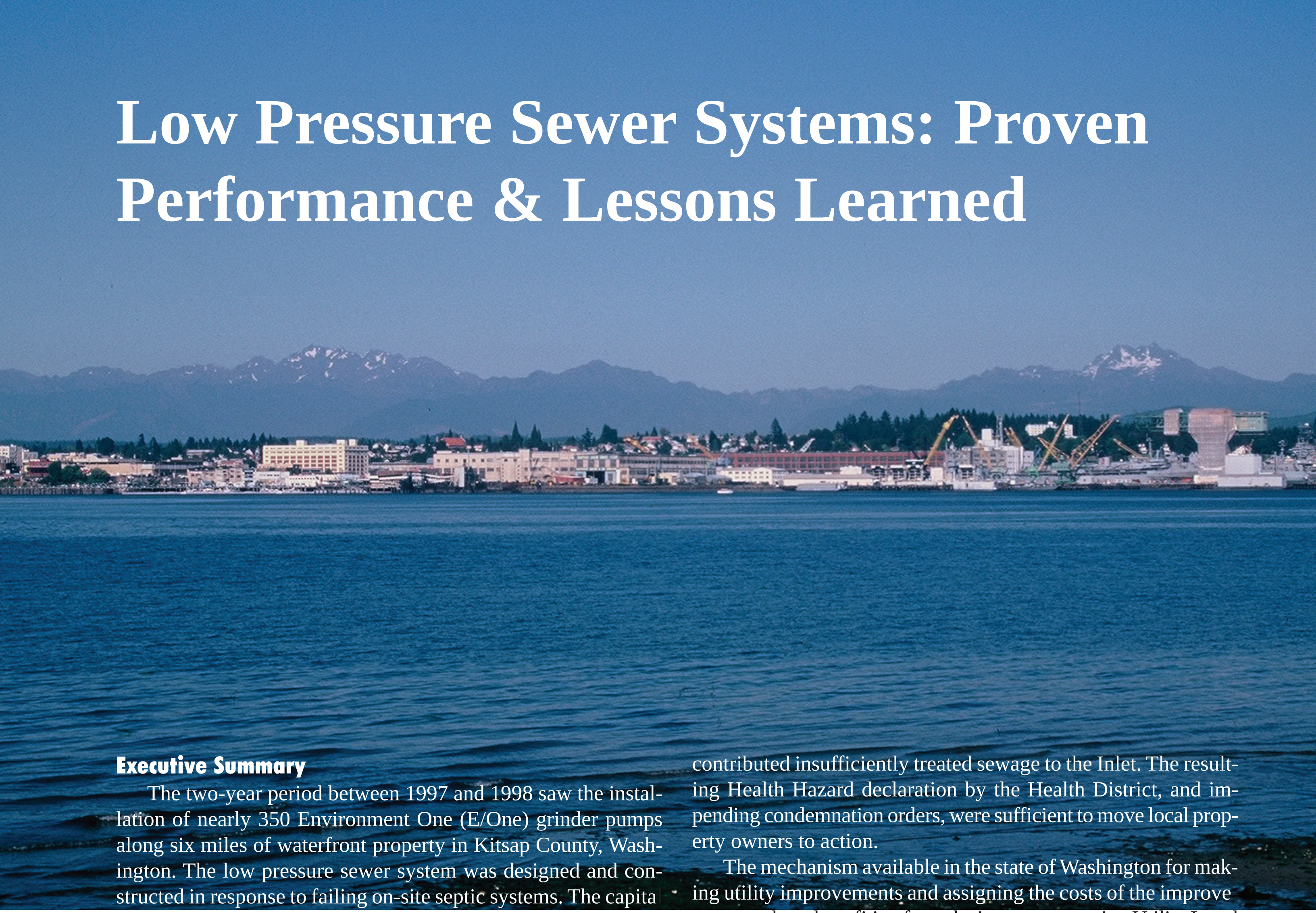

Low Pressure Sewer Systems: Proven Performance & Lessons Learned

Executive Summary

The two-year period between 1997 and 1998 saw the installation of nearly 350 Environment One (E/One) grinder pumps along six miles of waterfront property in Kitsap County, Washington. The low pressure sewer system was designed and constructed in response to failing on-site septic systems. The capital cost of the improvements was funded through a Utility Local Improvement District (ULID). A ULID is a funding mechanism for property owners whereby an opportunity is afforded to vote on the proposed improvements and assess their property to pay for the project costs.

The sewer system was installed under two separate ULID formations and, as a result, was competitively bid and awarded to two different contractors. Beach Drive was the first project and included the installation of 295 grinder pumps and about five miles of high-density polyethylene (HDPE) pressure main. Watauga Beach was the second project and included 52 grinder pumps and one mile of HDPE pressure main. The Watauga Beach system connects directly to the upstream end of the Beach Drive system.

