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Artificial Intelligence of Stormwater Operations

Eric Bednar
eab104@zips.uakron.edu

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Eric Bednar

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Abstract

The current infrastructure in our country will not be able to adequately support the growing demands of an exponentially increasing population. A rise in population contributes to a greater service demand necessary to treat sanitary sewer waste which in many cases contributes to the flow of combined sewers. When it comes to managing these combined sewers, rain and the snowmelt caused from climate changes are major factors that need to be addressed. Some water treatment facilities do not have the ability to treat the capacities or peak flows that a system experiences, resulting in combined sewer overflows which are both bad for the environment and an inconvenience to society. The almost 200-million-dollar project of Akron's Ohio Canal Interceptor Tunnel (OCIT) sparked interest in the topic of storm and combined sewer management especially the concept in-line storage to significantly reduce peak flows which is discussed later. This Akron sewer project has increased the capacity of Akron's combined sewer system. Increasing a system's capacity is just one of the improving the water treatment process. Other procedures include redirecting flows, installing valves to regulate peak flows, and monitoring combined sewer levels with remote devices just to name a few. Initially the focus was to be on the City of Akron's combined sewer treatment systems alone, but resources were made available that allowed an insight on what storm and combined sewer activities have been happening across the country. The implementation of real-time control systems, a form of artificial intelligence (AI), is becoming more common. This paper will look at multiple case studies of real-time control programs being utilized for a number of scenarios requiring different aspects of real-time control to gain a deeper understanding of their capabilities. This will help to determine whether or not these RTC programs can significantly benefit stormwater management facility operations and potentially eliminate combined sewer overflows.

Acknowledgements

A special thanks to those who provided input on the case studies described in this report including Christian Miller, PE from Louisville, KY, Joe Sagnis, Chief Operator from the wastewater treatment plant in Newburgh, NY, and Philip Pickering, PE from Philadelphia, PA along with Christopher Miller, Ph.D., PE from the University of Akron and Jesse Rufener, PE, CFM from GPD Group for directing the honors research project.

Introduction

Artificial intelligence (AI) according to ScienceDaily is "the study and design of intelligent agents where an intelligent agent is a system that perceives its environment and takes actions which maximizes its chances of success" [1]. This is a two-step process that first requires the intelligence agent to collect information about its current environment whether it be temperature, pressure, flowrates, chemical concentrations or any other characteristic in this case that can apply to water. Each step of the process can be beneficial on an individual level, but a combination of the two provides better results. In order to prepare for the future without spending billions of dollars on entirely rebuilding the existing infrastructure, an alternative solution can be utilized. The implementation of artificial intelligence in storm and combined sewer management can result in a more efficiently run system that can extend the performance life of existing operations without needing a complete replacement. Some of the uses for artificial intelligence can include monitoring and recording information about flows, using recorded data to control valves to decrease the peak flow entering treatment plants or other facilities, or simply notifying someone when a combined sewer overflow is about to occur. The main objective is examining artificial intelligence uses, in the form of real-time control systems, by analyzing a series of case studies that were discussed in an article titled "Smart Data Infrastructure for Wet Weather Control and Decision Support" by the

United States Environmental Protection Agency in August of 2018. A more in-depth understanding of these case studies will help determine the following question: does real time control implementation significantly improve stormwater control procedures?

Case Study I: Real-Time Control for Integral Overflow Abatement

Louisville, Kentucky

An article from the EPA stated that Louisville MSD was one of the first programs to utilize inline storage and is currently pioneering predictive real-time control systems [2]. The basic concept of inline storage and controlling conveyance is to essentially decrease the amount of peak flow in the combined sewer system. Figure 1 below shows what a typical hydrograph looks like. The only difference is that the rain flow would be in addition to the baseline flow of the sanitary component of the system. Initially, a wet weather event begins, which in turn causes the stormflow to increase. This hydrograph shows the peak stormflow at about 1 day. Peak flow, along with the total volume of combined sewer flow are the two major design components of a sewer system. The reason for an overflow is generally the inability to handle the peak flow. With the implementation of a real-time control system, the peak flow could be decreased by confining some of the combined sewer flow within the inline storage of the system. The stormflow line on the hydrograph would become flatter, treating the same volume of water over a longer period of time at a decreased rate.

