Combined Sewer Overflow Guidance Document

MOONSHOT MISSIONS

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Prepared by Moonshot Missions

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Below is a list of contributors who played a crucial role in the creation of this document:

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Executive Summary

Combined Sewer Systems were first created as a way to clean off the streets and collect the stormwater runoff, sanitary sewage, and industrial waste in one pipe to be discharged into waterways. Since their creation and the implementation of wastewater treatment facilities to treat the water, utilities have struggled with Combined Sewer Overflows (CSOs), which occur when the pipes reach their capacity from too much stormwater and the combined stormwater runoff, sanitary sewage, and industrial waste were designed to discharge into the waterways, bypassing the treatment plant, to prevent sewage backups into homes and onto streets. As precipitation and storm intensity increase, these CSSs are becoming even more susceptible to overflows and utilities across the country are working on implementing solutions to help prevent CSOs and backups in their communities. The majority of CSSs are located in the Northeast and Great Lakes region, and this document will focus on the specific climate and CSO challenges in the Great Lakes region (EPA, 2024).

The primary goals of this document are to:

1. Provide an overview of sources of CSSs and CSOs.
2. Outline monitoring and planning tools for utilities for CSO reduction.
3. Present a set of strategies and solutions to prevent CSOs.

These tools will be supported with case studies of successful implementation as well as potential funding sources to help reduce the financial impact of implementing solutions.

Chapter 1: Introduction

1.1 CSS Overview

Combined Sewer Systems (CSS) were established in the early days of modern plumbing as a way to collect stormwater runoff, sanitary sewage, and industrial waste all in the same pipe. These pipes were designed to discharge directly into waterways until the establishment of treatment plants in the early 20th century. While these piped systems were an improvement to the open waste ditches or other means of waste disposal that they replaced, they still pose a risk to public health when CSOs occur during heavy rainfall.

CSSs are designed with several discharge locations to allow excess flow beyond the capacity of the pipes to discharge directly into a waterbody during wet weather events. This discharge is referred to as a Combined Sewer Overflow (CSO). These CSOs range in frequency and volume depending on the configuration of the system. Some systems discharge every time it rains while others discharge only during certain storm frequencies.

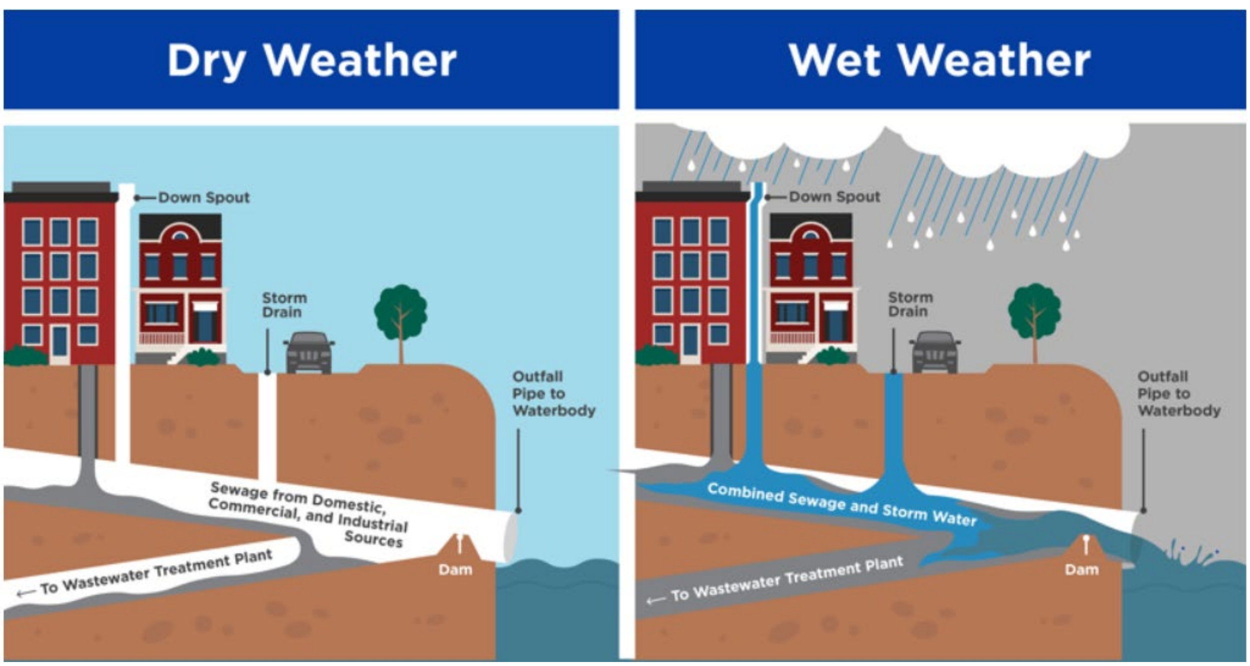

Figure 1. CSS Dry Weather vs. Wet Weather (Source: RVAH20, n.d.)

The EPA guidance and regulations prohibit any CSOs during dry weather flow. No matter the frequency or volume of CSOs, these events can contaminate the water body they are discharged into with pollutants from the roadways or other stormwater runoff, along with a smaller contribution from wastewater, and industrial waste. This contamination can contribute to long term water quality impairments and risk to public and environmental health.

There are approximately 40 million people in 32 states that are served by a combined sewer system with an estimated 850 billion gallons of wastewater discharged annually due to CSOs (Figure 2). These CSOs pose a risk to public and environmental health as they allow pathogens to enter the waterways that are used for recreation, fishing, and drinking water. CSOs may have a significant impact on smaller communities because they often lack the funding or capacity to implement additional storage or other improvements to help prevent CSOs.

Additionally, wet weather can significantly impact those communities with separate sanitary sewers causing separate sanitary sewer overflows (SSO). The majority of communities with CSS also have separate sanitary sewer as part of their collection system. SSOs need to be addressed in conjunction with CSOs as they may have a greater impact on the environment.

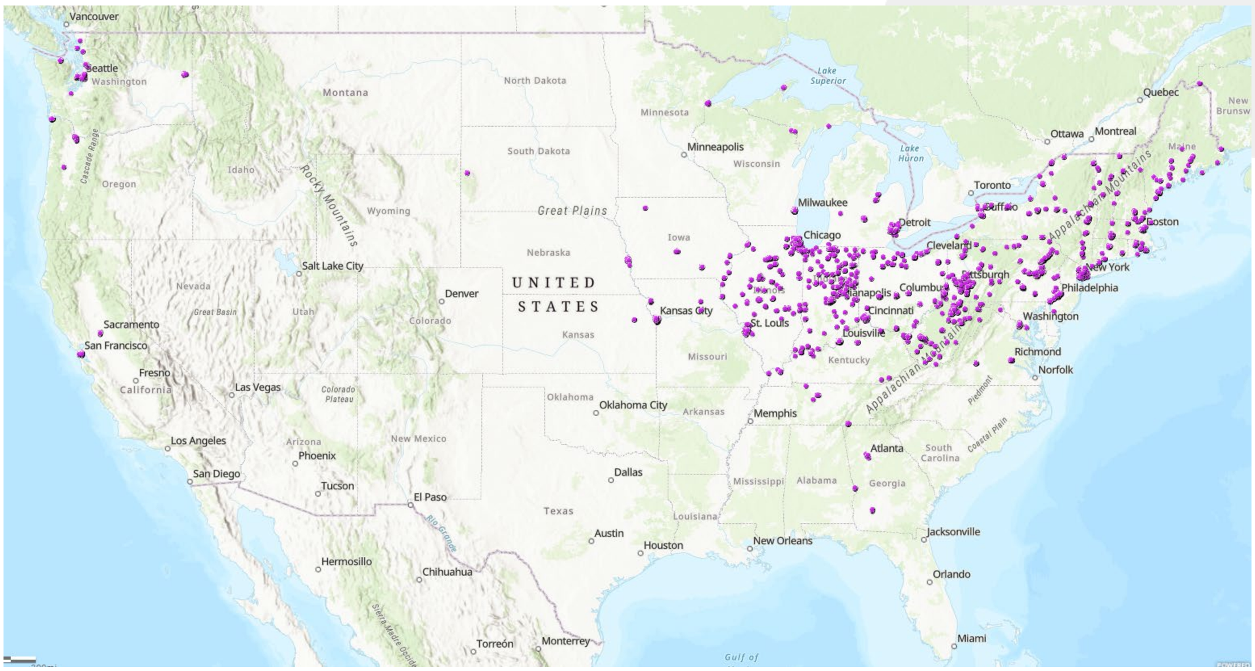

Figure 2. Map of CSS Locations in the US (Source: EPA, 2024)

1.2 CSS in the Great Lakes

Of the approximately 700 communities in the country with CSSs, 158 or 23% are located in the Great Lakes Basin. Lake Erie receives the most discharge from CSO communities with 93 CSSs discharging into the basin.

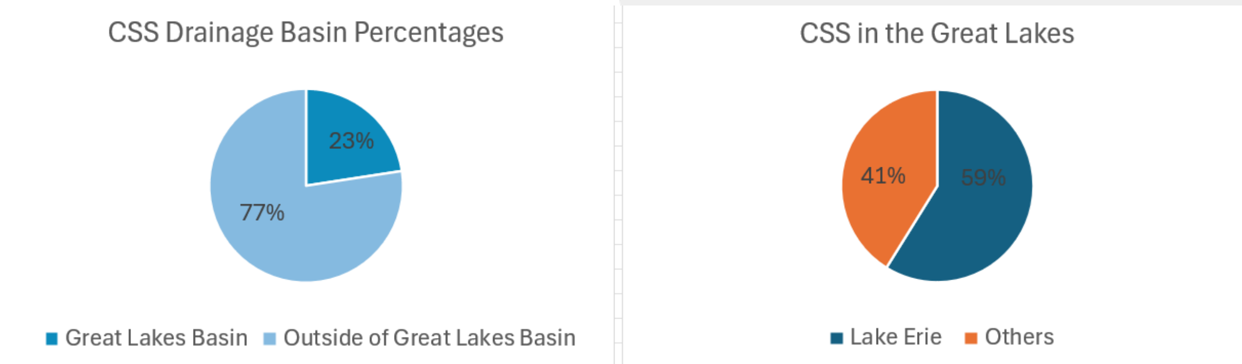

Figure 3. in the Great Lakes Drainage Basin

The 158 CSS communities discharging into the Great Lakes Basin reported approximately 22 billion gallons of untreated wastewater from CSOs and 26 billion gallons of wastewater only treated with primary treatment and disinfection discharged into the Great Lakes in one year (2014). The EPA has published specific Public Notification Requirements for Combined Sewer Overflows to the Great Lakes to help ensure timely notification to the public to help prevent public health risks from the pollutants from CSOs. Because of the major impact that CSOs have on the water quality in the Great Lakes Basin, the EPA also published a Report to Congress in 2016 to summarize the data for each CSS community in the Great Lakes and provide updates on the implementation of the communities' long-term control plans. This report can be found here (EPA, 2016).

The Great Lakes account for 21% of the global freshwater supply and roughly 30 million people rely on it as their source of drinking water and water for agricultural production (EPA, 2016). As an important source of water for so many, the water quality of the Great Lakes is incredibly important to maintain. With an increase in water levels, storm frequency, and storm intensity, the Great Lakes region is subject to an increased number of CSOs and therefore increased levels of pollutants entering the water source from the CSOs (Angel, et. al., n.d.). The Great Lakes have experienced all-time highs in water levels in 2019 and 2020 due to continuous above average precipitation and are projected to rise up to 17 inches in the next 20 to 30 years (Kayastha, 2022). For utilities already struggling to meet capacity during wet weather flows, these projections further threaten the infrastructure and treatment ability of their treatment plants and collection systems.

1.3 CSS Regulations

Efforts have been made to reduce the occurrence of CSOs, including the issuance of the EPA's CSO Control Policy in 1994 as well as updates to permitting and reporting requirements for utilities with a combined system. The CSO Control Policy has two phases to help communities address CSO challenges.

Phase I:

- Communities begin implementing the nine minimum controls which are discussed in further detail in 2.1 Permitting Requirements.
- Develop a Long-Term Control Plan (LTCP) (2.2 Long Term Control Planning)
- Submit the plan to National Pollutant Discharge Elimination System (NPDES) for permitting.

Phase II:

- Maintain the nine minimum controls.
- Implement the LTCP.
- Monitor water quality and report for permit requirements (3.4 Monitoring).

These regulations have helped reduce the CSO volume in the country in half from 2004 to 2020, from 850 billion gallons to approximately 425 billion gallons (EPA, 2024). The EPA estimates that as communities continue to implement and follow their long-term control plans, the CSO volumes will continue to decrease, with a projected 90% reduction by 2045. The EPA estimates that over 95% of CSS communities are in Phase II of the requirements of the CSO Control Policy and are actively implementing and maintaining the controls established in their LTCPs (EPA, n.d.).