As construction on Beach Drive proceeded and the formation of the Watauga Beach ULID began, it became obvious that some design changes and installation practices needed to be modified to address some of the problems on Beach Drive. This paper will quantify the performance and repair history of the two projects, offer explanations for the differences and summarize the lessons learned.

Project Background

The mandate to sewer waterfront properties in Port Orchard began with the local Health District conducting on-site sanitary surveys for the hundreds of World War II era homes located along Sinclair Inlet. The results of their testing implicated 21 percent of the 215 homes as having failing on-site septic systems that contributed insufficiently treated sewage to the Inlet. The resulting Health Hazard declaration by the Health District, and impending condemnation orders, were sufficient to move local property owners to action.

The mechanism available in the state of Washington for making utility improvements and assigning the costs of the improvements to those benefiting from the improvements is a Utility Local Improvement District (ULID). Through a voting process, each property owner may approve or disapprove of the proposed improvements. If more than 50 percent of the land area approves of the project and the estimated costs, the ULID is created. To the District, a ULID is an attractive method to finance sewer improvements because it provides a way for those benefiting from the improvements to pay for their benefit. The current ratepayers in the District do not have to subsidize improvements for growth or new connections. A ULID is also attractive to many property owners because it provides a way for the District to secure funding (normally at much better interest rates than private loans or home refinancing) and provide the option of paying for the improvements with annual installments over 20 years.

Forming a ULID introduces one interesting element into a project – direct involvement with property owners in making decision on the outcome of the improvements. Since a ULID is formed by a vote of the property owners and they are going to pay for the improvements through property assessments, they want to be involved in the process of planning and design of the project. The property owner's motivation is to minimize the capital cost of the project. This approach will best serve them in the end. The District's motivation is to minimize operation, maintenance and repair costs following the construction and turn over of the system to the District. These competing interests resulted in an engineering analysis of four different sewer collection systems for Beach Drive – gravity collection, low pressure grinder pumps, vacuum system and STEP system. Each system was evaluated based on topography, waterfront conditions (including groundwater considerations) and water quality issues (odor, septage strength, etc.) and an estimated cost assigned for capital costs and ongoing O&M costs as shown in Table 1.

Table 1: Sewer Collection System Alternatives

System Alternative	Estimated Construction Cost	Estimated Annual O&M Cost
Gravity Sewer System (including three lift stations)	$8,420,000	$25,000
STEP System	$2,336,000	$12,600
Vacuum System (with two vacuum stations)	$2,222,000	$14,700
Grinder Pump System	$1,912,000	$10,710

Once consensus was reached by property owners and the District's design engineer to use the low pressure grinder pump system, the District chose to use the Environment One (E/One) grinder pump. The E/One pump was the only grinder pump that could meet the head conditions (maximum 140 feet TDH) of the system and there was an extensive track record available from which to estimate future maintenance and repair costs.

Proven Performance

The District's design engineer used data from previous E/One projects, where maintenance and repair records were kept, to provide budgetary estimates to the District for annual repair costs after completion of the project. Table 2 identifies the previous E/One projects that were available for review in 1996 to estimate annual O&M costs.

Pre-Construction Maintenance Cost Estimates

Considering the age of comparable systems, technological advancements since previous projects were installed, economies of scale and personal experience, the design engineer estimated that the District should budget $38/year/pump for O&M. Since the District would not have operating costs for the pumps (electricity for the pumps is provided by the homeowner), the average annual expense for each pump consists of service calls (labor) and repairs (parts).

A reasonable way to project maintenance and labor costs is to calculate the *mean-time between service calls (MTBSC).* The MTBSC represents the average time between service calls on any given pump in the system.

$$\text{MTBSC} = \frac{(\#\text{ Pumps}) \times (\text{Years in Service})}{\#\text{ Service Calls}}$$

Again, based on previous projects, the designer estimated that the District could expect a MTBSC of 10 years, or about 3 service calls per month. It should be noted that not every service call results in a repair. Some service calls are for alarm situations or conditions that the technician can troubleshoot in the field and resolve without bringing the pump core back to the shop for repairs.

Post-Construction Maintenance Costs

The District carefully compiled data on service calls and repairs, including expenses for labor and parts, over the last seven years. The actual maintenance and repair costs for both projects combined is $23/pump/year and the MTBSC is 22 years. Table 3 shows a comparison between the pre-construction *estimates* and the *actual* post-construction data for the E/One sewer system.

Maintenance Costs: Grinder Pumps vs. Lift Stations

At one point during the design process for the Beach Drive project, the Board of Commissioners for the District considered a rate surcharge on grinder pump customers to cover what was *projected* to be higher maintenance costs than the District's existing customers. The decision was made to not charge grinder pump customers extra, but rather, wait and gather the data prior to making that decision.

