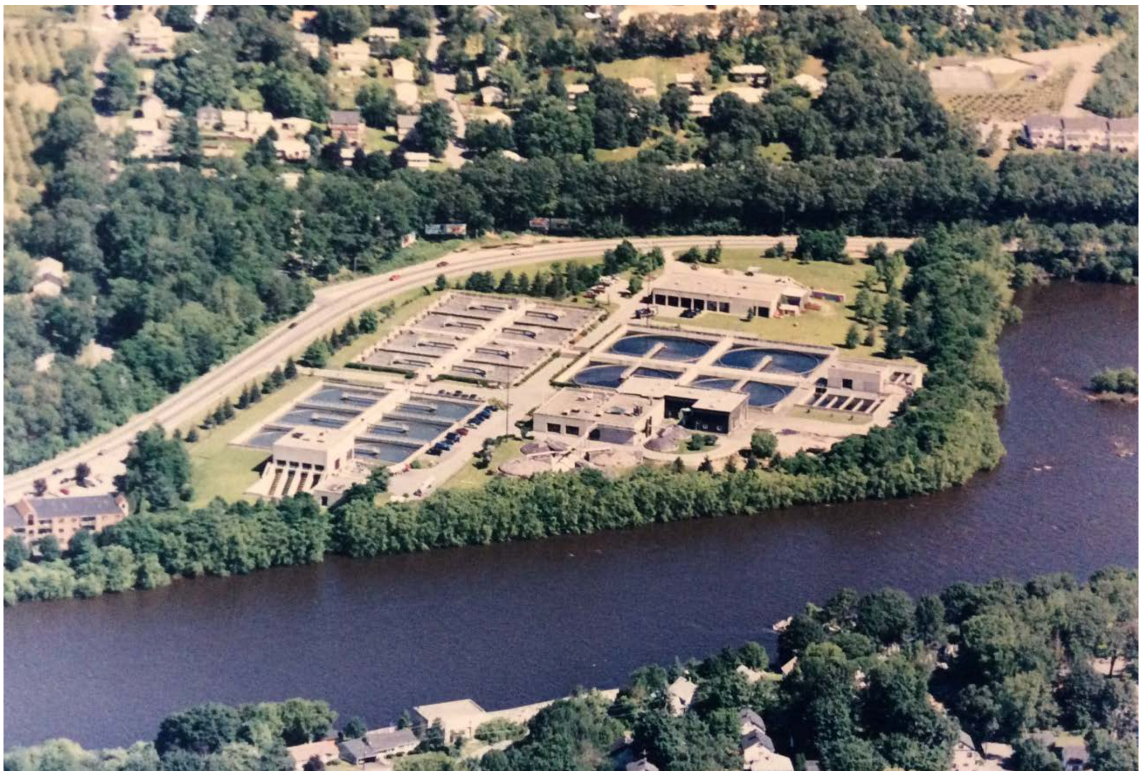
LOWELL WATER
Community ~ Health ~ Environment

Annual Clean Water Report

Reporting Year 2019



DUCK ISLAND
LOWELL REGIONAL WASTEWATER UTILITY

NPDES Permit Number: MA0100633

Report Date: May 1, 2020

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1. Introduction

Lowell Water is a public utility located in Lowell, Massachusetts that owns, maintains and operates a public drinking water utility; an extensive stormwater drainage system; a flood protection system; and a wastewater utility comprised by a large combined sewer system dating to the 1800s, newer separated conveyance systems, and a multi-modal wastewater treatment works that delivers efficient secondary-level treatment of dry-weather sewage flows as well as wet-weather flows up to 110 million gallons per day (MGD).

Lowell Water's mission is to provide a healthy water environment in and around greater Lowell, while delivering outstanding service to the community at reasonable rates.

This Annual Clean Water Report documents and summarizes the performance of the wastewater utility in complying with its National Pollutant Discharge Elimination System (NPDES) permit under the Clean Water Act during the current reporting year. The report is inclusive of programs implemented to maintain, repair and replace the sewerage network and CSO diversion structures as well as operation and maintenance of the Duck Island Clean Water Facility (Duck Island), which operates in accordance with its NPDES permit, its voluntary ISO 14001 Environmental Management System, and all applicable state and Federal regulations.

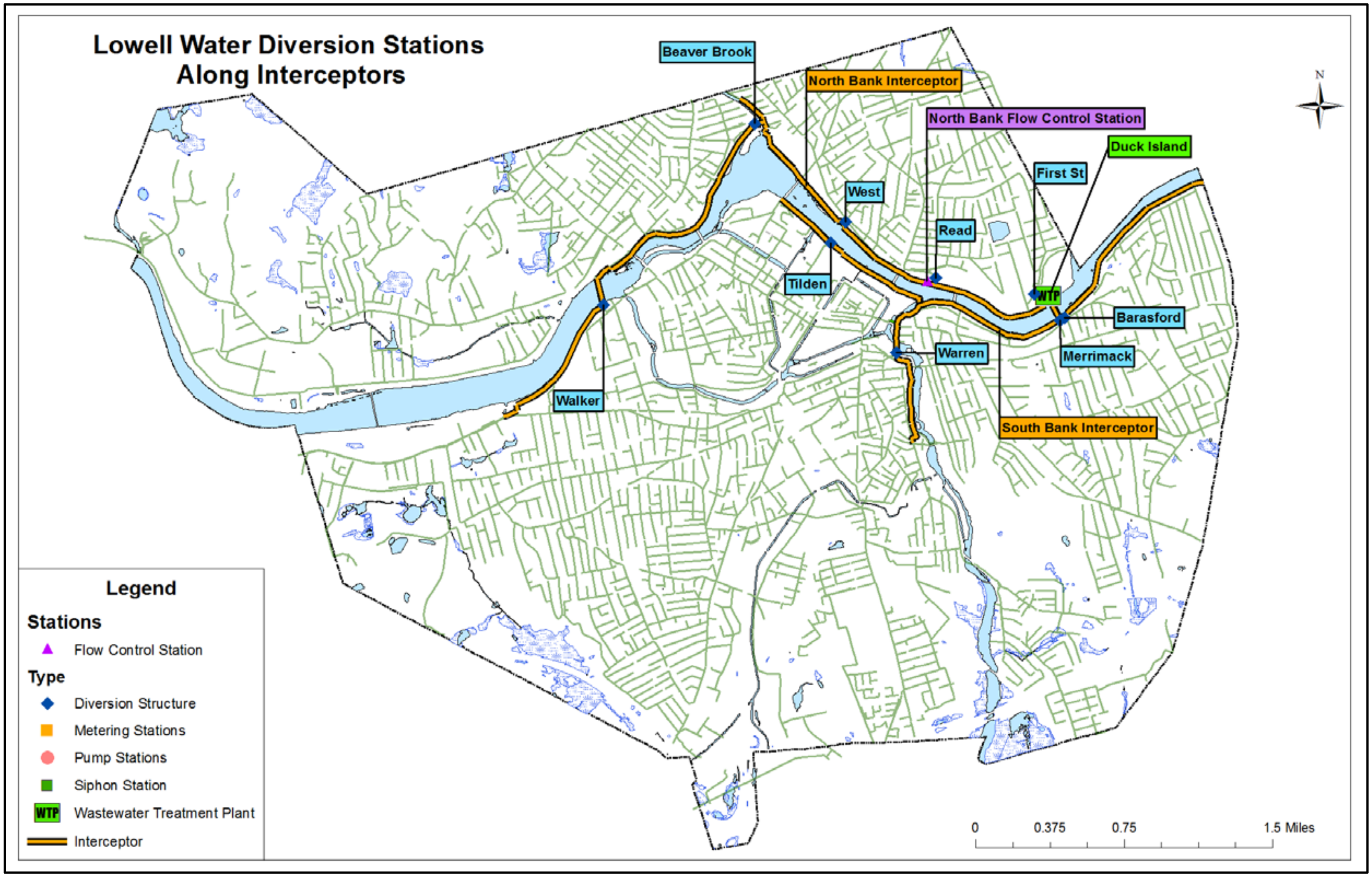
Lowell Water's sewer system consists of approximately 220 miles of gravity sewers and 12 sewage pumping stations. Ten miles of large-diameter (48-inch to 120-inch) interceptors located along the banks of the Merrimack and Concord Rivers collect wastewater from the sewer system and convey it to Duck Island. Duck Island was designed to provide biological (activated sludge) treatment for an average flow of 32 million gallons per day (MGD), with a short-term peak capacity of 62 MGD. A plan view of Duck Island and the interceptor system is provided in *Figure 1-1*, below.