Chapter 2: Combined Sewer System Permitting, Planning, and Monitoring

2.1 Permitting Requirements

The EPA created the National Pollutant Discharge Elimination System (NPDES) in 1972 to address water pollution. Part of this program includes the CSO Control Policy, which is a national framework for controlling CSO. All communities with CSSs are required to meet the standards of the CSO Control Policy and must hold a permit to discharge. The CSO Control Policy highlights Nine Minimum Controls that communities are required to implement. These include:

1. Proper operation and regular maintenance programs for the sewer system and CSO outfalls (3.8 Maintenance Best Practices).
2. Maximum use of the collection system for storage (3.2 Storage
3. Review and modification of pretreatment requirements to ensure that CSO impacts are minimized (3.4 Pretreatment).
4. Maximization of flow to the POTW for treatment (3.10 Maximize Wet Weather Treatment Capacity).
5. Elimination of CSOs during dry weather.
6. Control of solid and floatable materials in CSOs (3.4 Pretreatment).
7. Pollution prevention programs to reduce contaminants in CSOs (3.1 Public Outreach and Disconnection Programs and 3.4 Pretreatment).
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts (2.6 Public Notification).

9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls (3.4 Monitoring).

The EPA published a Guidance for Nine Minimum Controls saved here. In conjunction with implementing the Nine Minimum Controls, utilities are required to create a Long-Term Control Pan (2.2 Long Term Control Planning) and submit the information to the NDPES for review and approval. The NDPES review process typically includes the following components:

Figure 4. National Pollutant Discharge Elimination System (NDPES) Review Process

Over 95% of CSS communities have developed and submitted their LTCPs and are in the continued implementation and monitoring phase. This includes continued reporting on the occurrence of CSOs as well as continued water quality monitoring to ensure compliance with the Water Quality Standards (WQS). Monitoring requirements are discussed in more detail in 2 Monitoring below.

2.2 Long Term Control Planning

Phase 1 of EPA's CSO Control Policy requires that utilities develop a Long-Term Control Plan (LTCP) to address CSO challenges and Phase 2 includes the implementation of that plan. The requirements and details of an LTCP vary depending on the system and its challenges. However, all LTCPs should include the following basic components as outlined in the CSO Control Policy as well as incorporating the principles of the Nine Minimum Controls (2.1 Permitting Requirements):

- Characterization, Monitoring, and Modeling of the CSS: Assess the condition of the system to establish a baseline for developing goals and specific controls (2.4.1 CSS Condition).
- Public Participation: Gather input from the public during planning phases and inform the public about CSOs and ways in which they can reduce contribution to CSOs from their property (3.1 Public Outreach and Disconnection Programs).
- Consideration of Sensitive Areas: Identify sensitive areas and give them the highest priority for CSO reduction or elimination in the LTCP. If possible, relocation of the outfalls to sensitive areas is preferred. If this is not feasible, additional treatment of the

wastewater discharging to sensitive areas should be included in the LTCP (3.4 Pretreatment and 3.8 Maintenance Best Practices). As outlined in the CSO Control Policy, sensitive areas include:

- Outstanding national resource waters
- National marine sanctuaries
- Waters with threatened or endangered species or their designated critical habitat
- Primary contact recreation waters
- Public drinking water intakes or their designated protection areas
- Shellfish beds
- Evaluation of Alternatives: Provide a range of alternatives to achieve different goals for CSO reduction (Chapter 3: Combined Sewer Overflow Solutions). These can include specific goals for a reduction in the number of events or a reduction in the volume during wet weather events.
- Cost/Performance Considerations: Conduct a cost-benefit analysis on the identified alternatives. This should help in decision making by estimating the cost per unit of CSO reduction.
- Operational Plan: Include operating procedures for facilities to be implemented under the LTCP as well as an overall operating strategy for the utility to optimize CSO reduction. Examples of Maintenance Best Practices are included in (3.10 Maximize Wet Weather Treatment Capacity).
- Maximizing Treatment at the Existing Treatment Plant: Include a plan to implement necessary repairs or upgrades to optimize the volume of flow retained and treated at the plant (3.10 Maximize Wet Weather Treatment Capacity).
- Implementation Schedule: Provide a phased implementation schedule for the identified CSO reduction activities. This schedule should prioritize sensitive areas as well as take into consideration potential funding schedules and financial capacity.
- Post-Construction Compliance Monitoring Program: Provide a monitoring plan to track compliance and assess the effectiveness of CSO controls. Compliance determination should consider both demonstrative and presumptive approaches to defining overflows. This includes evaluating whether primary treatment and screening have been provided, which may impact whether an event qualifies as an overflow. Clear compliance criteria will help utilities assess progress toward CSO reduction goals. More details on compliance assessment can be found in Section (3.4 Monitoring).

An EPA published Guidance for Long-Term Control Plans with more details on the implementation of the plans can be found here (EPA, 1995).

2.3 Integrated Planning

Integrated planning was developed by the EPA to help municipalities coordinate and optimize projects across multiple Clean Water Act obligations, including CSOs, stormwater management (MS4), and wastewater treatment improvements. It takes a holistic approach to prioritizing wastewater and stormwater management projects while ensuring compliance with regulatory requirements. Integrated planning became a necessary tool as the cost of CSO LTCPs escalated and schedules began to extend out past deadlines across the country, It also facilitated the inclusion of green infrastructure and alternative technologies to existing CSO consent decrees and their LTCPs.

This approach coordinates multiple projects simultaneously to maximize cost-efficiency, streamline construction efforts, and minimize environmental impact. Instead of addressing one goal or solving a single issue at a time, integrated planning allows utilities to evaluate trade-offs determine priorities, use of triple bottom line analysis, project scheduling and implement solutions that tackle multiple challenges concurrently. This process is essential in determining affordability for all Clean Water Act obligations.

The EPA has developed a step by step guide for integrated planning which consists of six elements (U.S. Environmental Protection Agency, 2021):

- Element 1: Describe Relevant Requirements and Drivers
- Element 2: Characterize Existing Wastewater and Stormwater Systems
- Element 3: Make Connections with Stakeholders
- Element 4: Develop, Evaluate, and Select Preferred Alternatives
- Element 5: Measure Performance
- Element 6: Adapt for Success

By following this structured approach, municipalities can develop more efficient, cost-effective solutions that improve water quality while balancing regulatory obligations and community needs. A detailed breakdown of the EPAs integrated planning framework can be found here.

While LTCPs are a critical component of addressing CSOs, integrated planning can play a vital role in supporting projects related to LTCPs. It takes a broader approach and can help utilities leverage their LTCP projects while incorporating additional solutions that improve stormwater management, wastewater treatment plant upgrades, and community enhancements. Integrated planning also provides regulatory flexibility by allowing municipalities to phase in projects based on affordability and environmental impact rather than meeting rigid compliance deadlines. As a Clean Water Act obligation, drinking water should be included in the integrated planning activity, especially in the affordability impact. The impact on user rates need to include wastewater (including wet weather CSO), storm water and drinking water. This approach can also help when securing funding by bundling multiple projects together. Some examples include:

- Incorporating green with gray infrastructure to enhance performance and sustainability
- Including asset management needs of the utility or organization.
- Implementing real-time control (RTC) systems to dynamically manage flows and reduce CSOs.

- Reducing inflow and infiltration (I&I) while improving combined sewer system (CSS) performance.
- Leveraging community organizations and funding sources to support multiple projects simultaneously.
- Aligning CSO reduction projects with wastewater treatment plant upgrades to increase wet weather capacity.
- Consideration of drinking water needs.

Integrated planning is also a great way to include stakeholder engagement, ensuring that infrastructure investments align with community priorities while providing long-term environmental and public health benefits. Some benefits include (ArcGIS StoryMaps, n.d.):

- Faster water quality improvements and health protections.
- More cost-effective and affordable infrastructure investments.
- Consideration of investments that support community objectives.
- Innovative long-term solutions that reduce pollution sources rather than just controlling or treating discharges.
- Consideration of triple bottom line analysis to include environmental, economic and social criteria.
- Critical tool in negotiations with regulators over existing and new consent decrees.

By leverage resources across multiple avenues, integrated planning helps utilities prioritize investments while also fostering collaboration among stakeholders to drive long-term, sustainable infrastructure improvements.

The use of triple bottom line is a critical element of the integrated planning to determine the most cost-effective solutions from a holistic approach to the individual project level. It can also identify early action projects with significant cost-benefit relationships.

For case studies showing integrated planning in action, see here.

2.4 Monitoring

Monitoring CSO in a CSS system is an important step for utilities to take when working to address CSOs. Quantifying the volume of CSOs and understanding their impact on the waterways can help utilities in planning CSO reduction activities and are required to track the success of those reduction activities for permitting. The EPA has published a guide with additional details on monitoring and modeling found here (EPA, 1999). Significant advances have been made in the modeling world since the publication of this document. This modeling guide should only be used as a general reference.

Modeling is the most critical element of determining CSO controls, performance and regulatory compliance.

2.4.1 CSS Condition

As utilities continue to maintain and update their LTCPs, they need to understand the condition of their system and the specific problems they are looking to address. Characterization and monitoring of the condition of CSSs systems can include:

- Review of historic sewer system data (maps, plans)
- Survey and digitization of the pipe system
- Review of historical CSO and rainfall data
- Continued monitoring of current flow and CSO volumes
- Modeling of the system

See Appendix B for a list of recommended modeling tools and software.

Utilities can also monitor the condition of private sewer laterals and other potential private connections to the system through public outreach and pipe check programs (3.1.6 Pipe Check Programs).

If sewer separations are considered as a control technology, extensive study needs to be made of the private laterals in the system, including but not limited downspout connections, sump pumps, yard drains, parking lot drains, etc. Private sewer laterals can contribute a significant amount of wet weather flow and removal can be very costly and politically challenging.

2.4.2 CSO Volume

Utilities are required to track and report the estimated volume of CSOs that are discharged into the receiving waterways. Utilities can also track flow trends throughout the system to understand its response to wet weather events. There are a number of ways in which a utility can collect this information including:

- Flow monitoring at CSO outfalls
- Flow monitoring within the collection system
- Flow monitoring at the treatment plant

Other parameters can be collected to help utilities track their CSOs including:

- Flow level
- CSO event duration

Smart flow monitoring devices are discussed more in (3.8.2 Flow Monitoring and Data Analysis) and can be used to track CSO volumes at the outfall and throughout the collection system.

Other flow related data that can help determine the effectiveness of the implemented CSO controls include: number of dry weather overflows, number of CSO outfalls eliminated, and frequency of CSOs.

2.4.3 CSO Water Quality Impacts

Utilities with CSSs may be required to track and report water quality data to show the effectiveness of CSO controls and understand CSO impacts on the receiving waterway. This information should be collected in dry and wet weather conditions to compare pollutant loads and assess the effects of CSOs on water quality. The Post-Construction Monitoring Plan (PCMP) may also incorporate biological and hydraulic monitoring to evaluate the long-term health of receiving streams. This approach allows for an alternative assessment of biological stream health as a measure of meeting performance requirements.

The selection of sampling location is important and should consider other pollution sources, sensitive areas, and flow patterns. Where feasible, sampling should take place at:

- Upstream/Downstream of the CSO
- Upstream of the study area
- Downstream of other point source pollutants
- Upstream of tributaries
- At the mouth of tributaries
- Downstream end of the study area

Sampling requirements will be based on specific NPDES permitting requirements but the following parameters are likely required for CSS systems:

- Bacteria
- TSS
- BOD and DO
- pH
- Nutrients (phosphorus, nitrogen)
- Metals

Resources and tools for efficient sampling and monitoring are included in Appendix C.

2.5 Post-Construction Monitoring Plans

Post-Construction Monitoring Plans (PCMPs) are essential for evaluating the effectiveness of implemented projects and control measures outlined in the Long-Term Control Plan (LTCP). They ensure regulatory compliance and monitor impacts on receiving streams. A PCMP serves as a detailed protocol specifying water quality parameters to be sampled, sampling locations, and monitoring frequency. This information is vital for assessing current upgrades and ensuring they continue to meet the LTCP's intended outcomes, preserving water quality for environmental and public health protection. Typically, utilities collaborate with the National Pollutant Discharge Elimination System (NPDES) permitting authority to determine the parameters to be monitored. Developing a PCMP to compare pre- and post-construction metrics can be broken down into the following steps:

1. Purpose and Objectives

Clearly define the goals of post-construction monitoring, such as verifying compliance with regulatory requirements, assessing the effectiveness of control measures, evaluating water quality improvements in receiving streams, and identifying necessary operational adjustments.

2. Regulatory Requirements and Compliance Metrics

Ensuring regulatory compliance is a critical aspect of CSO upgrades. Regulatory requirements are typically outlined in the utility's NPDES permit and may include metrics such as pre- and post-construction CSO frequency and volume comparisons, water quality parameters (e.g., dissolved oxygen, total suspended solids, E. coli), and chemical and biological monitoring of receiving streams.