The District operates and maintains 11 large sewage lift stations throughout its collection system. The District's engineer compiled the annual operating and repair costs for these lift stations and compared them to the grinder pump system on an ERU basis. An ERU represents one equivalent residential unit, a common denominator between residential and commercial usage of the sewer system. Interestingly, the District found that the annual maintenance and repair of the grinder pump system amounted to $26/year/ERU. The annual O&M (including repairs) on the major lift stations amounted to $53/year/ERU – twice as much as the low pressure sewer system. The District has since resolved to *not* charge their grinder pump customers an additional monthly fee to cover maintenance costs.

Beach Drive Project

The Beach Drive project was completed in May 1998 and had a total of 295 grinder pumps installed through 2004. The average age of the pumps is seven years and the number of service calls during that period was 111. Therefore, the MTBSC for the Beach Drive Project for the period from 1998 through 2004 is 19 years. After seven years of operation, the MTBSC was nearly double the *estimated* MTBSC projected prior to the project.

The most common causes of service calls and repairs on Beach Drive were worn stators, electrical problems stemming from damage to direct bury cables or flooding of the pump accessway (the dry well portion of the pump station) and bearing failures. These types of service calls and repairs were directly attributed to problems with design and construction. The only cause of failure that can be attributed to the pump manufacturer is premature bearing failures, which accounted for 19 service calls. However, due to the high percentage of bearing failures on Beach Drive (6 percent on Beach Drive as opposed to 2 percent on Watauga Beach), there is some consensus that some of the bearing failures were not the primary mode of failure.

Table 2: Historical E/One Projects

Location	Number of Grinder Pumps	Average Age of Pumps	Annual O&M $/Pump
Cuyler, New York	41	17	$53.00
Fairfield Glade, Tennessee	955	16	$36.07
Pooler/Bloomingdale, Georgia	998	11	$13.24
Pierce County, Washington	900	9	$51.00
Sharpsburg/Keedysville, Maryland	780	5	$18.00

Note: Data taken from "Onsite Wastewater Treatment," Dec. 11–13, 1994, American Society of Agricultural Engineers

Watauga Beach Project

The Watauga Beach project was completed in November 1998 and had a total of 52 grinder pumps installed through 2004. The average age of the pumps is 6.5 years and there were eight service calls during that period. That equates to a MTBSC for Watauga Beach of 42 years! Obviously a MTBSC of 42 years is longer than the pump station life, but it indicates that significant improvement was made during the installation of the two grinder pump projects, so that the number of service calls made during the first 6.5 years of the system's life was very low.

One of the service calls on Watauga Beach was from a faulty core repair from Beach Drive and another one was a bearing failure. The remaining six service calls were the result of installation.

Lessons Learned

What did the District learn from these two projects? It became obvious in the early stages of construction on the Beach Drive project that several things needed to be done differently to reduce the number of service calls and the amount of time and money spent on repairs due to poor installation practices. Many of the installation problems could be attributed to design issues while others were simply the result of the actual construction. The following practices were identified as causes of excessive service calls and action was taken during the design and construction of the Watauga Beach project to minimize their effects.

Sewer Lateral Connections

The Beach Drive project provided for the District's contractor to install the grinder pump station on private property and install the pressure discharge line to the main in the street. The project made provision for the 4" sewer lateral installation between the home and the grinder pump station the responsibility of the homeowner. This was done primarily as a cost-cutting measure for the homeowners, giving them the option of hiring a local plumber or installing the lateral themselves. Many of these sewer laterals ran long distances, depending on the configuration and direction of their existing plumbing and the location of the grinder pump in the yard. This provision resulted in widespread poor quality installation that allowed sandy soil to migrate into the grinder pump sump. The granular material accelerated wear on the rubber stator. This was a very common service call within the first year of operation on Beach Drive.

Ensure a Watertight System

There were three causes of pump failures/service calls on the Beach Drive project that were attributable to water getting into the electrical components of the pump, 1) in-field manufacture of accessway extensions; 2) breaching the integrity of the direct-bury cable between the pump and the control panel on the house; and 3) backups from the wet well to the accessway.

The vertical distance between the top of the pump station (which is installed slightly above grade) and the invert of the inlet pipe is a critical measurement. The District pre-ordered the grinder pump stations with a total height of 58". If the sewer line from a house was lower than 24" below grade, an extension of the accessway was required to lower the inlet elevation. Approximately two dozen field extensions were required. Several of the field joints created by the extensions ended up leaking groundwater, resulting in water contacting the "breather patch" (an opening in the power cable in the accessway that allows atmospheric pressure to the motor housing). The result was pump motor failures and service calls.