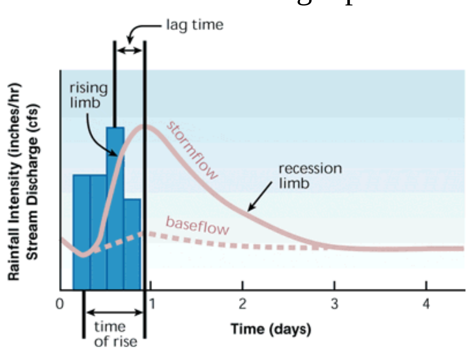

Figure 1: Typical Hydrograph.

This past month, an interview was conducted with Christian Miller, PE, from the Louisville MSD. He elaborated on their journey of real-time control. Christian Stated that although not being around for the original implementation of their RTC program, he heard there was initially skepticism from the operations staff prior to and following the installation. Much of the fear arose from the thought of an RTC system's automation being able to eliminate the need for human jobs, which was not and is not the intention [3]. When asked to comment on the systems operation and the amount of human involvement needed, Christian stated the following:

> "Our application of RTC is intended to maximize in-line storage; including recommending pump station effluent flows and modulating gates or dams in order to do so. Operations staff are utilized to maintain the mechanical and electrical components of facilities like normal, but we have additional staff dedicated to the operation and maintenance of the instrumentation and controls required for RTC" [3].

A need for human involvement is still a good form of checks and balances against an artificially intelligent system. This allows a human level of command in case the program malfunctions. They are able to check in real-time their system outputs to ensure the system is running properly. Alarms have also been installed to notify operators of program malfunctions so the necessary corrective actions can be taken [3]. As with most technology at this point in society, there are both advantages and disadvantages. One of the first advantages of integrating real-time control systems is that information can be easily recorded. Knowledge of information from past and current conditions can be used to modify and calibrate the system. The entire system could be monitored on the same network that may be modeled system-wide, as opposed to managing or monitoring each segment individually. The system is intended to operate fully automated during smaller events and only needing potential manual operator assistance during larger wet-weather events. One of the disadvantages discussed is the use of predicted forecasting. This would require continuous updating and calibration of the system in order to manage it optimally [2]. Another is that due to the size and complexity of Louisville's RTC system, it will be time consuming to expand technologically because of the necessary calculations that are required within Louisville's timeline for the system [3]. Real-time control implementation is just part of Louisville's long-term plan to eliminate combined sewer overflows according to the EPA [2]. Figure 2 below shows the size of the Southwestern Outfall which is an egg-shaped tunnel with a diameter or 24 to 27 feet and is part of the real-time control program in Louisville.

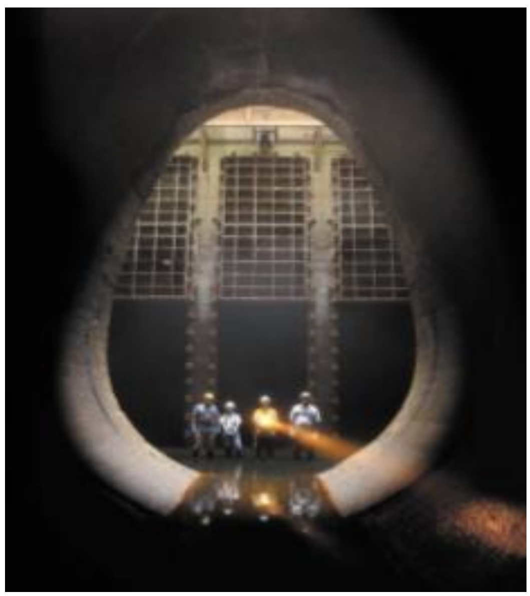

Figure 2: Southwestern Outfall, Louisville, KY

Minimizing and potentially eliminating combined sewer overflows is one of the positive effects of the implementation of this real-time control system. According to an article on the integrated overflow abatement plan of the Louisville and Jefferson County Metropolitan Sewer District, the real time control aspect of Project WIN (waterway improvement now) has numerous functions. One of which is a constantly updating Project WIN website with information of past, current, and future potential overflows and their locations. Residents can even sign up for email notifications if an overflow is likely to occur [4]. Notification of overflows and past knowledge of overflows can lead to more proactive operations on both a state-wide and a personal level. The future of the Louisville MSD's real-time control implementation appears fruitful. They plan to further increase their infrastructure by constructing additional storage and treatment facilities to continue the journey towards combined sewer overflow abatement.