During wet-weather conditions, a maximum flow of approximately 110 MGD is treated at Duck Island. Flow exceeding the capacity of the biological and secondary clarifier systems (secondary systems) causes activation of the high-flow treatment mode: high-flow treatment receives screening and clarification, which is followed by pre-chlorination before being mixed with water receiving biological treatment. This mixture is then disinfected and discharged into the Merrimack River in full compliance with secondary treatment standards.

Flow in excess of the high-flow treatment capacity is stored in the interceptor system through an automated network of gates controlled by computational algorithms designed for the purpose and implemented in a Supervisory Control and Data Acquisition (SCADA) system. Flows to the collection system that exceed this interceptor storage capacity are diverted as combined sewer overflows (CSOs) to the Merrimack River, the Concord River and Beaver Brook, as necessary to prevent sewer system surcharges that may cause sewage back-ups into homes and streets.

Lowell Water actively manages several programs vital to maintaining and operating the collection system and Duck Island effectively to implement CSO control, following the requirements outlined in its NPDES Permit at Attachment E: Nine Minimum Controls (NMC).

Figure 1-1. Lowell Water Collection and Treatment Systems Overview



These programs include the following:

1. Phase 2 Long-Term Control Plan (LTCP)
2. Capacity, Management, Operations and Maintenance Program (CMOM)
3. High-Flow Management (HFM) Program, including CSO monitoring and notification
4. Infiltration and Inflow (I/I) Reduction Program

This report serves as an up-to-date summary of these programs and highlights actions taken in Reporting Year 2019 to actively maintain and implement the NMC.

1.1 Permit History

In 2005, the United States Environmental Protection Agency (EPA) re-issued authorization to discharge under the National Pollutant Discharge Elimination System (NPDES) to the Lowell Regional Wastewater Utility (now Lowell Water).

NPDES Permit No. MA0100633 authorizes Lowell Water to discharge sanitary and industrial wastewater from its Duck Island Clean Water Facility and Combined Sewer Overflows (CSOs) from nine discharge locations, into the Merrimack River, the Concord River, and Beaver Brook. The current permit became effective on November 1, 2005.

NPDES Permit No. MA0100633 was reissued on September 25th, 2019, becoming effective on November 24th, 2019. This annual report follows the reporting practices under the prior 2005 permit, and modifications to annual reporting procedures under the new permit will be made for reporting year 2020 and onward.

1.2 Report Requirements and Layout

As part of the NPDES permit, Lowell Water is required to submit an annual report that summarizes CSO activity and precipitation (*Section 2.4*), certifies adequate recording of CSOs (*Section 2.5*) and inspection of CSO facilities (*Section 2.6*), and reports on Lowell Water's Nine Minimum Controls (NMC) program (*Section 2.3*).

Lowell Water is also required to submit an annual report on infiltration and inflow reduction (I/I) activities in its sewer collection system (*Section 2.7*), as well as Capacity, Management, Operation, and Maintenance (CMOM) corrective actions and other activities (*Section 3*).

1.3 Executive Summary

This annual report is designed to meet the requirements defined above, and to provide an annual record of relevant revisions to high-level planning and management of the utility. Additionally, in this RY2019 report, new submittal requirements under the revised 2019 permit are provided, specifically including:

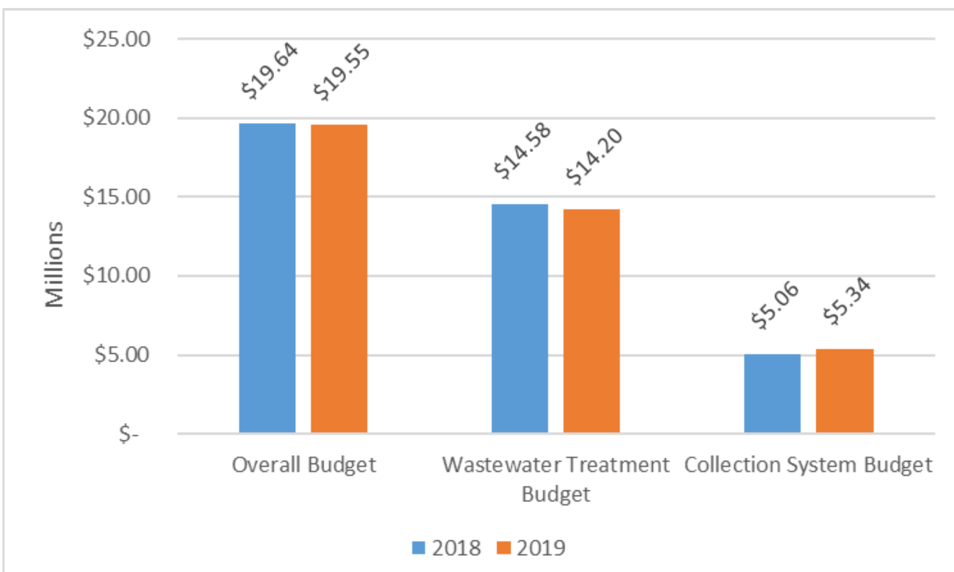
- CSO Public Notification Plan meeting 2019 NPDES submittal requirements (*Section 2.2.4*)
- Collection system operation and maintenance plan submittal (*Section 3*)

Lowell Water has continued to commit substantial personnel and financial investments toward reduction of CSOs, identification of inflow and infiltration, and maintenance and operation of its sewage collection and treatment systems.

Lowell Water's fiscal year (FY) 2019 budget totaled $19.6 million. This included funds for operation and maintenance of the Duck Island Clean Water Facility at $14.20 million, and collection system operation and maintenance funding at $5.34 million. Each of these figures includes direct costs such as salaries, wages, services and utilities; indirect costs for services provided by other City of Lowell departments and employee overhead costs; and debt service on prior work performed under capital improvement projects and Long-Term Control Plan (LTCP) projects directed toward high-flow management and CSO control. Similar funding levels were provided in 2018, as shown in *Figure 1-2*, below, and are projected for fiscal year 2020.

Lowell Water received approval from the City in 2019 for additional funding to support planned capital improvements and upgrades related to its Phase 3 LTCP and Integrated Plan (described at *Section 2.1.3*), which also includes critical infrastructure improvements to Lowell's drinking water system. This funding included $112M overall, with $68M allocated for wastewater infrastructure improvements and $44M to drinking water infrastructure improvements.

Figure 1-2. Fiscal Year Budget Summary



The primary areas of activity in 2019 are described in summary below, and the remainder of this report presents a detailed review of each program.

1.3.1 Long-Term Control Plan Updates

Details of Lowell's LTCP projects are provided in *Section 2.1*. The Phase 3 LTCP and Integrated Planning program resulted in submission of Lowell's first Integrated Capital Improvements Program (ICIP) to MassDEP and the US EPA in December of 2019. The ICIP is now under review by these regulatory authorities and has resulted in significant progress toward identifying new system-level improvements that are expected to achieve further reduction of CSOs and improve high-flow treatment performance in the coming years. The ICIP includes a project-ranking decision matrix that considers the impacts of each proposed project on the environment, public health and safety, infrastructure resilience, and other important metrics. Each design alternative was assessed in the ICIP in order to rank and prioritize projects. Further progress toward implementing the ICIP is contingent on regulatory approval of the plan.

Meanwhile, Lowell has continued to construct Phase 2 LTCP projects. Several of these projects were recently completed or brought to significant milestones, including:

- The North Bank Flow Control Station was brought online in 2018, marking the completion of a major milestone in Lowell's Phase 2 LTCP improvements, to fully utilize inline storage in Lowell's existing interceptor system. The facility provides additional in-line storage (approximately 0.75 MG), while most importantly providing a primary flow-control point for optimization of inline storage and conveyance of flow to Duck Island from the North Bank interceptor. This control structure allowed for the development of an optimization algorithm in SCADA to balance storage and conveyance of flow between the two main interceptors in Lowell's collection system: the North Bank Interceptor, which services about one third of Lowell's collection system; and the South Bank Interceptor, which services the remaining two-thirds of the system.

