CSO Discharge Tracking and Trending – United States Experience

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INTRODUCTION

Combined sewer overflows (CSOs) are a priority concern for the nearly 860 municipalities across the United States that have combined sewer systems. The United States Environmental Agency (EPA) identified 213 large CSO communities with more than 50,000 residents. CSOs are regulated under the Clean Water Act (CWA) and its National Pollutant Discharge Elimination System (NPDES) program, which permits and regulates wastewater discharges. In general, the State agencies, under a delegation agreement with the EPA manages NPDES permits. Both state and federal regulators have authority to enforce these permits.

Enforcement actions can include administrative orders and consent decrees (CD) associated with a CSO Long Term Control Plan (LTCP) typically 10 to 20 years to implement. It is recognized that EPA needs to improve current approaches to assess and track the outcomes resulting from these CD requirements and this is an evolving process.

Since the late 1990s, to satisfy NPDES permit requirements, many State regulatory agencies require their CSO communities to report overflow discharges (volumes, duration and frequency) on a monthly basis. The reported data was intended to establish a baseline for discharge conditions and set a quantitative basis for studying/assessing overall trends of outcomes while a community implement its LTCP. Typically, these requirements include gathering discharge data using automatic flow meters in each outfall and developing CSO discharge monitoring reports (DMR) and submitting to the State regulatory agencies.

CSO DISCHARGE MONITOIRNG CHALLENGES

Many CSO communities, nearly two decades, gained experiences with numerous challenges in obtaining accurate and consistent flow (i.e., velocity and depth) measurements in CSO outfall pipes. These experiences points that the most useful information from outfall monitoring locations with automatic flow monitoring equipment is CSO activation and perhaps depth at times. Velocity measurements at outfall locations have limitations, even with state-of-the-art technologies.

Experience showed that it is challenging to obtain reliable and consistent velocity measurements and that they contribute to significant uncertainty in flow and volume calculations. Both depth and velocity measurements cannot be calibrated due to installation of equipment in dry pipes. Due to practical consideration and safety reasons, entries into combined sewer outfall pipes are not desired while overflows are occurring. For these reasons, the in-situ depth and velocity measurements can neither be calibrated nor verified. Figure 1 shows a typical depth vs. velocity scattergraphs from an uncalibrated meter that was installed in a dry CSO pipe location and also from a calibrated meter in a wet pipe conditions located in a combines/interceptor upstream of a CSO regulator. The wide scatter noted in the CSO location which also varies from event to event and calculated flow data is highly unreliable for quantifying CSO discharges with level of certainty needed to effectively track, trend and assess efficacy of the expensive sewer system improvements. In comparison, a wet pipe installation with proper calibration can generally yield better flow estimates.