3. Monitoring Locations and Sampling Plan

Identify key monitoring locations, including CSO outfalls, affected receiving waters, upstream and downstream sites from discharge points, and areas pertinent to public health and environmental concerns, such as drinking water sources or recreational sites. Establish sampling frequency and duration to ensure that current upgrades meet water quality standards and to monitor long-term performance, addressing any unintended consequences and verifying the durability of control measures over time.

4. Data Collections and Parameters

Flow monitoring and rainfall data are essential to track CSO discharge volumes and durations. Specific water quality parameters will likely be outlined in the NPDES permit but a more detailed breakdown of those parameters can be found in section (2.4.3 CSO Water Quality Impacts).

5. Monitoring Methods and Equipment

Outline appropriate sampling methods and flow measurement technologies based on their specific locations, such as automatic samplers, manual sampling, flow meters, rain gauges, and other relevant water quality sensors. Additionally, conduct and document field observations and visual assessments.

6. Data Evaluation and Reporting

Utilize the collected data to establish baseline trends from the pre-construction period and compare them with long-term trends over time to analyze performance and water quality. The utility's NPDES permit will outline a reporting schedule for regulatory purposes. Gathering additional data beyond NPDES requirements can be beneficial for the utility to gain a comprehensive understanding of system operations.

7. Stakeholder Involvement and Public Communication

Given the significant impact of CSOs on public safety and the environment, it is important to identify key stakeholders and collaborate with them to achieve optimal system performance. Keeping the public informed about CSO occurrences and their water quality impacts is crucial. Conducting public meetings to communicate CSO-related activities and gather feedback is vital for leveraging resources and making informed decisions.

8. Contingency Plan for Non-Compliance

Outline corrective actions to be taken if CSO upgrades do not meet intended performance goals. The utility should have a backup plan to enhance operational procedures and prepare for future events.

2.6 Public Notification

Public notification of CSOs is one of the Nine Minimum Controls and is required as part of NPDES permitting. Timely public notification is important to mitigate health risks by keeping the public out of the waterways for recreational or fishing purposes. An effective public notification system includes:

- Signage
- Initial direct notification
- Follow-up or supplemental notification
- Annual notice

Signage should always be up to mark CSO discharge locations and potentially impacted areas. The signage may include information about the permittee, permit number, and contact information of someone who can answer any questions related to the CSO. The signage should also include that a portion of the storm water discharge contains treated wastewater and/or untreated human sewage during CSOs.

Initial direct notification should take place no less than four hours after becoming aware of a CSO occurrence. Notification should be sent to the local and/or state health department and to any other public entities that may be affected. Notification should also be sent directly to the public through social media, text, email, and/or notice on the utility's website. The initial notification should include:

- Location of the discharge and potentially affected areas
- Receiving waterbody
- Date and time that the discharge started
- Status of the discharge at the time of notification (continuing or ended)
- Contact information

Follow-up or supplemental notification should occur within a week of when the discharge has ended. The electronic notification should be updated to include the amount of discharge and the approximate time that it ended.

Annual notification is required by a specific date depending on permitting requirements and should include the following information:

- Location of each CSO discharge point and a description of any treatment provided
- Information on each CSO discharge (wet or dry weather) event (date, location, duration, volume, cause)
- Summary of available data
- Public access areas that may have been affected
- Precipitation data
- Contact information
- Summary of the CSO control activities implemented

A full guide for public notification of CSOs in the Great Lake Basins that was published by the EPA is available here (EPA, 2018).

Chapter 3: Combined Sewer Overflow Solutions

3.1 Public Outreach and Disconnection Programs

One of the most important and effective ways to address CSOs is to educate the public and raise awareness about the significance of such events. This is crucial for several reasons:

- Helps the public better understand and practice water stewardship.
- It makes it easier for utilities to gain public support when proposing large capital projects and rate increases.
- Enhances environmental and public health protection by fostering community-wide efforts to mitigate pollution.
- Encourages a collaborative alliance with the public, motivating property owners to take proactive steps to help reduce the impacts of CSOs on their own properties.

A significant portion of the water entering the collection system during wet weather events often originates from private property connections. By working with property owners to address these connections and implement improvements, utilities can achieve meaningful reductions in CSO occurrences.

3.1.1 Engagement

Consistent public engagement between the utility and the community is an effective way to bridge the information gap and create awareness about CSO system upgrades. Maintaining a strong public relations narrative—through news articles, television interviews with utility officials, or community newsletters—helps keep the public informed and up to date. Another effective approach is utilizing social media platforms to consistently share information about the utility's operations, ongoing efforts to control CSOs, and ways residents can contribute. This is particularly important during wet weather events when sewer capacity is limited, and reducing water use becomes critical.

In addition, some utilities offer automatic text alerts that customers can subscribe to, providing real-time updates on water reduction recommendations during wet weather events. Hosting community workshops, open houses, or educational events can further engage the public, creating a space for questions, feedback, and collaboration. Interactive tools, such as web-based dashboards displaying the current sewer system status and overflow risks, can also help increase transparency and build trust. Partnering with schools, local organizations, and community leaders can amplify outreach efforts and encourage broader participation in CSO mitigation initiatives.

One of the most important messages to convey to the public is that everyone plays a role in reducing CSOs. By actively engaging and contributing, the community can help minimize CSO events, reduce potential utility bill increases, and foster cleaner, more resilient local waterways. Promoting this sense of shared responsibility and mutual benefit can enhance public commitment to these initiatives.

3.1.1.1 Non-Profit Partnerships

Partnering with local non-profits, such as river keepers, urban sustainability organizations, environmental advocacy groups, local and regional park systems and community development organizations, can be a highly effective way to enhance public outreach and education about CSS. Additionally, collaborating with these organizations can help secure funding for shared goals, such as implementing conservation programs related to rain barrels and green infrastructure. Community-based non-profits also serve as valuable partners for gathering feedback from diverse stakeholders and ensuring that equity is prioritized in program development and implementation.

3.1.2 Updated Municipal Rules and Regulations

Municipalities can also eliminate private connection to the sanitary system through updating the sewer use ordinance rules and regulations for utility customers. Steps for updating and enforcing the new regulations are below:

1. Adopt new regulations through the utility and municipal government. These should include requirements under the new regulations (i.e., disconnecting applicable downspouts, installing a rain barrel, etc.). These regulations should also specify the areas they apply to, such as homes within a combined sewer system (CSS) or separate sanitary sewer areas where downspout and sump pump disconnections provide the greatest benefit. Additionally, consideration should be given to the potential political challenges of requiring

connection removals, as some connections may have been legal at the time of installation. Municipalities may need to explore financial assistance options to support homeowners in complying with these regulations.

2. Enforce new regulations. Municipalities can enforce and implement changes based on the new regulations through offering incentives or strictly through public outreach. If funding is available, the municipality can offer free disconnection services for a period of time to keep homes compliant with the new rules and regulations. If funding is not available, municipalities can inform the residents of the new rules and regulations and offer a period of time for them to make the appropriate changes.
3. Continued enforcement. Implementing rules and regulations against private connection to the sewer system will also benefit the municipality for future development and will prevent new connections from being made.

3.1.3 Rain Barrel Programs

Rain barrels are an effective way to reduce household water consumption and manage small amounts of stormwater runoff. While they can help divert some stormwater from entering the sewer system, their impact on reducing combined sewer overflows is minimal, particularly during large wet weather events.

Many private downspouts are connected to sanitary collection systems, increasing inflow to those systems. Implementing a rain barrel program and encouraging property owners to disconnect downspouts and redirect stormwater can still help reduce inflow and infiltration from private property. Additionally, rain barrels provide benefits to homeowners by reducing stormwater runoff that can contribute to localized flooding and lowering water consumption for irrigation.

Utilities can offer a variety of programs and/or initiatives to help encourage the usage of rain barrels throughout their systems. Options for programs and initiatives include:

- Programs:
  - Send informational pamphlets to residents with information on rain barrels and I&I. An example of a rain barrel care guide can be found here
  - Host education programs at community meetings or festivals to educate the community on rain barrels and their benefits
- Initiatives:
  - Stormwater fee discount if rain barrel is installed
  - Discount on stormwater fee equal to the cost of a rain barrel

Table 1. Advantages and Disadvantages of Rain Barrel Programs

Advantages	Disadvantages
Helps homeowners by reducing water consumption and potentially reducing stormwater runoff that could flood their property.	The amount of I&I reduced depends on the number of households willing to participate in the program.

Reduces the amount of I&I that enters the system from private properties.	Relies on public participation and upkeep.
Once the rain barrels are installed, there is limited cost or oversight needs for the utility.	Need to make sure that any overflow from the barrel is directed back into the downspout and not down the driveway or onto the neighbor's property.

3.1.4 Sump Pump Disconnection Program

Sump pumps are a primary source of inflow and infiltration from private property. While many sump pumps are connected to combined sewer systems, some connections may have been legally installed at the time of construction. However, these connections can increase unnecessary and preventable inflow into the collection system, raising the likelihood of overflows.

Municipalities can offer sump pump disconnection programs that provide various incentives, including:

- Free televised inspection of sewer lateral if joining the program
- Fully or partially paid disconnection of sump pump from the sanitary sewer
- Free sump pump inspections to determine compliance

Depending on the level of incentives and the structure of the sump pump disconnection program, an alternative approach could involve a reimbursement or credit program in which the property owner hires the contractor directly, rather than requiring the utility to perform work on private property. Other lower-cost disconnection programs can focus on public education initiatives to inform homeowners about the benefits and process of disconnecting sump pumps from the sanitary sewer system.

If the utility has the capacity, it can also be beneficial to conduct a full survey of sump pumps within their collection system and document those that are out of compliance. This can help utilities with potential permit requirements or help them budget for implementing a disconnection program.

3.1.5 Downspout Disconnection Program

Downspouts are another source of I&I from private properties that can increase the volume of I&I in the system. During heavy rain, each downspout on a home can send approximately 12 gallons per minute of water to the system it's connected to (Milwaukee Metropolitan Sewerage District, n.d.). Some downspouts are connected directly to the CSS while others drain onto paved surfaces that can eventually enter the CSS through indirect stormwater inflow. This runoff can increase the likelihood of a CSO. Downspout disconnection programs encourage residents to redirect flow from their roofs and downspouts to the following options:

- Rain barrels or other storage tanks
- Green lawn or garden spaces

Not all downspouts will be able to be disconnected and redirected so municipalities should enforce the following requirements for a downspout disconnection program:

- There should be sufficient green space or a rain barrel for the downspout to be redirected to
- New discharge location should be at least 5 feet from property lines or foundation walls
- Not at risk to increasing icy conditions in winter weather
- Discharge onto own private property and not onto public property or other private property
- Discharge to a level surface as to not increase risk of erosion

3.1.6 Pipe Check Programs

Many homeowners are unaware that they are responsible for the sanitary sewer lateral from their home and are therefore likely unaware of potential issues with their lateral. Unknown connections to the lateral or cracks in the pipe caused by roots or other structural problems could be leading to flooding in their basement and contributing to I&I and potential CSOs in the collection system. To raise awareness of the public's responsibility for their lateral and to help them assess and fix potential issues, utilities can implement pipe check programs. These kinds of programs can include a wide range of incentives for participation including:

- Discount on the utility bill
- Utility can pay for portion of any work required based on pipe inspection

Through the program, homeowners can choose through a list of utility-approved contractors to conduct an inspection of their home's lateral. Following the inspection, the contractor will provide information on the required repairs and depending on the incentives offered by the program, will inform the homeowner of the amount they are due. Once the work is completed, the homeowner will pay their portion and the utility will pay the rest or will provide a discount to the utility bill, depending on how the program is set up. For more information on a successful pipe check program, follow this link to the Milwaukee Metropolitan Sewerage District website.

3.2 Storage

Because CSOs occur when the collection system has reached full capacity, adding storage for the additional flow during wet weather events can help prevent or reduce the volume or frequency of CSOs. One of the nine minimum CSO controls that are enforced using the CSO Control Policy is the maximization of storage in the collection system. The storage capacity can be increased through in-line or offline storage methods such as pipe cleaning and maintenance or retention basins or tanks.

3.2.1 In-Line Maintenance Storage

Storage limitations within the pipes of a collection system are often due to obstructions downstream of the point of question. Methods as simple as cleaning out the pipes regularly can help increase the storage capacity. Additional measures as recommended by the EPA in this fact sheet include:

- Regular inspection and removal of obstructions
- Maintenance, repair, cleaning, and replacement of gates
- Upgrade, repairs, and/or adjustment of pumps
- Continued monitoring

These methods can all be included in a regular sewer maintenance plan to enforce the regular inspection, cleaning, and maintenance of the lines to allow maximum storage (EPA, 1999). For a more detailed breakdown on maintenance best practices see (3.8 Maintenance Best Practices).

3.2.2 Retention Basins

Retention basins can be installed in-line or offline in a collection system. In-line basins are typically less costly to install since they do not require additional piping to divert and pump the flow but offline basins can offer more storage capacity depending on the location.

