Thinking Globally and Acting Locally to Preserve a Natural Wonder

Septic tank replacement using a low pressure sewer system (LPS)

Part 1 of 3

By Clark A. Henry and Michael Crowley, E/One,
and Wayne Ackart, Town of Jerusalem (New York)

The Town of Jerusalem, New York, is a picturesque settlement blessed with year-round recreational activities, award-winning wineries, a portfolio of properties listed on the National Register of Historic Places and desirable real estate on the shores of the glacier-formed Keuka Lake.

Beneath the surface, however, the turn of the millennia found failing septic systems were threatening the region's scenic landscape. The Keuka Watershed Improvement Cooperative (KWIC) verified that deteriorating septic systems mixed randomly with a few primitive holding tanks were compromising the lake's water quality.

The town had required homes to be scrutinized every five years. If an existing septic system flunked inspection, corrections were required which often included the installation of a new tank and drain field at a cost of $20,000 to $30,000 per residence. In many instances there was not enough room to put in an up-to-date replacement.

A PRIME LOCATION

One of the primary reasons why lakefront homes are sought after in Jerusalem is the pristine shoreline held dear by 4500 residents and thousands of visitors. However, eutrophication generated by septic seepage and other sources of nutrient loading frequently lead to poor water quality resulting in blooms of aquatic vegetation, algae and a potential change in the ecological balance of aquatic habitat.

The town recognized a solution was needed but its particular situation presented some challenging site conditions.

The Y-shaped Keuka Lake is one of the eleven Finger Lakes, so called because of their north-south axis in the west-central region of upstate New York. Its 11,730-acre surface area stretches about 20 miles (32 kilometers) long but from east to west it spans a narrow half-mile to two miles wide. Most of Jerusalem's waterways flow into the lake where Keuka College and Keuka Lake State Park also reside.

Hundreds of vacation homes (seasonal occupancy is only approximately 20-percent full-time residents) are located very close to the lake, often on small building lots with very little room for septic leach fields. A high water table and ineffective subsurface drainage means the drain fields have poor percolation to begin with, so decline is rapid and inevitable.

The region's geography is gashed by several gullies and deep ravines that run down to Keuka Lake; valleys and rolling hills used primarily as farm land; and, steep slopes on the waterfront.

It was precisely the natural beauty and rocky terrain the region prizes that would make it laborious, environmentally disruptive and almost certainly cost-prohibitive to excavate for conventional gravity sewering.

BUILDING A PLAN

Gravity sewer systems are the original central sewers with origins in the Roman aqueducts and are almost as old as the biblical city of Jerusalem itself. The bulky systems might require rock blasting and digging trenches 20 to 30 feet (6.1 to 9.1 meters) deep to install large mains and lift stations.

When planning began in late 1999, the town calculated the probable construction cost for a conventional-type system was six million dollars, almost 50-percent more than a $3.2 million low-pressure sewer system (LPS) also being considered. A decade later, a top-level summary of project costs calculated a final tab of $4,080,000 including administrative ($190,000), technical services ($600,000), construction ($2,920,000) and contingency ($370,000).

Community leaders in Jerusalem were aware of several successful regional and local LPS installations. The project team, consisting of representatives from the Town of Jerusalem; Clough, Harbour & Associates LLP (CHA); Siewert Equipment Company; and Environment One Corporation, investigated these projects and learned from them.

Over a period of several years the project team researched the type of

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sewer system that would best serve residents. Because of topographical constraints, the Town determined that the most economically and environmentally favorable solution was to construct a low-pressure sewer system.

LOW-PRESSURE SEWER SYSTEMS

LPS technology is a simple, effective and inexpensive solution which has been effectively used for more than forty-five years to collect and convey wastewater. The technology was initially adopted in the United States and Scandinavia and is increasingly utilized throughout the developed world. Published case studies of well implemented and smoothly operating systems are widely available.

Low-pressure sewer systems begin at a grinder pump station installed at each residence, which accepts wastewater, grinds its contents into fine slurry and transports it through small-diameter, 2- to 4-inch (51 to 102 millimeters) PVC pipes buried just beneath the frost line to roadside force mains or treatment facility.

The proposed LPS for the Town of Jerusalem eliminated the need for 12 lift stations with a total cost savings of $900,000. Nor did it require a rock excavation outlay pegged at $775,000.

Unlike conventional gravity central sewers, which use up to 24-inch (610 millimeter) pipe and require deep excavation, an LPS system is not destructive to the landscape's natural or built features and requires less maintenance.

