Integrated Web-Based Flow Monitoring and Hydraulic Modeling in Erie County, New York

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Like many municipal wastewater utilities, the Erie County Department of Environment and Planning/Division of Sewerage Management (DSM), located in Western New York is continually seeking methods to maximize treatment of its sewerage flows, minimize overflows and prioritize collection system maintenance and capital improvements. The DSM initiated development of a web-based tool in 2006 to significantly improve the way these goals are achieved. This web-based system has initially been developed for Erie County Sewer District No. 6, which contains more than 80 mi. (129 km) of sewer and serves approximately 18,000 customers in the City of Lackawanna. The web-based system was developed by a five-firm team: Conestoga-Rovers & Associates, TECsmith, Inc., Telog Systems, Inc., Computational Hydraulics International and eSolutions Group.

This innovative web-based tool, known as the Real Time Flow Monitoring System and Hydraulic Model, allows County staff to obtain up-to-the-minute status of sanitary sewer flows and operation within the District 6 trunk collection system. In addition, it allows modeling of *what if* scenarios regarding new flows, capital improvements and modifying operations rules. Ultimately, the DSM anticipates expanding this system during the next three years to incorporate all of the County's sewer districts,

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which serve more than 300,000 customers and contain 1,000 mi. (1,600 km) of sewers, 87 pumping stations, seven treatment facilities, and five overflow retention facilities.

Presented herein are the key elements involved in developing the web-based model, how these elements were integrated and examples of how this system can be used to optimize collections system operations and improvements. Also outlined is the approach planned for expanding the current online system to serve the entire DSM collection system.

8.1 System Development

To develop this web-based tool, three commonly used technologies that are important to collection system decision-making are integrated: remote wireless flow monitoring, geographical information systems (GIS) and computerized hydraulic modeling. The website platform serves to receive and store all data and to provide an end-user interface to allow access to the system. The GIS database links the real-time data to the hydraulic model to allow the user to rapidly identify current trunk sewer system status, as well as predict system response to future storms and improvements.

Preparation of these three technologies for incorporation into the system was performed between May and August 2006. Website development proceeded parallel to flow monitoring, GIS database and SWMM model development. Integration of these key elements into a single website occurred between August 2006 and February 2007. Sections 8.1.1, 8.1.2 and 8.1.3 present how the flow monitoring, GIS database development and hydraulic model were developed for this demonstration. Section 8.1.4 outlines the website and how these three commonly used technologies were integrated.

8.1.1 Real-Time Wireless Flow Monitoring

A key challenge to this demonstration involved obtaining flow and rain data representative of District 6 operations while remaining within a limited budget. The monitoring locations used in the District are shown on Figure 8.1.

Three manhole-based flow monitoring sites are being used to collect flow data from the eastern portions of District 6; these are located on Maple Grove Avenue, Willet Road and Martin Road. Sigma 930 velocity-area (V-A) flow meters are used, which are equipped with primary and redundant

level sensors. The flow meters are connected to Telog RU-33 remote telemetry units (RTUs), which transmit data using switched-packet cellular communications technology. An antenna is installed in the pavement adjacent to the manhole, enable communication between the RTUs and website.

Figure 8.1 District 6 data monitoring locations.

Switched-packet cellular communications technology was selected because of its speed, portability and excellent reliability. During the demonstration, the communication success rate for the three wireless monitoring locations ranged between 91% and 95%. The DSM currently uses a radio telemetry system to obtain data from the overflow retention facility (ORF) and pumping stations. However, data transmission is slowed during wet weather conditions, and storms can interfere with the radio signals. In addition, the existing system is not conducive to portable flow meter installations, such as manholes.

Two existing flow meter stations supplement the remote wireless installations. The first is the influent flow meter to the Lackawanna Wastewater Treatment Plant (WWTP). The second station is located at the overflow retention facility (ORF), where data from the ORF Main Meter (measures flow from the eastern part of the District to the WWTP), and ORF overflow, return flow and basin levels are obtained. Data from the WWTP and ORF were transmitted to the website via existing land-based phone lines. Two rain tipping-bucket gauges are installed to measure precipitation: one at Willet Road and one at the ORF. Considering the size of the system (6.1 mi.² or 15.9 km²), two gauges are considered adequate for the demonstration project. A portable V-A meter was also installed downstream of the Main Meter to facilitate hydraulic model calibration; this meter was removed in March 2007. The remaining instruments are still in operation.