Offline retention basins can be covered or uncovered but are typically covered for better odor control and safety. These basins can also be located upstream or downstream of the combined sewer system depending on the locations available and the storage capacity needed. Offline retention basins require the following components:

- Parallel lines to divert the flow from the main lines in the collection system to the basins for storage.
- A basin sized for the design criteria (more information on sizing is included below)
- Flow control downstream of the diversion or at the retention basin outlet to regulate the flow in and out of the basin to prevent problems from too much volume in the storage
- Provide provisions to drain the storage basin in 24-28 hours after the event to prevent odor issues. Several tank cleaning methods are available such as tipping buckets and flushing gates. Properly drained and cleaned tanks may eliminate the need to cover the basins.
- Gravity-in and gravity out are the ideal situation for operating a storage tank. Although not always possible to have both, gravity-in is the preferred situation to prevent excessive pumping requirements.

Retention basins should be designed to not only reduce the occurrence and volume of CSOs, but also to optimize the treatment of flow at the receiving wastewater treatment plant.

Therefore, the sizing of retention basins should be based on the treatment capacity of the plant compared to the expected wet weather flows as well as factors such as the desired reduction in CSO volume and/or CSO occurrences.

The runoff estimated from these models or others like them can be added to estimated sewer flow from the users in the area to determine total flow expected during certain storm return intervals. This total can be compared to the treatment plant capacity for the approximate volume of additional storge needed in the system.

The retention time of flow in the retention basin is another important design factor to consider. Flow control in the retention basin helps keep the volume in the tank from going septic, keeps the basin from overflowing, keeps solids from accumulating, and can help keep untreated water from being discharged into the receiving waters. Flow can be controlled with fixed or moveable devices downstream of the diversion or at the outlet of the retention basins. Because the flow from combined sewage can become septic if the wastewater is held for a long period of time, a utility might consider aerating the retention basin if the conditions of the system do not allow discharge in a timely manner.

3.2.3 Underground Tunnels

Offline underground storage tunnels are installed often parallel to the existing system to divert and store some of the flow volume that would otherwise be sent through the collection system. These tunnels are designed to hold a certain capacity during targeted storm events and then release the flow back into the system for treatment after the rain event is over. These are often installed starting at a diversion structure at a CSO outfall and convey the water to a pump station (if gravity is not an option) that will then pump the water back into the system when ready. The discharge end of the tunnels should also be equipped with an outfall to allow flow release during storm events above the design flow. Additionally, underground tunnels can also be used to convey dry and wet weather flow if the existing sewer interceptor needs repair or replacement. While underground storage tunnels are extremely effective at reducing the number of overflows, they are a major capital improvement undertaking and are costly to install.

3.3 Stormwater Fee

Since stormwater must be treated as regular sewage in CSSs, it is important that property owners pay their fair share and that costs are distributed equitably. Stormwater fees are typically calculated based on the area of impervious surface a property has. Most utilities that implement a stormwater fee use a measurement called an Equivalent Residential Unit (ERU) to standardize calculations across property types.

An ERU defines a specific unit of impervious surface area, typically based on the average impervious surface of a residential property. Since most single-family homes have similar impervious surface areas, utilities often classify single-family homes as 1 ERU. The use of multiple ERUs becomes more relevant for large industrial and commercial properties that have significantly more impervious surface. This approach enables municipalities to assess fees fairly by considering each property's contribution to stormwater runoff.

While the size of an ERU varies by city, it is generally around 2,000 square feet. Steps to determine and calculate an ERU are outlined below:

1. Calculate the Average Impervious Area:
    - Measure the impervious surface area in square feet for each property in the service area.
    - Add up all impervious surface area for the service area.
    - Divide the total impervious surface area by the number of properties in the service area to determine the average impervious surface area (ERU).

ERU Size (sq. ft.) = Total Impervious Area of Sample (sq. ft.) / Number of Properties in Service Area

Example:

- Total impervious surface area for 100 properties = 250,000 sq. ft.
- Number of properties = 100
- ERU Size = 250,000 / 100 = 2,500 sq. ft.

2. Apply the ERU
    - Measure the total impervious surface area for the property and divide by the ERU size to determine the number of ERUs.
    - Number of ERUs = Total Impervious Area of Property (sq. ft.) / ERU Size (sq. ft.)

Example:

- A commercial property has 10,000 sq. ft. of impervious surface.
- ERU size = 2,500 sq. ft.
- Number of ERUs = 10,000 ÷ 2,500 = 4 ERUs.

3. Determine the Fee
    - Multiply the number of ERUs by the utility's fee rate per ERU to calculate the stormwater fee.
    - Stormwater Fee = Number of ERUs × Fee per ERU

Example:

- Fee per ERU = $10/month
- Non-residential property assigned 4 ERUs
- Stormwater Fee = 4 × $10 = $40/month.

Stormwater fees can also be used to engage customers in reducing stormwater runoff by encouraging participation in green infrastructure projects or downspout disconnection programs. Utilities often offer discounts or credits on stormwater fees to incentivize actions like installing rain barrels, green roofs, or permeable pavements. These measures help customers reduce their contributions to CSOs and assist the utility in increasing system capacity during wet weather events.

Many utilities also implement tiered fee structures to promote equity. Under this model:

- Customers with lower income levels or properties with minimal impervious surfaces pay lower fees.
- Properties with larger impervious areas are placed in higher tiers and charged more, reflecting their greater contribution to stormwater runoff.

By aligning stormwater fees with property characteristics and incentivizing sustainable practices, utilities can fairly distribute costs, engage the community, and mitigate the impact of CSOs. For an example of a stormwater fee tiered based credit program see Northeast Ohio Regional Sewer Districts Stormwater Fee Credit Policy Manual.

3.4 Pretreatment

An effective way to reduce the impacts of CSOs is to employ pretreatment before the water is discharged into local waterways. Since the majority of CSO discharge consists of clear water, primarily a result of wet weather events, pretreatment methods such as screening to remove debris and large inorganic materials, as well as applying a disinfectant can significantly minimize their environmental impact.
While nutrients are more challenging to remove during pretreatment due to the need for biological or chemical processes, the diluted nature of CSOs during wet weather often results in lower nutrient concentrations compared to untreated sewage. However, CSOs still pose risks due to the presence of pathogens, organic pollutants, and other contaminants.

3.4.1 Inorganic Removal

Removing inorganic materials is crucial for reducing the impacts of CSOs as these materials, such as plastics, metals, and other debris, do not degrade naturally and can pollute waterways, posing risks to the environment and communities.

3.4.1.1 Netting and Screening

Physical bar screens are highly effective when installed at overflow points to prevent large debris from entering waterways. In some cases, automatic bar screens are used to continuously collect and remove debris, ensuring maximum hydraulic capacity during CSO events. While these systems are highly effective, they are also more expensive to implement and often require significant structural modifications to overflow points.

As a more cost-effective alternative, netting can be installed at overflow points. Although netting is not as precise or efficient as bar screens, it can still play an important role in reducing the discharge of large debris. It should be noted that netting technologies may have excessive maintenance requirements, especially if your system has a significant leaf load in the fall.

3.4.1.2 Grit Removal

Grit removal is another effective way to reduce the impact of CSOs. In addition to being used as pretreatment at WWTPs, grit can be removed throughout the collection system before reaching overflow points. This is often implemented at lift and interceptor stations, frequently in conjunction with screening systems, typically using an inline method.

In larger CSS, grit traps or high-rate filtration systems are commonly utilized at overflow points. Furthermore, grit removal technologies are often employed in CSO storage tanks or basins, typically through the use of grit traps or separators.

3.4.2 Disinfection

Disinfection is one of the most common methods used to mitigate the impacts of CSOs. As a critical component of the pretreatment process, it focuses on reducing pathogens to protect public and environmental health. Traditional methods, such as chlorination, often require significant infrastructure and land space to ensure adequate retention times. In contrast, newer technologies like ultraviolet (UV) disinfection and peracetic acid offer faster, more compact solutions that can be implemented more efficiently. These advancements are making disinfection more adaptable to the variable flow conditions typical of CSOs, while also addressing space and operational constraints.

3.4.2.1 Chlorination

Chlorination is one of the most traditional methods of disinfecting wastewater, but it can be challenging to employ as a CSO pretreatment method. Chlorine is added in either gas or liquid form to inactivate pathogens. After chlorine is added, it requires a specific detention time to achieve effective disinfection. Following this, a dechlorination chemical, typically sodium bisulfite, is added to neutralize the chlorine, ensuring it does not pose a threat to aquatic or human life downstream.
While chlorination is one of the most proven and widely used methods of disinfection, it requires significant space and infrastructure to provide the necessary detention time. Additionally, the process is prone to human error, as constant monitoring and dosage adjustments are required for both chlorination and dechlorination. This can be particularly challenging for CSOs, where flow rates can fluctuate rapidly depending on the severity of the wet weather event. Chlorination also brings a significant public safety concern as many CSO location are in remote and/or residential areas.

Table 2: Chlorination Treatment Summary

Contact Time	10–30 minutes or more
Infrastructure	Large footprint: Requires storage tanks for chlorine, detention tanks for contact time, and dechlorination systems.
Residuals	Leaves residual chlorine; requires dechlorination (e.g., sodium bisulfite).
Flow Variability	Requires careful monitoring and adjustments during flow changes.
Environmental Impact	Potentially harmful byproducts.

3.4.2.2 UV Light

UV light is one of the safest and most efficient forms of disinfection. It uses high-intensity UV rays to damage the DNA of pathogens, rendering them unable to reproduce and cause harm to the environment or humans. The intensity of the light can be adjusted based on the strength of the pathogens and the required dose, while retention time is closely monitored to ensure adequate disinfection. This can be challenging in CSSs, where flow rates fluctuate significantly. Unlike chemical disinfectants such as chlorine, UV disinfection does not involve the use of chemicals or require a neutralizing agent, making it an environmentally friendly option.

Table 3: UV Light Treatment Summary

Contact Time	Minutes
Infrastructure	Moderate footprint: Requires UV reactors (clearwater chambers), power systems, and regular lamp cleaning equipment.
Residuals	No residuals: disinfection occurs during exposure only.
Flow Variability	Requires light intensity and flow adjustments to ensure adequate retention time. Sensitive to water clarity requires pre-treatment for high turbidity.
Environmental Impact	No byproducts; environmentally safe.

3.4.2.3 Ozone

Ozone is a gaseous disinfectant used to oxidize and destroy pathogens effectively. It is highly efficient and works rapidly, making it suitable for treating CSOs. However, its high reactivity and toxicity require stringent safety measures.

Table 4: Ozone Treatment Summary

Contact Time	Minutes
Infrastructure	Moderate to large footprint: Requires ozone generators, contact chambers, and off-gas destruction units.
Residuals	No residuals: ozone decomposes quickly.
Flow Variability	Handles variability well with proper design.

Environmental Impact	Can produce byproducts and reduce DO in receiving waters.

3.4.2.4 Peracetic Acid (PAA)

PAA is a strong oxidant that is applied in liquid form. It acts similarly to chlorine but does not require additional chemicals for neutralization, making it more environmentally friendly. PAA also requires a short contact time, which makes it much more efficient. In addition, it also has a long shelf life.

Table 5: Peracetic Acid Treatment Summary

Contact Time	Minutes
Infrastructure	Small footprint: Requires dosing equipment and storage tanks for PAA.
Residuals	No harmful residuals; breaks down into acetic acid, oxygen, and water.
Flow Variability	Handles variability well due to rapid disinfection.
Environmental Impact	No harmful byproducts.

3.4.2.5 Advanced Oxidation Processes (AOPs)

AOPs are chemical treatment methods that generate hydroxyl radicals, which are highly reactive and effective against pathogens and organic contaminants. These radicals are typically produced using combinations of oxidants and energy sources, such as ozone, UV, and hydrogen peroxide. Depending on the specific application, AOPs may utilize one or more of these components in different configurations.

Table 6: Advanced Oxidation Processes Summary

Contact Time	Minutes
Infrastructure	Large footprint: Requires reactors, UV or ozone generators, and hydrogen peroxide storage tanks (if applicable).
Residuals	No residuals: hydroxyl radicals are short-lived.
Flow Variability	Effective under variable flows with proper system design.
Environmental Impact	Minimal environmental impact; highly effective pollutant removal.

3.5 I&I Reduction

I&I reduction programs can apply to both separated and combined sewer systems. Reducing the amount of I&I entering a CSS can reduce the overall volume of flow in the system and can help prevent or reduce the amount of CSOs.

3.6 Separation

Sewer separation is the most effective method for reducing CSOs. By creating two distinct systems—one for sanitary sewage and another for stormwater—utilities can completely eliminate the possibility of CSOs if the entire system is converted. However, this solution is also among the most expensive and challenging to implement.

In many cases, utilities focus on separating specific sections of the system that are more cost-effective and feasible to address, rather than undertaking a full separation. This targeted approach allows for significant reductions in CSOs without the extensive costs and disruptions of a complete overhaul.

The difficulty of sewer separation is compounded by the fact that most CSSs are located in older, densely populated metropolitan areas. These systems, often decades or even over a century old, are typically buried beneath significant infrastructure, adding further complexity and expense to separation projects.

