Real-Time Collection System Monitoring: Saving Money, Protecting the Environment, and Improving Your Public Image

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The Issue

Maintenance of the collection system places a constant demand on a utility's resources for personnel, equipment, and management. All collection systems suffer from progressive and occasionally catastrophic occurrences due to restrictions and blockages. Fats, oils, and grease (FOG) can accumulate on pipe walls and serve to constrict flow. Tree-root intrusion, sediment buildup, and debris can also contribute to flow restrictions. Given enough time, these sources of restriction and blockage will progressively impact the capacity of a pipe. The tipping point occurs unpredictably when the restricted capacity can ultimately no longer handle peak flows. For collection systems that suffer from inflow and infiltration (I&I) issues, this tipping point of capacity can occur seemingly quickly and result in a sanitary sewer overflow (SSO). During a dry season, the capacity may still be sufficient to handle daily peak flows, and yet, as seasonal rains show up, the reduced capacity is challenged with the arrival of a wet season. Unable to handle these flows, an SSO occurs.

This article will look at the impact of SSOs, the current methods for addressing them, and new, emerging technologies that can reduce the number of SSOs and potentially reduce capital requirement for this reduction.

The Range and Scope of Sanitary Sewer Overflows

Spills are not an isolated problem. While the reasons for overflows vary, they are prevalent. The U.S. Environmental Protection Agency (EPA) estimates that as many as 75,000 overflows occur each year in the United States[1]. In its 2009 report card on U.S. wastewater infrastructure, the American Society of Civil Engineers (ASCE) estimated that 890 bil gal of raw sewage were released annually into rivers, streams, and lakes, and it gave the country's wastewater infrastructure its lowest grade, a D-. In its 2013 report card, it was stated that an investment of $298 billion is needed, with 80 percent of the expense in collection system pipe[2].

The political and legal ramifications are that SSOs are an ongoing issue and a legal violation of the 1972 Clean Water Act. Repetitive, continuous, or high-volume occurrences can easily gain the attention of both state and federal environmental agencies, leading to lawsuits, fines, and mandated remediation.

Local Impact of Spills

Locally, SSOs can have a manifold impact, such as rendering waterways off limits for recreational or commercial use and creating a public health threat. They can also damage property, and news reports of sewage spill events can be quite unwelcome by the public, creating a negative perception of the utility and eroding public confidence. Very often, these news stories will result in pressures on politicians who, in turn, will engage the local utility staff to discuss ways to address the issue.

Undoubtedly, spills have a substantial cost impact. By their nature, spills are unplanned events and, as such, cannot be properly anticipated, and therefore, budgeted. As a result, a utility can find itself spending precious budget monies that were once earmarked for projects that would bring improvements or upgrades. Most costs associated with spills do nothing to enhance or improve operations or assets; therefore, sewer spills are nothing more than a drain on budgets and resources.

Sanitary Sewer Overflows: Best Accounting Practices

While a small handful of utilities have a full and comprehensive understanding of all costs associated with an SSO, many more fall short in realizing the true range and profound impact it has on costs. There are many essential factors that must be recognized in order to arrive at an accurate cost of a spill. Why is an accurate accounting important? With it, a utility will understand the real cost of a spill and drive better economic decisions for preventing one. Without an accurate accounting, e.g., leaving out associated costs, a spill's true cost may be hidden, lowering its priority to decision makers, and extending or exacerbating the underlying problems that caused the spill.

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The Three R's

A full accounting for costs includes more obvious elements, such as those that are directly associated with a spill, as well as indirect costs, such as administrative reporting. One way of looking at costs is to think of the "three R's": remediation, reporting, and reconciliation.

- *Remediation* refers to the response and cleanup processes.
- *Reporting* refers to the post-spill analysis and subsequent notifications as required by internal procedures, and state and federal law.
- *Reconciliation* refers to consequential post-spill costs, which could range from fines to litigation to public relations, and all the actions necessary to support these.

Remediation

Once a spill emergency occurs, the utility's response, dictated by standard operating procedures (SOPs), is actuated, and consequently, the cost meter is set in motion. Typically, the response will include equipment, like a vacuum/pressure spray truck, a crew of at least two people, and materials required to enable cleanup. Less sophisticated accounting practices when establishing a statistic for the "average cost of a spill" would tend to look at the labor costs only. Representatives for a moderately sized southeastern city recently cited that the "average cost of a spill for us is $400." They accounted for the cost of labor only, while the cost of the truck operation and the materials used was left out.