Flow, basin level and rain gauge data are sampled in five-minute intervals. Data are transmitted to the Telog data host site every 15 minutes. Automated daily maintenance calls are made to upload all of the data collected to the host site.

8.1.2 GIS Database

The DSM's existing GIS database formed the basis of mapping for this project. The database information included existing sewers, force mains, pumping stations, roads, parcels, buildings, and manholes. Review of the database indicated that the information was generally accurate. However, limited engineering-grade information was available on manhole rim and invert elevations, which are critical for development of a hydraulic model.

To obtain the necessary elevation data, a kinematic global positioning system satellite (GPS) survey was performed on 313 manholes. These manholes represent the District 6 trunk sewer system, defined as pipes 12 in. (300 mm) in diameter and larger. Using New York State and United States Geological Survey (USGS) monuments, a Leica SR20 GPS unit was positioned and used to collect reference data. After reference data was collected, a Leica GS20 rover unit was used to communicate with the base unit and collect invert and rim data, with a target of sub-cm accuracy. A level loop survey was performed to obtain elevation data where sub-cm accuracy was not achieved. The survey data has been used to update the DSM's GIS database. Street information from New York State's Accident Location Information System (ALIS) was also used in updating GIS information.

8.1.3 SWMM Model Development

The model is developed to extrapolate the real-time data to determine up-to-the minute trunk sewer system operating conditions (e.g., flow, hydraulic grade, presence of surcharging, etc.). The model also has been designed to use historical or simulated input data to evaluate trunk sewer operation under past or future (predictive modeling) conditions.

The online model is driven by the latest hydraulics engine (USEPA's SWMM5) and a storm/sanitary system modeling-specific graphical decision support system (PCSWMM). PCSWMM provided useful tools for displaying results that could be integrated into the website. A website screen showing the District 6 SWMM model on the GIS interface is shown in Figure 8.2.

Figure 8.2 District 6 SWMM model schematic.

The Lackawanna sewer system contains more than 80 mi. (129 km) of sewer, 1,800 manholes, six pumping stations, a 4.5-mgd (17,000-m³/d) wastewater treatment plant, and a 5-million gallon (18,900 m³) ORF. The model consists of the trunk sewer system network and generally includes sewers 12-in. (300-mm) in diameter and larger, with several smaller diameter pipes included to permit connectivity. Catchment areas are

assigned to key node locations in the system for dry weather flow and wet weather response contributions.

The SWMM model contains five pumping stations, as well as the three screw pumps operating at the ORF. One small-capacity pumping station was omitted from the model because the discharge was not significant. Pumps are connected to manholes downstream of the force mains.

The four-cell ORF was simplified and included as a single storage node with the combined volume of the four cells. A sluice gate controls flow past the ORF. During high flow conditions, the sluice gate limits flow past the ORF, such that inflow to the WWTP does not exceed its hydraulic capacity of 8 mgd (30,300 m³/d). Excess flow enters the ORF, where it is stored until inflow to the WWTP decreases to an acceptable level, after which a return gate is opened to drain the ORF volume back into the sewer system. If the capacity of the ORF is exceeded, it overflows to an adjacent creek after receiving primary treatment and disinfection.

The operation of the ORF and return gates is modeled using three weirs; two to direct flow into the ORF, and a third to control the return flow to the system. Detailed control rules in the model are used to adjust the two weir heights for directing flow into the ORF. When modeled WWTP peak flows subside, the return flow weir height is decreased to allow volume stored in the ORF to return to the system.

Dry weather flow patterns were manually calibrated at each flow meter location. Daily patterns were determined from flow monitoring records during periods with no precipitation. The average flow at each monitoring location was divided between the contributing sewer catchment areas. Monthly dry weather flow patterns were incorporated into the model to reflect seasonal variation.

Modeled wet weather flows were calibrated using a combination of manual calibration and the genetic algorithm (GA) automatic calibration tool provided in PCSWMM. The rainfall dependent infiltration and inflow (RDII) parameters in SWMM form the basis for wet weather calibration. These parameters consist of three overlapping triangular unit hydrographs, representing the slow-, moderate- and fast-responses of the sewer system. Each of the three hydrographs is characterized by three parameters (R-T-K):

- R - the response ratio (the fraction of rainfall that enters the sewer system)
- T - the time to peak in hours (the delay between the start of precipitation and the system response)
- K - the recession ratio (the ratio of the recession time to the time to peak)

These nine parameters were adjusted for each model catchment area to achieve a good fit between the observed and modeled response. Seasonal RDII parameters are included in the model.