Case Study II: Real-Time Control to Monitor Discharges for Reporting/Public Notification

Newburgh, New York

The case study that takes place in Newburgh, NY deals with using real-time control measures to determine when combined sewer overflow events occur. Based on the EPA's article on smart infrastructure, this form of artificial intelligence and real-time control seems to be one of the less complex of the case studies analyzed. Combined sewer overflows are typically caused when a link in the system is unable to handle a peak flow of water. There are instances when the pressure of the water is even strong enough to displace manhole lids. Figure 3a below shows a generic picture of a combined sewer monitoring device. Newburgh initially used monitoring devices that needed to be located at the bottom of the channel, coming into direct contact with the flow [2]. One of the improvements to the CSO monitoring operations in Newburgh was that long-range sensors were able to be utilized, allowing them to stay above the flow of the sewer and in some cases, at the top of the manhole itself. This concept is shown on the following page in figure 3b.

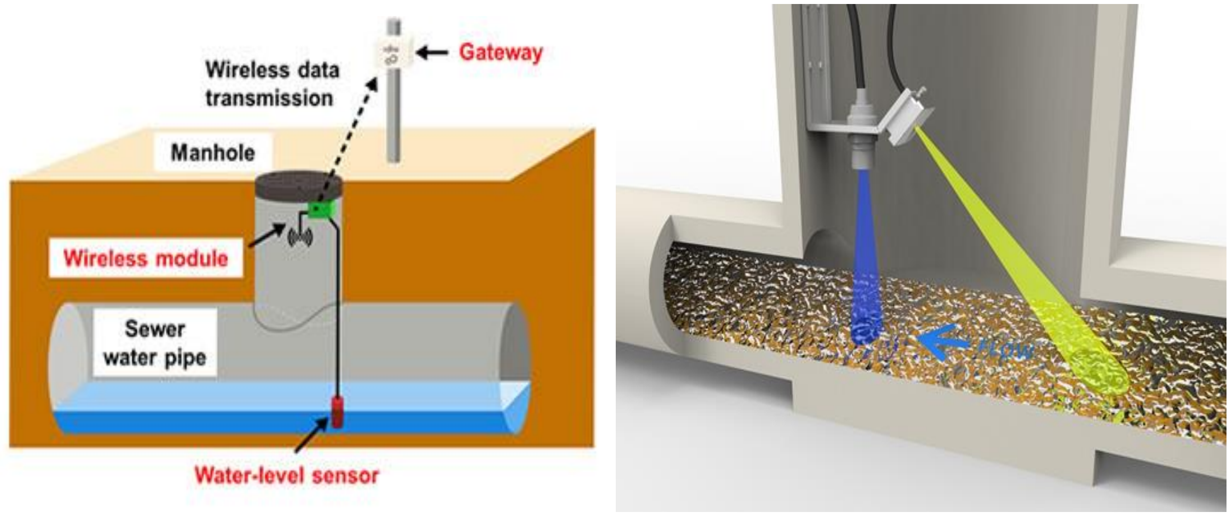

Figure 3a (left): Typical Submerged Water-Level Sensor.
Figure 3b (right): Improved Sensor With No Water Contact.