- The West Street Flood Control Pump Station was rehabilitated and brought online in 2018, meeting the demand for a long-outstanding flood-damage-control system to protect residents on the north bank of the Merrimack River. The Flood Control Pump Station had previously been functioning alongside the CSO diversion station at West Street, but the pumping equipment was no longer reliable. West Station still acts as a gravity-flow CSO diversion station during average wet-weather events, but now also has the capacity to pump against the hydraulic pressure of the Merrimack River when it is in flood stage, thus preventing flooding in the upstream catchment areas.

- Bar-racks were previously installed in several of Lowell's CSO diversion structures to protect siphons and other flow-control elements in the collection system. These structures were identified through past capacity assessments as significant obstacles to maximum conveyance of flow to Duck Island. These assessments indicated that these bar-racks were frequently contributing to increased CSO discharges, and could be replaced by less obstructive features while still protecting the collection system. In late 2018 through 2019, the bar-racks at Merrimack, Warren, Walker and Beaver Brook diversion stations were removed in order to allow increased conveyance at these facilities, as well.

- Capital improvements to Duck Island were initiated in 2018 through finalization of design plans and awarding of contracts to major equipment and construction contractors. These improvements are currently underway, and include upgrades to remote stations to improve reliable conveyance of flow, and improve communications and SCADA control. Improvements at

Duck Island include replacement of all ten primary and secondary clarifiers (eight of ten replacements have now been completed), which will increase the reliability and capacity of these treatment processes.

- Additionally, automation of the chlorine dosing to the high-flow treatment line is in progress to further ensure that high-flow treatment discharges reliably meet secondary-treatment standards, while maximizing use of excess primary clarifier capacity during wet weather, as instructed in the 2005 NPDES permit (Appendix E, Nine Minimum Controls).

1.3.2 CSO Control and Precipitation Trends in 2019

Detailed descriptions of Lowell's High-Flow Management Program development and current practices are provided in *Section 2.2*, and detailed annual records for 2019 are presented for review in *Section 2.4.* Brief summary statistics for the year are provided here.

Lowell experienced a wet year in 2019, with 158 days of precipitation measured at one or more of Lowell's four rain gauges distributed throughout the collection system. Two of these rain gauges were added in 2018 to improve precipitation measurement critical to informing the validation of Lowell's collection system model. Total precipitation for 2019 was 43.25 inches.

This precipitation required activation of Lowell's High-Flow Treatment mode 88 times throughout the year, resulting in the successful capture and treatment of 537 MG of flow in excess of the biological-treatment system capacity, while still providing treatment to secondary treatment standards. CSO diversions related to these events totaled 284 MG in 2019. The 'capture rate', a key performance indicator defined as the ratio of total CSO discharge volume to total treated high-flow, was 53 percent for the year.

1.3.3 Infiltration and Inflow Reduction in 2019

Lowell Water submitted to MassDEP an Infiltration and Inflow (I/I) Control Plan in early 2020, as an addendum to the Integrated Capital Improvements Plan (ICIP) submitted in December of 2019.

Section 2.7 of this report includes this I/I Control Plan and additionally provides a detailed review of monthly average flow rates under dry- and wet-weather conditions. This allows extrapolation of I/I estimates throughout the year. Seasonal trends related to high-water levels in the Merrimack and its tributaries have been established in prior reports and were again observed in 2019.

The CMOM program continues to function as an I/I prevention program through inspection, repair and replacement of damaged sewer mains that would otherwise contribute to overall groundwater infiltration of the collection system.

Lowell's Site Stormwater Planning Program is a central component of I/I control efforts. By collaborating with City Engineers and the Department of Planning and Development (DPD), Lowell Water manages this program to identify opportunities for practical site improvements to control private inflow into the combined sewer system as private properties are redeveloped or first built, by either reducing stormwater discharged from sites in combined catchments or requiring storage to delay the peak flow conveyed from the site.

In addition to the conventional metrics used to quantify infiltration and inflow (I/I) in Lowell's system, Lowell Water established a pilot project in 2018 specifically designed to survey and identify primary points of entry for I/I utilizing conductance probes to screen the collection system at major junctions. This method of evaluating potential I/I sources is less expensive and may be more efficient than traditional methods utilizing flow surveys for this purpose. The pilot project identified one inflow source to the collection system in downtown Lowell where an overflow connection to the Upper Pawtucket Canal contributed inflow to the South Bank interceptor. The connection was sealed in the fall of 2018, and a more comprehensive survey program has since been designed to implement this screening protocol throughout the collection system in 2019. More details on this conductance-survey program are detailed in the I/I Control Plan at *Section 2.7*.

1.3.4 Capacity, Maintenance, Operation and Management (CMOM) in 2019

Lowell Water continued to fund its CMOM program at a rate of roughly one-quarter of its total operating budget in 2019. This investment involved $1.04 million of cleaning, inspection and repair work performed in 2019, which included:

- Replacement of 845 feet of sewer and drain line
- Repair of 9,261 feet of sewer and drain line with cured-in-place-pipe (CIPP)
- Repair and replacement of 46 catch basins
- Repair and replacement of 6 manholes
- Associated paving, test pits, and sidewalk repairs
- Cleaning of 12,000 feet of sewer and drain lines
- Video inspection of 15.1 miles (79,494 feet) of sewer and drain lines
- Handling of 504 collection-system work-order requests
- Handling of 505 catch basin, residential sewer-backup and street-flooding reports
- Bi-annual street sweeping yielding removal of 328 tons of sediment and debris prior to entering the collection system
- Cleaning of 510 catch basins yielding 448 tons of sediment and debris captured in these basins

Section 3.6 includes a more detailed presentation of sewer rehabilitation work performed in 2019.

Continued opportunities for improvement to Lowell's CMOM program are discussed at bi-weekly collection-system meetings attended by multiple core staff including the Collection System Supervisor, CMMS Administrator, Drinking Water Distribution System Supervisor, City Engineers, Lowell Water Engineers, and the Executive Director of Lowell Water. These meetings serve as the foundation for dissemination and discussion of institutional knowledge regarding these critical public infrastructure systems and serve as an entry point for identification of new ideas and improved procedures continually under review and assessment by Lowell Water staff.

The expected identification and procurement of an advanced CMMS integrated with GIS, previously identified in the 2017 annual report, was postponed due to funding shortages related to updated capital improvement costs. Lowell will continue to seek funding and coordination between the City's departments to identify an improved CMMS system as soon as possible.

The remainder of this Clean Water Report presents the details of each of these programs in a manner intended to provide a history of development and key decisions previously made in each program. Each section of the report ends with a more detailed discussion of specific actions or opportunities for improvement identified in 2019.

2. High Flow Management and CSO Control Plan and Annual Report

This section of the 2019 Clean Water Report presents a summary of Lowell's work to date to manage high-flow events in a manner that provides effective and efficient treatment over the dynamic flow ranges experienced in our combined sewer system.

- *Section 2.1* summarizes past long-term control plan (LTCP) phases and coincidental capital improvement projects to the extent relevant to CSO control and the High-Flow Management (HFM) program. The present phase of work is then discussed, including a summary of progress toward completing the Phase 2 LTCP and milestones reached so far in developing the Phase 3 LTCP under the newly adopted Integrated Planning framework.
- *Section 2.2* summarizes the current HFM program as practiced in 2019 and discusses planned improvements in 2020.
- *Section 2.3* presents the Nine Minimum Controls identified in Lowell's 2005 NPDES permit in tabular format and references the specific sections of this report that address those controls.
- *Section 2.4* presents annual records from Lowell's CSO monitoring and notification program.
- *Section 2.5* provides certification required under the NPDES permit regarding accuracy of CSO activation records presented in the previous section.
- *Section 2.6* provides certification required under the NPDES permit regarding CSO structures inspection and maintenance.
- *Section 2.7* presents Lowell's infiltration and inflow control plan and related actions taken in 2019.

2.1 Summary Overview of Long Term CSO Control Capital Program

Lowell has aggressively pursued a cost-effective path to reduce combined sewer overflows (CSOs) to the maximum extent practical while keeping sewer rates affordable.