8.1.4 Website Development

The Erie County Demonstration Project is designed and implemented in Microsoft Internet Information Services. The application is managed between two servers, a web server to process web requests and host the business logic to the end user, and a database server to manage tabular data and communication with the Telog website that contained the raw flow monitoring data (Moore, 2006).

The framework surrounding the application is Microsoft .NET Framework v1.1 and was written in C#, which provides the application with the ability for future expandability to the website's structure. This framework provides the key components for communication and synchronizing operations between the major products used in this application:

1. ESRI ArcIMS 9.1;
2. PCSWMM Web Engine;
3. Telog Instruments Flow Database Management Software;
4. Microsoft Sharepoint Site.

Figure 8.3 schematically illustrates the interaction of the various servers and software packages. The ESRI ArcIMS application provides the end user with the graphical interface for viewing and plotting information on a flat imaged view within the District 6 system boundary (van Veldhuisen, 2001). ArcIMS is also used to dynamically render specific views generated based on the active model (examples presented later); these dynamic views are created instantly when generating a new model using PCSWMM. The data that is generated from PCSWMM can be funneled and populated onto the ArcIMS interface for a graphical user experience.

The PCSWMM Web Engine provides the ability to statistically analyze computed SWMM response functions (e.g. computed time series for depth, flow, storage volume, etc.) and populate the model GIS layers with the results. The web-based GIS viewer uses the computed attributes to generate detailed thematic views for a specific model based on specified parameters, such as duration of surcharging, maximum flow depth, pipe diameter, and minimum and maximum pipe velocity (Schreiner, et al., 2000). To demonstrate the flexibility of this approach, the web-based system can

present a graphical view of the locations and extent of potential high surcharging levels and overflows by creating a theme based on the duration for which computed head exceeds a specified alarm point for each node. The PCSWMM Web Engine removes a layer of work required on the model side and automates the process of generating output files online. The files are stored and saved for future recall. Included in the PCSWMM Web Engine is the ability to use the data from a model being graphically displayed on the ArcIMS interface to graph and scatter the information based on conduit or link selections.

Figure 8.3 Schematic of demonstration website interaction.

A direct link is provided from the real-time website to the Telog Instruments hosted database to allow the user to access and analyze raw flow data. The framework application of the real-time website processes 15-min synchronization requests sent to the Telog Instruments database server. The data is accumulated and stored locally to facilitate requests to run the SWMM model (Kuhns and Askov, 2003). Data collected in each 15-min interval is compared with the previous data collected in the past 48 h in order to screen for compare missing data, consistency and accuracy.

The Microsoft Sharepoint Site provides the end user(s) with the ability to corroborate findings and upload documents to a central data repository. Examples of files that are uploaded are (but not limited too): calibration

work files, health and safety plans, project correspondence, maps, schematics, and drawings.

8.2 Website Function

The real-time website enables the varied components (GIS, flow monitoring and SWMM model) to act in a coordinated fashion, providing the user with the ability to see results in a user-friendly environment. The ArcIMS interface provides a visual access tool that allows many different types of users (e.g., operations and maintenance staff, engineers and management) to use the flow database and hydraulic modeling components with minimal training. In other words, the user does not need to have expertise in configuring flow data software or hydraulic modeling to obtain the key information from the website. Thus, the website can be used for multiple purposes: determining current trunk system status, maintenance planning and capital improvement planning.

Core functions provided with the GIS interface include map navigation, layer/legend management, printing/plotting, measurement, query functions, and export and reporting tools. The website initially generates a view of the SWMM model of the entire district. As the user zooms in on an area, more mapping detail is displayed and an orthographic map can be displayed. The user can modify the layers to bring up all of the system sewers/force main, parcels, manholes and other data stored in the GIS database. The user can also call up the GIS database for visible layers.

