With no road access to the sewer line crossing Miller Creek in King County, Wash., the Southwest Suburban Sewer District had to airlift materials for the rehabilitation project. PACE Engineers/SWSSD

BACK TO NATURE

Rehabilitating aging infrastructure in environmentally sensitive areas

Kenneth H. Nilsen and Peter Sanchez

Much of the utility infrastructure in the Pacific Northwest was constructed more than 60 years ago and is approaching the end of its design life. In past decades, many utility systems were constructed in ravines containing streams, magnifying the problem of aging infrastructure. As development and surface runoff have increased, the flow in these streams has increased dramatically, often leading to channel erosion and slope instability. These utility systems, which were constructed under or adjacent to stream channels with sufficient cover, are now being threatened with the effects of potential failure, which could cause significant environmental damage.

In King County, Wash., the Southwest Suburban Sewer District (SWSSD) faced a potentially catastrophic situation when it found that a sewer line beneath a stream was in danger of becoming completely separated from the trunk line. Within 3 months, SWSSD was able to successfully rehabilitate the sewer line and protect against future environmental impacts in the area.

Vigilance is essential

SWSSD provides sewer service within portions of the cities of Normandy Park, Burien, Des Moines, and Seattle; Sea-Tac International Airport; and unincorporated King County. SWSSD, which was formed in 1945, serves approximately 3200 ha (8000 ac) and has more than 25,400 current accounts. The district has more than 430 km (270 mi) of sewer lines, ranging from 150- to 900-mm (6- to 36-in.) pipe size, much of which was constructed in the 1950s. SWSSD does not have a combined sewer system, but it does experience high infiltration and inflow in several of the older sections of pipe. SWSSD owns and operates two secondary rotating biological contactor wastewater treatment facilities, one on Miller Creek and the other on Salmon Creek.

According to district records, as part of Utility Local Improvement District (ULID) No. 9, SWSSD constructed a 750-mm (30-in.) concrete sewer trunk line along Miller Creek in 1966. This trunk line was designed to convey flows to the Miller Creek treatment facility owned and operated by the district. Record drawings for this trunk line show the sewer pipe crossing Miller Creek in approximately 14 locations between the treatment plant and First Avenue South. At the time of construction, an access road was constructed along the entire length of the pipeline. The record drawings also show the sewer line was constructed 1.2 to 1.8 m (4 to 6 ft) below the stream channel. The summer base flow for this line, according to district staff, is approximately 7570

District staff discovered that sewer lines and several manholes, which previously were buried beneath the stream, had been exposed. PACE Engineers/SWSSD

Boulders were bagged at the staging area and then airlifted to the project site. PACE Engineers/SWSSD

m^3/d (2 mgd). Winter peak flows are approximately 37,850 m^3/d (10 mgd). This flow represents approximately two-thirds of the total flow to the treatment plant.

Because much of SWSSD's older infrastructure is approaching the end of its design life, SWSSD has begun a program to systematically upgrade and/or replace those older sections. Unfortunately, all of the district's lines ultimately flow toward its two treatment plants located in narrow ravines adjacent to two major salmon-bearing streams. Due to the limited access to the sewer lines in these two ravines, SWSSD has implemented a rigorous maintenance inspection program to walk these ravines several times a year during low stream flows and after significant flood events to look for signs of erosion and potential impacts to its sewer system.

An urgent problem is discovered

During a maintenance walk in June 2007, following a winter of record rainfall, district staff discovered that several manholes in the Miller Creek ravine were now fully exposed to high stream flows, and that an unrestrained 22.5-degree vertical–horizontal bend that had previously been buried 1.2 to 1.5 m (4 to 5 ft) below the stream was exposed and in jeopardy. Any further down-cutting or movement of this sewer line could lead to a total separation of the trunk line, causing catastrophic environmental impacts to a major salmon spawning creek.

The district was previously aware that the streambank near Manhole (MH)-12 had eroded, leaving the upper 1.5 m (5 ft) of the manhole fully exposed to high stream flows. In this June 2007 inspection, the district staff noted that a portion of the sewer trunk line near MH-15 also was exposed. Following that initial reconnaissance, PACE Engineers Inc. (Kirkland, Wash.) was contracted to conduct a topographic survey of the stream and sewer line from MH-11 to MH-17, and identified approximately 43 m (140 ft) of pipe that were at risk of damage. The project team believed this risk would be very high if corrective action was not immediately taken before the 2007 winter flows.