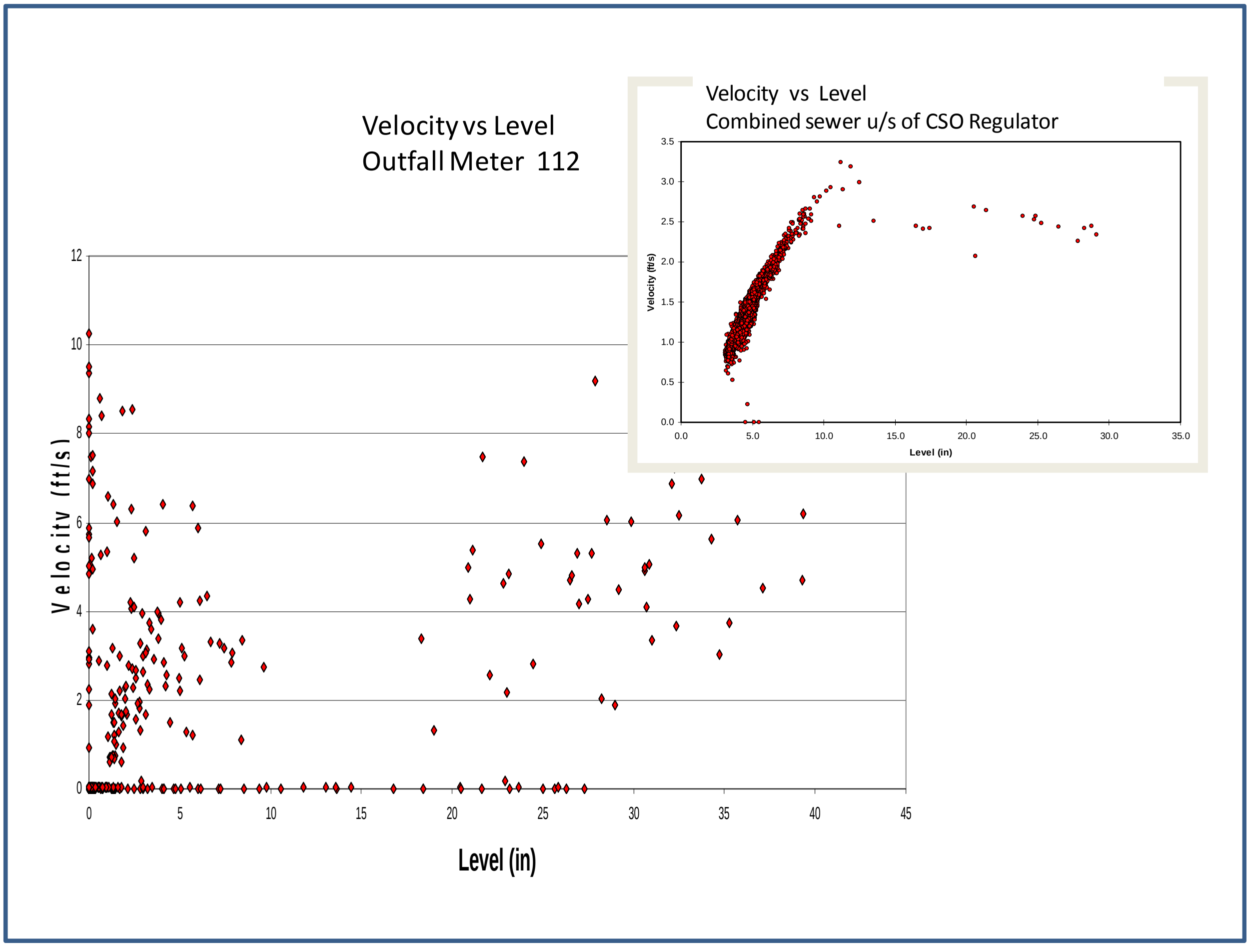

Figure 1. Outfall Monitoring Data Consistency/Reliability Challenges

Experience with extensive outfall monitoring also indicated that CSO discharge activation data is the most useful information. Lessons learned pointed that relying upon the outfall monitoring equipment alone to estimate overflow volumes may lead to inconsistent and unreliable information for CSO data tracking/trending in addition to the gaps in reporting due to potential equipment down time. The DMR data reported based on entirely monitoring data may add more complexity (in addition to the annual rainfall variations, system changes, etc.) when the communities and regulatory agencies analyze data to assess the impacts of the system improvements and associated major capital and operational investment.

INTEGRATED MONITORING AND MODELING APPROACH

Some progressive communities (e.g., The Citizens Energy Group (CEG) in the City of Indianapolis, Indiana in the Midwestern United States) concluded that integration of system overflow activation/flow monitoring and a sewer system hydraulic model yields in better reporting and tracking/trending of CSO discharges than either system alone (WEF 2005, 2012).

Based on long-term experiences with outfall flow monitoring, it has been determined that the calibrated/validated hydraulic model (with ongoing outfall monitoring data) simulated in a continuous mode would provide a more cost-effective, reliable, and consistent method for generating continuous CSO discharge data to meet NPDES permit requirements. This proven integrated monitoring and modeling method supports better reporting, tracking, and trending of CSO discharges, and enhances the performance of both monitoring and modeling programs on an on-going basis.