Table 7. Advantages and Disadvantages of Separation

Advantages	Disadvantages
Reduces or eliminates basement and street flooding.	Extensive construction, noise, and disruption to businesses and residents.
Reduces or eliminates sanitary discharges into receiving water bodies.	High costs due to layout complexities and required mitigation for stormwater discharges.
Decreases pathogen exposure and improves water quality.	Increased stormwater discharges may offset water quality benefits if not properly managed.
Can be coordinated with other infrastructure improvements for cost-effectiveness.	All of the public and private wet weather connections are extremely difficult to remove
	If the separation is not completely achieved, you may create SSOs.

3.7 Green Infrastructure

Green Infrastructure (GI) may be a cost-effective alternative to traditional gray infrastructure for reducing CSOs. GI utilizes natural solutions, such as vegetation and other natural materials, to absorb or retain excess rainwater, preventing it from entering the CSS. Beyond reducing CSOs, GI enhances the aesthetic appeal of urban areas and can often serve as parks or public recreation spaces. It also fosters public engagement by partnering with community-based programs, such as non-profits or conservation organizations. These collaborations not only raise awareness about water conservation but can also help secure funding for the construction and maintenance of GI projects. A detailed list of GI vendors that included projects, products, and services in the Great Lakes Region, can be found here.

3.7.1 Environmental Justice

Utilizing GI to enhance public engagement also provides significant benefits to disadvantaged parts of the community facing environmental justice (EJ) challenges. Communities with EJ concerns are often the most vulnerable to the impacts of CSOs, as infrastructure in these areas is typically less reliable compared to more affluent neighborhoods. GI not only helps beautify neglected or abandoned parts of the city but also addresses environmental justice concerns while reducing the risks associated with CSOs. Engaging with the public, particularly in EJ areas, empowers residents to have a voice in shaping the landscape of their community. Some specific EJ benefits of GI include:

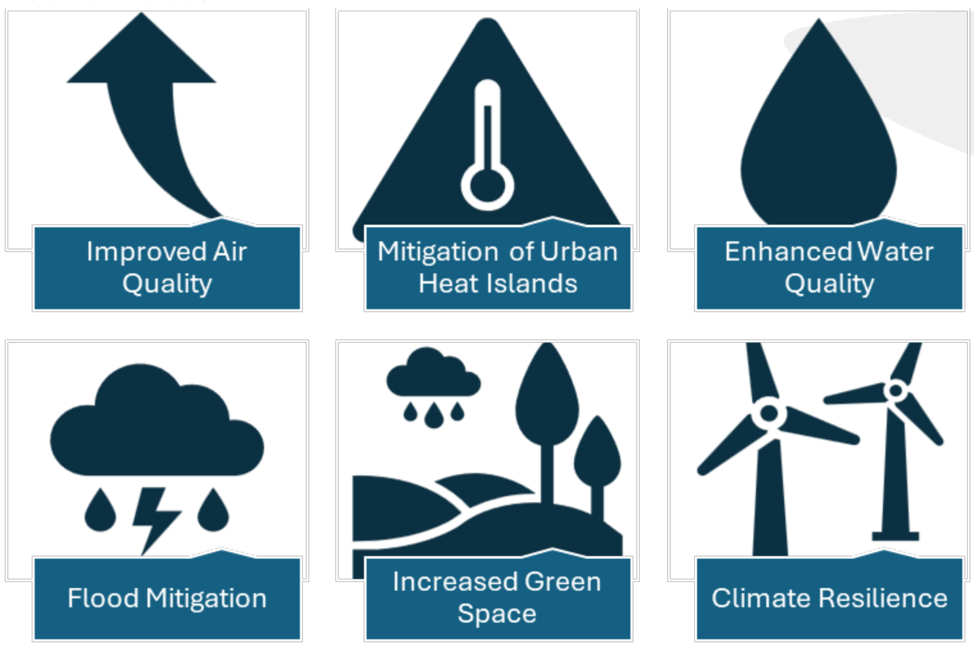

Figure 5. Environmental Justice Benefits of GI

3.7.2 Types of Green Infrastructure

There are several types of green infrastructure (GI), each offering distinct advantages. The implementation of GI depends on various factors, including available space, location, ground permeability, and costs. The purpose of GI is to remove the storm water prior to entering the CSS. In highly urbanized areas where space is limited, permeable pavements, green roofs, and urban tree canopies are often the most suitable options. Conversely, in areas with more available space, rain gardens, constructed wetlands, and vegetated swales may be more appropriate. Below is a breakdown of the different types and methods of GI, along with an overview of the types of reductions they provide:

Table 8. Types of Green Infrastructure

TYPE OF GI	COMMON METHODS	FORM OF I&I REDUCTION
PERMEABLE PAVEMENTS	Porous asphalt, permeable concrete, pavers	Allows stormwater to infiltrate the ground, reducing surface runoff that can enter the sewer system as inflow. Prevents stormwater from overwhelming sewer systems during heavy rain events. Specialty maintenance is required with permeable pavements beyond your traditional services
BIORETENTION SYSTEMS	Rain gardens, bioswales	Captures and filters stormwater through vegetation and soil, slowing down runoff and reducing the amount of water that reaches the sewer system. Also helps remove contaminants.
GREEN ROOFS	Vegetated roofs, rooftop gardens	Absorbs rainfall, reducing the volume of water that runs off roofs and into sewer systems. Helps decrease peak flows during storm events.
INFILTRATION PRACTICES	Infiltration basins, trenches	Directs stormwater into the ground, preventing it from entering the sewer system through cracks or faulty connections. Enhances groundwater recharge, reducing infiltration sources.
VEGETATED SWALES	Grass swales, tree-lined swales	Slows and treats stormwater, promoting infiltration and reducing the amount of runoff that enters the sewer system.
CONSTRUCTED WETLANDS	Wetland basins, marshes	Treats and slows stormwater, reducing the volume and speed of water entering the sewer. Helps manage peak flow and infiltration.
URBAN TREE CANOPY	Street trees, park trees	Intercepts rainwater through tree roots, reducing runoff and increasing soil infiltration before water reaches the sewer system.
RETENTION PONDS	Wet ponds, stormwater basins	Retains stormwater onsite, slowly releasing it to reduce peak flows. Helps to settle out pollutants and reduce the volume of water entering the sewer system during heavy rain events.

For a list of GI vendors and construction firms in the Great Lakes region utilized by the Milwaukee Metropolitan Sewerage District, see Fresh Coast Guardians.

3.7.3 Green and Gray Infrastructure

While GI offers many benefits, it may not always be the most suitable or effective option for reducing CSOs. In instances where GI is not appropriate, traditional gray infrastructure, also known as storm sewer infrastructure, may be a better choice. Gray infrastructure typically consists of storm drains, catch basins, culverts, and other man-made structures that convey stormwater to the CSS. Both green and gray infrastructure have distinct advantages and are better suited for specific situations. A comparison of green and gray infrastructure can be found below:

Table 9: Green and Gray Infrastructure

FEATURE	GREEN INFRASTRUCTURE	GRAY INFRASTRUCTURE
COST	Often lower initial costs: maintenance and construction can be cost-shared with community programs. Non-traditional maintenance costs.	Higher initial costs and traditional maintenance expenses.
ENVIRONMENTAL IMPACT	Enhances biodiversity, improves air and water quality, and reduces urban heat island effects.	Can disrupt ecosystems; does not provide environmental co-benefits.
FLOOD MANAGEMENT	Mitigates localized flooding by soaking up or slowing stormwater.	Controls flooding effectively through large-scale conveyance systems.
SPACE REQUIREMENTS	Requires open or available land for implementation, such as bioswales or rain gardens.	Compact systems; can be implemented underground in dense urban environments.
AESTHETIC VALUE	Adds beauty to urban areas, creates green spaces, and supports recreational opportunities.	Offers no visual or aesthetic benefits; often hidden or utilitarian in appearance.
COMMUNITY ENGAGEMENT	Encourages collaboration with local groups and raises awareness of environmental issues.	Limited public interaction or engagement; typically designed and managed by engineers or municipalities.
DURABILITY	May degrade over time without proper maintenance; vegetation health is critical.	Typically designed for long-term durability and requires periodic structural maintenance.

CLIMATE RESILIENCE	Adapts well to climate change by absorbing excess rainwater and reducing heat.	Vulnerable to overloading during extreme weather events; less adaptive to changing climate conditions.
CONSTRUCTION DISRUPTION	Minimal disruption; can be integrated into existing landscapes incrementally. GI construction in conjunction with sewer separations will result in significant disruption.	Significant disruption during installation, especially in dense urban areas.
SCALABILITY	Suitable for small-scale projects, can be challenging for large urban areas without substantial space.	Scalable for large urban applications; handles large stormwater volumes efficiently.

3.8 Maintenance Best Practices

One of the most crucial components in minimizing CSOs is the proper maintenance of the collection system and its components. Due to the complexity of CSS, it includes a wider variety of components compared to standard sanitary sewer systems and presents numerous potential points of failure. Implementing a robust maintenance program as part of a utility's operations can help operators identify key areas and equipment prone to challenges, allowing them to prioritize these areas to ensure the system operates effectively.

3.8.1 Asset Management Program

CSSs are complex systems with many moving parts. They comprise various structural, mechanical, hydraulic, and electrical components, all of which require careful maintenance to ensure optimal operation. Implementing an asset management program is one of the most effective ways to track each component, its condition, and its history.

An asset management plan can also help identify critical assets and develop a risk profile, aiding in prioritization. Keeping detailed records enables better planning for repairs, routine maintenance, capital replacements, and long-term funding solutions. A typical asset inventory should include the following information: equipment type, location, age, material, manufacturer, and expected life expectancy.

There are six core components of an Asset Management Plan (Camden County Municipal Utilities Authority, 2015):

Figure 6. Asset Management Plan Components

3.8.2 Flow Monitoring and Data Analysis

Flow monitoring and data analysis are among the most effective methods for ensuring the successful operation of a CSS. This is typically achieved by installing flow meters at key locations throughout the system to detect surges or bottlenecks. These flow meters are often integrated into a smart sewer system, which facilitates streamlined data analysis and improves the ability to predict peak events. By correlating flow data with rainfall patterns, operators can identify areas prone to overflows and determine where maintenance efforts are required. Monitoring flow also helps operators and maintenance personnel pinpoint potential backups caused by blockages or equipment failures.

3.8.3 Sewer Pipes

Since sewer pipes are the primary avenue for water flow in a CSS, it is crucial that they are regularly inspected and maintained. A typical cleaning program involves high-pressure jetting, which should be performed every 3–5 years, with high-priority areas cleaned annually or on an as-needed basis. This process removes built-up grease, sediment, and debris to maintain the system's maximum hydraulic capacity.

CCTV inspection typically follows cleaning to visually assess the condition and integrity of the pipes. While CCTV inspection is not always essential after every cleaning, it is important to maintain detailed records of the pipes' condition and equipment as part of an asset management program. Additionally, CCTV can help identify areas prone to inflow and infiltration (I&I), enabling proactive maintenance and repair efforts.

3.8.4 Manholes

Manholes are one of the most important components of any sewer system, serving as essential access points to the piping network below. However, they are also among the most common sources of I&I. Manhole lids are often improperly sealed or misaligned, allowing significant inflow as water runs over them. Additionally, the structural components of manholes, which are often old, tend to crack and deteriorate over time, leading to substantial infiltration.

Regular monitoring and documentation of manhole conditions are crucial. This process helps prioritize repairs and maintenance in critical areas. Manhole inspections are often performed alongside sewer cleaning and CCTV inspections; however, areas identified as more critical should be inspected more frequently. For manholes in poor condition, more frequent inspections may be necessary, as deteriorating components can break apart and fall into the sewer system, reducing hydraulic capacity and potentially causing backups and CSOs.

3.8.5 Street Sweeping

In CSSs, litter and debris can easily enter the collection system through sewers and catch basins. Regular street sweeping is an effective method to not only keep streets clean but also prevent debris from entering the collection system and, ultimately, being discharged through CSO outfalls, which would further pollute local waterways. Additionally, litter and debris in the collection system can threaten operations by clogging catch basins, sewer lines, wet wells, and pumps.

3.8.6 Catch Basins

Regular catch basin cleaning is an essential maintenance practice in a CSS as it helps prevent debris accumulation and minimizes flood risk. In the Great Lakes region, this practice is particularly important during the fall when leaves from trees collect in the streets. If streets are not swept regularly and leaves are not collected in a timely manner, this debris inevitably ends up in catch basins, potentially causing blockages. Routine cleaning and inspection, especially during the fall and spring in the Great Lakes region, are crucial to reducing flooding and maintaining hydraulic capacity throughout the system, thereby decreasing the likelihood of CSO events.

3.8.7 CSO Regulators and Weirs

CSO components, such as weirs, flow control gates, and throttling pipes, are crucial to inspect regularly, calibrate, check settings, and exercise (if applicable) to ensure proper operation and remove any debris that may accumulate on or behind them. Regular maintenance helps maintain optimal hydraulic capacity and prevents system overloading during peak flow events.

