North American Society for Trenchless Technology (NASTT)
NO-DIG 2006

Nashville, TN
March 26-28, 2006

TRENCHLESS TECHNOLOGY PROVIDES A UNIQUE AND UNLIKELY SOLUTION TO STORM WATER ISSUES AT SEA-TAC INTERNATIONAL AIRPORT

Robert J. York[1], Kimberlie Staheli[2], Keith Parker[3], and Albert Shen[4]

[1] Port of Seattle, Seattle, WA
[2] Bennett / Staheli Engineers, Seattle, WA
[3] R.W. Beck, Seattle, WA
[4] Port of Seattle, Seattle, WA

ABSTRACT: The Port of Seattle was faced with having to provide additional treatment to their storm water run-off. Their existing drainage basin SDE4 is nearly 200 acres and is nearly entirely impervious. The Port was faced with adding a large detention/treatment facility for Basin SDE4 in a very tight location adjacent to a major arterial and one of the main vehicle entrances into the terminal. This new facility had to be installed over 20 feet deep and was estimated to cost $15 to $20 million. Operations costs would be high, since maintenance access to the treatment components would have been problematic. Pumping to another treatment location posed many of the same tight site constraints along with numerous utility conflicts at the airport site, as well as reliability issues. However, by using trenchless technology and constructing a 54-inch tunnel, the Port was able to extend the pipeline, allowing construction of the detention/treatment facility in a much more favorable location with good access and minimal site constraints. In addition, tunneling allowed installation of the pipeline at a sufficient depth to avoid conflicts with existing utilities. The construction cost of the tunnel and the detention/treatment facility was estimated to be less than $10 million, a $5 to $10 million saving.

This paper details the design approach that lead to the use trenchless technology and provides a case history of the tunnel construction that included two drives of 54-inch pipe, 588 and 1182 feet in length, jacked through glacial till soils.

1.0 INTRODUCTION

Seattle-Tacoma International Airport (STIA), owned and operated by the Port of Seattle, was the 28th busiest airport in the world in 2004. Figure 1 shows the location of STIA in relation to nearby cities, transportation routes, and water bodies. STIA sits on roughly 1,300 acres located approximately 10 minutes south of downtown Seattle and 20 miles north of Tacoma. It is situated on a plateau roughly 2 miles from Puget Sound. Runoff drains in all directions to small local creeks that flow into Puget Sound and to the Duwamish River to the east. Several of the streams are used for salmon spawning and there are currently efforts underway to restore other for salmon spawning,

Figure 1 Location of STIA

Recent airport expansion increased the level of public scrutiny on the impact of stormwater discharges on the local water bodies. A Section 401 Water Quality Certification was issued to the Port to allow its expansion projects to proceed. One condition of this certification required the retrofitting of existing portions of the airport to meet current stormwater standards. In addition, the Port's renewed NPDES permit contained new effluent limits for stormwater discharges that will be effective starting in 2008. Faced with this situation, Port management initiated a new capital program focused exclusively on improving the existing stormwater systems and designing new systems to ensure compliance.

The goal of the stormwater capital program was to implement strategies that would allow STIA to comply with all permit conditions in a way that was defensible to the airlines, the public, and regulatory agencies. In addition to the need to attain compliance with new permit conditions, a key consideration was cost – the airline industry has been suffering through its worst recession in history. Since the Port passes the majority of the cost of building and operating new projects onto the airlines in the form of landing fees and emplanement charges, scrutiny on any spending was intense and cost justification was paramount. Life cycle cost analyses were performed to determine and justify the most cost-effective solution.

Another key driver was schedule. The permits required an expedited retrofitting of the stormwater systems at the airport such that all the improvements needed to be complete before 50 percent of the new impervious surface associated with airport expansion would be created. A timeline of only 5 years was available from the creation of the program to the successful implementation of all the facilities.

Because of the high development density of the existing airport, any stormwater improvements would be difficult to implement. Potentially innovative technologies or combinations thereof would be necessary for implementing the suite of Best Management Practices (BMPs) necessary to meet the future effluent limits.

Finally, all stormwater improvements needed to be consistent with the airport's wildlife hazard management plan. FAA Advisory Circulars specifically discourage open water within 10,000 foot of an active runway. Working cooperatively with the Airport Biologist, techniques were developed to mitigate any wildlife attraction posed by the new stormwater infrastructure.