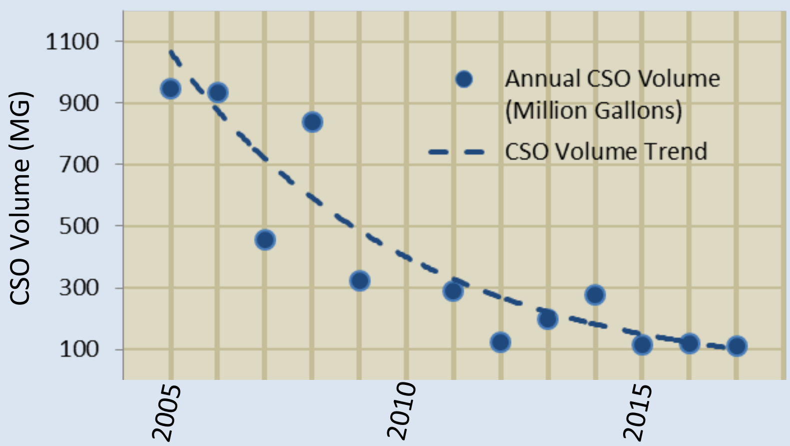
Beginning in 2002, Lowell submitted its Phase I Long Term Control Plan (LTCP) for CSO control. At the start of this phase, Lowell was the largest CSO discharger on the Merrimack River, consistently discharging greater than 500 million gallons (MG) per year, and greater than 1 billion gallons in some years. Since that time, Lowell has invested more than $120M in the CSO control measures described in the remainder of this section.

The result of these efforts is best conveyed through the trend presented in *Figure 2-1*, below, demonstrating a reduction in overall CSO discharge volumes on the order of 80% over the period of LTCP investment.

In 2014 Lowell submitted its Phase II LTCP. The final projects included in Phase II have experienced construction schedule over-runs and are still underway with expected completion dates in mid-2020.

At present, the City is faced with competing needs for critical infrastructure upgrades within the City, as well as new compliance obligations related to stormwater discharges (MS4). This competition for extremely limited financial resources has led Lowell to adopt the Integrated Planning Framework recommended by EPA to responsibly balance the financial investments needed to meet these critical stormwater, wastewater and drinking water infrastructure goals as efficiently and expediently as possible. This Integrated Planning program forms the core of the Phase 3 LTCP and is discussed in more detail, below.

Figure 2-1 Annual CSO Discharge Volumes (2005-2017)



The remainder of this section presents a brief summary of each phase of LTCP development and implementation to date.

2.1.1 Phase 1 LTCP (2002-2013)

In February 2002, the utility submitted its first LTCP. This LTCP identified a phased program of improvements that was developed with the intent that the city assess its ongoing implementation of the Phase 1 program to identify the benefits and determine where additional work would provide the largest environmental benefit for the least cost.

On June 16, 2003, the city received an administrative order from the U.S. Environmental Protection Agency that presented a compliance schedule for the city to implement this phased approach and move forward with the Phase 1 LTCP.

Phases planned, designed and implemented in this period included Phase 1 and sub-phases 1A, 1B and 1C, with parallel capital improvement upgrades at a total investment of $120 million. Projects completed in this phase are summarized below.

Table 2-1 Phase 1 LTCP Investments

Project	Investment
Sewer separation	$50 million
Wet-weather operations upgrades	$40 million
Treatment facility process improvements and high-flow management program	$25 million
Emergency treatment-facility upgrades	$5 million

Clearly the largest investment in Phase 1, Lowell's sewer separation projects resulted in 15 miles of new drainage pipes and removed public and private inflow from nearly 600 acres of combined sewer basins; another eight miles of sewer lines were rehabilitated to reduce infiltration and inflow (I/I) into Lowell's combined sewer system (CSS), at a total cost of roughly $50 million.

Wet-weather operations investments coupled with treatment-facility process-control improvements culminated in the design and implementation of an automated High-Flow Management program (HFM) based on core principles of the NMC specified in Lowell's 2005 NPDES wastewater permit: maximizing peak flow to the treatment facility by utilizing excess primary treatment capacity, and maximizing interceptor storage.

Central to these efforts were $4 million in upgrades to Diversion Structures to increase conveyance and utilize existing interceptor pipeline storage, including new control gates, instrumentation and SCADA equipment for remote operation and automated control of CSOs.

The High Flow Management Plan describing the operational procedures resulting from these improvements was submitted to EPA in 2011 and is managed as an ongoing program by Lowell staff to seek continual improvements, as detailed further in *Section 2.2*.

Another $7M were allocated toward treatment facility improvements at Duck Island, including gravity thickener and aeration blower upgrades that increased biological treatment capacity and performance.

Also implemented in this phase, Lowell developed and committed to an ongoing infiltration and inflow reduction program that included a sump pump disconnection program and significant investment in continual sewer rehabilitation projects throughout the city's aged infrastructure network (see *Section 3.5* for updates on this aspect of the Capacity, Management, Operations and Maintenance [CMOM] program).

2.1.2 Phase 2 LTCP (2014-Present)

Planning for Phase 2 began in 2012 and was finalized in 2014. As in Phase 1, an adaptive management approach was taken to target expenditures to the greatest expected return on investment, evaluate the benefits of those improvements, and adjust planned projects based on the results of previous work.

In this phase, Lowell Water committed $40 million to parallel CSO control and critical capital improvement projects. Projects totaling $30 million directly addressed CSO control measures through capital improvements, as shown in *Table 2-2*, below.

Table 2-2 Phase 2 LTCP Investments

Project	Investment
West Station Flood Pumping	$4 million
Treatment facility peak-flow capacity and treatment improvements	$16 million
Sewer relief across catchment basins to reduce surcharging	$2.5 million
North Bank Interceptor storage	$2 million
Sewer separation	$2.5 million
Phase 3/Integrated Plan development	$2 million
Green infrastructure community improvements	$0.5 million

Rehabilitation of the West Street Flood Pumping Station, which utilizes the existing CSO diversion structure to drain floodwaters from at-risk areas of the city during extreme river levels, was recently completed and approved by the US Army Corps of Engineers (USACE) in 2018. While this project does not offer an increase in CSO control, it serves as an example of the integrated water resources management role that Lowell Water takes in the City and serves to protect a densely populated portion of the city from catastrophic flood risks through use of an existing CSO facility.

Treatment facility peak-flow capacity and performance improvements included review and revision to the Duck Island Clean Water Facility's hydraulic and process-control models, which enabled re-evaluation of optimal flow set-points. Coupling these optimizations with installation and integration of real-time TSS probes at the end of each of the Facility's treatment processes allowed improvement of the HFM protocol. The SCADA system now looks at TSS and flow through the facility to forecast effluent TSS discharges, so that operators can control the inflow rate to deliver as much flow to the facility for treatment as possible while maintaining secondary treatment levels.

Sewer relief at the Marginal Street project provided a hydraulic overflow connection between an inadequately sized sewer line in Marginal Street and a nearby interceptor in an attempt to eliminate combined sewer surcharges in that neighborhood. While this project was largely successful, occasional surcharges still occur, and full elimination of these surcharges through construction of storage tanks in the affected area are a priority feature in the ICIP submitted for approval in December 2019.

The North Bank Flow Control Structure, which allows additional inline wet-weather storage, was brought online in 2018. This structure is located near the Read Street diversion station, at a point where the North Bank interceptor has a significant drop from one interceptor pipe segment to the next. An actuated flow-control gate was installed upstream of this drop, in order to increase in-line storage capacity between Read and West stations. Upstream of the gate itself, a storage chamber with a capacity of approximately 0.75 MG was constructed, as well, and the site is under consideration for expansion to a screening and disinfection facility, as described in the ICIP currently pending regulatory review.

Phase 2 capital improvement projects still underway at the time of this report and that are expected to improve HFM or otherwise contribute to increased CSO control include:

- Primary and secondary clarifier upgrades, which will improve the reliability of these treatment processes and increase overflow weir heights to allow greater hydraulic throughput with equal or better solids retention. At the time of this report, five of the six primary clarifiers have been replaced, and three of the four secondary clarifiers have been replaced. The remaining two clarifiers are expected to be operational by the end of June 2020.
- Remote station upgrades, which will improve flow through some of the CSO diversion stations and increase reliability of communications and reporting between central SCADA servers and these stations. This includes removal of the bar racks at some of the stations where these had been observed to reduce conveyance and contribute to CSO discharges. Bar racks have been removed from Merrimack, Warren, Walker and Beaver Brook stations since late 2018. SCADA improvements have been completed at Varnum, Cannington, Trotting Park, Pyne School and Beaver Brook stations. All outstanding SCADA improvements are expected to be complete by the end of June 2020.
- Automated chlorination of the high-flow treatment line that conveys primary effluent flows in excess of secondary capacity to the blending well immediately upstream of the chlorine contact chambers. Studies conducted in late 2018 suggest that automation using existing total residual chlorine (TRC) probes at the end of the high-flow treatment line can improve the reliable disinfection of wet-weather flows by modulating chlorine pump speed to maintain constant chlorine residual at the upstream end of the contact chambers. Chlorine pumps were replaced in 2019 and code to automate dosing was developed and deployed to the SCADA codebase. Full automation is almost available, pending installation of a new automated valve in the high-flow treatment chlorination line.