THE ROLE OF GRINDER PUMPS

The grinder pump manufactured by E/One is a self-contained unit is barely bigger than a washing machine with a one horsepower motor, controls and level-sensing built into a single unit. It is activated automatically and runs for very short periods. Electrical consumption of the grinder pump is low—a household that uses 250 gallons (946 liters) of water per day should consume less than 10 kilowatt-hours per month to run the pump.

E/One has assembled more than 500,000 grinder pumps at its Niskayuna, New York, headquarters. Its pumps comprise the largest installed base of pressure sewers in the world and E/One alone provides LPS service to more than one million people worldwide.

The town chose E/One because it has a proven record of successful installations around lakes with conditions similar to the Town of Jerusalem's proposed project. Other E/One waterfront LPS jobs include Martha's Vineyard, Baja California (Mexico), Hawaii, and many lakefront communities around the United States.

A CLOSER LOOK AT BLUFF POINT

In order for the town's LPS to maximize its impact, planners chose to site the project at Bluff Point, which gives Keuka its distinct Y shape and is one of the more dramatic lakeside hills in the Finger Lakes. It provides scenic vistas from many of its roadways and cottages along the shore.

Most of the residences are located lakeside on East Bluff Drive and are below the road elevation. The lakeshore elevation of 715 feet (218 meters) is on average 25 feet (7.6 meters) below the centerline of the road. Toward the north end of the district, the road is 50 feet (15.2 meters) or more above the lakeshore elevation. Most residents would be required to have a sewage pump to pump up to a gravity sewer located under the road.

A gravity system to service these far-flung residences distributed on roller coaster elevations was not feasible. With LPS, the wastewater discharged from the grinder pumps can be propelled uphill from the homes, through diverse ground challenges and even around contours. It is effective for distances at more than a mile from force mains or water treatment facility.

E/One, the town determined, was the only manufacturer offering a proven semi-positive displacement type grinder pump able to perform under higher head conditions present in this project.

Unlike centrifugal pumps, the E/One grinder pump produces a nearly constant discharge rate over a wide range of head conditions, including negative head.

The project plan plotted a 5.5-mile (8.9 kilometers) long LPS that discharged into a manhole and flowed to an existing treatment facility in the neighboring Village of Penn Yan. An agreement was reached between the two municipalities that the Town of Jerusalem would pay Penn Yan based on the anticipated flows the new LPS system would be discharging into the treatment plant.

The town decided it would own and operate the new system. The homeowner’s only responsibility would be to provide electrical power (estimated at $24 annually) to operate the grinder pumps. The Town utilized blanket property easements so it possessed the flexibility to locate the grinder pump stations wherever necessary on the small rocky building plots.

ENVIRONMENTALLY-FRIENDLY INSTALLATION

As with thousands of other installations, E/One's grinder pumps were set in the footprint of the property’s septic tank or just adjacent to it making the installations far less environmentally disruptive to private landscapes.

The equipment included the following:

- 29,000 LF of force main pipe
- 30,000 LF of pressurized lateral pipe
- 265 E/One Series 2000 grinder pump stations and alarm panels
- 265 check valves and curb (shut off) valves
- 25 concrete vaults for flushing connections and air relief valves
- 25 flushing connections
- 5 air release valve stations
- 1 bioxide feed odor control system

Because of the seasonal occupancy of most town residents, three informational community meetings were held on Memorial Day, the Fourth of July and Labor Day of 2000. A referendum regarding the project was voted on during a meeting held on Memorial Day of 2001. The referendum passed by a three-to-one margin.

A LOOK AHEAD

A decade after the installation was complete, the Town of Jerusalem and E/One decided to revisit the project. Parts Two and Three of this article provide a ten-year (2003-2013) review of Operation and Maintenance (O&M) data and a hydraulic performance analysis comparing expected design flows to quantitatively measured flows for the 265-unit septic tank replacement project. ■

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Thinking Globally and Acting Locally to Preserve a Natural Wonder

Septic tank replacement using a low pressure sewer system (LPS)

Part 2 of 3

By Wayne Ackart, Town of Jerusalem (New York),
and Clark A. Henry and Michael Crowley, Environment One

The transition from independent septic systems to a centralized low-pressure sewer (LPS) collection system has economic, environmental and altruistic advantages to communities like the Town of Jerusalem, New York.

A decade after the installation was complete, the Town of Jerusalem and E/One decided to embark on a unique study: Parts Two and Three of this article provide a ten-year (2003-2013) review of Operation and Maintenance (O&M) data and a hydraulic performance analysis comparing expected design flows to quantitatively measured flows for the 265-unit septic tank replacement project.

Three key conclusions regarding this LPS are evident from the data: the system is reliable and cost-effective, hydraulically flexible and improves quality of life.