Raw flow data is stored for viewing and analysis via the website. Data can be viewed for any time period in either time series or scatter plot format. Active-X controls are programmed to allow the user to view individual data points. Functions also are provided to allow graphs to be printed and data points to be downloaded in Excel-spreadsheet format. Time-series plots can be overlaid to compare flow measurements between the various monitoring sites and response to rainfall. Scatter plots are used to validate data. Users also are provided with data collection system health reports, which track communications success rate, battery strength and alarm history.

Maintenance and system operation alarms are also visible via the website interface map. A maintenance alarm will be initiated should communications success falls below 90%, if a sensor failure or low battery voltage occurs, or if the differential between primary and redundant sensors exceed a user-specified set point. System operation alarms include surcharging, high flow

at the ORF Main Meter or an ORF overflow. Designated personnel also are notified by email.

The website can be used to initiate, review and evaluate SWMM model results. The most powerful of these requests is initiating a real-time model. At the click of a button, the user can request a model run for the previous 48-hours of flow and precipitation data collected; run-time for these requests is approximately five minutes. This allows up-to-the minute access to sewer system operation, including thematic mapping (color-coded) and model reports, as well as time-series plots and animated sewer profiles of the trunk sewer system. Using the desktop version of PCSWMM, the user can develop model runs for historical and simulated precipitation events. In addition, the desktop PCSWMM is used to evaluate *what-if* scenarios involving sewer improvements and system expansion. Once completed, the model runs can be uploaded into the real-time website for review and evaluation by all users.

Advanced mapping and visualizations functionality is provided with the plot and profile functions. The GIS mapping interface enables users to select a node or link to develop a time-series plot or profile from the hydraulic model summary map. Time-series plots can be developed for depth, head, flow, velocity, Froude No., and capacity. The plot properties, such as line colors and types can be customized and stored between sessions. Actual flow meter data also can be inserted into the plot to enable comparison plotting, as well as automatic error analysis of the model with the most commonly used error functions. The profile function provides an easy to understand rendering of hydraulic grade line and user control based on all details and data presented in the profile. Animation of the profile is provided for the entire model run length to allow observing development of surcharging events. Additionally, plots and profiles can be copied to a clipboard to enable inclusion in reports.

Example website screen shots of the user interface are presented in Figures 8.4 through 8.7. In Figure 8.4, the user has used the zoom function in the area of the Lackawanna WWTP to select four SWMM model links (sewer pipes) for a time-series plot. The selected links are highlighted in red. Note that an orthographic mapping background can be selected on the user interface. Figure 8.5 shows the time-series plots for the selected links; the selected model period (July 27, 2006) is shown in the upper left corner of the screen. Figure 8.6 shows a full extend of the District 6 boundary, and the user is selecting a thematic map for maximum pipe velocity. Figure 8.7 shows the maximum pipe velocity thematic map with the user looking up the GIS database for a point of interest.

Figure 8.4 Website interface – selection of SWMM model links for plotting.

Figure 8.5 Time-series plot for links selected in Figure 8.4.

Figure 8.6 Website user interface – selection of a thematic map.

Figure 8.7 Maximum pipe velocity thematic map – accessing GIS data.

8.3 Examples of Real-Time Website Benefits

This integrated system can be used as a predictive tool to rapidly evaluate operational and capital improvements. Examples of how this system can be used include the following:

8.3.1 Maximizing Conveyance to WWTP

During project development, a storm event on July 27/28, 2006 was identified as an opportunity for maximizing conveyance of flow to the WWTP. Figure 8.8 shows the relationship of the WWTP to the ORF and its flow control sluice gate (taken from the website). The Lackawanna WWTP has a hydraulic capacity of 8 mgd (30,300 m³/d). Influent flows beyond this capacity are bypassed, disinfected and discharged directly into the plant's receiving stream. When flows from the eastern part of the District exceed 6.75 mgd (25,500 m³/d), the sluice in front of the ORF begins to close, diverting flow into the ORF for storage. At the time of the July event, the real-time system was not available for use.

Figure 8.8 Location of Lackawanna WWTP and District 6 ORF.

Wet weather was experienced on consecutive days, which is shown on Figure 8.9 (screen shot from website). On July 27th, approximately 4.6 cm of precipitation was experienced, including about 0.31 in. (0.8 cm) in a five-minute period. The ORF Main Meter measured flows in excess of 6.75 mgd (25,500 m³/d) and the sluice gate closed partially to divert flow to the ORF. The intensity of this storm caused WWTP influent flows to approach 13.5 mgd (51,200 m³/d). To counteract this flow spike, operators temporarily closed the sluice gate, which resulted in all flow from the eastern part of the District to be discharged into the ORF. The storm resulted in the ORF to fill up in about 6 hours; the ORF had a peak flow of about 30 mgd (114,000 m³/d) during this time. The ORF had sufficient volume to contain the storm-derived flows, but was almost completely filled.