Example Case Study: CEG, Indianapolis, Indiana

The Citizens Energy Group (CEG) currently serves the wastewater needs of the Marion County in central Indiana. Population in the service area is approximately 903,000, based on 2010 Census data. Approximately 400 square miles of service area is served by both combined and separate sewer systems. More than 30 combined and sanitary interceptors convey wastewater flows to two advanced wastewater treatment plants (AWTP). The combined sewer area covers about 55.5 square miles, located primarily in the older sections of the city, and currently contains 131 permitted CSOs.

Within the combined sewer system, there are four major watersheds served by four components of the interceptor sewer network. The interceptor sewers serving the Pleasant Run/Bean Creek, the Pogues Run, and the South Fall Creek watersheds flow into a centrally located core interceptor sub-network that directly serves the White River watershed. This central interceptor sub-network then conveys the wastewater into two AWTPs. Figure 1 depicts four major watersheds in the combined sewer area and the Belmont AWTP.

In late 1990s, to address the NPDES permit requirements for CSO discharge reporting to the State agency, the Indiana Department of Environmental Management (IDEM), CEG/City of Indianapolis has reviewed options to determine a relatively accurate approach with consistent performance. The city has a long history of applying monitoring and modeling technologies to support CSO control planning. These two technologies were combined to characterize the CSO impacts under existing conditions and to support the early CSO LTCP development efforts in