2.0 COMPONENTS OF STORMWATER CAPITAL PROGRAM

A total of 13 new flow control facilities were needed to be built to detain runoff and release it at controlled rates. In addition, each of thirteen outfalls had to be retrofitted to meet new effluent limits that would be effective in 2008. The sub-basins that serve these outfalls are shown in Figure 2.

2.1 Impacts to STIA

2.1.1 Airfield Areas

It was found that runoff from runways and taxiways is generally clean if it passes through vegetated filter strips prior to discharge. The newly created third runway was designed to incorporate properly sized vegetated filter strips wherever practicable. In existing airfield areas, the Port optimized the ability of vegetated filter strips to provide water quality treatment. Conveyance systems were modified where short-circuiting of runway/taxiway runoff directly to catch basins occurred, forcing the runoff through grassy areas. In addition, re-vegetation and soil improvements were implemented in areas where the vegetated filter strips in existing infield areas were found to be deficient.

2.1.2 Landside Areas.

Landside activities at STIA include runoff from roads, buildings, and parking areas. There are 6 different landside sub-basins, each with different challenges. In the northeast (SDN1) sub-basin, BMPs include coating metal roofs, a wet pond incorporated into a detention pond and bioswales along roadway shoulders.

In three sub-basins, runoff from pollution generating surfaces was eliminated either by changing activities or eliminating runoff up to the water quality design storm