FINDING THE RIGHT MEASUREMENTS

Perhaps the self-evaluation could predict future performance by revisiting the past. "In business, the idea of measuring what you are doing, picking the measurements that count like customer satisfaction and performance … you thrive on that," Bill Gates once said.

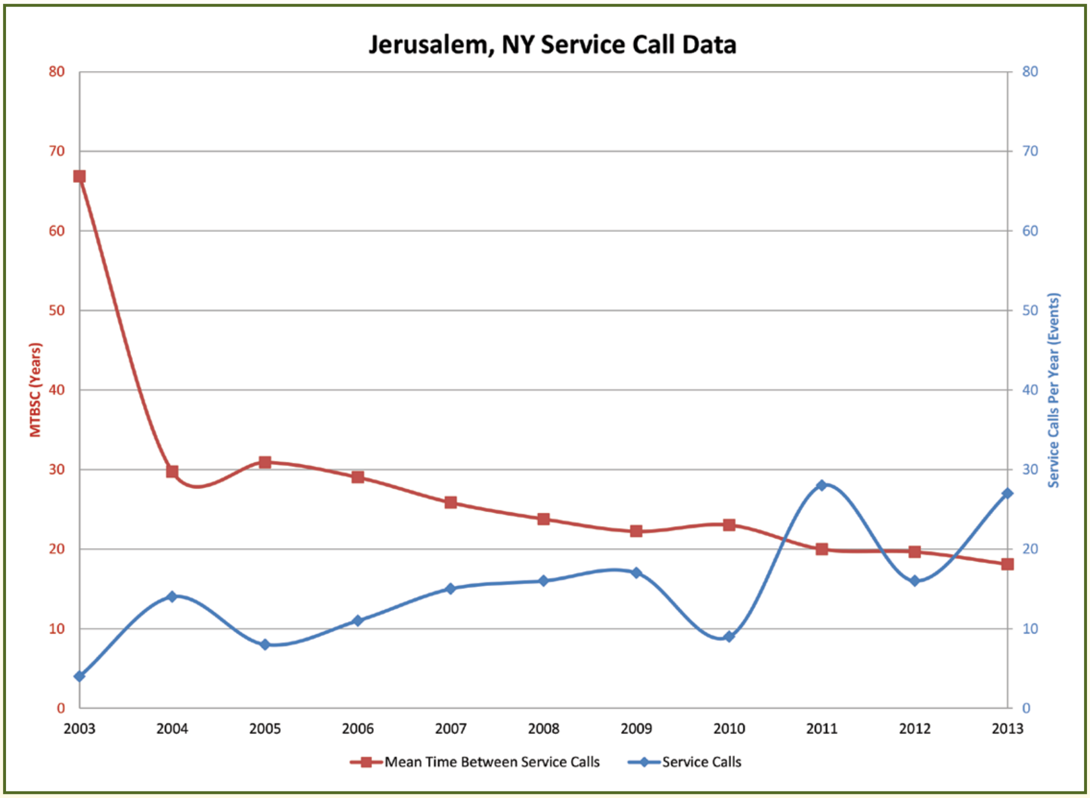

Figure 1: Service calls and the MTBSC for the ten-year period under analysis.

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Operation and maintenance records and invoices from the Town of Jerusalem files were analyzed for the period from January 2003 through December 2013. Office and maintenance personnel were interviewed regarding their experiences with the project.

The project team of Clough, Harbour & Associates LLP (CHA); Siewert Equipment Company; the Town of Jerusalem; Environment One Corporation (E/One); and local plumbing company Dean Roberts Plumbing and Heating established a procedure for addressing service calls and system maintenance. All parties were factory trained and certified by E/One field service personnel.

The New York Association of Consulting Engineers gave its 2003 Silver Medal Engineering Excellence Award to Clough, Harbour & Associates for the Town of Jerusalem Low-Pressure Sewer System Design.

It noted the "Survey, design, and construction services for 29,000 linear feet of low-pressure sewers and associated grinder pump stations. A significant portion of the sewer was installed using directional-drilling techniques in order to minimize disturbance in this lakeside sewer district."

Simple removal and installation of the pump for service is inherent to the design of the E/One grinder pump. The station's components are accessible by removing just three bolts on the access lid. Homeowners experience minimum downtime and a maintenance crew can repair and test the damaged core in the shop.

Service calls were initially routed to Town of Jerusalem maintenance personnel. An initial field assessment was performed. If the pump required repair, Dean Roberts Plumbing and Heating was contacted. A representative removed the pump from the grinder pump station, installed a replacement pump, transported the pump requiring service back to their service shop, repaired it and readied it for return to use.