3.8.8 Pumps and Pump Stations

Pumps and pump stations are among the most critical components of a CSS because they are essential for elevating and accelerating flow to the WWTP. When pumps fail or operate sub-optimally, the CSS can be significantly affected, potentially resulting in catastrophic system failure. Given the complexity of pumps, which consist of multiple electrical and mechanical components, implementing a routine and preventative maintenance program is crucial. This approach helps reduce the risk of failure and minimizes CSOs. Maintenance should follow the manufacturer's specifications, but additional attention should be given to high-risk portions of the system to ensure reliability.

In addition to pumps, pump stations also include other vital equipment and infrastructure, such as controls, wet wells, control valves, flow meters, screening systems, backup power supplies, and various electrical components. The proper maintenance of all these elements is essential for ensuring the efficient and reliable operation of the system. Some common preventative maintenance tasks for pump stations are (Camden County Municipal Utilities Authority, 2015) :

Table 10. Pump Station Maintenance

Task	Description
Wet Well Cleaning	Inspect wet wells for accumulation of grit/floatables and promptly remove accumulated materials.
Compressors and Seal Water System Maintenance	Inspect and maintain hydraulic accumulator compressors and the seal water system.
Alarm Testing	Inspect and maintain electrical and alarm system.
Monitoring Oil Levels	Perform preventive maintenance for pumps, generators, and engines.
Pump Clogging/Rag Removal	Inspect and remove and clogging or rags when they are found.
Lubrication of Pump Motor and Bearings	Inspect and lubricate pump motor and bearings, as needed.
Ground Maintenance Around Pump Stations	As needed during the growing season and snow removal.

3.8.9 Backup Generators

CSSs are designed to mitigate the risks and impacts associated with wet weather events, which can often be extreme and increase the likelihood of power loss. Backup generators are a critical component of a CSS, as they ensure the system can continue functioning during power outages. Proper maintenance of these generators is essential to reduce risk. Regular testing and operation of backup generators are crucial to verify they run optimally, detect power loss, and effectively transfer power to the components they safeguard. This practice is one of the most important measures for maintaining a reliable CSS during emergencies.

3.8.10 SCADA and Monitoring Systems

SCADA (Supervisory Control and Data Acquisition) systems and monitoring components, such as flow meters and sensors, are essential for ensuring that a CSS operates efficiently, particularly during wet weather events. These systems provide operators with critical data to make informed decisions about when and where to pump or initiate a CSO event when the system reaches capacity. Monitoring equipment and controls also play a key role in remotely operating equipment. Regular testing, calibration, and software updates are crucial to maintaining the accuracy and reliability of these systems, ensuring optimal operation and minimizing the risk of failure during critical events.

3.8.11 Overflow Gates and Valves

Overflow gates and valves are critical components in a CSS and represent potential points of failure. These structures typically discharge into freshwater sources such as lakes or rivers, and improper maintenance can result in significant issues. If not properly maintained, they can cause prolonged untreated sewage overflows into water bodies or backups within the system if they fail to open when the system reaches capacity. To ensure optimal system operation, regular inspections, exercising of the equipment, and preventative maintenance are essential. Additionally, tanks and other CSO facilities should have remote cameras to visually monitor the facility.

3.8.12 Overflow Storage Tanks

Overflow storage tanks tend to accumulate significant amounts of sediment as they hold large volumes of untreated water for extended periods. Because this water contains a high concentration of particulates, these particles settle at the bottom of the tank over time. Additionally, debris and inorganic material also collect in these basins and must be removed. Regularly removing sediment and debris is essential to maintain tank capacity, reduce the resuspension of solids during high flows, minimize odors, limit nutrient release when the tank is reused, and prevent equipment clogging. Periodic inspections of the tanks are also necessary to ensure their structural integrity.

3.8.13 Trash Screens and Filters

Since CSSs operate with high hydraulic velocities, they can quickly accumulate significant amounts of inorganic material during influxes of water. Trash screens and filters are designed to capture most of this material; however, if not properly maintained, they can significantly reduce the system's capacity. While some screens operate automatically, most screens at overflow points are manual and require regular monitoring and maintenance to ensure proper functionality.

An example of a maintenance schedule for a CSS can be found below. However, this is just a general example; each utility should develop a schedule tailored to their specific needs and equipment requirements, following manufacturers' specifications.

Table 11. General Maintenance Schedule

INFRASTRUCTURE/ EQUIPMENT	MAINTENANCE ACTIVITY	FREQUENCY	ACTIONS
SEWER PIPES	Cleaning	Annually or as needed for high priority areas. Otherwise, every 3-5 years.	Use high-pressure jetting or mechanical rodding to remove grease, sediment, and debris.
	CCTV Inspection	As needed for high priority areas. Otherwise, every 5-7 years.	Inspect for blockages, cracks, structural damage, or root intrusion using cameras.
MANHOLES	Inspection	Monthly or as needed.	Check for structural damage, blockages, or missing components.
	Cleaning	As needed or in conjunction with sewer pipe cleaning.	Remove sediment and debris, especially before storm seasons.
CATCH BASINS	Cleaning	Annually, with increased frequency (bi-annually) in areas prone to heavy debris accumulation or flooding.	Use vacuum trucks to clean and ensure unimpeded flow.
	Structural Inspection	Annually	Inspect for cracks, deterioration, or settling.
STREET SWEEPING	Cleaning	Monthly	Street sweeping vehicles are to be used to collect debris from road curbs and gutters.
CSO REGULATORS AND WEIRS	Inspection and Cleaning	Monthly	Remove debris and ensure weirs are operating correctly to control overflow thresholds.
	Adjustment and Calibration	Annually	Ensure proper flow diversion by calibrating gate heights and overflow setpoints.
PUMPS	Lubrication	Monthly or according to manufacturer's specifications.	Lubricate bearings and moving parts as per manufacturer specifications.

	Inspection	Weekly	Check for vibration, unusual noise, leaks, and overheating.
	Pump Performance Testing	Annually	Measure pump efficiency, flow rate, and head pressure.
BACKUP GENERATORS	Testing and Run Time	Monthly	Conduct load tests to ensure functionality during power outages.
	Fuel System Inspection	Quarterly	Check for fuel contamination or leaks in diesel or natural gas systems.
	Full-Service Maintenance	Annually	Perform oil changes, filter replacements, and coolant checks.
SCADA AND MONITORING SYSTEMS	Sensor and Meter Calibration	Sami-annually or as needed	Calibrate flow meters, level sensors, and pressure gauges.
	Software Updates	As Released	Update software to the latest version to ensure functionality and security.
	System Testing	Annually	Perform a full system test, including alarms and remote monitoring.
OVERFLOW GATES AND VALVES	Inspection	Monthly	Check for rust, obstructions, or operational issues.
	Lubrication	Semi-annually or per manufacturers specifications	Lubricate hinges, stems, and moving parts to prevent seizing.
	Exercising	Annually	Operate gates/valves to confirm proper opening and closing.
OVERFLOW STORAGE TANKS	Sediment Removal	Annually or as needed	Remove accumulated sludge and debris to maintain capacity.
	Structural Inspection	Annually	Inspect for cracks, leaks, or corrosion in concrete and steel structures.
	Pump and Valve Maintenance	Quarterly	Ensure pumps and valves within tanks are operational.
TRASH SCREENS AND FILTERS	Debris Removal	Weekly or as needed	Clear trash and debris, especially after storm events.
	Structural Inspection	Quarterly	Inspect for damage, rust, or clogging in screens and filters.

3.9 Capacity, Management, Operation, and Maintenance (CMOM)

Aside from a typical maintenance plan, utilities can incorporate a Capacity, Management, Operations, and Maintenance (CMOM) program to better manage and maintain their collection systems. CMOM is a dynamic framework that proactively integrates industry-wide wastewater practices to optimize the operation and maintenance of collection systems.

CMOM emphasizes (Wisconsin Department of Natural Resources, n.d.):

- **Capacity:** Protecting the sanitary sewer system's ability to convey wastewater effectively.
- **Management**: Managing the system proactively to prevent issues.
- **Operations**: Operating the system efficiently and effectively.
- **Maintenance**: Maintaining system assets to maximize their useful life.

The purpose of CMOM is to shift utilities from a reactive approach toward a proactive strategy for managing and maintaining their collection systems. For utilities that already have maintenance programs in place, implementing CMOM allows them to optimize their current practices with a forward-thinking, strategic approach.

A detailed video on CMOM can be found here.

The primary goals of a CMOM program include:

- Ensuring NPDES compliance
- Reducing infiltration and inflow (I&I)
- Minimizing SSOs and CSOs
- Optimizing overall system performance
- Extending the longevity of system assets
- Maintaining adequate funding and resource allocation
- Performing routine cleaning and maintenance activities
- Enhancing environmental protection
- Safeguarding public health and safety

CMOM planning involves setting performance targets and developing clear action plans to achieve these targets. This approach involves setting an initial goal, implementing it, evaluating its effectiveness, and subsequently establishing additional goals to progressively enhance the operation and maintenance of the collection system.

The main components of a CMOM framework are:

1. Capacity Assessment & Assurance
    - Establish a baseline by evaluating the utility’s current conditions, documentation, procedures, and performance.
    - Utilize the EPA checklist for initial assessments (available here).
    - Key considerations include:

    - System inventory and mapping
    - Capacity analysis
    - Organizational structure evaluation
    - Flow monitoring and assessment
2. Management
    - After initial assessments, identify areas for improvement and create an action plan outlining goals and timelines.
    - Key considerations include:
        - Clearly defined goals and objectives
        - Effective organization and staffing
        - Legal and regulatory compliance
        - Clear communication and reporting protocols
3. Operations
    - Operational adjustments must reflect the utility's clearly defined goals and objectives.
    - Essential operational elements include:
        - Development of Standard Operating Procedures (SOPs)
        - Emergency response planning
        - Preventative operations planning
4. Maintenance
    - Implement maintenance practices to support operational goals and maximize system efficiency.
    - Key maintenance considerations include:
        - Preventative and predictive maintenance schedules
        - Scheduled cleaning and inspections
        - Identification and repair of infiltration/inflow (I&I) sources
        - Robust asset management practices
5. Performance Monitoring & Continuous Improvement
    - Continuously track outcomes and refine processes to sustain improvement.
    - CMOM emphasizes consistency, monitoring progress, and successive goal setting for ongoing system enhancement.
    - Key activities include:
        - Regular system performance monitoring
        - Audits and periodic program reviews

3.10 Maximize Wet Weather Treatment Capacity

As part of the EPA's nine minimum controls for CSOs, maximizing wet weather treatment capacity is a critical step in meeting compliance requirements. This involves both simple and complex modifications to the CSS and WWTP to direct as much wet weather flow as possible through the treatment process, rather than allowing overflows to occur.

When considering such modifications, it is essential to address regulatory compliance as well as treatment and capacity limitations. For significant treatment capacity changes or enhancements, maintaining detailed documentation and communicating with regulators throughout the process is crucial. While significant operational or structural changes will likely require regulatory approval, minor operational adjustments—such as optimizing treatment processes without physical modifications—may not.

Implementing a process to maximize wet weather treatment capacity can be broken down into the following steps:

1. Conduct an Engineering and Process Evaluation

Assessing the capacity of the sewer system, pumping stations, WWTP, and associated infrastructure is the foundation for implementing capacity changes. It is also important to analyze flow patterns using historical data and modeling to better evaluate potential solutions. Care should be taken to prevent excessive surcharging of existing sewers.

2. Develop a Wet Weather Plan

After the initial evaluation, set flow objectives and determine the maximum amount of flow the WWTP can handle without compromising treatment standards. Using these objectives, prioritize solutions based on feasibility, cost, and impact. The most cost-effective way to achieve immediate results is to focus on solutions that utilize existing infrastructure and equipment.

3. Optimize Pumping and Flow Control

Utilize existing pumps and flow diversion systems to implement protocols that maximize pump operation and redirect flow to underutilized basins, thereby increasing hydraulic capacity. Examples include:

- Bypassing secondary treatment during peak flows.
- Automating pump controls.
- Adding flow meters and level sensors.
- Repurposing old or unused basins.

In some cases, temporarily taking aeration basins offline or diverting solids to unused offline basins can help maximize hydraulic flow through the plant without risking solids washouts.

4. Enhance Storage Capacity and Conveyance

Develop protocols to maximize the use of storage within the collection system by temporarily holding excess water in unused basins or sections of the collection system with available capacity. Gradually release the flow as WWTP capacity becomes available. Additionally, routine cleaning of sewer lines and pumping stations is essential to allow for maximum hydraulic capacity within the collection system.

5. Monitor and Adjust

It is critical to maintain detailed performance records of flow, influent, and effluent parameters at the WWTP. Consistently evaluate the effectiveness of process modifications. This practice helps operators and managers refine their operation and maintenance plans, ensuring the plant meets hydraulic and regulatory capacity requirements while minimizing CSOs.