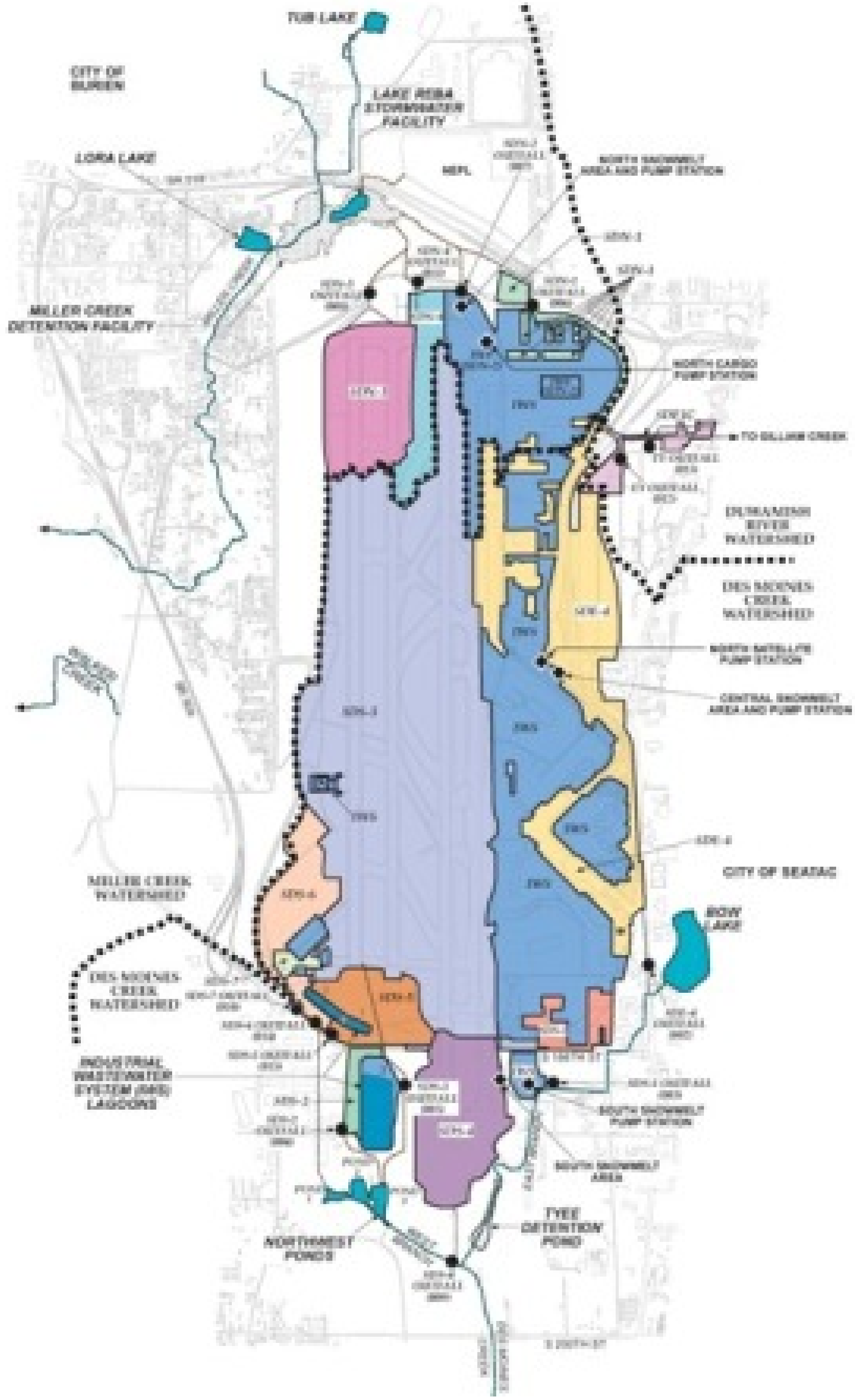

Figure 2 Drainage Sub-Basins at STIA

3.0 ALTERNATIVES FOR STIA

In other sub-basins where land availability allowed, bioswales, Ecology Embankments, and vegetated filter strips were installed, coupled with numerous source controls.

However, due to non-availability of land, such measures were generally not possible in the large SDE4 sub-basin that serves the main terminal, parking, and terminal drive areas. An alternatives analysis was performed that looked at three different options for flow detention and water quality treatment:

1. Source controls and distributed treatment along with in-stream detention.
2. Source controls plus end-of-pipe treatment and off-line flow control in a large subterranean vault located along International Boulevard located near the existing conveyance system.
3. Source controls, plus end-of-pipe treatment and flow control in a remote location south of the airport.

The first option was the option originally considered during initial planning of the project. This option would have been relatively inexpensive. However, the Port was concerned about the ability of source controls by themselves to consistently meet the effluent limits included in the latest NPDES permit.

The second option would have involved a large underground (60-feet wide by 210-feet long) detention vault that would be approximately 35-feet deep. The existing storm sewer in this area was 16-feet deep. The vault would need to be located adjacent to a busy arterial in one of the most congested areas around the airport. Estimated construction cost for the underground vault was approximately $10,000,000. Additional cost would be needed to provide water quality treatment.

In addition to construction difficulties and high cost, maintenance access would be very difficult. The treatment system would need to be located 20-feet below water surface. Confined space entry would be needed to access the system.

The third option was developed by “looking outside the box.” The Port owned unused property approximately one-half mile south of the confluence of all drainage pipes into one combined pipe. This site would provide adequate room for a detention pond and treatment system, plus room for expansion. There was sufficient elevation difference so that the stormwater could flow to this location by gravity. All new facilities could be located at grade. The location was also convenient for maintenance.

The problem was that a new conveyance pipe needed to be installed to allow the stormwater to be routed to this area,

There were three options to provide the new conveyance pipe:

1. Open cut along International Boulevard.
2. Pump over a hill from the point of connection to the new detention/treatment area.
3. Use trenchless technology (tunneling) techniques to install a new gravity conveyance pipe.

The first conveyance option would have been very costly due to traffic control and likely utility interferences. The second conveyance option was not desirable due to the cost and maintenance requirements for a new stormwater pump station that would have had to pump approximately 52,000 gallons per minute of flow. After a review of available geotechnical information, tunneling techniques appeared viable. It was therefore decided to tunnel the stormwater to the remote location, where detention and treatment would be installed.

4.0 DESIGN CONSIDERATIONS

The proposed alignment connecting the existing storm sewers to the north with the pond area to the south had several vertical constraints and some goals for the horizontal alignment.

4.1 Horizontal Alignment

A desired goal was to keep the tunnel within Port property or within public right of way to avoid the need to obtain easements. A number of alignments were considered that would require varied bore lengths, access shaft locations, easement requirements, etc. A preferred alignment began to emerge, but due to a pivot point, it would require a shaft for the tunnel near a main airfield access point for commercial and construction vehicles. The access point is known as Gate E-45. Detailed layouts around Gate E-45 were prepared and several meetings were held with Port landside and air operations personnel and security staff due to concerns over construction near the gate. After much discussion an acceptable location for the access shaft was agreed upon that would limit impacts to traffic through Gate E-45 while still allowing the tunnel alignment to stay within Port property and public rights of way. A plan view of the tunnel shaft is shown in Figure 3.