Service records show a "Standard Repair" was often performed consisting of pump stator, pressure switch and start contactor replacement.

RELIABILITY AND MEAN TIME BETWEEN SERVICE CALLS

Mean time between service calls (MTBSC) was calculated to be approximately twenty-eight years. During the 10-year period, 165 calls were recorded on 274 pumps.

Only 70 of the 274 pumps on the project experienced a service call.

However, 27 of these 70 pumps experienced two or more service calls. These "repeat calls" accounted for 71 of the 127 calls or 56-percent of the calls.

The root causes of these calls were traced to the following and were quickly corrected. Many were attributed to excessive disposal of cooking grease into the wastewater stream by several homeowners and root penetration and obstruction of the inlet line between homes and grinder pump stations.

A spike in service calls was experienced in 2011 due to a prolonged power outage.

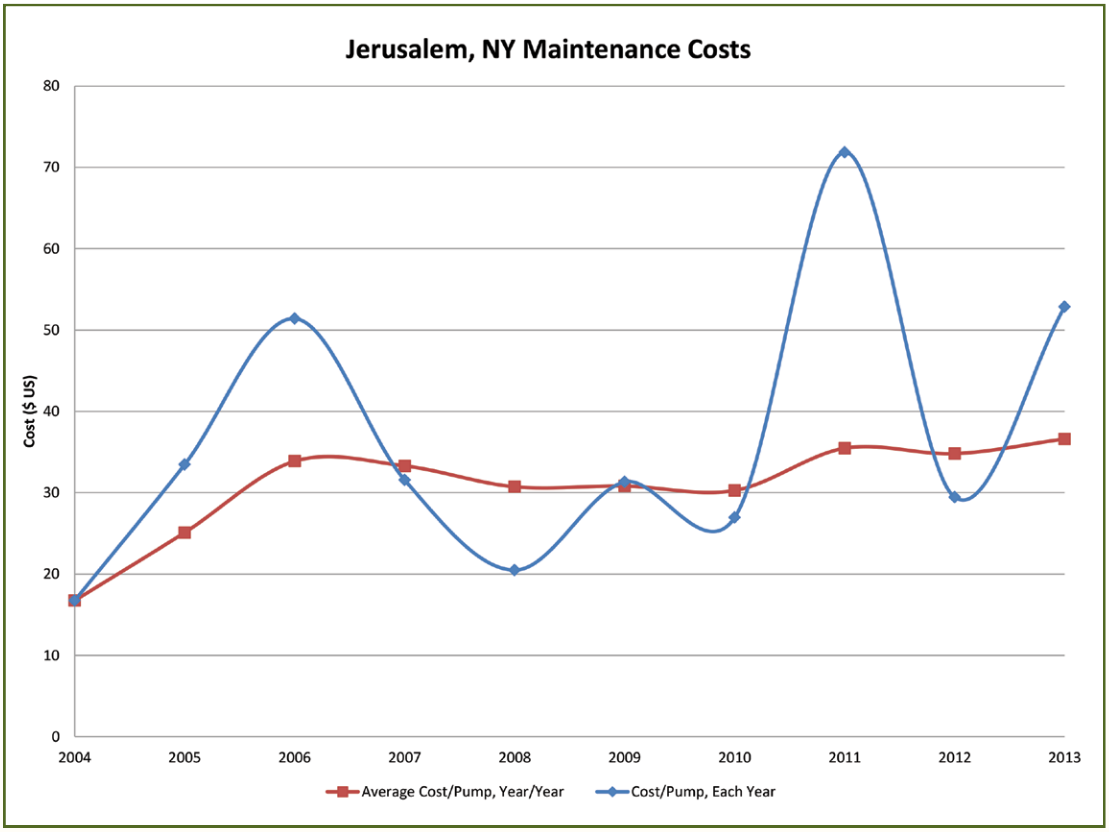

Figure 2: *Annual maintenance cost per pump for the ten-year period under analysis.*

Power was out for an extended period of time and homeowners inadvertently continued to use water. This resulted in several flooded stations and a variety of flood related call outs.

OPERATION & MAINTENANCE (O&M) COSTS

Figure 2 and the interviews reveal several observations: During the ten-year period, the O&M cost per pump was approximately $37 per pump per year (excluding power). This is consistent with many other E/One LPS installations which typically report O&M costs ranging from $30 to $50 per pump per year.

Initial O&M costs were very low from 2003 through early 2005 due to the focus the project team placed on installation training and inspection of installations.

Costs increased in 2005 due to a significant number of relatively expensive pump motor repairs. This problem was traced to a manufacturer's defect in a push-to-run switch used on the grinder pump alarm panel.