A more comprehensive analysis would account for those costs (and more) to seek a true total cost. Adding in the amortized cost of the capital equipment used (the truck), its operational costs (insurance, fuel and maintenance, and materials used for cleanup, like bits for grinding tree roots), and chemicals used to clear grease blocks yields a much larger cost-per-spill incident.

The point is that a full accounting of all direct and indirect remediation costs yields a true picture of the immediate impact on the utility. What once seemed insignificant now may emerge as a major issue, where the real cost of an SSO will reprioritize decisions that can, in turn, drive costs down and lower spill frequency.

Reporting

Provided that a spill has been remediated, typically the next step is to assess the event. Universally, across all states and federal regulations, the quantity of the spill must be determined. This estimate, and it is *only* an estimate because, obviously, the utility staff was not at the spill location at the beginning of the spill event, will determine the necessity and type of reporting. In order to determine reporting requirements, the spill volume analysis must be performed. The reportable volumes will vary by state and must also meet the federal (EPA) requirements. In Florida, any spill of 1,000 gal or more, any spill into a waterway, or any spill that threatens the public health is to be reported[3]. In other states, such as California, all spills, no matter how large or small, must be reported, with the threat of criminal prosecution in failing to report a spill.[4] While a comprehensive full accounting of costs includes the time for analysis and corresponding reports, less robust accounting does not. It fails to examine the drain on the management, administrative, and technical resources necessary to meet mandated requirements. Optimized accounting values includes the time involved and places a price on it to get it right.

Reconciliation

These costs can be the most significant by far, the least apparent, and the most politically and legally charged. Fines, being an obvious part of this group, are easy to evaluate and quantify. Obviously, state and federal mandates based on such factors as volume, environmental impact, and more, will determine the fine levy.

Reconciliation implies that a utility is "making it right." Sometimes though, this can be extremely costly. Take, for example, the case in a well-heeled Southern California beach community. A sewage spill occurred in a residential community, resulting in the flow making ingress to a homeowner's expensive home. The homeowner, being an attorney, determined that he didn't want to go through the hassles of remediation. In this case, he literally handed his house keys to the utility's manager and said "you bought my house." The city realized that the cost of litigation, plus potential recompense to the homeowner, would cost more than his asking price, so it bought the house for $1.5 million. Litigation and compensation will heavily factor into the cost equation.

Then there is the cost of public relations. Invariably, most reported spills will consequently reach the media, generating stories on the television news, online, and often "above the fold" on the front page of the local or regional newspaper. These news stories will consequently generate statements and reactions from public officials, calling for explanations of what occurred, why it happened, what is being done in response, and what it portends for the future.

Lost business can occur because of a spill, and the business owners may file a suit against the utility for compensation, or spills can happen in the ocean or waterways where recreational swimming or fishing occurs. These can result in public affairs and economic nightmares for a utility.

Spills can also attract the attention, and subsequently, the legal threats, of nongovernmental organizations (NGOs), whose missions are based on protecting the environment.

Internal relations, as well, are time-consuming within an organization. Multiple meetings with multiple employees, usually from a variety of disciplines, will take place for analyses, reports, and task-assigning, and the costs for all of this can pile up. To help determine the true cost of a spill, some value can and should be applied here, i.e., calculating the number of people involved and the total hours of the meetings and actions required, times each employee's hourly rate.

Cleanout Methods

Utilities use a variety of means to stem the number of SSOs. Without question, routine cleanout maintenance helps, as it tends to keep obstructions from forming in the collection system. Simply increasing the cleanout cycle, especially at critical locations where buildup is known to occur (high frequency cleanout sites), can have a positive effect as well. Many utilities have managed their collection systems in this manner and reduced the incidence of spills, but with varying degrees of success. For example, one large West Coast city established an aggressive, high-frequency cleanout program divided into three frequencies of every three months, every six months, and every nine months; subsequently, the number of spills dropped by 60 percent.

There are drawbacks, however, that should be considered with high-frequency cleanout. This is an ongoing, recurring process that is heavily dependent on expensive equipment, such as vacuum/pressure spray trucks and labor. A consistent process will be expensive, create a demanding schedule, and increase wear and tear on field equipment, requiring higher long-term equipment costs.

Establishing the frequency of cleanout cycles is typically based on historical information. For example, a Florida city found that a manhole that had been cleaned out just six weeks earlier had an overflow. Upon investigation, it found, somewhat surprisingly, that the cause of the spill was buildup. Thus, to avoid a future spill, the utility established a cleanout frequency of once every three weeks. This was twice as frequent as previously done, with the thought process being that it was allowing a healthy "margin of safety" between cleanouts. While somewhat extreme, it does illustrate the foundation of how frequencies are established at most utilities.