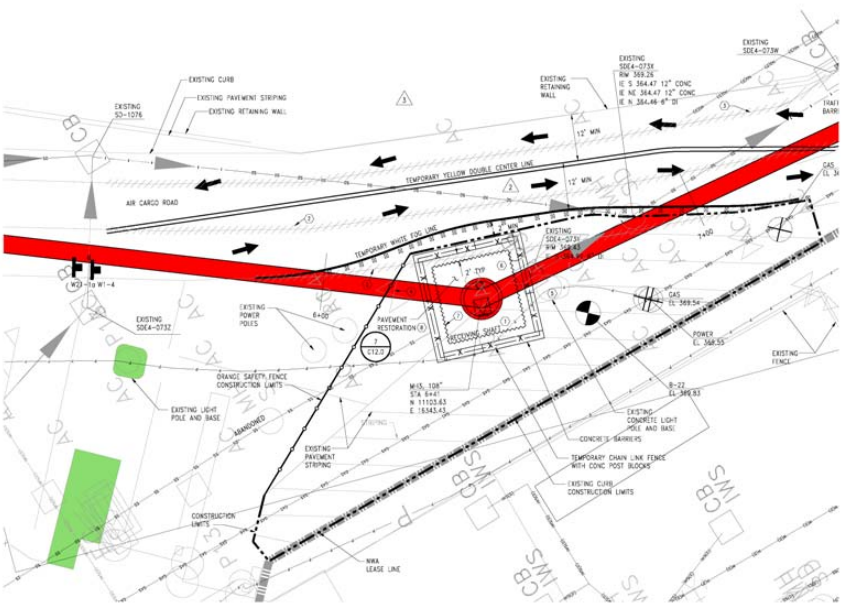

Figure 3 Reception Shaft Proximity to Gate E-45

Figure 4 Gate E-45 Photos

4.2 Vertical Alignment

The vertical alignment was relatively confined due to gravity flow requirements. Because of topography, the proposed vertical grade was well below existing utilities. Near surface utility conflicts were possible at shaft locations based on the optimal pivot points for the pipeline.

There was however, one major conflict. The Port had long range plans for improved access to the airport from the south. A preliminary road alignment had been prepared that included a below ground section that would cross the proposed tunnel south of Gate E-45. When Northwest Airlines constructed a major hanger facility, a "lid" for this tunnel was constructed which effectively set the future roadbed grades, as can be seen in Figure 4. This road alignment pushed the tunnel deeper that would normally have been required. To mitigate this as much as possible, the vertical alignment stayed as high as possible to the Gate E-45 access shaft. At this point, the vertical alignment drops 11 feet so the tunnel will clear any future road that is constructed.