The switch was prone to shorting out in the closed position. This caused the grinder pump to run continuously resulting in excessive wear on the entire pump. Occasionally the pump motor would become damaged due to excessive heat and require replacement.

The practice of typically performing a "standard repair" on pumps mentioned in the maintenance procedure section above contributes to slightly elevated O&M costs. This practice may lead to the replacement of components that still have several years of useful life remaining.

However, since all pumps are owned by the Town of Jerusalem, it is understandable that they would invest in upgrading a pump when the opportunity presents itself. This practice slightly increases the O&M cost per pump per year. However, it also lengthens the MTBSC at minimal cost.

A LOOK AHEAD:

Part Three of this article provides a ten-year (2003-2013) review of hydraulic performance analysis comparing expected design flows to quantitatively measured flows for the 265-unit septic tank replacement project. ■

Thinking Globally and Acting Locally to Preserve a Natural Wonder

Septic tank replacement using a low pressure sewer system (LPS)

Part 3 of 3

By Wayne Ackart, Town of Jerusalem (New York), and Clark A. Henry and Michael Crowley, Environment One

By the year 2000, failing septic systems were damaging the ecology of Keuka Lake in Jerusalem, New York. They were replaced with a low-pressure sewer system (LPS) that consisted of 265 grinder pumps. Part 1 provided an overview of the project while Part 2 began a ten-year analysis of it with an examination of operation and maintenance (O&M) data. Part 3 probes the project's 2003 through 2013 hydraulic performance comparing expected design flows to quantitatively measured flows.

HYDRAULIC DESIGN AND PERFORMANCE

The installation and start-up of LPS systems often occurs over a time period of several months. When LPS is used with new home construction projects, complete build-out of a system may take several years. This often leads designers to wonder how a system will function hydraulically while fewer than anticipated homes are connected to the piping network.

Prior to achieving design capacity, fewer connected homes generate less wastewater flow rates with lower pipeline velocities. Lower pipeline velocities may allow particulate in the wastewater to drop out of suspension and begin to accumulate on the walls of the pipe thereby increasing the possibility for clogging.

In the case of the Town of Jerusalem, the study found the system operates at less than 50 percent of expected design flows with no adverse effect on system pipelines or equipment performance.

The first homes connected to the system are located on the far right side. The discharge point of the LPS that leads to the treatment plant in Penn Yan is on the left side. Following the pressure main from right to left, additional homes are connected and the pipe diameter increases accordingly.

PREDICTED PERFORMANCE

A hydraulic system design analysis was performed using construction drawings supplied by Clough, Harbour and Associates, LLP (CHA) and E/One's Design Assistant software program. The results are summarized below.

The analysis reveals a system with key design parameters within industry recognized ranges.

- Anticipated water flow per home = 150 gallons (567.81 liters) per day.
- Maximum Total Dynamic Head (TDH) = 128 feet (39.01 meters),

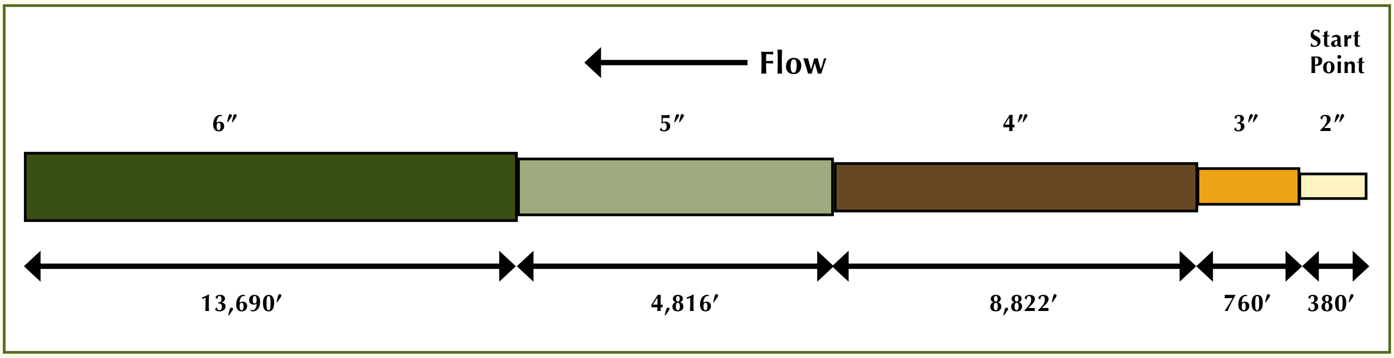

Figure 3: *Simplified sketch of the LPS pressure main installed in the Town of Jerusalem.*