The district immediately launched a remediation project, the goals of which were to stabilize and protect the exposed sections of sewer line, prevent significant environmental impacts to Miller Creek, and provide ongoing protection of the district's assets. Accomplishing these goals was challenging because there was no longer road access to the affected section of sewer line and the exposed lines were surrounded by regionally significant environmental areas.

What caused the problem?

To stabilize this reach of Miller Creek and protect the pipe, it was important to assess why the stream down-cut in this reach. A stream geomorphologist and a surface-water engineer walked the site several times in July to ascertain the reasons for the stream down-cut and assess what could be done to fix the stream. It appeared that two main factors contributed to this problem: The stream was constrained in width due to the geological conditions and the riprap revetment on each streambank, and this narrowing of the channel led to very high stream velocities and corresponding scour. There also was a grade change in the stream profile in this reach, which, combined with the high velocities, led to head-cutting of the stream channel and created a complete barrier to upstream fish migration.

It was likely that accelerated erosion would continue to occur in Miller Creek beyond the segments of pipeline being considered for repair in this project, and this would require an ongoing monitoring and inspection program to proactively prevent future problems at any of the 14 identified stream crossings.

Table 1. Project costs billed to district

Item	Estimated cost	Actual cost
Topographic survey	$20,000	$17,000
Stream assessment	$5000	$9000
Permitting	$7500	$10,000
Design	$15,000	$20,000
Construction	$300,000	$148,000
Construction field engineering	$25,000	$24,000
Contingency	$75,000	$0
Total project costs billed	$447,500	$228,000

Remediation options

To eliminate the risk and associated environmental impacts of the sewer trunk line breaking or separating at the joint of the 22.5-degree bend, the district had three strategic options to consider:

Option 1: Relocate the sewer trunk line out of the ravine.

Option 2: Redirect the flows from the trunk line to existing and/or new lines outside of the ravine.

Option 3: Stabilize the stream channel and protect the existing sewer line by raising the stream grade within the at-risk section.

Options 1 and 2 would require extensive analysis and system modeling to optimize the routes and sizes of required conveyance facilities, would likely involve additional lift stations, and would disrupt a number of neighborhoods in nearby cities. Both of those approaches would thus be very expensive, and neither one could be implemented in time to reduce the risk of exposing the pipe to the upcoming winter high stream flows. For these reasons, the analysis focused on developing alternatives for Option 3, stabilizing the existing stream reach. To accomplish this and to protect the sewer trunk line, it was imperative that the stream channel be raised to its historic (1966) conditions and that it be constructed in such a way that the stream velocities under anticipated winter flow conditions would not erode and down-cut the channel in the area of the repair. This could be done by strategically placing boulders and large woody debris along with appropriately sized streambed gravel into the stream.

Lack of access

The biggest concern was not necessarily what should go into the stream in order to raise the channel but, rather, how to gain access to the project area to do the work. The project team evaluated the following alternatives to provide access and emergency repairs to the exposed pipe reach and to MH-12:

Alternative 1: Airlift (by helicopter) the necessary equipment and materials into the project area.

Alternative 2: Reconstruct the existing road that was used to build the original sewer line to get the necessary equipment and materials into the project area.

Alternative 3: Access the site from the existing access road from First Avenue South along the Walker Creek Preserve and use a highline to convey equipment and materials from the ridge above Walker Creek down to Miller Creek.

Alternative 4: Construct an access road across private property to the north down the slope to Miller Creek.

After lengthy deliberation, Alternative 1 was selected. Suitable mechanical excavating and lifting equipment would be airlifted by helicopter into and out of the area of the repairs, as would the necessary materials (boulders, large woody debris, streambed gravel, and anchoring components). This approach would minimize the area of disturbance and could be completed in the shortest possible construction period because virtually the entire project time would be spent working directly on the repair/restoration. This alternative also would have the shortest potential period for permit review because the area of disturbance would be small. The three other alternatives had combinations of highly problematic logistics, unlikely permitting success, a larger environmental footprint, and longer and/or costlier construction periods.

Project environmental constraints

The environmental issues associated with this project were daunting. First, if the sewer trunk line were to fail, either Miller Creek would flow into the pipe, drying up the creek and overwhelming the treatment plant, or 7570 m^3/d (2 mgd) of wastewater would flow from the pipe into the creek, severely affecting the environmental health of the stream. In either event

The Spyder Hoe excavator was chosen for its ability to "walk" up the creek channel with minimal environmental disruption. PACE Engineers/SWSSD

The proximity of the project to Sea-Tac International Airport required close coordination with the Federal Aviation Administration. PACE Engineers/SWSSD

the environmental impacts would be significant and the potential regulatory response could be severe. The second environmental consideration was the ability to secure permits from the resource agencies. The ability to secure these permits in a timely fashion was the driving force in the alternative selection process. In order to meet the aggressive 3-month construction timeframe, the project team met with all of the relevant resource agencies to discuss the project, review the alternatives, solicit their input, and attempt to secure a commitment on issuing the required permits prior to the upcoming rainy season.