Figure 8.9 Wet weather event on July 27/28, 2006.

Figure 8.9 shows that flows to the WWTP subsided during the six hours following the storm. By about midnight on July 28th the WWTP had an excess capacity of approximately 4 mgd (15,200 m³/d). However, flows continued to be diverted to the ORF, thus resulting in a small overflow to the receiving stream. These overflows received primary treatment and

disinfection. The second storm had a rainfall of about 0.4 in. (1.0 cm). The second storm was less intense, but because the ORF was full, much of the RDII from this event overflowed into the receiving stream. The ORF had a peak overflow rate of 8.5 mgd (32,300 m³/d). If this system were available to the operators at the time of the storm, the operators would have been able to quickly recognize that more flow could have been conveyed to the WWTP (including draining the ORF), thus reducing or eliminating the ORF overflow.

8.3.2 Identifying Manhole Surcharging

The website has a summary view function that allows the user to quickly identify key issues in the District 6 collection system. Figure 8.10 shows a thematic view taken from the website for duration of significant surcharging at manholes. The darker dots represent areas where surcharging has resulted in water surface depths within 6.5-ft. (2-m) of grade, thus showing areas where overflows could be potentially occurring.

Figure 8.10 Thematic view showing surcharging locations (7/27/06).

8.3.3 System Maintenance Plans

Another powerful view available to users is of maximum flow velocity in pipes. This can be used to identify where low velocities are prevalent in the collection system during wet weather events. These lower-velocity areas are at greater risk for reduction in sewer capacity due to sedimentation. Figure 8.11 shows a screen shot of the maximum velocity thematic map during the July 27/28, 2006 wet weather event. In this view, about one-third of the pipes are near or below minimum settling velocity. If these pipes cannot achieve flushing velocities during storm events, they will likely require more focus for flushing than those pipes having higher velocities. Therefore, this information can be used in developing and maintaining a sewer flushing program.

Figure 8.11 Thematic view showing maximum pipe velocities (7/27/06).

8.3.4 What-If Scenario Evaluations

This web-based tool provides a user with the ability to model (off-line) and upload *what-if* scenarios for all of the users to view. This can be performed to predict the impact of proposed developments, to optimize system

operation or to determine the benefits of potential capital improvement projects. The authorized user has the ability to download a selected model from the website and edit the model with the desktop version of PCSWMM to represent desired scenarios. Once the scenario is complete, the user can then choose to load the edited model back onto the website to share the results with other users.

The following is an example of one of these what-if scenarios that was modeled as a demonstration for this project: The Willet Road Trunk Sewer Optimization. The Willet Road trunk sewer is located in the southeast quadrant of District 6 and carries flow from a predominantly residential area. The trunk sewer includes 12-in. (300-mm) and 15-in. (380-mm) diameter pipes. This trunk sewer is known to have capacity issues; complaints of surcharging and surface flooding as a result of precipitation events are common (see Figure 8.12).

Figure 8.12 Profile of Willet Road trunk sewer (7/27/06).

The existing sewer performance was examined using a recorded precipitation event from the project study period, the July 27, 2006 storm, which had a total of about 1.8-in. (4.6-cm) of rainfall, and was approximately a two-year event. The existing condition model calculated surface flooding in three locations along the Willet Road trunk sewer for this event. Figure 8.12 displays the HGL in the sewer profile with the three

surface flooding locations. The model scenario was used to determine what system improvements would be necessary to eliminate this surface flooding. Figure 8.13 shows the resulting HGL if the recommended improvements are made.

A key finding from this evaluation was that the entire trunk sewer did not require replacement to mitigate overflows during a two-year storm event. About 6,000 lineal feet (1,800 m) less of sewer would require upsizing. This reduction in sewer replacement would equate to approximately US \$1,000,000 in savings.

Figure 8.13 Profile of Willet Road with proposed improvements.