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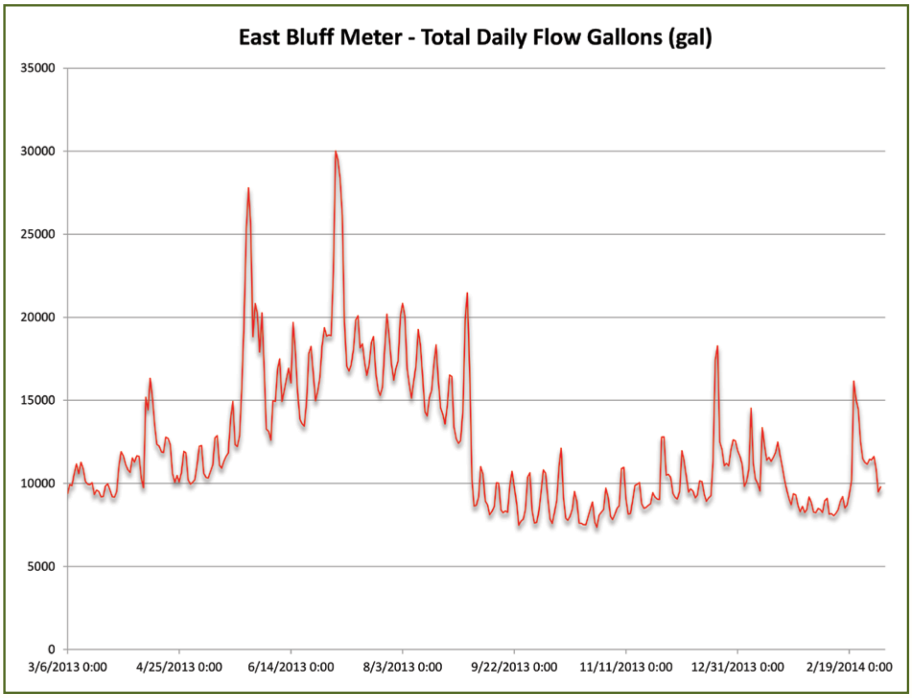

Figure 4: *Plot of flow in gallons per minute in the 6-inch (152.4 millimeters) pipe measured just prior to the discharge point per 24-hour time period.*

which complies with E/One's rating of its 2000 Series grinder pump of 138 feet (42.06 meters).

- Maximum pipeline flow rate (at discharge point) = 39,300 gallons (148,767 liters) per day.
- Maximum pipeline velocity = 2.2-fps in most branches (2-fps is the industry standard).
- Retention time = 30 to 40 hours (this exceeds typical target of 10 to 12 hours). The project team recognized this and included the bioxide odor control system.

MEASURED PERFORMANCE

A flow meter was attached to the pressure main prior to the discharge point as shown in Figure 3. Measurements were recorded over the period of March 2013 through February 2014. Flow rates vary widely throughout the year as shown in figures 4, 5 and 6 due to the seasonal occupancy of the homes in the system. Observations include winter flow rates typically range from 7000 to 9000 gallons (26,497.88 to 34,068.71 liters) per day while summer (May to August) flow rates typically range from 20,000 to 30,000 gallons (75,708.23 to 113,562.35 liters) per day.

The data in figure 5 shows a spike in flow rate during the Fourth of July weekend period of 2013. We observed that the highest flow rate occurs during the summer and typically ranges from 30 to 40 gallons (113.56 to 151.42 liters) per minute.

Figure 6 shows a low flow rate during the late October through early November period of 2013. We observed that the lowest flow rate occurs during the winter and typically ranges from 7 to 9 gallons (26.5 to 34.07 liters) per minute.

The data from figures 5 and 6 can be used to calculate the actual velocity of the wastewater at the location of the flow meter in the pipeline during the summer peak and winter lull. This is essentially the velocity of the wastewater at the discharge point of the LPS system.

V = 0.4085 q / d2

Where:
V = velocity in feet per second (fps)
q = volume flow in gallons per minute (gpm)
d = inside diameter of the 6-inch pipe in inches (inches)

Summer velocity = 0.71-fps = 0.4085 (50) / (5.349)2
Winter velocity = 0.19-fps = 0.4085 (9) / (5.349) 2

PERFORMANCE COMPARISON

The measured pipeline velocities in the system at the discharge point are significantly lower than the predicted velocities. Even peak summer velocities are less than half of the target velocity of two-fps. These variations are most likely because of the following:

- **Lower than anticipated water usage by homeowners:** An estimate of 150 gallons (567.81 liters) per day was used to calculate the predicted performance. Daily water usage is probably lower due to the seasonal nature of the homes.
- **Lower occupancy even during summer peak periods:** Many of the homes in the system are summer or second homes.
- **The location of the measuring point:** Measurements were taken in the 6-inch (152.4 millimeters) diameter pipe at the very end of the low-pressure sewer system. It is very likely that many locations within the system reach much higher velocities.