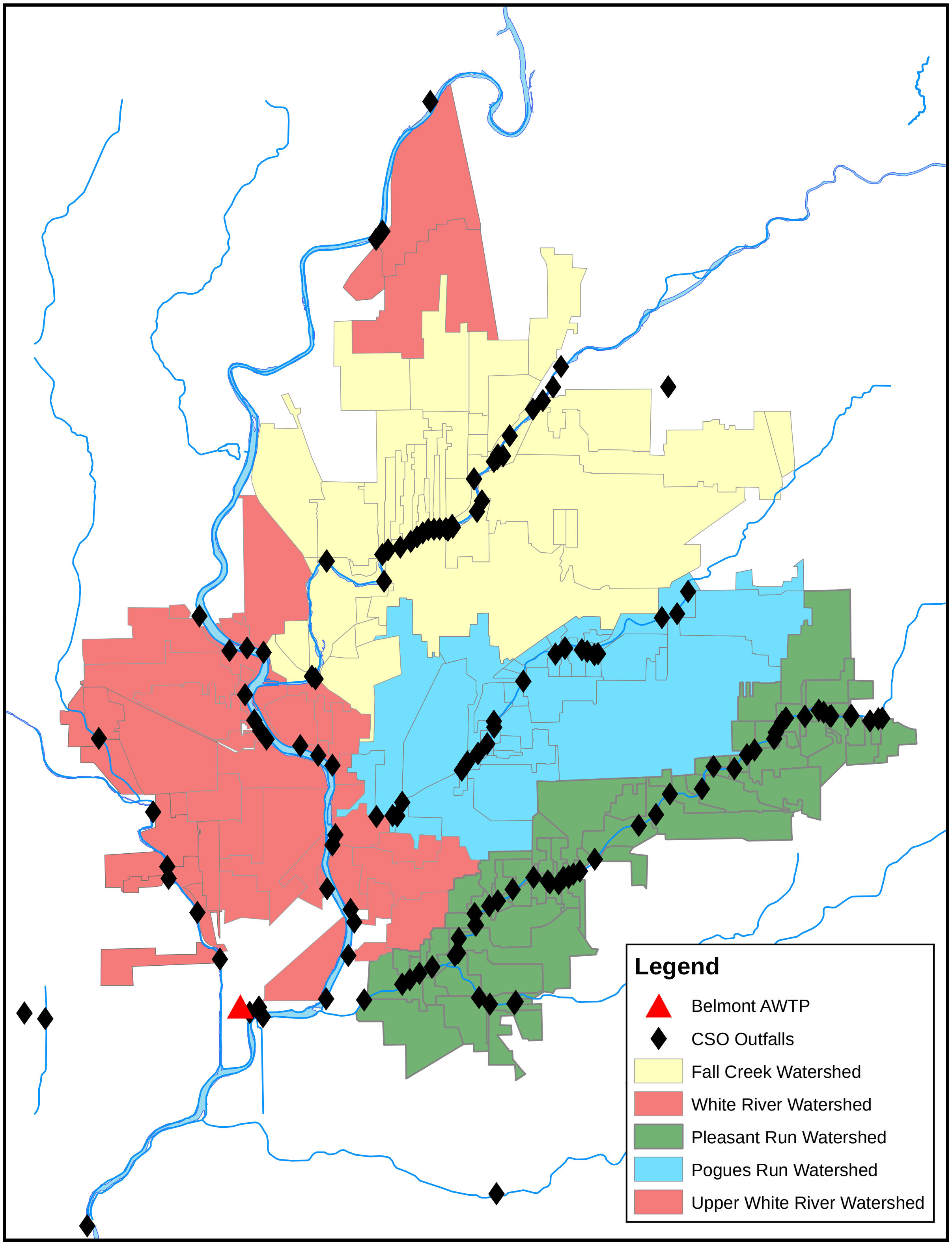

Figure 2. Indianapolis combined sewer watersheds (Source: CEG, Indianapolis, IN)

1990s. The city understood the strengths and limitations of monitoring and modeling techniques. Specifically, the city has had firsthand experience with the challenges of operating and maintaining a large number of permanent flow meters and in obtaining accurate and consistent flow (i.e., velocity and depth) measurements in CSO outfall pipes.

The city concluded that the CSO discharge activation data is the most useful information from outfall monitoring locations with automatic flow (depth and velocity) monitoring equipment. Velocity measurements at outfall locations have limitations, even with state-of-the-art technologies.

City determined that relying upon the outfall monitoring equipment alone to estimate overflow volumes may lead to inconsistent and unreliable information in addition to the gaps in reporting due to potential equipment down time. The DMR data reported based entirely on monitoring data may add more complexity (in addition to the rainfall variations, system changes, etc.) when the CEG and regulatory agencies analyze data to assess the impacts of the system improvements. Based on their experience with outfall flow monitoring, the city determined that the calibrated/validated hydraulic model simulated in a continuous mode would provide a more cost-effective, reliable, and consistent method for generating continuous CSO discharge data to meet NPDES permit requirements.

In summary, city concluded that integration of system overflow activation/flow monitoring and calibrated hydraulic model yields in better reporting and tracking of CSO discharges than either system alone (Figure 2). As a result, the city proposed generating the CSO DMR based on continuous simulations using the calibrated hydraulic model that was developed to support preparation of the CSO LTCP. The hydraulic model is to be validated by CSO discharge activation data from outfall monitoring locations along with permanent interceptor monitoring locations with automatic flow (depth and velocity) monitoring equipment. This was in lieu of widespread installation, operation, and maintenance of automatic area-velocity flow meters in more than 130 CSOs.