2.1.3 Phase 3 LTCP and Integrated Capital Improvements Plan

At present, Lowell Water is working in collaboration with EPA and the Massachusetts Department of Environmental Protection (MassDEP) to develop an integrated planning program which will follow the EPA Integrated Planning Framework, as discussed above. While it is expected that this approach will allow Lowell to balance CSO control investments with other infrastructure needs like stormwater control and drinking water reliability, Lowell remains committed to reducing CSOs through effective control strategies as quickly as possible. The Integrated Capital Improvements Plan (ICIP) was submitted in December 2019 and is under review by EPA and MassDEP.

As has been discussed above, Lowell's investments in CSO control to date have focused primarily on optimizing the use of existing infrastructure prior to investing in new infrastructure, whether that may be in the form of separate drainage systems, additional storage capacity, or wet-weather treatment. This approach has been aligned with meeting the requirements in Lowell's 2005 NPDES permit to maximize flow to the treatment facility through use of excess primary clarifier capacity and to maximize storage in the collection system prior to allowing diversions to occur.

The Integrated Planning program focused significant efforts on assessing the extent to which these requirements have been maximized, including additional flow metering and collection-system model (SWMM 5.1) validation. The collection-system model was updated to include logic controls for flow through actuated gates as currently installed and controlled (including the new North Bank Flow Control

Station), and the removal of hydraulic restrictions through CMOM and recent upgrades (e.g., the removal of bar-racks at CSO stations where they were restricting flow).

Initial review of the flow-metering data and the model simulation results suggests that Lowell has approached the maximum limit for utilization of its existing infrastructure to control CSOs. Achieving this goal was considered the first logical step during the Phase 1 LTCP, and now that it has been largely attained the focus will necessarily shift to assessment of new infrastructure options to eliminate the 'remaining' CSO discharges relative to pre-control levels of discharge.

To this end, Hazen and Sawyer worked with Lowell Water personnel to develop a CSO Control Alternatives Analysis. This analysis, detailed in the ICIP currently under review, utilized the validated collection-system model to simulate several different scenarios of modifications to the collection system and treatment plant using alternative available technologies. The results of these simulations, all run under a common 'typical year' of hydrologic events, resulted in a ranking of these various technologies according to their ability to meet the intended objectives of minimizing CSO discharges and total cost to achieve those reductions (i.e., maximizing cost-benefit ratio). The leading alternatives were assessed through more detailed simulation and analysis, which in turn led to selection of the recommended suite of controls to be designed and implemented going forward.

As an example, it was previously mentioned that the Read Street flow-control structure may be exceptionally well suited for design of a wet-weather facility that would provide screening and disinfection of wet-weather flows. The benefit of such a facility in terms of annual untreated CSO discharge reduction has been estimated to be on the order of 50% reduction of total untreated CSO volume in a 'typical year' identified for the model simulation baseline. Such a control strategy would allow for rapid improvement to the water quality downstream of Lowell, in a manner consistent with practices established in other Merrimack River communities (e.g., Nashua, NH).

Empirical support for this control strategy from a water-quality perspective was established in 2018 through Lowell's water-quality monitoring program (*Clean Stream Initiative*), which collected in-stream bacteria (*E. coli*) concentration data during and for several days after storm events which activated the similarly designed Nashua wet-weather facility. Throughout these sampling periods, upstream water quality did not violate the single-sample maximum bacteria criteria.

The ICIP is currently under review by US EPA and MassDEP, and further development of the projects proposed therein is contingent upon approval by these agencies.

2.1.4 Other Programmatic Activities Directed at CSO Control

Lowell recognizes the critical need to reduce CSO impacts on the Merrimack River and its tributaries. The City is also acutely aware of the cost of these controls and the impact of these costs on the City budget and other critical public programs. Lowell understands that CSO systems are a by-product of past administrative and later legislative actions that have significantly reduced Federal assistance to communities working toward Clean Water Act (CWA) compliance.

As a result, Lowell Water's External Relations program is focused on leading a conversation with other utilities and clean water advocates to create an organized and urgent call to Congress to increase funding of CSO control activities throughout the nation. It is Lowell Water's optimistic hope that investment in clean water can again become a national priority, and that the struggles of more than 700 combined sewer communities – vestiges of the pre-regulatory industrial era – will be recognized as a national issue with need for Federal support.

2.2 High Flow Management Program and Annual Report

Lowell Water's High Flow Management program (HFM) has been developed to maximize the treatment and storage of wet-weather flows with existing infrastructure prior to investing in planning and construction of new infrastructure. This program's conceptual groundwork lies in the Nine Minimum Controls (Appendix E of Lowell's 2005 NPDES wastewater permit), wherein it is explicitly stated that Lowell should maximize flow to the treatment plant through utilization of excess primary treatment capacity and maximization of the existing collection system for in-line storage. Accordingly, and as described above, Lowell has invested heavily in developing this program over the past 17 years.

This section of the report provides a detailed presentation of the current HFM protocol as practiced in 2019.

2.2.1 HFM Protocol

Lowell Water developed and implemented a Supervisory Control and Data Acquisition (SCADA) network, which allows operators to remotely control and monitor gates, valves, and pumps directly from the Operations Center at Duck Island. In addition to equipment at Duck Island, remote monitoring and control was enabled at all eight active CSO diversion stations along the interceptor system. Lowell Water has developed automated wet-weather protocols implemented through algorithms in the human-machine-interface (HMI) programming package RSLogix provided by Rockwell Automation.

The current protocol is implemented as a combination of reactions taken to increase or decrease flow to Duck Island and to accordingly increase or decrease flow through collection system structures in response to the network of level and flow sensors in the collection system and at Duck Island. These reactions are predominantly automated through control rules established in SCADA but are continually reviewed and assessed by head operators throughout any given event. At any time, operators may change the automated system response based on their professional experience in order to avoid undesirable outcomes or to increase throughput at the plant when conditions allow.

Simply expressed, the HFM protocol follows the logic:

1. Maximize flow to the Duck Island treatment facility
2. Maximize use of available storage in the collection system's interceptors upstream of flow-control gates
3. Prevent sewer surcharging by diverting flow through CSO stations

With a bit more detail, the North Bank and South Bank interceptors are controlled primarily by gates at the North Bank Flow Control Station and at Merrimack Station (on the South Bank). These gates are kept open to levels that do not restrict flow under normal (dry) conditions. Upon the start of a wet-weather event, these gates are adjusted to allow free gravity flow to the facility until the biological treatment system has reached maximum capacity (this is a variable range dependent on process performance and external factors, but generally lies within 60-75 MGD).