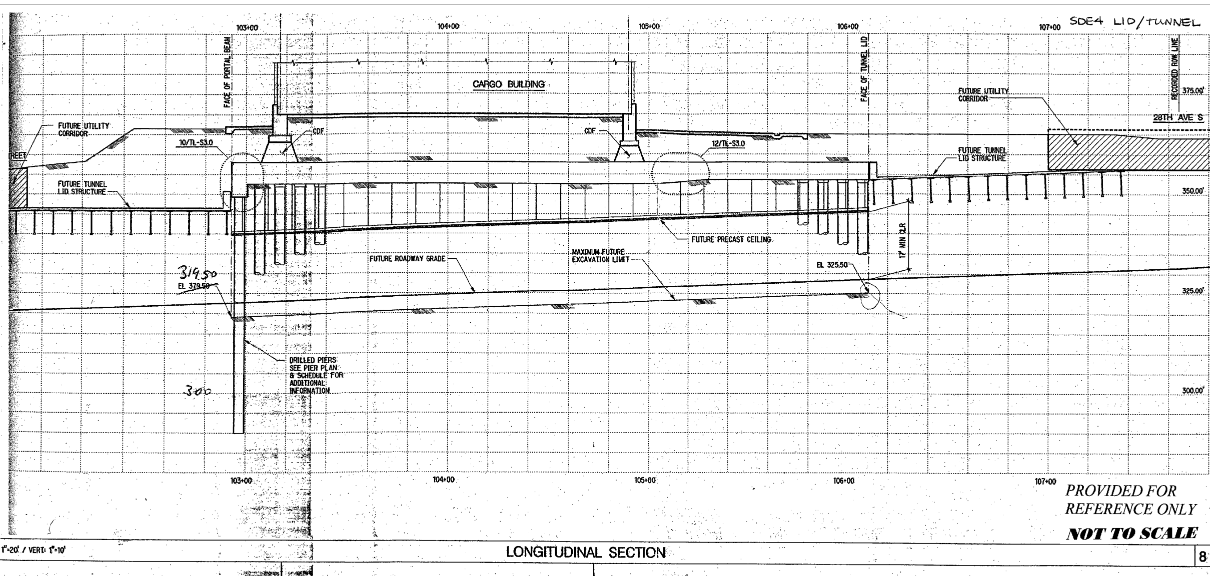

Figure 5 Northwest Airlines Cargo Building with Future Tunnel Lid Structure

5.0 TRENCHLESS ALTERNATIVES

A thorough geotechnical investigation was conducted to identify the soils along this relatively narrow zone through which the pipe had to be placed to determine whether trenchless methods were feasible. The geotechnical investigation revealed dense glacial till soils throughout the length of the alignment. These dense tills, common to the Northwest, have a history of standing vertically and tunneling well. However, they are also known to contain scattered boulders and cobbles. Although groundwater was encountered in the drilling, piezometers were installed so that the groundwater could be monitored over time. Although groundwater was present during drilling, often groundwater dissipates quickly in the glacial till as the groundwater is often perched due to variations in the permeability of the soil layers within the till. Therefore, piezometers were used to investigate the long-term groundwater behavior at the site. Figure 5 shows a vertical cross section of one of the two tunnel drives with geotechnical information interpreted from the borings.

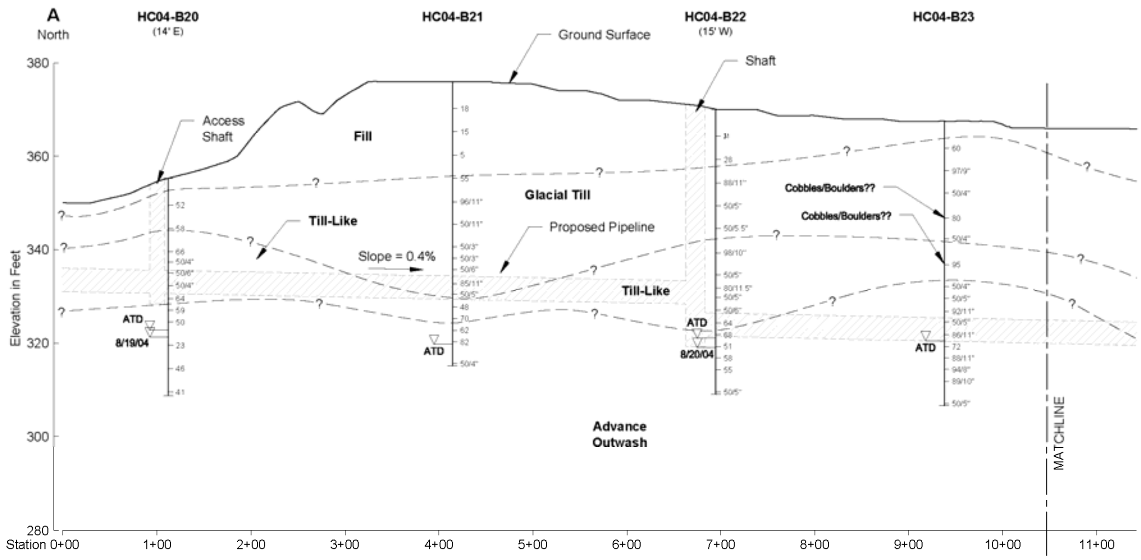

Figure 5 Cross Section of 588 ft Drive with Geotechnical Interpretation

Groundwater monitoring was done specifically to investigate the feasibility of using open shield tunneling. The risk of specifying microtunneling as the only allowable construction method was high with the possibility of encountering large boulders within the glacial till soils. Allowing the use of open shield tunneling lowered the construction risk. Although it was agreed that open shield tunneling would not provide the line and grade accuracy that could be gained with microtunneling, there was enough flexibility in the grade due to lowering the pipe because of the Northwest Airlines “lid” structure that the grade accuracy could be sacrificed. The second tunnel drive with the lowered elevation to deepen the tunnel below the lid structure is shown in Figure 6.