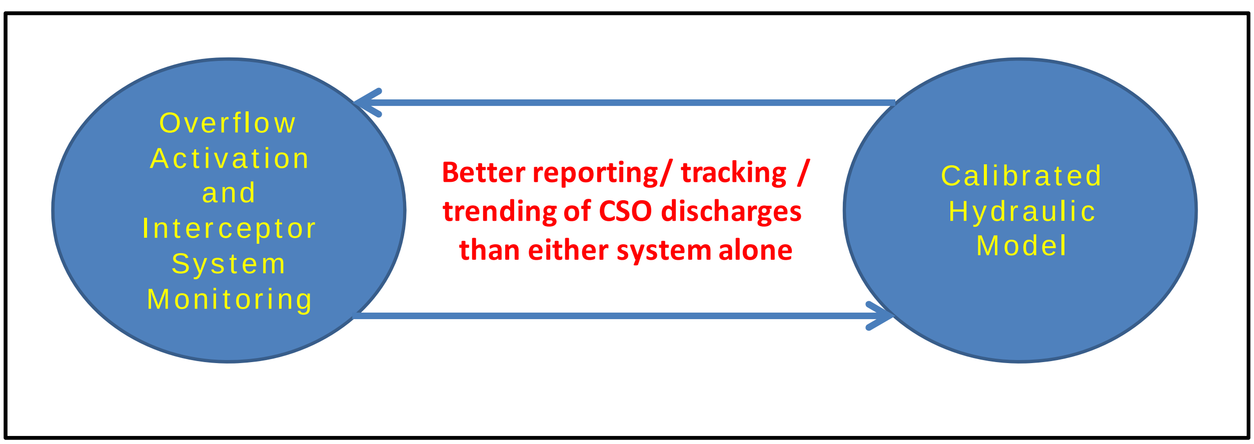

Figure 2. Integrated monitoring and modeling approach for CSO DMR preparation (Source: CEG, Indianapolis, IN)

The city's proposal was accepted by IDEM and as a result the NPDES permit requires that the city must report, on an ongoing basis at 6-month intervals, CSO volume and duration from each outfall based upon a hydraulic model of the sewer system.

In 1999, for the first time, the city has formally adapted an integrated monitoring and hydraulic modeling approach for developing DMR to meet NPDES permit needs and establish a sound basis to evaluate the efficacy of future CSO control projects. This approach involved continuous monitoring to characterize the system flows and overflows, and application of this data for maintenance/ recalibration of the city's hydraulic model that reflects system operational changes as well as constructed system improvements. The DMRs were prepared on 6-month intervals based on hydraulic model simulations on continuous basis and include daily CSO discharge information, including volume and duration.

This practice of generating DMRs has continued since 1999, and is currently ongoing to meet the NPDES permit requirements. At the time of this writing, more than twelve years of CSO discharge monitoring data is available from 24 individual 6-month CSO DMR prepared.

Monitoring System: More than 130 CSO outfall locations currently have automated monitors in place to support CSO DMR preparation and myriad of CSO control program needs. In addition, 19 area-velocity meters are located at selected locations as required by their NPDES permit but with expectation that CSO activation data is the most useful information collected. These meters are regularly maintained by CEG.

Hydraulic Modeling System: CEG's hydraulic model currently is a matured tool and has been calibrated and maintained using flow monitoring data from interceptors, CSO regulators and the CSO outfalls. For ongoing DMR preparation purposes, CSO volume data generated by the calibrated model is continue to be cost-effective and more reliable than data collected by using automated flow monitors alone in the city's current 130 CSO outfalls. The model-based data has been supporting to deliver consistent performance and facilitate a reliable trend analysis on overflow characteristics.

CSO Discharge Monitoring Report: The Indianapolis CSO DMR includes daily CSO discharge volume and duration data for each outfall and the information is tracked by each receiving watershed within the system along with rainfall data. The CSO basin-specific rainfall data is derived from the city's radar-rainfall system. In addition to presenting the information by each CSO, the DMR provides a daily summary of discharges, grouped by various watersheds within the system. The CSO discharge data is presented at various levels in order to assess it at micro and macro scales, and to assist in data application for various purposes.

The model-based DMRs are prepared within 6 months after each 6-month reporting period. For example, the DMR for the reporting period January through June 2015 is generated by December 2015. This 6-month duration allows for performing a number of steps:

1. Review of collection system improvements and modifications relevant to DMR preparation for the reporting period;
2. Review of improvements due to operation and maintenance activities;

3. Collect and review radar- and rain gauge-based rainfall data;
4. Collect and review outfall monitoring data;
5. Update the hydraulic model as necessary to reflect system improvements and operational changes;
6. Conduct 6-month continuous simulation and validate the model results with observed CSO activation data and system monitoring data; and
7. Prepare the DMR;
8. Prepare a list of future improvements/adjustments needed for outfall monitoring systems.

CSO Discharge Data Tracking and Trending

The primary purpose of the DMR is to meet NPDES permit requirements and to allow establish discharge trends. The long-term data found to be useful in tracking CSO discharges over a period of time and establishing the overflow trends in relation to the varying rainfall conditions and progressive system improvements to control CSOs. The data trending analyses on precipitation and overflow data helped to demonstrate /discern the complex nature of widely varying precipitation patterns and associated CSO discharges. They also showed general trends of CSO reduction with substantial completion of system improvements and/or changes in operational practices.