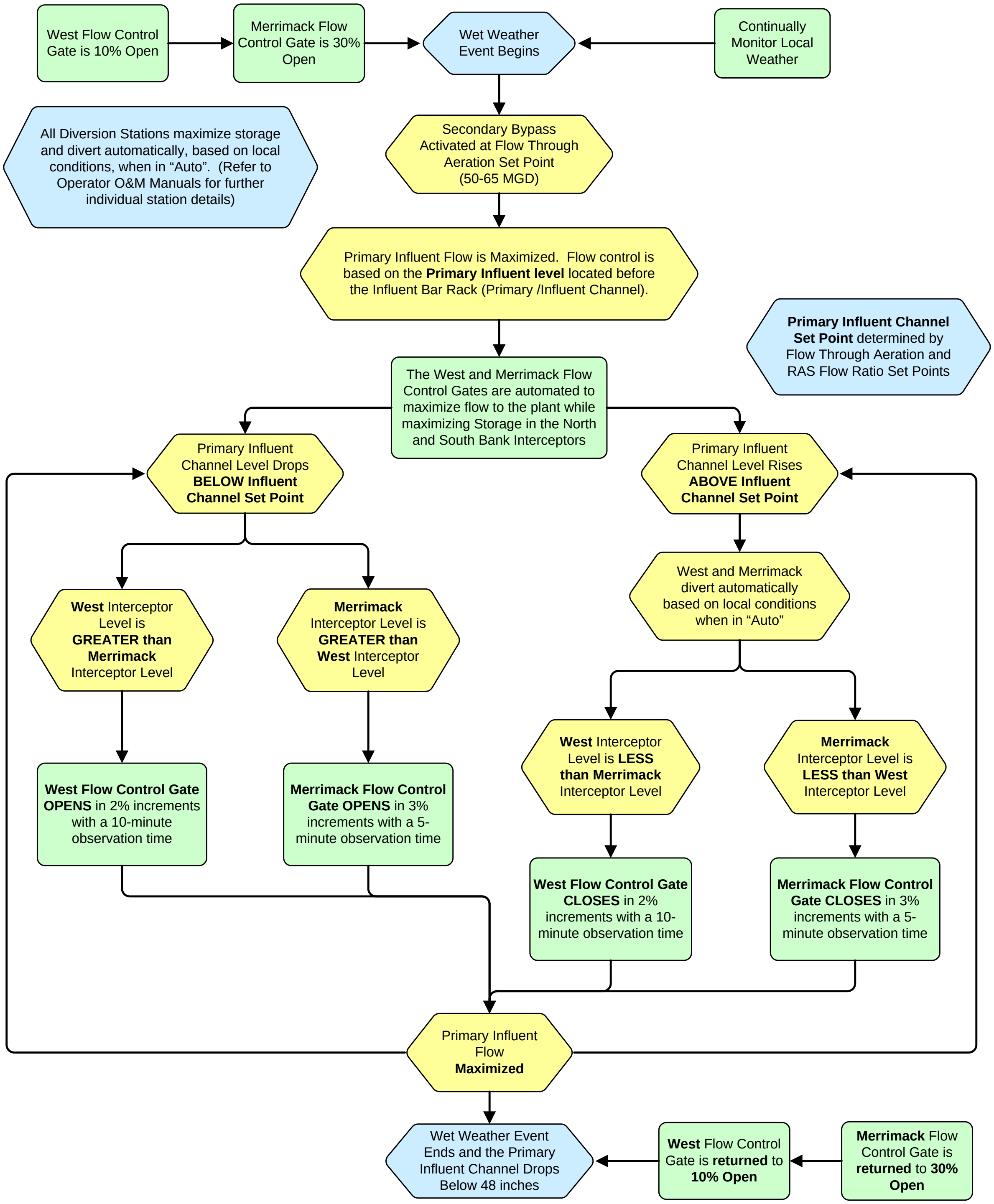
Upon maximization of flow to the biological treatment system, the high-flow treatment line is opened to allow excess primary treatment capacity to be conveyed to the blending well at the outlet of the secondary clarifiers. The hydraulic capacity at Duck Island is currently restricted to an instantaneous peak flow rate of 120 MGD, and an average hourly flow rate of 105 MGD. Flows in excess of this upper limit are not allowed, and so result in the control gates modulating to maintain the maximum flow rate. As these gates modulate, levels in the interceptor rise until they are within one foot of the interceptor crown. Upon crossing this threshold, excess flows are diverted through CSO stations to prevent sewer surcharging.

At present, chlorine pumps are installed for manual dosing of the high-flow treatment line to allow for additional disinfection of the primary effluent. This primary effluent is blended with secondary effluent at the blending well, and then enters the chlorine contact chambers prior to discharge at the Duck Island outfall. High-flow treatment continues in this manner until the plant-influent flow rate falls below the biological treatment capacity, whereupon the high-flow line is closed.

As this process occurs, total suspended solids (TSS) meters continuously record the quality of primary and secondary effluent. SCADA calculates a mass balance to forecast effluent TSS concentrations and displays this information to the operators. If TSS concentrations are forecasted to exceed allowable secondary-treatment levels, flow to the plant is reduced and the collection system responds by modulating its gates to increase storage and, if necessary, discharge at CSO stations.

Figure 2-2, below, provides a visual representation of the HFM protocol, as followed at present.

Figure 2-2. Automated High Flow Management Protocol



2.2.2 HFM Improvement Actions in 2019

The following actions have been undertaken to inform improvements to the HFM program in 2019.

Comprehensive SCADA Upgrades

The SCADA system that serves as the core architecture for the HFM Plan was upgraded in 2019 to improve communications, reliability and overall security. These upgrades included migration to a new secure server that improves the integrity of the SCADA system while increasing access to those who need it most at the treatment facility.

High Flow Treatment Chlorine Dosing Automation

In 2018, Lowell Water staff conducted sampling of chlorinated high-flows at the end of the high-flow treatment line and through the chlorine contact chamber to support automation of high-flow chlorine dosing. Results suggested that development of an automated chlorine-dosing rate based on the total residual chlorine (TRC) probe at the front of the chlorine contact chambers may be beneficial to ensure optimal dosing by modulating the chlorine-pump speed to maintain a constant residual chlorine level at that point. In 2019, these results were assessed further to develop SCADA control algorithms relating pump speed and chlorine dosage to improve reliability and efficiency of disinfection and de-chlorination. The chlorine pumps were replaced, and full automation of chlorine dosing will be available upon installation of a new automated valve in the high-flow treatment chlorination line.

High Flow Management Plan Update

Lowell Water engineering staff began a station-by-station review of measurements taken at CSO stations that factor into HFM automation protocols. These measurements were originally developed in 2009-2011 by Lowell staff and CDM, during the initial design of the HFM program. After eight years of active management experience, a comprehensive revision to the 2011 HFM Plan is due. Several measurements are to be considered during this review process, including structure elevations; river stage elevations; level sensor settings; gate opening ranges; SCADA flow calculations and control algorithms; and flow meter validation.

As this review process continues in 2020, the HFM plan will be revised and updated to reflect the current system state, which has changed significantly over the years. Submission of the final HFM plan to EPA and MassDEP was included as part of the ICIP schedule.

2.2.3 HFM Meetings

Central to the HFM program is a recurring bi-weekly meeting at which Lowell Water staff from the Operations, Maintenance and Engineering divisions convene with the Executive Director to discuss recent high-flow events and assess performance of those events. Recurring action items include review of gate positions, system levels and flows, and precipitation records to assess opportunities for improvement; review of plant discharge sampling data to ensure that treatment levels meet permit limits; status updates on SCADA improvements and previously identified opportunities for improvement.

2.2.4 CSO Public Notification and Reporting Plan

Since 2018, Lowell has provided near real-time notification of CSO discharges to interested parties via emails sent by Operations staff as they occur. Detailed reports of each CSO event and High-Flow Treatment performance are sent to all parties after proper validation of instrument and communication records within ten days of the end of a high-flow or CSO event. Lowell has also designed more 'readable' notification reports in response to concerns presented by downstream community representatives that standard reporting formats were difficult to understand.

Lowell engineering staff have been actively involved in communication and collaboration with special interest groups like the Massachusetts Coalition for Water Resources Stewardship, Massachusetts Rivers Alliance, the Merrimack River Watershed Council, and others to identify the primary objectives of public notifications that may be delivered in a timeframe manageable from a utility perspective while still meaningful to the general public.

Lowell continued to engage in this public outreach project through 2019 by participating in the development of the Merrimack River District Commission and has representatives on that organization's Steering Committee as well as its Technical Advisory Group.

Many of these voluntary standard procedures were stated as requirements in Lowell's 2019 NPDES permit, which requires submittal of a public notification plan (provided herein). Specific requirements of the 2019 permit include (at Part I.F.3(g)):

- Initial notification, to be provided no later than four hours after becoming aware by monitoring, modeling or other means, and to include the date and time of probable CSO discharge, CSO [outfall] number and location.
- Supplemental notification, to be provided within 24 hours after becoming aware of the termination of a CSO discharge, and to include the CSO [outfall] number and location, confirmation of the CSO discharge, and the CSO date, start and stop time.
- Annual notification, to be submitted by March 31, and to include the number of CSO activations and volume of each, status and progress of CSO abatement work, and contacts for additional information on CSOs and water quality impacts on a website.