It is very common for an LPS to operate at lower than anticipated pipeline velocities. In fact, almost all systems serving new home construction operate at lower than expected flows during the build out period. Figures 7 and 8 below are of sections of pipe removed from two such projects that served as LPS validation tests by E/One many years ago.

When this system was installed in 1972, initially only one home was connected resulting in a pipeline velocity of only 0.26-fps. This section of pipe was removed sixteen months later when forty-one homes were connected. The pipeline velocity at that point is calculated to be 1.87-fps.

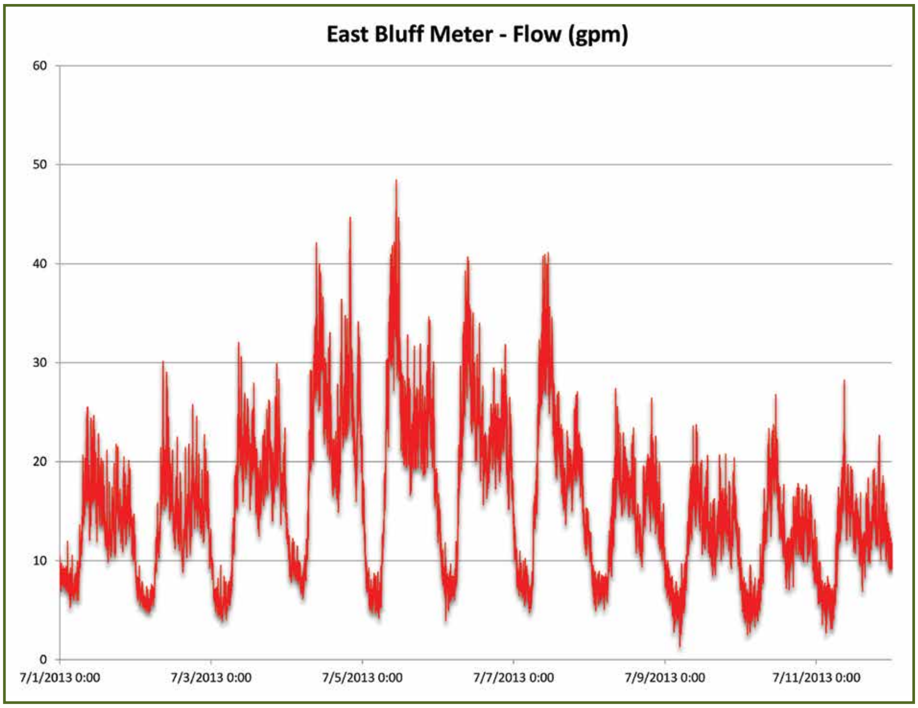

Figure 5: *Plot of "summer" flow in gallons per minute in the 6-inch (152.4 millimeters) pipe measured just prior to the discharge point.*

Initially only nine pumps were connected yielding a calculated velocity of 1.72-fps. The system operated under these conditions for more than two years. Eventually additional homes were added and the predicted velocity of two-fps was reached.

This data demonstrates the flexibility of LPS systems that utilize positive displacement pumps with near vertical H - Q pump curves. If debris does begin to build up on the inner walls of the system piping, the effective diameter of the pipe is reduced. The flow rate from the progressing cavity pump is essentially unaffected due to the vertical nature of its curve.

The velocity equation below shows that if the flow rate remains constant and the pipe diameter is reduced, the velocity will increase. This increase in velocity creates a self-scouring effect on the pipeline.

V = 0.4085 q / d2

CONCLUSIONS

The transition from decentralized, independent septic systems to a centralized LPS is viewed as a tremendous success by a wide variety of stakeholders. The quality of the lake water improved significantly.

Homeowners are now allowed to improve their properties by winterizing their homes, building additions and in some cases constructing entirely new structures.

The financial agreement for sewage treatment between Jerusalem and Penn Yan was based on anticipated design flows. The actual measured flows shown in figures 4, 5, and 6 reveal on average the system discharges much less wastewater into the treatment facility than was anticipated.

Based on this information, the town is planning a much larger follow-on LPS project to convert additional homes presently using septic systems to LPS.

