased to a speed as high as 8 inches per minute, the general consensus was that whatever had been preventing the forward progress of the ram had been overcome, and ramming was allowed to continue until the completion of the pipe section.

6. DAYLIGHT AT LAST

The final 40-foot pipe section was welded on to the 30-inch casing, bringing the total length of the pipe to 200 LF. After the tool had been attached and ramming had commenced, advancement rates were observed to be approximately 2 inches per minute on average. Ramming continued until the ground at the exit location began to bulge and crack, releasing a thin stream of water. The ram was stopped to allow the water to bleed off, during which time a small soil dam was constructed to filter silt out before reaching the creek. As the contractor had placed hay bales and silt fencing to protect the creek below the exit location prior to ramming, it was assured that no contamination would reach the creek, a concern that was of high priority to Island County Public Works.

As workers hand-excavated to expose the pipe face, it became apparent that the amount of water within the pipe would soon overpower the filtering capacity of the soil dam. Consequently, it was decided to use the vacuum truck to remove water and spoils from the exit location despite the extremely steep slope of the ravine in that area (Figure 5). After the flow of water slowed down, a small pit was excavated around the exit location and water jetting by hand was commenced to wash out additional spoils. Numerous wood chunks and splinters were removed from inside the casing, including one substantial piece 19 feet in length and 30 inches in diameter. Additionally, a thick wire cable was found with both ends severed. Marked wear on the bullet teeth of the cutting shoe indicated that these materials may have played a role in delaying the forward progress of the pipe ram.

After inspection by the owner, it was decided that the 30-inch casing would be rammed 16 more feet to more fully bridge the distance between the casing and the bypassed creek. Advancement of the casing was performed without incident. However, after completion of the ram, cracks displacing up to 5mm were observed on Saratoga Road directly above the alignment.

Figure 5: Daylight of the 30-inch casing. The bullet teeth can be seen around the edge of the cutting shoe.

Construction on the second contract commenced in September of 2008 (Figure 6). After installation of the 24-inch HDPE liner, workers plugged the 30-inch casing on the north (downstream) side of Saratoga Road with an expansive cement-based grout. Pea gravel added to the grout mix and additional plywood bracing added to the plug helped to prevent a blow-out as grout was pumped into the annular space between casing and product. The remainder of the project was successfully completed in October of 2008.

Figure 6: Installation of the 24-inch HDPE product pipe

7. LESSONS LEARNED

Several valuable lessons were learned throughout the multiple phases of the project. Firstly, the initial failed installation attempt illustrates the necessity of construction using trenchless methods suitable to the geotechnical conditions of the project area. Since auger bore pipe jacking is not capable of providing continuous face support, the method is typically limited to stable soils located above the water table or in those soils that can be dewatered along the entire alignment. In comparison, pipe ramming provides continuous face pressure through the development of a soil plug at the forward end of the ram. As groundwater was observed during the initial geotechnical investigation, the design should have addressed the potential of soils flowing and flooding the casing.

Secondly, the special circumstances of the existing 54-inch casing and the clearly sensitive overlying road made design of the second installation a challenge. The close working relationship between the Owner and the Engineer enabled successful integration of all project elements and allowed for the concerns of the Owner to be fully addressed in the culvert design.

Thirdly, the amount of wood encountered beneath Saratoga Road proved to be markedly different than expected during design, almost completely stopping forward advancement of the pipe. However, the Owner and Contractor were able to work together during construction to direct the successful completion of the culvert. Lastly, the use of two contracts during the bid phase of the project proved to be valuable as it limited bidders to companies with direct experience in each phase of construction.

8. REFERENCES

GeoEngineers (2008) Geotechnical Engineering Services, Proposed Culvert Replacement, Saratoga Road, Whidbey Island, Washington, dated 14 April.

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