Lowell's CSO Public Notification Plan is as follows:

1. Continuous monitoring of CSO discharge at all active CSO outfalls through the SCADA network.
2. Initial notification to all subscribers via email and/or text message within four hours of the start of a CSO discharge.
3. Supplemental notification is initially provided within four hours of the termination of CSO discharges to all subscribers. This message includes the date and time at which the CSO diversions stopped.
4. Full report provided within 10 days showing each station's hourly discharge duration and volume, including rainfall and high-flow treatment performance metrics.
5. Annual report of all events posted online in Lowell's Annual Clean Water Report (*Section 2.4).*

2.3 Nine Minimum Controls Report

The Nine Minimum Controls (NMC) are stipulated in Lowell's 2005 NPDES permit at Attachment E: Nine Minimum Technology Based Controls Documentation and Implementation Guidance. EPA states therein that "EPA has made a Best Professional Judgment (BPJ) determination that adequate implementation of these nine minimum control measures satisfies technology based requirements (Best Practicable Control Technology Currently Available (BPT), Best Conventional Pollutant Control Technology (BCT) to control and abate conventional pollutants and Best Available Technology Economically Achievable (BAT) to control and abate non-conventional toxic pollutants."

Given this BPJ on the part of EPA, Lowell Water has invested heavily in the NMC technologies, as detailed in this section and elsewhere in this report. *Table 2-3* details the documentation required by EPA to demonstrate: 1) that alternatives were considered for each of the nine minimum control measures, 2) the reasoning for the alternatives selected, 3) that the selected alternatives have been implemented, and 4) that the permittee has developed a schedule for actions that have been selected but not yet fully implemented.

The remainder of this section discusses Lowell's work to date toward implementing the NMCs as practicable since issuance of the permit in 2005. Where a particular control is covered in detail in another section of this report, the reader is referred to that section for more information.

Table 2-3 Nine Minimum Controls

Control	Documentation Requirements	Reported At/Details
1. Proper operation and regular maintenance programs for the sewer system and combined sewer overflow points	a. Organizational O&M responsibilities chart b. Funding allocated for O&M c. List of critical facilities and structures (regulators, tide gates, pumping stations, sections of sewer lines prone to sedimentation or obstruction) and inspection plan (locations, frequency, procedures, documentation, reporting of periodic and emergency inspections and maintenance) d. Summary of safety training and equipment provided to inspection and maintenance personnel e. Summary of technical training and maintenance equipment provided to inspection and maintenance personnel.	a. **Section 3.1.1** b. **Section 1.3** c. **Section 3.2.8** d. **Section 3.1.2** and **Section 3.2.3** e. **Section 3.1.2** and **Section 3.2.3**
2. Maximize Use of the Collection System for Storage	a. Identification of maintenance or design deficiencies that restrict the use of otherwise available system capacity b. Adequacy of tide gate maintenance and repair procedures c. Document the method for optimal setting of regulators d. Document procedures for identification and removal of obstructions to flow. Include a summary of the locations where sediment is removed, the number of times each year the sediment is removed and the total quantity of material removed each year	a. **Section 3.4** b. **Section 2.6** c. **Section 2.2** d. **Section 3.3.3** and **Section 3.4.3**
3. Review and modification of the Industrial Pretreatment Program (IPP) to assure CSO impacts are minimized	a. Review legal authority and identify those activities for which the community has or can obtain authority to address CSO induced water quality violations (e.g., authority to require non-domestic dischargers to store wastewater during precipitation events or require them to implement runoff controls) b. Inventory non-domestic dischargers that may contribute to CSO induced water-quality violations c. Assess whether identified dischargers cause or contribute to CSO induced water-quality violations by using monitoring, dilution calculations or other reasonable methods d. Evaluate and propose feasible site-specific modifications to address non-domestic dischargers identified as significant	See Annual Pretreatment Report, submitted separately by Lowell Water's Pretreatment Coordinator at present
4. Maximization of flow to the treatment facility	Evaluate and implement where possible: a. Use of off-line or unused POTW capacity for storage of wet-weather flows b. Use of excess primary treatment for treatment of wet-weather flows. If the use of excess primary capacity will result in violations of the NPDES permit limits, the community shall get approval from the permitting authority prior to implementation	**Section 2.1** (history) and **Section 2.2** (current practice)
5. Prohibition of CSO discharges during dry weather	a. Document that monitoring and inspections are adequate to detect and correct dry-weather overflows (DWOs) in a timely manner b. Document that inadequate DWOs due to inadequate sewer system capacity have been eliminated c. Document that DWOs due to clogging of pipes and regulators or other maintenance problems have been eliminated to the maximum extent practicable	a. **Section 2.2** b. **Section 2.4** c. **Section 2.4**
6. Control of solid and floatable material in CSO Discharges	Document that low-cost control measures to reduce solids and floatables discharged from CSOs have been implemented to the maximum extent practicable. Alternatives shall include: a. Baffles in regulators or overflow structures b. Trash racks in CSO discharge structures c. Static screens in CSO discharge structures d. Catch basin modifications e. End-of-pipe nets f. Outfall booms (on surface of receiving water)	Street sweeping is implemented bi-annually throughout Lowell, which serves to reduce the amount of litter washed into the collection system. Catch basins have hoods to minimize the amount of floatables leaving the basin and sump to minimize the amount of solids leaving the basin. Further opportunities will be explored to further reduce discharge of solids and floatables from CSO outfalls in Lowell. More details at **Section 3.3.3**

Table 2-3 Nine Minimum Controls

Control	Documentation Requirements	Reported At/Details
7. Pollution prevention programs that focus on contaminant reduction activities	a. Prevention through increased public education and awareness b. Control of disposal (garbage receptacles, collection and education) c. Control of illegal dumping (law enforcement, public education, disposal programs) d. Street cleaning e. Hazardous waste collection days	a. Lowell's website was revised in 2019 to include visual graphics depicting how the *collection* and *treatment* systems operate, and how they can take actions to reduce impacts on operations and maintenance. b. Hazardous waste collection days are held regularly at Duck Island and other programs are actively managed by the City's Solid Waste and Recycling Office, which also manages a public radio program addressing this subject. c. Lowell Water supports a catch-basin labeling program to notify residents not to dispose of wastes in these receptacles. 150 catch basins were labeled in 2018. d. **Section 3.3.3** e. Addressed at (b)
8. Public notification to ensure that the public receives adequate notification of CSO occurrences and CSO impacts	a. Ensure that the public receives adequate notification of CSO impacts on pertinent water use areas, particularly beach and recreational areas affected b. Where applicable, provide users of these types of areas with a reasonable opportunity to inform themselves of the potential health risks c. The minimum control level, found in Section C.2.e. of the permit, is posting of CSO discharge points	**Section 2.2.4**
9. Monitoring to effectively characterize CSO impacts and the efficacy of CSO controls	a. If possible, initiate monitoring and/or inspection activities above and beyond the minimum control levels specified in this permit b. Examples include CSO monitoring or receiving water monitoring for pollutants of particular concern to better characterize quality of the CSOs and their impacts on all receiving waters	Lowell contributed matching funds to the US Army Corps of Engineers (USACE) *Merrimack River Watershed Assessment Study*, which conducted extensive water-quality monitoring and modeling tasks from 2003-2018. This study is now complete and a final report is forthcoming from USACE. Additionally, Lowell Water carried out extensive wet-weather CSO and receiving water monitoring in 2018 and has shared this data with the Merrimack River Watershed Council, Merrimack River District Commission, MassDEP and US EPA. In 2019, Lowell purchased a *Fluidion* ALERT system, which has been used extensively in Europe to improve monitoring of in-stream water-quality impacts of CSOs. Lowell is continuing to develop a monitoring program utilizing this equipment in 2020.