It is very easy to see why high-frequency cleanout procedures are attractive as a solution to SSOs. First, these are well-established processes; second, many regulatory agencies recommend a rigorous cleanout program; and finally, many managers believe that there are no alternatives. Yet, what may be a common element in all of this is that there is a fundamental lack of knowledge concerning the ongoing condition of the collection system. Therefore, an exaggerated and costly response is thought to be required, and the decision to deploy more personnel and more equipment is a much better alternative than more SSOs, more public scrutiny, more NGO involvement, or more private-citizen lawsuits.

Spot Inspections and Collection System Dynamics

In a study of more than 2,000 sites across the U.S., and using data from an eight-year period, it was found that buildup leading to an SSO is a "progressive process," in up to 98 percent of all occurances[2] where the progression can be evident over the course of weeks or even months. The cause of a progressive buildup will vary, with FOG being the primary cause, followed by root intrusion, sedimentation, debris, and degradation.

Unfortunately, those who are managing the collection system are, for the most part, flying blind. They do not know the overall condition of the collection system and individual sites; it's quite difficult to recognize systemic changes and

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to know if the condition of the collection system is stable or degrading.

Of course, one method to assess the condition of the collection system is to perform spot checks. These visual inspections by employees, or using more sophisticated methods such as video cameras, can provide some feedback. These methods are limited as they only produce a snapshot view of the collection system, not an ongoing picture of the system's dynamics. It does not provide any information about progressive changes that are taking place unless a series of inspections for each site are scheduled. Additionally, spot inspections are labor-intensive. If a utility has hundreds of sites to inspect, then multiple visits to hundreds of sites become burdensome and impractical on an ongoing basis.

For example, a site that historically required a yearly cleanout cycle is now handling influent from a newly opened strip mall, complete with seven new restaurants. The FOG content in the flow has increased (even with well-maintained grease traps), yet the collection system cleanout maintenance schedule, based on history, has not changed. The FOG built up slowly, but at a more rapid rate than prior to the mall being built. Later, a series of rainstorms hit the area. The FOG reduced the capacity of the system just enough so that normal peak events couldn't be handled and an overflow occurred.

Past habits for cleanouts did not catch up with the current conditions and the mall manager had no way of determining that these changes were occurring. A spot inspection might have helped, but without continuous inspections, a changing condition, with marginal changes in capacity, may not be uncovered.

Addressing the Issue With High-Tech Solutions

Over the past several decades, technologies have been developed to cost-effectively monitor collection systems, including sewer pipelines, manholes, and lift stations. A handful of devices are available, designed to provide an indication of an event that is occurring in a given location, and these devices aid in preventing overflows by sending an alarm to the user(s) for a reactive response.

There are two distinctive classes of devices. The first type of device is classified as single-purpose/basic alarm devices (SP/BAD), and the second type is true real-time monitors (TRM). They are quite different in functionality and benefits to users, and each is examined.

Single-Purpose/Basic Alarm Devices

These devices are simple in design and were created for a single purpose: to provide an *alarm only*. Should a given site have an upstream blockage in the pipe that, in turn, leads to a rising flow level where an overflow may result, they will send an alarm. These devices are not designed to provide any data or information about the collection system. The greatest appeal of SP/BAD is their perceived low purchase price relative to more advanced devices. It should be noted that installation can add to the cost appreciably, as there is a necessity for confined-space entry.

These devices use simple floats that are mounted in a fixed position. The floats are actuated when the rising water makes contact and a signal is sent via a cellular network to users indicating that the float has "tipped." The use of floats is one of the reasons that the SP/BAD hardware costs are somewhat lower than other devices, yet users must also accept that the well-established limitations of floats are occasional inconsistency and reliability, as they can fail to actuate. For example, a grease blanket can build and rise at a site and the float will not tilt, and therefore, not provide a signal, or the float may be tied off to the side during maintenance and left there unintentionally, also leading to an overflow with no alarm.

These devices also suffer from communications issues; the cellular device, signal quality, and communications capability can vary widely. Sewer systems are specifically built to maximize gravity; therefore, there will be more sewer lines in the lowest-lying area of any given geography. Where poor signal quality is present, consistent communication is suspect. It is paramount that when deploying SP/BAD for alarms, an impending spill event must be communicated with extremely high reliability. Without this, the devices fall short of their core mission.