An additional problem with the old sensors is that they required extensive calibration equipment, a great deal of maintenance and in some cases, replacement due to heavy flows. That no longer poses a threat to the real-time control sensors that have been installed. The wireless satelite controlled sensors are more maintenance friendly than the old telemetry sensors that required hard phone lines for each sensor. Based on a interview with Joe Sagnis, the Chief Operator at the Newburgh, NY Wastewater Treatment Plant, he seemed very optimistic about the implementation of the RTC monitoring program. During our interview he stated that initially, the staff and operators supported the upgrade to this new technology. The sensors were not posing a threat to human jobs which was seen in other case studies. Joe said that they still have similar procedure as far as overflow inspection goes. Once they receive a notification of a potential overflow threat, a crew is sent out to the manhole which is what happened prior to the new sensors. He was also proud to discuss the benefits of easier data collection with the RTC sensors as opposed to the older ones [5]. Data collection may be overlooked in some cases, but it is the basis for future development and improvements of technology. Once the data is recorded, models can be continuously updating in order to track correlations between certain wet-weather events and combined sewer overflows. Another key aspect of real-time control systems is the need for operator and management support. If the staff is on the same page and can be trained to understand how the equipment and system works, there is a better chance that the implementation will be fruitful. Newburgh's ability to continue crew interaction with the sensors is definitely an advantage. The interaction between a user and the system can educate a user to understand the system itself and gain a further understanding of how the real-time control system plays an important role in the combined sewer collection and monitoring process.

Case Study III: Real-Time Control to Manage Retention Pod Discharge

Philadelphia, Pennsylvania

Water quality is a common issue that arises in stormwater management. A variety of stormwater control measures (SCM's) and best management practices (BMP's) can be used to improve the quality of our surface waters. Stormwater quality and especially post-construction stormwater runoff, which can be a major issue, could both be influenced by the implementation of a real-time control system. In this Philadelphia case study, a retention pond was the chosen mechanism to improve the water quality of runoff on an 8-acre property. The basin was not reaching the water department's regulations, so the basin had to undergo some changes. According to the EPA's article on smart data infrastructure, the components of this RTC system included installing a 6-inch actuated valve, a water level sensor, and a form of communication technology to connect to a cloud-based software that uses the water level data of the basin and storm forecasts to determine the setting of the valve [2]. Figure 4a and 4b below taken by the Philadelphia Water Department are photographs from the retention pond showing the newly installed real-time control system.

Figures 4a (left) and 4b (right): PWD Retention Pond Real-Time Control System & Valve

Real-time control operations at this retention pond can be fully automated, requiring little to no involvement or need for human manual operation. Another advantage of the implemented RTC system is that users have access to recorded long-term monitoring and control data that can be used to help design future projects. As far as RTC operations go, the City of Philadelphia takes pride in being at the forefront of innovation [6]. Philip Pickering, the Engineering Supervisor of the Philadelphia Water Department stated, "…(It) has worked exactly how we hoped it would. It's been a huge success so far" [7]. They did not appear to be skeptic before introducing the new actuated valve and real-time control program. The processes that control the discharge from the retention pond can be rendered as a process to control the flow going into a wastewater treatment plant for treatment. There were multiple factors that influenced the valve's setting including allowable discharge rates, water quality, storm retention time, and flood protection objectives. All of these aspects apply to real-time control combined sewer management operations. With the implementation of a real-time control sensor and valve combination, sites such as this property that would generally create a significant amount of runoff during a storm event can be managed in such a way that the runoff has little or no impact on a combined sewer system during a wet-weather event.