6. Plan for Long Term Improvements

Once all processes have been evaluated and operational changes have been implemented to provide sufficient data, utilities can identify long-term infrastructure upgrades. These improvements will further enhance the collection system and WWTP's hydraulic capacity while ensuring compliance with water quality standards.

Chapter 4: Case Studies

4.1 Akron, OH

4.1.1 Background

The City of Akron, Ohio sewer system serves approximately 350,000 customers and approximately 18.5% of the 841-mile sewer system is made up of combined sewers. Akron is situated at the edge of the Great Lakes Basin and Ohio River Basin. However, the entire combined sewer system drains exclusively into the Cuyahoga River Watershed which flows into the Great Lakes Basin. The Cuyahoga River has been listed as impaired by bacteria, nutrients, and dissolved oxygen in the past. Major sources attributed to the impairment include municipal discharges, combined sewer overflows (CSOs), urban runoff and industrial discharge. Restoration options included long term control plans for CSOs, urban runoff controls, habitat protection and restoration, septic tank improvements, point source controls and public education.

The Cuyahoga River has seen significant water quality improvement in terms of chemical and biological standards. These improvements in the 80s and 90s are directly related to Akron's efforts to eliminate sanitary sewer overflows (SSO), upgrades to the Water Reclamation Facility (WRF), full implementation of an Industrial Pretreatment Program, implementation of the Combined Sewer Overflows (CSO) Nine Minimum Controls and implementation of an individual Municipal Storm Water permit. The water quality had improved to the point of supporting the biological integrity of the river and supporting the return of the Great Blue Herons to the region.

Despite these previous improvements, Akron still discharged approximately 1.2 billion gallons of CSO and 1.2 billion gallons of biological secondary bypass from the treatment plant annually. Akron has made tremendous progress in reducing the frequency and volume of CSOs from their system. Even before the issuance of the Consent Decree and development of a Long-Term Control Plan (LTCP) in 2014, the City proactively took steps to address CSOs. In 2006, Akron constructed the Cuyahoga Street Storage Facility that reduced overflows by almost 30%. Additionally, wastewater treatment plant upgrades were completed by the end of 2021, increasing the plant's full biological treatment capacity from 90MGD to 280MGD. Today, the plant can provide full biological treatment with zero secondary bypasses (one of the few facilities in the country with no biological secondary bypasses).

With the issuance of the Consent Decree that requires zero untreated overflows and secondary bypasses in the typical year by 2027, Akron agreed to develop and implement an LTCP which included 26 major projects. Major projects include:

- Constructing additional storage basins
- Separating portions of the combined system
- Installing two storage tunnels
- Treatment plant upgrades to increase capacity
- Significant Capacity, Maintenance, Operations and Management (CMOM) Program

Akron also implemented green infrastructure throughout the system in conjunction with the gray infrastructure projects included in the LTCP that helped increase the effectiveness of the projects and provided significant ancillary benefits for the community without increasing the cost significantly.

To date, twenty-four of the projects have been completed and one is under construction. Additional alternatives are being considered and reviewed for the remaining project.

4.1.2 Planning/Strategy

To prioritize the implementation of the projects included in the LTCP, Akron developed an Integrated Plan that considered environmental, economic, and social aspects of each project. The plan also considered other options to meet the LTCP performance criteria such as green infrastructure, providing additional conveyance, partial sewer separation, sewer lining, in-place rehabilitation, real time controls and non-CSO water quality projects. The projects were ranked in these categories and considered for which projects would be able to be implemented together based on the cost, location, and construction sequencing of the projects. For example, they installed one of the storage tunnels first rather than installing them at the same time in order to evaluate the performance of the first tunnel and make any adjustments needed for the second tunnel. They were also able to spread out their resources more by installing them consecutively rather than simultaneously. They also started with the most cost-effective projects first to help with budget, resource planning, and water quality.

Akron also implemented innovative green infrastructure and public outreach strategies in conjunction with the implementation of the LTCP projects. The green infrastructure projects (discussed more in Section 3.1 below) increased the effectiveness of the projects and also provided triple bottom line benefits to the community. The public outreach programs (discussed more in Section 5.0) helped the public understand the work and progress being made with the rate increases on their sewer bill and helped communicate how the public can participate in improving water quality.

4.1.3 Implementation

Akron's implementation process combined new construction with the modification of existing infrastructure. Several different approaches were employed, each initiative offering distinct value in reducing CSOs.

4.1.3.1 Combining Green/Gray Infrastructure

One of the key initiatives Akron implemented was to address CSOs with the integration of green and gray infrastructure. Both types of infrastructure served distinct purposes in mitigating CSO challenges and were strategically deployed to maximize overflow reduction to achieve zero overflows in the modeled typical year.

Upgrades and implementations of gray infrastructure included storage basins, underground tunnel storage, upsizing existing sewer pipes and interceptors, and sewer separation projects.

Green infrastructure has also played a significant role through initiatives such as rain gardens, infiltration planters, rainwater harvesting systems, permeable pavements, tree boxes, complete/green street, and more. One of the most successful aspects of Akron's green infrastructure program has been the development of the urban tree canopy. This initiative has significantly reduced surface runoff while enhancing the city's greenery. The utility has a policy requiring two trees to be planted for every tree removed for the construction of a CSO project. To support this effort, the utility partnered with a local tree company to launch a tree-planting campaign aimed at increasing public awareness and promoting tree planting throughout the city. Trees were provided with large tags to provide the public with information on the value of trees. Furthermore, they have invested in a nursery to grow their own trees called Project ACORN (Akron Community Owned Restoration Network). The program will create jobs, facilitate workforce reentry, and establish a newly skilled workforce.

In many cases, the utility has combined elements of green and gray infrastructure to maximize the effectiveness of its projects. This approach was commonly applied in sewer separation projects and storage basin construction, ensuring that both ecological and engineering solutions worked together to address CSO challenges.

4.1.3.2 Increasing Storage and Plant Capacity

The utility has significantly increased its storage capacity through the construction and implementation of multiple storage tanks and an underground tunnel, with a second tunnel currently under construction. Two main projects that have had a substantial impact are the Cuyahoga Street Storage Basin (Figure 1), which can hold up to 9.5 million gallons and achieved approximately a 30% reduction in CSOs when it was brought online in 2006. Additionally, the Ohio Canal Interceptor Tunnel (OCIT) has been a critical component of these efforts. The tunnel measures 27 feet in diameter and 6,240 feet in length, with a storage capacity of 25.6 million gallons. The tunnel conveys and stores both dry and wet-weather flows from nine locations throughout downtown Akron, which are then conveyed via gravity to the WWTP for treatment.

The tunnel is modeled to remove 467 million gallons of CSO per year. Construction for the OCIT (Figure 2) began in 2016, and it was put into service in June 2020.

Figure7. Cuyahoga Street Storage Basin

Figure 8 Ohio Canal Interceptor Tunnel (OCIT)

Figure 9. Northside Interceptor Tunnel Construction

Construction has also recently begun on the Northside Interceptor Tunnel, which is designed to store an additional 10.65 million gallons. Additional information and real-time updates on this project can be found here.

Inline storage has also been maximized as part of the utility's Capacity, Management, Operation, and Maintenance (CMOM) program. Through the CMOM program, the utility has implemented a strategic maintenance and cleaning schedule for its 841-mile sanitary collection system, yielding significant results by increasing hydraulic capacity with clean and clear pipes. The program has also focused on I&I reduction through spot repairs and pipe rehabilitation, further reducing the amount of clear water entering the collection system. Akron budgets approximately $6 million a year on lining projects. The Consent Decree requires all sewers to be inspected and cleaned on a five year cycle.

The treatment plant has undergone significant upgrades to increase its capacity. Major projects include:

- Rehabilitating aeration basins, including the addition of step feed technology, which increased secondary treatment capacity from 90 MGD to 220 MGD.
- Adding Biological Chemically Enhanced Primary Treatment (BioCEPT) tanks providing an additional 60 MGD of treatment above the secondary treatment capacity of 220MGD.

This provides for full biological secondary treatment of all flows entering the Water Reclamation Facility.

- Upgrading the Headworks originally constructed in 1954 to improve solids removal efficiency from the CSO storage facilities and overall system, and to convey up to 280 MGD. This was not an LTCP project but determined to be a needed asset management need.

With these upgrades, the treatment plant can now achieve 100% biological treatment without any secondary bypass.

4.1.3.3 Real-Time Decision Support System (RT-DSSS)

One of the most dynamic initiatives Akron implemented was the use of real-time controls (Figure 3), or smart sewer systems. This system includes multiple sensors and meters throughout the collection system to evaluate wet weather conditions. These sensors monitor CSO storage facility capacity, sewer trunkline capacity, and flow rates. This system ensures every operator is managing wet weather flows the same way.

The flow in the collection system is managed by several diversion structures and weirs that passively divert water into the storage facilities. The water is held until the capacity in the sewer system is available, at which point the flow can be reintroduced and treated at the plant. The real-time control system uses measurement data from the sensors to provide recommendations to the operators.

This technology has enabled storage facilities to dewater while a storm is still ongoing or to allow simultaneous overflows at a controlled rate when basins reach maximum capacity, thereby reducing the overall impact of CSOs. The use of real-time controls ensures that all CSO facilities operate as efficiently as possible while achieving the highest environmental benefits.

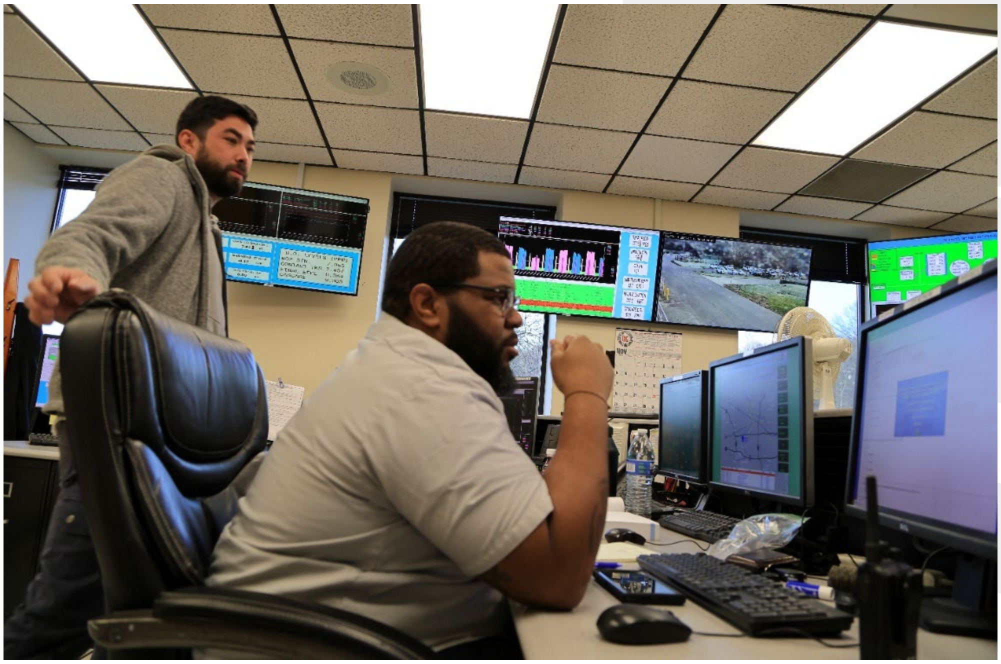

Figure 10. Real Time Control Center

4.1.4 Funding

The estimated cost for the projects implemented under the LTCP is approximately $1.2 billion. Funding for the projects implemented under the LTCP largely came from the rate payers. Over the past 10 years of planning and implementing the projects, sewer rates for Akron have increased by 269% (Figure 4) leading to one of the highest rates in Ohio. While the rates have increased and the sewer rates are 5 times the water rates, the community outreach and engagement that Akron has conducted have helped minimize public resistance of the rate increases and fostered understanding of how the funds are being utilized.
Additionally, the Cuyahoga Street storage facility, implemented prior to the LTCP, received partial federal funding.

Akron has used the Ohio EPA Water Pollution Control Loan Fund (WPCLF) state revolving loan fund for all of the major projects. Working with Ohio EPA, Akron has received low interest loans with extended payment schedules up to 45 years in some cases. Akron has also received additional interest reductions by participating in the Ohio EPA Water Resource Restoration Sponsor Program (WRRSP).