CSO policy promulgated by EPA in 1994 requires characterization of CSO discharges on an average annual basis to support LTCP development. The efficacy of CSO controls are also to be evaluated on an average annual basis. Wide variations are observed in year to year precipitation patterns and associated CSO discharges from the combined sewer systems. Therefore, it is critical to review the sewer system CSO response with respect to a range of precipitation conditions when establishing control measures or assessing the efficacy of CSO improvements. Long-term averages of CSO discharges should be considered when assessing effectiveness of the projects constructed in reducing CSOs to the target level of control.

For example, Figure 3 shows a sample display of system wide CSO discharge data for the 12-year period. This example CSO tracking/trending graph shows the wide variations in yearly precipitation versus estimated CSOs. Figure 3 also shows an indication of how the estimated ratio of rainfall to CSO volume varied year to year on the system wide basis. It is observed that CSO responses are directly influenced by rainfall characteristics and also system improvements. Therefore, changes in CSO trends after completion of system improvements should be evaluated with consideration to observed rainfall variability. Also, the progression of monitoring and modeling systems also has some impact on the increased accuracy of the CSO estimates over time. Long term trending of rainfall variability and CSO behaviors would be useful to assess impacts of wastewater system improvements. Figure 3 shows a discernable trend of reduced annual overflow, since system improvements made at the Belmont AWTP, along with improved operational strategies for wet-weather treatment in 2007 and 2008.

Similar analyses were possible at each watershed level and by individual outfall level. Overflow frequency data reported in CSO DMR can also be used in the trending analysis, if desired. As the CEG moves forward with the implementation of CSO control projects, the CSO discharge