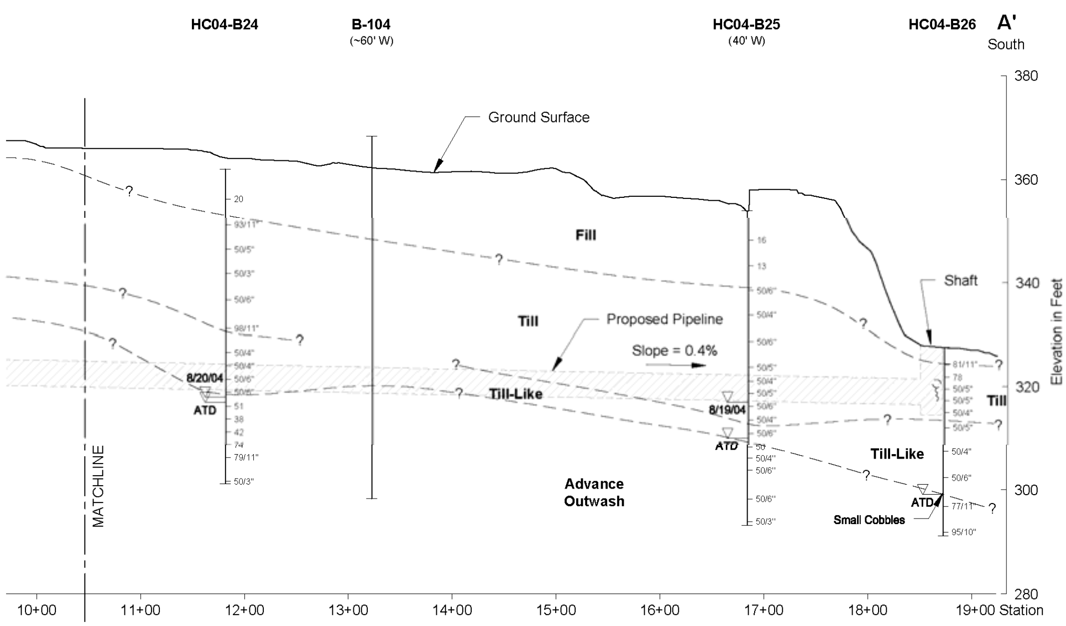

Figure 4 Cross Section of 1,182-foot Drive with Geotechnical Interpretation

After many discussions on risk/cost benefits of bidding one versus two trenchless alternatives, it was decided to specify only open shield pipe jacking as the trenchless construction method for the project. Figure 6 shows an open shield pipe jacking machine as specified for the project.

Figure 5 Open Shield Tunneling Machine Looking from Front (left) and from Inside (right)

6.0 BIDDING THE PROJECT

When the project went out to bid, one of the contractors put in an RFI (request for information) asking the Port if microtunneling would be accepted as an approved alternative for open shield pipe jacking on the project. The Port considered this request and decided to issue an addendum that included a microtunneling specification. The addition of the microtunneling specification was necessary as there were different machine and construction monitoring requirements for microtunneling than for open shield pipe jacking and the Port wanted to be sure that certain parameters were adhered to by the contractor should microtunneling emerge as the low bid alternative.

When the project was bid, the low bidder submitted on microtunneling in lieu of the originally specified open shield pipe jacking alternative. The contractor stated that the microtunneling was cost effective in this particular case due to the availability of the equipment at the time of the bid as well as the high costs associated with open shield pipe jacking on drive lengths longer than 1,000 feet due to the inefficiency of removing tunnel spoils with muck carts and locomotives.

Construction of the pipeline is planned for early 2006 and details of the construction will be presented at the No Dig 2006 conference.

7.0 CONCLUSIONS

Trenchless technology provided an unlikely to the solution stormwater issues at the Port by providing a conveyance pipeline to a detention pond and an end-of-pipe treatment facility. The new $4,000,000 54-inch diameter conveyance pipe will be microtunneled nearly 2,000 feet to an area where the stormwater flows to a detention pond followed by filter cartridges. The new pipe also segregated STIA flow from that of other jurisdictions. The detention facility has been designed to provide flow equalization to optimize treatment and meet the standard that at least 91 percent of the annual runoff volume be treated.