Three key conclusions regarding this LPS system are evident from the data. The system is:

- **Reliable and Cost Effective:** Mean time between service calls was calculated to be 28 years. The O&M costs were found to be approximately $37/year/home. Construction costs for a low-pressure sewer system were determined to be 50 percent lower than construction costs for a conventional gravity system.
- **Hydraulically Flexible:** Wastewater velocities at the discharge point are as low as 0.19-fps in the winter and reach a peak of only 0.71-fps during peak occupancy summer

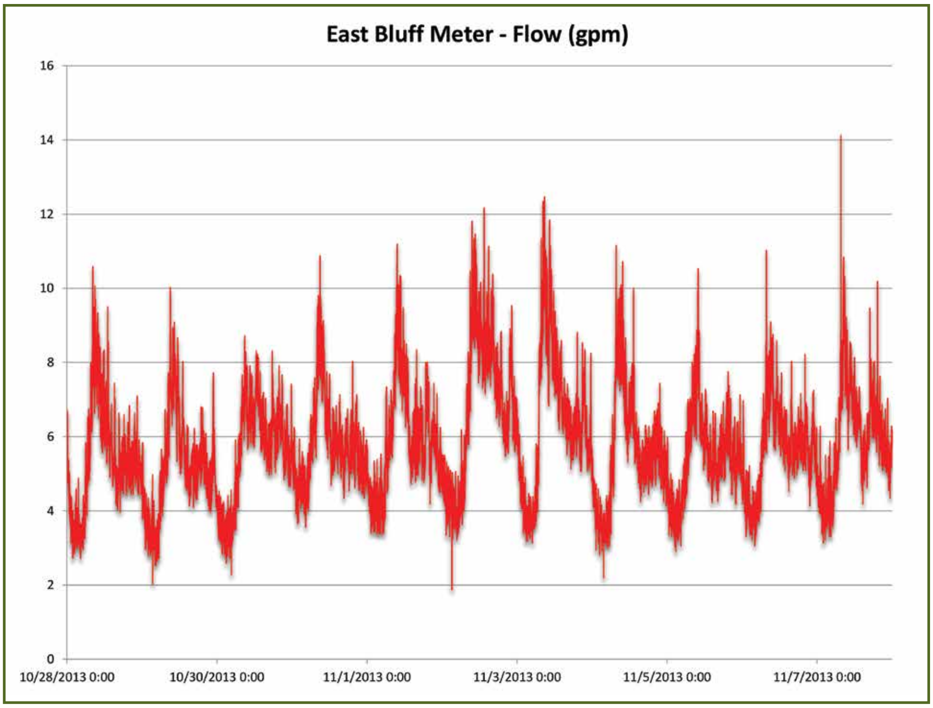

Figure 6: *Plot of "winter" flow in gallons per minute in the 6-inch (152.4 millimeters) pipe measured just prior to the discharge point.*

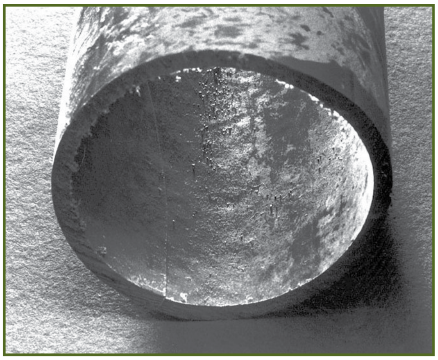

Figure 7 *from Golfview, Indiana, is a picture of a section of 4-inch (101.6 millimeters) diameter SDR 26 PVC pipe that was removed from the system.*

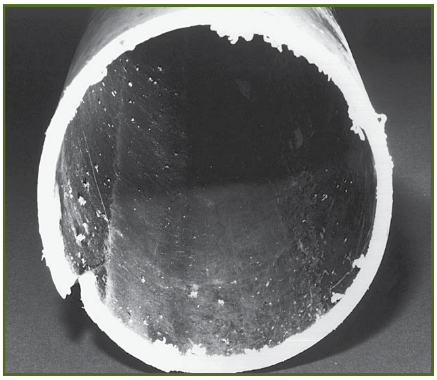

Figure 8 *from Grandview Lake, Indiana, is a picture of a section of 3-inch (76.2 millimeters) diameter SCH 40 PVC pipe that was removed from the piping network.*

months. Despite these lower than expected velocities, there is no evidence of debris accumulation. The system does not require manual flushing or any other preventive maintenance to prevent clogging.

- **Quality of Life Improved:** The transition from septic systems to LPS allowed homeowners to free their minds from the constant worry of septic system maintenance and failure; once again obtain building permits to improve their homes and property values which had been halted due to poor lake water quality measurements; and, feel good about "thinking globally and acting locally" to improve the water quality of their glacier-carved lake. ■

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