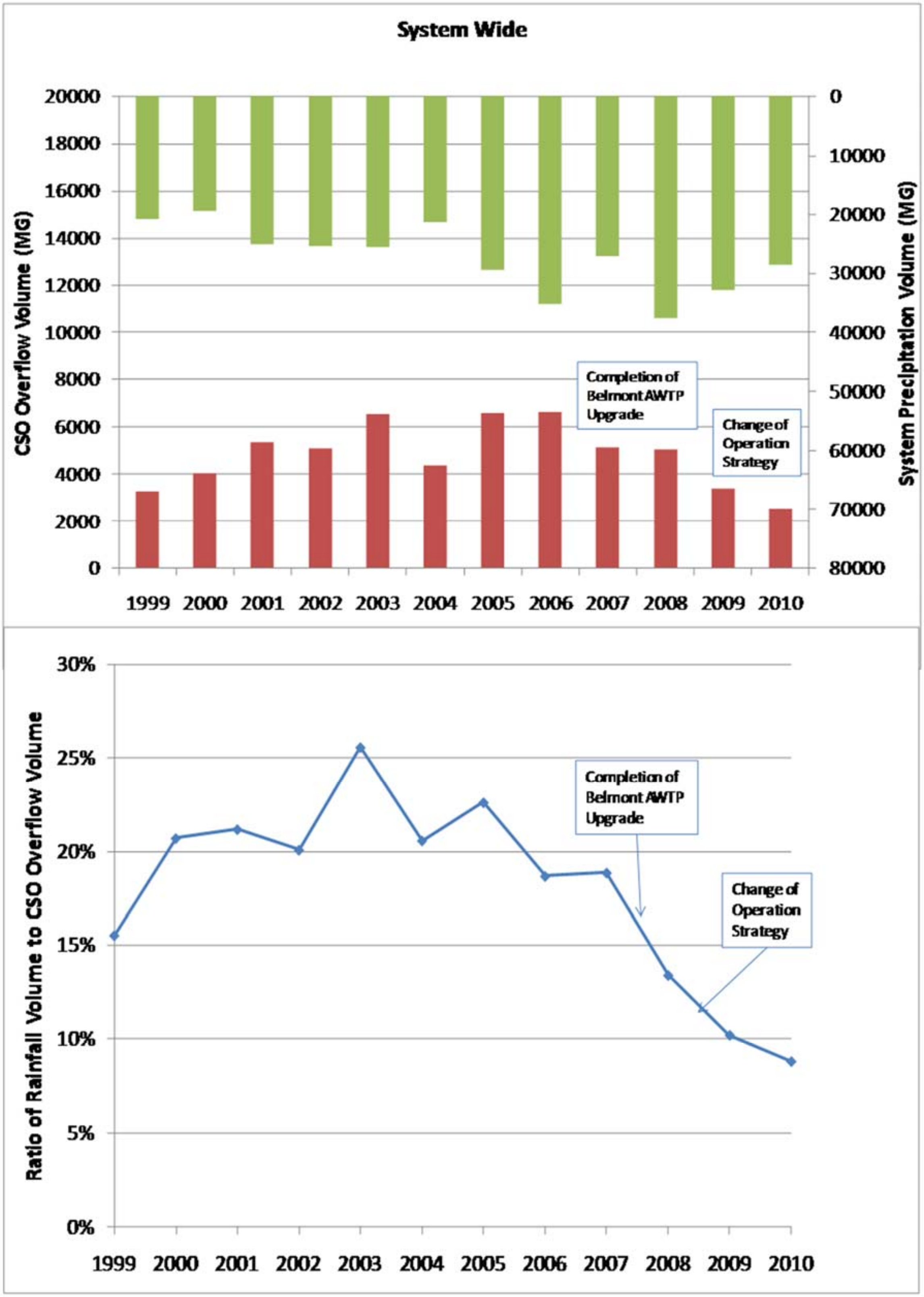

Figure 3. Example System-wide CSO discharge tracking and trending (Source: CEG, Indianapolis, IN)

database can be effectively used to demonstrate overall trends of system-wide CSO discharge reductions over time.

CONCLUSIONS

Reliable and consistent approaches are critical in preparing ongoing CSO discharge monitoring reports to track long-term trends in discharges. Outfall flow monitoring presents many challenges and relying upon the outfall monitoring equipment alone to estimate overflow volumes may lead to inconsistent and unreliable information. The CSO discharge data reported based entirely on monitoring data may add more complexity (in addition to the rainfall variations, system changes, etc.) when assessing the trends of CSO in relation to completed system improvements.

An integrated monitoring and hydraulic modeling approach found to be effective to report CSO discharge data establish a sound basis to track and trend CSO as the system improvements are being completed over a long-term. Continuous simulations with the calibrated hydraulic model validated by CSO activation and system monitoring data are the most cost-effective, reliable, and consistent method to generating CSO discharge reports. Ongoing maintenance of both monitoring and modeling systems are keys to the success of the integrated monitoring and modeling approach to generate meaningful CSO discharge data.

The existing system performance and the impacts of system improvement must be evaluated on an average annual basis. Wide variations are observed in year-to-year precipitation patterns and associated CSO discharges from the combined sewer systems. Long-term CSO DMR data will provide a sound and consistent approach in evaluating overflow characteristics in relation to precipitation conditions and assessing the performance and effectiveness of the CSO LTCP projects. This long-term data is critical to evaluate the average annual performance against the target level of CSO control for the constructed projects.

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REFERENCES

Vallabhaneni, S.; Chan C.; Chu, D.; Masbaum, B.; Flynn, F. (2012) *12-years of CSO Discharge Reporting/Tracking/Trending using an Integrated Monitoring and Modeling Approach*. Proceedings of the Collections Systems Conference 2012; St. Louis, Missouri, June 3-6; Water Environment Federation (WEF): Alexandria, Virginia.

Vallabhaneni, S.; Masbaum, B.; Mazza, M. (2005) *CSO Discharge Reporting and Tracking;* Proceedings, 78th Annual Water Environment Federation Technical Exhibition and Conference, Washington, DC. Nov 1- 3, 2005; Water Environment Federation (WEF): Alexandria, Virginia.

Citizens Energy Group, City of Indianapolis. *CSO Discharge Monitoring Reports*