Through implementation of several of the Integrated Plan projects and corresponding Consent Decree modifications Akron has reduced the overall cost of the LTCP as follows:

- CD Amendment No. 1 (2016) estimated savings of $83 million with Main Outfall Sewer Upgrades
- CD Amendment No. 2 (2019) estimated savings of $77 million with Green/Conveyance Projects and alternative technology at WRF

- CD Amendment No. 3 (2023) estimated savings of 38 million with "right sized" Northside Interceptor Tunnel.
- Proposed Amendment No. 4 (2025, currently under appeal) estimated $209 million with replacement watershed projects

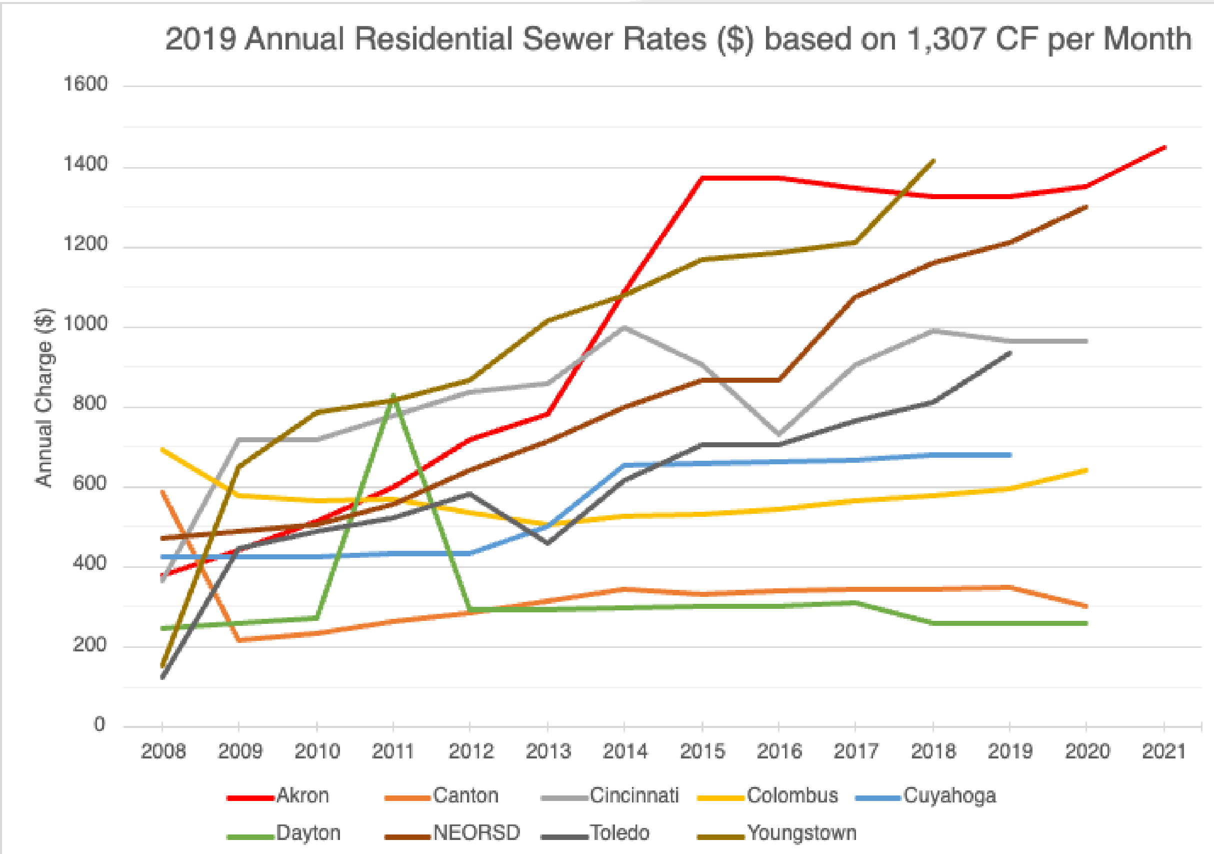

Figure 11. Akron Rate Increases Over a Ten Year Period in Comparison to other Ohio Communities

4.1.5 Community Engagement

Community engagement played a key role in the success of the CSO reduction efforts. Akron has hosted a wide variety of events and initiatives to spread awareness including:

- School visits: Representatives from Akron conduct outreach to schools, including hosting and participating in STEM programs and helping students prepare for internships with participating firms.
- Through the All Akron Student Engineering Program (AASEP), Akron coordinates with area consultants and businesses to provide summer internships for juniors and seniors in Akron schools.
- Clean-up activities: Several cleanup activities have been hosted in Akron to help keep the community clean and keep the public engaged.

- Information mailings: Akron distributes a variety of materials including informational pamphlets and advertisements for upcoming events.
- Complaint Hot Line: Akron maintains a hot line for citizens to call in with questions or concerns. Akron tracks the questions and responses to completion to ensure that everyone receives a timely response.
- Rain Barrel Program: Akron received a grant to purchase 200 rain barrels during the first phase of implementation, followed by another 500 after the success of the first phase. The rain barrels were distributed to homeowners and helped reduce their water and sewer bills and provide watershed education
- Public meetings: Akron presented at ward meetings, different community groups, and hosted open houses at the Water Reclamation Facility to encourage public participation.
- Stakeholder group meetings and events: Akron implemented an Integrated Plan Stakeholder Group as part of their LTCP implementation. This allowed direct communication between Akron staff and the public during the planning process to ensure public input and concerns were taken into consideration.
- Annual education event: Akron hosts an annual Blue Heron Homecoming event to spread awareness of the work they're doing as well as the efforts that the public can make to help protect the environment and waterways. The event averages 500 visitors pear year.
- Tunnel opening event: Before the construction of the storage tunnel, Akron hosted an event to allow the public to view and take pictures with the large tunneling machine and hosted tours of the project. The event was attended by over 2,000 people.
- Tunnel tours: During construction of the tunnel, Akron hosted weekly bus tours of the tunnel project, storage basins and green infrastructure projects throughout the sewer shed.

Because of their efforts to educate the community on decision making and include the community in project activities, Akron has received support from the public through all phases of the Integrated Plan and CSO LTCP implementation.

Figure 12. Blue Huron Homecoming Event

4.1.6 Outcomes

Akron has been successful in reducing CSOs in their system through the implementation of their LTCP, implementation of portions of the Integrated Plan and other complementary projects. Since the Consent Decree was issued, they have reduced the combined CSO and wastewater treatment plant secondary bypass volume from 2.4 billion gallons a year to less than 3 CSOs in a typical year from the Ohio Canal Interceptor Tunnel, totaling approximately 100 million gallons at the completion of the program in 2027. Actual performance of the system has exceeded the projected modeled performance.

The water quality in the Cuyahoga River has drastically improved with the reduction of CSOs. The river is now a designated Ohio Department of Natural Resources (ODNR) water trail and the Cuyahoga Valley National Park is building access to the river for recreational use. The ODNR is also beginning to stock sturgeon into the river and the Great Blue Heron and Bald Eagle population has returned to the region.

Figure 13 The Little Cuyahoga River in 2024

4.1.7 Future Outlook

Akron's CSO reduction projects have been designed conservatively, with future, potentially more severe weather in consideration. In recent years, the area has already experienced shorter duration, higher intensity storms that the upgrades have been able to handle and still reduce the occurrence of CSOs.

The real-time controls that are in place are used to continuously track and model the system's response to storms of different sizes and has shown that the upgrades are conservatively designed to handle larger storms. With the increased storage in the system through the tunnels and the increased capacity at the plant through upgrades, Akron is well equipped to monitor and control the amount of wastewater coming into the system and minimizing untreated discharges into the river.

In addition to the CSO projects, Akron is promoting a significant Tree Canopy project "Planting Change, 100K Trees for Akron" to fight climate change.
This demonstrates the critical importance of proactively integrating climate resilience into infrastructure planning to safeguard communities and ecosystems from the impacts of increasingly severe weather patterns.

4.2 Camden, NJ

4.2.1 Background

The Camden County Municipal Utilities Authority and the City of Camden have made great efforts to reduce the occurrence of Combined Sewer Overflows (CSOs) in their system. Following the completion of their Long-Term Control Plan (LTCP), they have implemented several projects aimed at reducing the occurrence and volume of CSOs as well as flooding from combined sewage throughout the community. They have prioritized community benefit through the use of green infrastructure and pipeline replacement, targeting the most vulnerable areas of their community.

4.2.2 Planning/Strategy

Camden focused on four major aspects of CSO management when planning their efforts to reduce CSOs:

- Reduce the generation of combined sewage
- Optimize sewage conveyance capacity
- Optimize sewage treatment capacity
- Mitigate impact of CSOs

By focusing on these aspects, Camden was able to streamline their CSO reduction approach and prioritize projects based on cost-effectiveness and overall CSO reduction volume. They were also able to build off of lessons learned from previous project implementation by implementing projects utilizing similar strategies in targeted areas throughout the community.

4.2.3 Implementation

Camden implemented projects with the following strategies:

- Reduce the generation of combined sewage: One of the first steps that Camden took to reduce their CSOs was to reduce the generation of combined sewage to start with. They implemented green infrastructure strategically in order to maximize stormwater capture and also reduce the potential for combined sewage flooding in basements, streets, etc. They prioritized places where residents had been experiencing flooding from combined sewage. Green infrastructure is one of the most affordable options for reducing the amount of combined sewage, but in some cases, separation of the storm and sewer systems is the best option. While this option is costly, it is the most effective at preventing combined sewage overflows and if implemented in strategic locations, it can be a cost-effective option. Camden separated their combined sewer system in locations that provided the most impact while being feasible for construction and feasible within their budget.
- Optimize sewage conveyance capacity: Camden also implemented projects to increase the capacity of their combined sewer conveyance system to help prevent backups and flooding into homes and other parts of the community. They focused on improving their sewer cleaning efforts, slip lining failing sewer lines where possible, replaced failing lines and increased the size where feasible, and consolidated CSOs where possible. Camden consolidated some of their CSO outfalls by conveying combined sewage from one outfall to the next downstream outfall to make use of additional storage capacity (if available) in the sewer line between the two outfalls.
- Optimize sewage treatment capacity: Optimizing treatment capacity is incredibly important for the control of CSOs by helping to avoid volumetric bottlenecks and

allowing more combined sewage to be treated rather than discharged during heavy rain. Camden worked to reduce I&I in their system to allow more room at the treatment plant during wet weather events as well as obtained approval for wet weather bypass of secondary facilities in order to achieve partial, primary treatment of additional flow during extreme weather events. This helped ensure that the plant could at least partially treat as much flow as possible during wet weather.

- Mitigate impact of CSOs: While Camden's focus was on the reduction of CSO volume as a whole, they also worked to help mitigate the impact of CSOs when they do occur. They installed solids/floatables control devices such as screening or netting systems at the end of CSO outfalls. They also keep lower sludge blankets in the plant if a significant wet weather event is expected to avoid higher solids concentration during the event.

4.2.4 Funding

The Camden County Municipal Utilities Authority and the City of Camden worked together to implement the upgrades to both the treatment plant and the collection system to help reduce the occurrence of CSOs. Because the two entities have worked together on these projects, the cost is spread out among the entire regional system that includes 37 towns. This helped them to implement the projects without having to raise utility rates or implement additional fees.

Camden also received State Revolving Fund (SRF) funding for almost all of the improvements made including the plant expansion, volume bottleneck removals, separation, netting system installation, and green infrastructure. The SRF loan funding was provided with a 30-year loan period with 1% interest. The FEMA BRIC grant program was not available at the time but it is a great opportunity and Camden would have sought funding from this program had it existed during the development of their CSO control projects.

4.2.5 Community Engagement

Community engagement was an important factor in the success of the project implementation and ongoing success of the CSO reduction plan. Camden was one of the earlier adopters of green infrastructure and quickly realized that the public was much more interested and engaged with projects such as rain gardens throughout the community rather than learning about increased capacity at the treatment plant or other large infrastructure projects. Getting the community excited about and engaged in the green infrastructure throughout the community also helped the utility spread information about other infrastructure projects and their importance.

As part of their efforts to reduce CSOs, Camden established Camden SMART (Stormwater Management and Resource Training). This group was a collaborative effort between the City of Camden, Camden County Municipal Utilities Authority, Rutgers University, the New Jersey Department of Environmental Protection, a local nonprofit, and a community tree foundation to launch a city-wide green infrastructure plan. This plan included hosting a public hearing in each of Camden's 20 wards to listen to the public and gain better understanding of where flooding is occurring. The group made commitments to implement green infrastructure in every ward and to focus on flooding reduction in areas experiencing flooding from CSOs.

4.2.6 Outcomes

Since the start of the program, Camden has reduced the number of combined sewer outfalls from 38 to 30. Of the 30 outfalls that remain, all of them have netting installed for solids control. The state has also issued permits that require cleaning every 5 years (as part of the 5-year permit renewal cycle). This has helped ensure that the sewers are clear of any blockages that contribute to flooding and to ensure full capacity is available in the pipes. Wet weather capacity at the treatment plant has increased by 50% and out of the 30 outfalls in the community, all but 3 of them are meeting requirements of more than 85% of the combined sewage to be captured and treated during wet weather flow.

4.2.7 Future Outlook

Although Camden was able to implement the projects for CSO control without implementing a stormwater fee or increasing utility fees, this option is likely to be considered in the future to provide funding options for any future projects. Camden also plans on completing projects related to the last 3 outfalls that remain to meet the goal of 85% wet weather capture. These projects include either installing a tunnel for storage or increasing the pipe size to provide additional capacity. The end goal is to meet the 85% wet weather capture city-wide.

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