Analysis

Each of these three case studies utilize artificial intelligence in the form of real-time control systems. Real-time control, decision and monitoring systems allow for more instantaneous system operation. The New York case study uses sensors installed in manholes to determine if there is an overflow. Real-time control monitoring devices can be used as proactive devices as opposed to reactive ones. Newburgh still sends workers to the site if a sensor is triggered. Knowing that an overflow is likely before going to the site to inspect as if there had been no monitor, could result in preventative actions such as finding a way to contain the overflow depending on its location. Throughout each of these case studies, there were certain themes and lessons to learn. One of the key points that Christian Miller from Louisville touched on was the need for team communication and staff buy in. It is crucial that there is a well-established team with each member knowing their responsibilities [3]. The members also need to be aware of any operation and maintenance that the system may require along with any necessary precautions if the system were to fail. Christian also stated during the interview that the real-time control system would work best with an up-to date facility that would not require as much functional maintenance that could negatively impact the RTC processes. During the New York case study, the sensor placement was one of the complications that had to be faced. Fortunately, they were able to find a solution using the long-range sensors which also ended up requiring les maintenance than the original short-range telemetry sensors. This goes to show that each real-time control system implementation may be unique, but there are numerous solutions to help optimize the new technologies. Throughout the Philadelphia implementation of the real-time control system, they remained confident in the improvement of technology. As long as they stand by and support RTC, that is half of the battle. Retrofitting catchment areas with large potential quantities of runoff to delay or eliminate the runoff from combined sewer systems can decrease the stress from large peak flows on sewer systems and in turn greatly improve water quality. Each case study showed an RTC program that was user specific, but they were all seen as beneficial and proved to increase combined sewer operations by reducing peak flow during wet-weather events, organizing and collecting data to further understand combined sewer processes, or even just simply notify the public or authorities when an overflow could be expected.

Conclusions

Real-time control systems can improve the current infrastructure of today. They can be as simple as installing some sensors on manhole covers to detect changes in flow, or as complex as rerouting wet-weather combined sewer flows in order to decrease the peak flows seen by certain pipe segments or by treatment plants themselves. Real-time control is the next step in the journey of improving today's infrastructure. Programs that continuously collect and monitor data on combined sewer systems with regards to wet-weather flows and combined sewer overflows can be implemented to optimize current processes at a fraction of the cost of reconstructing infrastructure. All three of these case studies show different levels of complexity. In order to properly utilize a real-time control system, the operators and users should have a clear understanding of how the processes themselves work and the program responds in the way it does. That is why there should be training programs for the operators and managers of the systems to be able to understand what the system is doing in case of malfunctions or problems that result in the need of human override. This human interaction focused design is important for the success of the real-time control program implementation and operation. The application of real-time control solely depends on the user's need for it. A system will be more complex if it is fully automated and is made up of multiple algorithms to determine outcomes for the system compared to just simply monitoring and recording data. Endless solutions exist, but the bottom line is that with the right support from operators and the proper technological programs, real-time control systems can optimize water collection and treatment, and in turn reduce combined sewer overflows and improve water quality. All of this can be possible with technological upgrades to optimize the current infrastructure which is a cheaper option than simply rebuilding all infrastructure with systems that can handle larger peak flows. Based on these case studies, real-time control does indeed improve stormwater management operations.

References

[1] "Artificial Intelligence." *ScienceDaily*, ScienceDaily, 2019, www.sciencedaily.com/terms/artificial_intelligence.htm.

[2] "Smart Data Infrastructure for Wet Weather Control and Decision Support," U.S. Environmental Protection Agency, Washington, D.C., 2018.

[3] Christian "Wolffie" Miller II, Interviewee, *PE: Engineer III Louisville MSD.* [Interview]. 12 March, 2019

[4] Louisville and Jefferson County Metropolitan Sewer District, "Integrated Overflow Abatement Plan." *Integrated Overflow Abatement Plan*, 1 of 3, Metropolitan Sewer District, 2009. msdprojectwin.org/Portals/0/Documents_Extra/IOAP/archive/IOAP_2009-09_30_Volume1/MSD_IOAP_Vol_1_Exec_Sum20090930.pdf.

[5] Joe Sagnis, Interviewee, *Chief Operator of Newburgh, New York Wastewater Treatment Plant.* [Interview]. 19 February, 2019

[6] City of Philadelphia. "Philadelphia Uses Smart Technology to Manage Stormwater Runoff and Reduce Pollution." *Microsoft Customers Stories*, 2 Aug. 2017, customers.microsoft.com/en-us/story/philadelphia-government-azure.

[7] Philip Pickering, Engineering Supervisor of the Philadelphia Water Department. "Philadelphia Uses Smart Technology to Manage Stormwater Runoff and Reduce Pollution." *Microsoft Customers Stories*, 2 Aug. 2017, customers.microsoft.com/en-us/story/philadelphia-government-azure.