As previously stated, the SP/BAD provide alarms-only by design; they do not produce any collection system data whatsoever concerning level changes. In interviews with users of the SP/BAD devices, it was stated that "all that's necessary are alarms." This bears some truth, provided that the alarms are reliable, and there can be a substantial savings versus TRM systems.

There is another substantial cost factor that must be considered. In a study of more than 2,000 monitored sites across the U.S. in a seven-year span, the analysis revealed that surcharges occurred more than 81 percent of the time outside of the typical first-shift work hours[5]. In other words, organizations are responding to spills four out of five times when worker overtime may be required, and in a majority of instances, after dark, which carries with it a higher injury risk. The key point is that organizations are reacting to an alarm and they are doing it at inopportune, more costly, and higher-risk times. The TRM systems, complete with predictive capability, can lower these risks and costs associated with unplanned, reactive responses to alarms.

True Real-Time Monitors

The TRM, a more advanced class of device, provides a wide range of capabilities. In fact, the only real comparison of TRM to SP/BAD is that both have alarming capability. Unlike the SP/BAD, which is a single-purpose system, the multifunction TRM can acquire data on an ongoing basis, enable real-time viewing of remote sites, support bidirectional communication, provide predictive analysis of trends occurring at remote sites, provide level and flow data, and assist with report generation. Users can employ this system to acquire data to assess I&I, drive collection system maintenance programs using predictive modeling, and acquire collection system data for improving asset management planning.

Users can be notified should the flow level reach a prescribed alarm point. Of course, in a collection system, the aforementioned predictive trend capability would be preferred over an alarm. This trend tool enables operators to avoid spills by alerting them to unusual water-level conditions long before a spill occurs, and provides times, days, or even weeks of time to schedule corrective action.

The TRM is an ultrasonic-level monitoring system that acquires data on an ongoing basis. Utilizing a satellite system, users are assured the highest levels of connectivity through a highly redundant network of 66 satellites in low-earth polar orbit. This satellite system has an extremely well-established track record for reliability and security. The U.S. Department of Defense uses the same network for critical military communications.

The TRM can acquire level data with an IP-68-rated ultrasonic sensor, also referred to as the distance sensing module (DSM). This sensor operates without the need to contact the flows, thus substantially reducing necessity for maintenance. The sensor is crystal-oscillator-controlled and temperature-compensated, assuring ongoing precision and no calibration. It also has high resolution (better than 0.10 in.). These features result in an exceptionally low maintenance and highly reliable sensor where the false positive rate is less than 1 in 200 million, and the known instance of missed events is less than .02 percent.

Perhaps the most essential portion of the TRM system is the access to graphical and comma-separated values (csv) data. A dedicated website enables users to access, view, and interact with remote sites via a web browser. All software and user data is hosted in the "cloud," meaning

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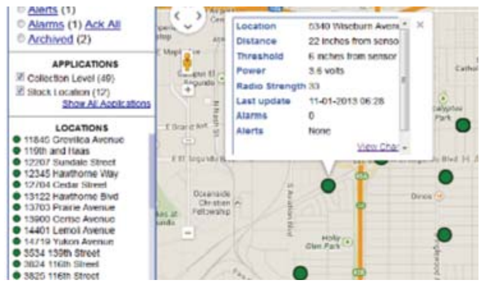

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that the interface and data storage is maintenance-free, secure, and stored indefinitely.

Upon logging in, the user will be presented with a map of all TRM locations. Details for any given site are accessed by clicking on the location on the map, or an address list. The user is then presented with the default graph of one week's diurnal flows. Any date range can be selected to view the chart and data history.

This highly flexible system also has protocols for seeing "advisories" of changing collection system conditions, "alerts" for notifying users of maintenance cycles, and "alarms" for either a surcharge or an intrusion.

Predictive Trend Analysis

Continuous real-time monitoring and data acquisition provide a powerful benefit of being able to view ongoing trends at each remote site, including manholes and lift stations. The TRM functions by scanning, assessing, and reporting on all remote sites, seeking anomalies to level trends. It also reviews and analyzes all of the level data from all sites in search of changes in levels that may indicate something different in the collection system. Users receiving advisories are directed to look at specific sites, which may require remedial action, and they are specifically designed to be an advanced warning system that helps identify the remote sites of a collection system. Most importantly, they seek to avoid an alarm where users can schedule maintenance or other actions, well in advance of a potential event.