Washington State Department of Fish and Wildlife (WSDFW). WSDFW was very supportive of the project based upon the potential significant impacts if the pipe were to fail, but noted that additional mitigation measures might be required, including removal of an existing fish barrier. Because the consulting engineer had a long collaborative history with the WSDFW habitat manager on previous stream restoration projects, WSDFW agreed to expedite the permit process.

Washington State Department of Ecology (WSDOE). Since this project work was within state waters, a 401 Water Quality Certification was required by the state. Acquiring this permit can be very time-consuming, and WSDOE would not issue the permit until approvals had been secured from the U.S. Army Corps of Engineers.

U.S. Army Corps of Engineers. The Corps permitting process can take 6 to 18 months and is often difficult. The consulting engineer approached the Corps about the possibility of declaring this project an emergency, thereby bypassing the permit process. The Corps preferred that a permit application be submitted for their expedited review with an anticipated permit date on about Sept. 1. The project included a number of habitat mitigation measures including the placement of large woody debris and other in-stream habitat structures as well as the removal of a partial fish barrier. These measures allowed the Corps to provide an expedited review of the project under one of their Nationwide Permits for habitat restoration. This allowed both the Corps and WSDOE permits to be issued.

City of Normandy Park. The consulting engineer met with staff from the city, who agreed to expedite their sensitive-area approval as well as the grading permit.

State Environmental Protection Act (SEPA). In terms of complying with the State Environmental Protection Act, SWSSD, as its own lead entity, declared the project an emergency, which allowed this project to be SEPA-exempt.

Flexibility of design

While each of the permitting agencies required engineering plans showing the proposed improvements and identifying both short-term and long-term construction impacts on the environment, it was important to maintain flexibility in the design based upon the actual field conditions. Therefore, engineering plans were developed that showed several types of stream and bank stabilization measures with their approximate locations, but leaving the option to rely on the engineer in the field to determine their actual types and locations. This flexibility required a full-time engineer in the field directing the contractor's placement of in-stream and bank stabilization structures.

Pulling it all together

Locating large-enough equipment. Once the preferred alternative was selected and all of the resource agencies were on board with the solution, the challenge was to find equipment large enough to complete the project. To complicate matters, the Western states were in the middle of the fire season, and most helicopters were already under contract with the U.S. Forest Service and other agencies in fighting wildfires. After an extensive search, the district was able to contract with a White City, Ore., company to provide the helicopter service. The company had one week between jobs, and its availability became the critical path.

To minimize impacts to the stream, riparian corridor, and sewer line, the project team had recommended that the placement of material be done with a special excavator called a Spyder Hoe. This equipment, unlike a tracked hoe, would be able to "walk" up the creek channel as well as "step" over obstructions as high as 1.5 m (5 ft) with few or no environmental impacts, and perform the necessary excavations and material placement without placing any extraneous loads on the existing sewer pipe. A Hillsboro, Ore., company was contracted to provide these services.

FAA coordination. Since this project was slightly more than 1.6 km (1 mi) from Sea-Tac International Airport, close coordination with the Federal Aviation Administration (FAA) was required to not only stay out of the airport airspace, but also because the FAA limited the flight path the helicopter could take while transporting materials. Fortunately, the entire location between the staging area and the pipe failures was on forested SWSSD property that contained no houses within the potential crash zone.

Safety. Aerial crane work is extremely dangerous, not only for those in the helicopter but also for the contractor's ground crew, district personnel, and engineering support services on the ground. Daily safety meetings were mandatory, and strict operational procedures were established and followed.

Dewatering. One of the requirements of the Corps of Engineers's permit was that the stream flows be bypassed around the work area. Prior to dewatering, fish screens were installed both upstream and downstream of the project area. This would isolate the work area from any fish migrating either upstream or downstream through the project area. The area between these screens was then electro-fished so that any fish within this area could be removed and transported downstream prior to dewatering the project area. To dewater the project area, the helicopter airlifted two large diesel pumps and more than 90 m (300 ft) of discharge pipe to the project area. The pumps were turned on every morning to dewater the work area. To avoid having to man the pumps at night and run them 24/7, the contractor had to make sure there was no exposed soil within the work area that would cause downstream turbidity.