Appendix: Case Study Interview Notes

Case Study I: Louisville Notes – Email Responses

Q: What was the perspective of the implementation of a real time control system before implementing? and after implementing? (Was there any skepticism about the program or was it greatly looked forward to)
A: I wasn't around for the original implementation, but from what I've heard there was quite a bit of skepticism from our Operations staff before and immediately following the original implementation of RTC. I get the impression that when management was presenting RTC as "automation" the first thought on the mind of staff was that it would eliminate the need for jobs, when that was not the intention (and is still not the intention) by any means.

Q: How did the implementation of RTC affect how the treatment system is run? (Is there more or less human involvement, are there checks in place to make sure the system is automating the right outputs)
A: For us RTC is used more extensively in the collections system, not the treatment system. Our application of RTC is intended to maximize in-line storage; including recommending pump station effluent flows and modulating gates or dams in order to do so. Operations staff are utilized to maintain the mechanical and electrical components of facilities like normal, but we have additional staff dedicated to the operation and maintenance of the instrumentation and controls required for RTC. The most significant impact to our treatment system is that is allows two of our largest treatment plants to take higher flow for longer duration of time during rain events. And since the system operates in real time, each time step serves as a check to ensure the proper output and implementation at the RTC sites. There are also a variety of alarms programmed that notify of any malfunctions or other conditions that may affect the operations and the system can make appropriate adjustments.

Q: Has RTC made the process easier? (What are some of the benefits as far as recording overflow information and collecting data over an extended period of time)
A: The instrumentation and communications equipment installed at RTC facilities has allowed for a consistent approach to the operation of these facilities and consistent data collection, which promotes consistency and accuracy in reporting. Our RTC system is intended to be fully automated during small storm events, however when larger storm events occur our staff have the ability to put the system in manual mode and operate it remotely.

Q: What would you recommend to change about the system if anything?
A: The RTC system itself is incredibly valuable in its current state and the first items that come to mind when thinking of improvements are related to how we implemented the system originally; for example we could have improved our communications to staff about the original intention of RTC in order to gain more support at the time, and there are certain facility improvements (e.g. gate upgrades) that we could have made earlier that may have reduced some of the stress on our staff dedicated to the operation of said facilities during wet weather. One potential improvement to the RTC system is that the complexity and sheer size of our system has, at times, limited potential options for expansion due to the calculations that are required within the timeframe that we've established for the system to provide set points.

Case Study II: Newburgh Notes - Summary

Q: What was the perspective of the implementation of a real time control system before implementing? and after implementing? (Was there any skepticism about the program or was it greatly looked forward to)
A: Newburgh seemed optimistic to take the next step in improving their systems. Modern technology is better than the older version so of course it will be better.
Q: How did the implementation of RTC affect how the treatment system is run? (Is there more or less human involvement, are there checks in place to make sure the system is automating the right outputs)
A: There is still human involvement because crews go out to the location of the overflow notification to monitor and follow the same procedures as before.
Q: Has RTC made the process easier? (What are some of the benefits as far as recording overflow information and collecting data over an extended period of time)
A: Yes, the process is more accurate and data on the overflows can be recorded and saved.
Q: What would you recommend to change about the system if anything?
A: They seemed satisfied with ho the program is working. If something better comes along they will be accepting and optimistic towards that as well.

Case Study III: Philadelphia Notes - Summary

Q: What was the perspective of the implementation of a real time control system before implementing? and after implementing? (Was there any skepticism about the program or was it greatly looked forward to)
A: Philadelphia seemed optimistic towards the implementation of a real-time control program.
Q: How did the implementation of RTC affect how the treatment system is run? (Is there more or less human involvement, are there checks in place to make sure the system is automating the right outputs)
A: The automated valve controls decreased the need for human involvement to control the discharge from the retention pond.
Q: Has RTC made the process easier? (What are some of the benefits as far as recording overflow information and collecting data over an extended period of time)
A: There is decreased need for human interaction so the program can run by itself. It is much easier.
Q: What would you recommend to change about the system if anything?
A: The program seems to be running exactly how they want it to be.