Predictive advisories and their ability to shift from reactive to proactive scheduling offers an opportunity for true transformational change in an organization. Specifically, managers who were once "flying blind" and not knowing the behavior of the collection system can now view remote sites graphically with a few keyboard strokes. Where managers were once forced to employ labor-intensive and historically based high-frequency cleanout routines, they can now use default to scheduling cleanouts as needed. But more than this, they are assured that no SSOs will occur where TRM units are installed.

Asset Management

Real-time remote monitoring of the TRM also places a powerful capital tool in the hands of utility management. Conventionally, aging pipes are refurbished, replaced, or expanded at a cost per mile ranging from hundreds of thousands to millions of dollars. Data acquisition through TRM enables better decisions regarding "if" and "where" to direct capital resources; as a result, projects can be prioritized. Asset investments are then targeted to the areas where they are needed most; as a result, a more immediate and substantial return on investment will be achieved. In other cases, data may show that some projects may be deferred and even avoided, and with no increased risk of spills. Therefore, with data acquired upfront, better decisions are made, resulting in potentially millions in capital cost savings.

Knowing the Real Bottom Line: SP/BAD Versus TRM

As previously noted, the SP/BAD devices have known reliability, float, and communication reliability issues, and users must factor in the higher potential for a spill to occur in order to truly assess the real cost of ownership. Even with a very low probability of 1 percent error, where in 100 surcharge events one spill will occur, there is a substantial and impactful effect on cost.

A 2014 case illustrates this quite well. A utility purchased four SP/BAD devices for their alleged lower cost. The utility believed that it was saving 50 percent, as it simply compared hardware cost of the SP/BAD to the hardware cost of the TRM. Unfortunately, the utility failed to make any inquiries concerning installation and found out that the SP/BAD system installation required confined-space entry (the TRM did not). This alone reduced the cost gap to 30 percent. Even so, there was still a real savings on paper. Within four months of installation, however, one of the alarm sites had an overflow where the SP/BAD failed to provide an alarm. This incident lead to a series of costs for remediation, reporting, and reconciliation, and the fine alone exceeded $15,000. This single event and all associated costs erased all savings, and the actual total cost of ownership after one year of operation was more than 25 percent higher. Even more discouraging is the fact that the risk for a similar future event remains.

Case Study: A Different Approach and a Better Solution to High-Frequency Cleanout

A Florida utility was maintaining an aging collection system that had a high frequency of spills due to a combination of progressive buildup, which was sometimes rapid, compounded with I&I issues. From 2009 through 2012 the utility was challenged with year-over-year declines in revenue during the Great Recession. One of management's responses to the revenue decline was to impose a hiring freeze. Attrition over the course of four years successfully reduced operating expenses, but concurrently added substantial strain to standard maintenance practices and schedules.

This utility's field operations department, in particular, was responsible for collection system cleaning. Its staff reduction declined to a point where it was at 68 percent of the prerecession levels. This steep decline in field personnel raised challenges to cleanout schedules; the utility could not keep up and did not have the information it needed to assess the condition and dynamics of the collection system.

The utility provided service to a wealthy, waterfront community, with a concentration of multimillion-dollar homes. The area's collection system required constant, high-frequency maintenance, and yet, the utility didn't have the resources to assure that the threefold risk of environmental damage (it was surrounded by water), public health due to proximity to homes, and political pressures could be addressed. The utility needed to take a different approach, and could not simply throw people and equipment at the problem any longer. It needed transformational change.

In 2012, it installed TRM systems at six of its one-dozen remote systems, and each was placed at a site that would monitor and protect dozens of downstream manholes where a blockage occurred and the progressive level rise would back up to the monitored site. Since installation, data showed that for 86 times (out of 86 events), the system detected and prevented an overflow. Additionally, the utility was able to cut the frequency of cleanout by 61 percent.

The trend tools were added in 2014, which resulted in additional savings where field supervisors were able to now rely on an automated, once-per-day scan of each remote site. This important addition meant that the online viewing of sites was prioritized via an advisory email.

This utility will continue to add more TRM systems, as it has realized the benefits of substantial savings with lower labor at former high-frequency cleanout sites, with the added assurance that it is protected from SSOs.

Conclusion

The challenges of the collection system, due to its dynamic nature, means if utilities are to meet increasingly strict enforcement of the Clean Water Act, they must look to new techniques and technologies to achieve real savings and lower risks. Embracing new technologies offers the opportunity for transformational change, where not only can utilities cost-effectively and safely comply with regulations, but they can also gain valuable knowledge and insights about their collection systems. This knowledge enables better decisions for maintenance and asset management alike.

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