8.3.5 Sewer Investigations and Rehabilitation

The web-based model also can be used to facilitate the ability to prioritize catchments by the amount of RDII occurring in each area. This would allow utility managers to focus on the areas of disproportionately higher RDII for investigation and rehabilitation, thus gaining the best value for their dollar.

Programs where this prioritization of investigative activities would be beneficial include development of video inspection, and dye and smoke testing programs in preparation of sewer rehabilitation. For example, catchments that are found to respond quickly to precipitation events would be investigated using smoke testing to identify roof leader connections or other cross connections. Those catchments that respond slowly to precipitation events would be video inspected to evaluate pipe conditions.

8.4 Shifting from Demonstration to Full-Scale

A large question was answered during the demonstration: can GIS, flow monitoring and hydraulic modeling be integrated onto a web-based system and used to manage of operations? - Yes. The next question: how do we go about implementing a full-scale system?

Figure 8.14 Schematic of full-scale website architecture.

The DSM's total service area is more than ten times the size of District 6, and has been growing as it merges the assets of adjacent towns and villages. Therefore, the full-scale system must be expandable. Another important

component to be provided in the full-scale system is to bring the ability to develop, modify and run the SWMM model over the web. In addition, the system should have an open-architecture design to allow for future upgrades performed by DSM personnel, as well as the ability for DSM staff to expand and modify the GIS interface to incorporate other functions. Figure 8.14 schematically illustrates the architecture of the full-scale system.

A service oriented architecture (SOA) approach will be used in developing the application, which represents the current trend in software engineering. Generally, SOA refers to a system developed from a number of autonomous services typically bundled together using applications programming interfaces (APIs). The benefit of using SOA is to provide a transparent, highly modular architecture that can be rapidly extended and reconfigured to meet the changing needs of the DSM. Based on this design principle, a SOA, thin-client, Web 2.0 approach will be used to provide system functionality without using Active X, Java applets or other thick-client based technology.

Three servers would be used: a database server, web server and a work server. The database server would be used to host the flow monitoring data, the web server would act as the user interface and the work server would be used to run the hydraulic model functions. Components that would comprise the website are as follows:

- An ESRI ArcGIS Server 9.2 (AGS) based client-side user interface to facilitate work flows,
- AGS and ArcObjects based server-side procedures to provide access to GIS functionality,
- Telog's Enterprise software (flow monitoring management) integration with the AGS interface, providing access to the most current flow data from the database server,
- PCSWMM.NET client-side and server-side integration to facilitate online modeling through a custom-built MS Windows service using a common language specification,
- A user management system capable of delivering a customized user interface based on pre-defined user roles, and
- A custom designed Windows service capable of scheduling threads and managing requests between servers to optimize the system's performance without impacting the system's usability.

8.5 Summary

The project team was commissioned by the DSM to develop and demonstrate a website that integrates and maximizes the value of three commonly used technologies for operating and managing wastewater collection systems: wireless flow monitoring, GIS and hydraulic modeling. This project was initiated because the DSM wants to garner a significantly greater understanding of their collection system. Because targeted users are geographically spread out across a system with more than 1,000 mi. (1,600 km) of sewer, the DSM required the system to be web-based. The website provides real-time information from flow meters and key facilities (e.g., WWTP and ORF). A SWMM-based hydraulic model uses data (real-time or stored historic values) to extrapolate the information at the monitoring points to simulate operation in the entire trunk sewer system.

The GIS platform enables different types of staff (operators, maintenance personnel, engineers and management) to use this website with minimal training to access the critical information for their needs. For example, while SWMM modeling alone can provide some of the information obtained from the website, the user must have proficiency in the program for its proper use. In addition, input files must be developed each time a user wants to run new data. The website user does not need expertise in GIS and flow database software programming or SWMM modeling to obtain the critical information on the collection system. With the click of a button, the user can obtain up-to-the-minute model results; the website collects the most recent real-time data, creates the input file (past 48-hours), and runs the model in about five minutes.

The website will greatly facilitate DSM's efforts in:

- learning how their system operates and responds to various precipitation events;
- identifying problem areas in their collection system and defining their magnitude;
- development of maintenance and wet weather operating plans;
- obtaining an accurate picture of system capacity;
- prioritizing sewer rehabilitation programs;
- optimizing capital improvements plans;
- determining the impact of development; and
- allowing the DSM to spend money in the right place, which is consistent with DSM's asset management approach.

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