The power cable installed between the pump stations and the

Table 3: Pre- and Post-Construction Maintenance and Repair

	Pre-Project Estimate	Actual Post-Construction	Savings
MTBSC	10 Years	22 Years	12 Years
Average Number of Service Calls/Year	35 Calls	16 Calls	19 Calls
Average Maintenance $/Year	$13,186	$9,009	$4,177

Note: This data is for the combined Beach Drive and Watauga Beach systems.

control panel on the wall of each home had a direct bury rating and was installed as such. There were several cases were it was determined that either during installation or subsequent yard work by some homeowners, that the cable sheathing had been nicked and water vapor was allowed into the wiring and wicked back into the motor housing. The result was pump motor failures and service calls.

The primary cause of service calls was attributable to worn stators that prematurely failed due to the introduction of abrasive material (sandy soil) into the pump station during the installation of the sewer lateral. When a stator is worn down, the capacity of the pump diminishes and an alarm is set off. The responsibility to call the District in an alarm situation lies with the homeowner. If the homeowner fails to contact the District in a timely manner, the water from the wet well backs up through the influent sewer line and through the wet well vent pipe. The 2" PVC vent pipe has a friction fit through the plastic lid. As water backs up the vent pipe and spills onto the ground, some water also runs down the outside of the vent pipe back into the accessway, flooding the breather patch and allowing water into the motor housing. The result was pump motor failures and service calls.

These electrical failures became obvious in the first six months of installation and use by the homeowners. The design for the Watauga Beach project was under way at the time and several changes were made to prevent the same problems on the Watauga Beach project.

Applying the Lessons Learned

The first change made during the design of the Watauga Beach system was to eliminate all homeowner involvement in the construction, thus preserving the integrity of the work by holding the contractor for the District accountable for meeting the District's specifications for installation, cleaning, testing and startup. The District's contractor was required to plumb all pipe on the project, even if the contractor had to go under the house and redirect the plumbing to the new grinder pump station.

The District also pre-ordered the pump stations for the Watauga Beach project. The pump stations were ordered with a taller accessway to accommodate lower sewer line elevations, eliminating the need to add accessway and field joints during construction. In addition, the District required the direct bury cable to be installed in conduit for protection and had each vent pipe silicone caulked at the interface with the pump station lid.

Based on these changes, the District estimates that service calls were reduced on the Watauga Beach project by 20 percent, representing about a $5,300 savings on the project. In hindsight, the District realizes that, had these lessons been known prior to the Beach Drive project, the potential savings could have been $30,000.

The District also recognized the need to educate the new customer. This education included such instruction as what *not* to flush down the drain, to be careful not to get beach sand into the sewer system and not put raised gardens over the top of the pump station lid. We had to help the customer recognize that when the alarm goes off, they should silence it and immediately call the District office for service. Often, working with the customer was most difficult because they simply didn't understand how the system worked or didn't care. The District has developed ways to work closely with homeowners by sending periodic newsletters explaining how the system works and what should be avoided. The maintenance crew also helps explain problems to homeowners when service calls are made so that the problem will not happen again. These ongoing efforts have helped reduce the number of service calls.

Summary

The Beach Drive and Watauga Beach projects were designed to solve an environmental health and safety problem. Failing septic systems were polluting Sinclair Inlet and posing health risks to homeowners whose failed systems often left raw sewage pooling in their yards.

The ULID process and the District's cooperation with property owners resulted in a successful capital improvement that resolved the health hazard. After seven years of operation, the District has increased the MTBSC for the pump stations and reduced the annual maintenance costs. The District has also learned several key lessons that facilitated even greater savings on the Watauga Beach project. As a result, three key elements are recommended to others embarking on the design and construction of a grinder pump system:

1. **Interview and qualify a design engineer that has completed these types of projects before.** Find an engineer that knows the latest developments and improvements in these systems. This alone will potentially save tens of thousands of dollars in construction changes and much more in long-term maintenance and repair costs.
2. **Carefully apply local regulations and applicable bidding laws to obtain a *qualified* and *conscientious* contractor.** The quality of the work is important in keeping the system clean and problem free. Often, even though the low bidder must be accepted, a partnering relationship can be established when the Owner or Engineer make special efforts to help the contractor understand prior to the start of the project, the need to work together to avoid the types of problems outlined in this paper.
3. **Have an experienced inspector on site!** The District found that the inspector made all the difference. He knew just what to look for and where to give the contractor special instructions. In addition, the District's inspector inevitably got to know the homeowners and this helped to develop the ongoing relationship that will exist between the District and the homeowners.

About the Author

Chuck Mayhew, PE, is the district engineering for Karcher Creek Sewer District. This paper was originally presented at the Hawaii Water Environment Association Annual Conference, February 2005.