Fish passage. One of the key elements in securing approval from the resource agencies was to remove an existing fish barrier as part of the streambank and sewer line stabilization. This work involved reconstructing a section of the stream channel that was head-cutting; this was accomplished with a double rock weir in compliance with WSDFW design standards. This collaborative effort between SWSSD and the resource agencies was critical for the success of this project.

Division of responsibilities. This project was a collaborative effort among the district, the engineer of record, and the contractors. The consulting engineer was responsible for the design, all permitting, procurement of contractor services,

Table 2. Project costs paid directly by the district

Item	Actual cost
12-in. minus gravel	$559.53
Streambed gravel	$15,857.84
Boulders	$4476.87
Logs/root wads	$4400.00
Pump rental	$7837.77
Excavator rental	$3190.02
Safety equipment	$240.78
Inflatable plug rental	$366.37
Fuel	$200.00
Sandbags	$620.16
Straw mat	$98.01
Miscellaneous	$47.82
Total direct district expenditures	$37,895.17

Lessons learned

In order to protect aging utility infrastructure, especially those located within environmentally sensitive areas, a number of lessons can be taken from this example:

Know the system. It is critical that utility providers know their systems: the location of the utility assets, when they were constructed, what type of material was used, and what external factors could threaten the utility's integrity. This type of information ideally is tracked in a geographical information system, but at a minimum, there should be a system to track this information.

Adhere to a rigorous maintenance program. Especially when a utility is located in an environmentally sensitive or remote area, an ongoing maintenance program with scheduled activities must be in place to protect the assets. A potential problem may not be known prior to a failure, which can often lead to severe consequences.

Identify issues before they become problems. By being proactive in this effort, utilities often can prevent failures in which their ability to reduce the risk and capital expenditures are beyond their control.

Take a collaborative approach. Utility personnel who find themselves in a situation where immediate action is needed should enlist the support of the permitting authorities, resource agencies, and the public. By giving these entities a forum in which their concerns can be heard and incorporated into the solution where practical, utilities can prevent adversarial confrontation and can form a collaborative team approach to the solution.

Post-construction, the stream channel has been raised to its 1966 conditions and constructed to minimize future erosion. PACE Engineers/SWSSD

engineering direction in the field, and overall project coordination. SWSSD purchased all of the materials, provided a staging area for the materials and a landing pad for the helicopter, cleared brush and dead trees within the work area, set up and maintained the bypass pumping required to dewater the creek within the work area, and loaded gravel, rock, and boulders into the helicopter bucket and media bags. The helicopter contractor coordinated with the FAA and delivered all materials into the work area. The excavation contractor was responsible for placing all materials required to stabilize the stream channel and the streambanks per the design specifications.

The results of thinking outside the box

In June 2007, the district had discovered the problem of exposed pipe and manholes in Miller Creek. By September 2007, the consulting engineer had completed the remediation design, secured all of the required environmental permits, and contracted with an aerial crane operator (helicopter) and a general contractor to construct the improvements by the fisheries' mandated completion date of Sept. 30.

Overall, about 360 Mg (400 ton) of material (including logs, boulders, and streambed gravel), two diesel-powered pumps, more than 90 m (300 ft) of suction and discharge hoses, pallets and plywood to build a platform for the pumps, a fuel tank, and sandbags were airlifted. Ultimately, more than 45 m (150 ft) of sewer line were stabilized and more than 90 m (300 ft) of stream were reconstructed. The project was highly successful in not only stabilizing the stream channel and protecting the 750-mm (30-in.) trunk line, but also in removing a fish blockage caused by the stream down-cutting. Through a cooperative effort with the resource agencies, this project was completed on time and under budget.

The approach taken on this particular project was not conventional, but by knowing the concerns of all parties involved, a creative solution was developed that met all of the goals and objectives, including minimizing the environmental impacts and meeting the very tight time constraints.

Kenneth H. Nilsen *is vice president of PACE Engineers Inc. (Kirkland, Wash.).* ***Peter Sanchez*** *is Sewer Department supervisor at the Southwest Suburban Sewer District (Burien, Wash.).*

Project costs

Since the district's board of commissioners had declared this project an emergency, normal procurement procedures were waived and the district was able to contract directly with any contracting vendor that best met its needs.

Based upon discussions with contractors, the consulting engineer prepared an estimate for total project costs; they are compared with the actual project costs in Table 1 (p. 46). The items directly procured by the district on this project (outside of the two construction contracts) are summarized in Table 2 (p. 49). These costs are in addition to the amounts listed by the consulting engineer, and the fuel cost is an approximation. District personnel worked on the project a total of 382 hours, which is not included in the overall project costs.