2.4 Precipitation, High Flow Treatment & CSO Data

Lowell Wastewater Utility
High Flow Treatment and CSO Control Report
January 01, 2019 - December 31, 2019

Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)		
01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)
1/1/2019	47.97	97.21		1	0.48	0.15		1	5.50	6.93
1/2/2019	31.52	35.88								
1/3/2019	31.33	37.14		1	0.02	0.01				
1/4/2019	32.84	39.29								
1/5/2019	35.40	43.54		1	0.11	0.03				
1/6/2019	34.20	40.35								
1/7/2019	32.82	37.68								
1/8/2019	34.64	58.48		1	0.01	0.01		1	0.83	0.23
1/9/2019	39.66	66.79		1	0.02	0.01		1	2.38	1.11
1/10/2019	33.05	37.84								
1/11/2019	31.89	35.75								
1/12/2019	31.45	38.07								
1/13/2019	31.65	38.49								
1/14/2019	35.81	50.43								
1/15/2019	33.86	49.41								
1/16/2019	26.60	31.31								
1/17/2019	25.96	33.65								
1/18/2019	25.60	29.15								
1/19/2019	25.71	32.51								
1/20/2019	25.46	32.27								
1/21/2019	25.71	31.63								
1/22/2019	25.06	29.81		1	0.02	0.02				
1/23/2019	25.14	30.21		1	0.24	0.09				
1/24/2019	74.02	104.25	104.25	1	1.06	0.23	0.23	1	15.37	27.39
1/25/2019	41.21	89.89		1	0.01	0.01		1	0.75	0.47
1/26/2019	35.50	43.02								
1/27/2019	34.12	41.21								
1/28/2019	32.17	36.93								
1/29/2019	30.80	37.17								
1/30/2019	30.39	35.76								
1/31/2019	29.45	34.14								
2/1/2019	28.71	32.92								
2/2/2019	28.69	36.97								
2/3/2019	28.67	37.34		1	0.04	0.03				
2/4/2019	29.86	38.78		1	0.10	0.04				
2/5/2019	29.91	37.87		1	0.01	0.01				
2/6/2019	33.72	81.40		1	0.44	0.11		1	2.27	2.33
2/7/2019	39.61	82.32		1	0.09	0.04		1	3.87	3.13
2/8/2019	32.96	47.93		1	0.12	0.04				
2/9/2019	30.17	37.62								
2/10/2019	30.09	37.74								
2/11/2019	29.11	33.52								
2/12/2019	28.22	32.94								
2/13/2019	49.14	67.63		1	1.06	0.20		1	7.60	2.94
2/14/2019	31.30	37.64		1	0.01	0.01				
2/15/2019	32.70	42.90		1	0.03	0.02				
2/16/2019	32.30	41.26								
2/17/2019	30.19	37.77								
2/18/2019	30.34	37.54								
2/19/2019	28.89	33.13								
2/20/2019	28.39	32.61								
2/21/2019	30.88	41.95		1	0.41	0.14				
2/22/2019	30.01	39.49		1	0.11	0.05				
2/23/2019	28.70	37.17								
2/24/2019	49.06	95.14		1	0.44	0.13		1	8.63	9.72
2/25/2019	32.96	39.88		1	0.01	0.01				
2/26/2019	30.66	35.25								
2/27/2019	30.61	35.61								
2/28/2019	30.69	35.34		1	0.08	0.06				
3/1/2019	29.71	33.80								
3/2/2019	30.53	40.01		1	0.01	0.01				
3/3/2019	29.92	38.56		1	0.11	0.11				
3/4/2019	30.81	40.01		1	0.12	0.06				
3/5/2019	28.66	33.19		1	0.08	0.02				
3/6/2019	28.01	32.43								
3/7/2019	27.58	31.77		1	0.04	0.02				
3/8/2019	27.15	31.27		1	0.17	0.06				

Date	Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/19 12/31/19	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
1/24/2019	1	7.25	6.77	1	3.58	0.78	1	6.83	7.36				1	2.73	0.65	1	0.58	0.08	1	3.93	5.37	1	7.83	21.96	1	7.83	42.97

Lowell Wastewater Utility
High Flow Treatment and CSO Control Report
January 01, 2019 - December 31, 2019

Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
3/9/2019	27.64	35.04		1	0.01	0.01																															
3/10/2019	34.65	66.78		1	0.45	0.13		1	4.48	1.92																											
3/11/2019	36.26	53.22		1	0.12	0.03																															
3/12/2019	30.91	36.30																																			
3/13/2019	30.00	34.78																																			
3/14/2019	31.31	38.16																																			
3/15/2019	41.00	81.25	81.25	1	0.41	0.20	0.20	1	1.82	2.34	1	1.45	1.04				1	1.45	1.94										1	0.38	0.26	1	1.12	2.20	1	1.45	5.44
3/16/2019	49.11	82.12	82.12					1	4.67	5.60	1	0.73	0.19				1	0.70	0.14													1	0.75	0.40	1	0.75	0.73
3/17/2019	37.34	44.35																																			
3/18/2019	35.34	40.50																																			
3/19/2019	34.36	38.34		1	0.01	0.01																															
3/20/2019	34.89	38.96																																			
3/21/2019	33.16	38.37																																			
3/22/2019	37.00	46.58		1	0.29	0.07																															
3/23/2019	33.03	41.08		1	0.08	0.05																															
3/24/2019	32.81	44.40						1	4.75	3.12																											
3/25/2019	33.08	46.84						1	6.30	4.43																											
3/26/2019	30.10	34.04																																			
3/27/2019	30.43	35.94																																			
3/28/2019	30.06	35.51																																			
3/29/2019	33.61	47.17		1	0.04	0.02		1	7.45	3.95																											
3/30/2019	28.45	41.36						1	1.72	0.64																											
3/31/2019	33.45	60.90		1	0.21	0.08		1	5.18	5.74																											
4/1/2019	30.02	46.36		1	0.01	0.01		1	2.17	1.22																											
4/2/2019	28.73	32.92																																			
4/3/2019	30.66	34.11		1	0.12	0.05																															
4/4/2019	28.24	32.45																																			
4/5/2019	27.67	31.44		1	0.07	0.04																															
4/6/2019	30.01	34.92		1	0.11	0.04																															
4/7/2019	27.94	34.42																																			
4/8/2019	33.03	51.73		1	0.34	0.08		1	5.52	2.18																											
4/9/2019	28.76	38.81		1	0.14	0.08																															
4/10/2019	31.04	38.85		1	0.84	0.50																															
4/11/2019	28.02	32.93																																			
4/12/2019	25.34	36.00		1	0.06	0.06																															
4/13/2019	35.92	58.01		1	0.24	0.07		1	2.72	1.24																											
4/14/2019	28.42	37.04		1	0.05	0.02																															
4/15/2019	50.31	77.72	77.72	1	1.10	0.52	0.52	1	14.02	12.70	1	2.40	0.82	1	0.35	0.01	1	1.65	2.81				1	1.28	0.29				1	1.12	1.63	1	2.37	3.00	1	2.40	8.56
4/16/2019	31.80	37.08																																			
4/17/2019	31.59	38.27																																			
4/18/2019	31.22	37.67																																			
4/19/2019	30.55	35.83																																			
4/20/2019	34.66	70.74		1	0.23	0.13		1	2.70	1.85																											
4/21/2019	36.52	60.39		1	0.20	0.11		1	1.87	1.48																											
4/22/2019	47.01	104.62	104.62	1	1.15	0.27	0.27	1	7.15	10.62	1	2.08	0.41				1	2.28	3.30													1	2.23	2.00	1	2.28	5.71
4/23/2019	50.77	66.95	66.95	1	0.23	0.16	0.16	1	14.38	8.36	1	3.02	0.63				1	1.98	2.84													1	5.05	2.91	1	5.05	6.38
4/24/2019	40.09	43.65		1	0.06	0.03																															
4/25/2019	38.43	42.55																																			
4/26/2019	43.79	81.36	81.36	1	0.75	0.38	0.38	1	4.70	6.37	1	1.90	0.39				1	0.52	0.32				1	0.43	0.13				1	0.67	0.61	1	2.58	3.30	1	2.58	4.75
4/27/2019	62.83	83.70	83.70	1	0.57	0.20	0.20	1	23.08	24.53	1	4.35	0.90	1	0.45	0.01	1	1.78	1.60				1	0.17	0.05				1	0.33	0.30	1	7.88	8.80	1	7.88	11.66
4/28/2019	44.55	50.58		1	0.01	0.01		1	11.35	4.45																											
4/29/2019	40.11	46.02																																			
4/30/2019	41.67	45.70		1	0.14	0.05																															
5/1/2019	40.42	44.75																																			
5/2/2019	47.40	65.41		1	0.35	0.19		1	17.65	10.47																											
5/3/2019	39.59	62.96		1	0.21	0.09		1	5.98	3.26																											
5/4/2019	39.22	51.34		1	0.09	0.06		1	1.88	0.44																											
5/5/2019	36.53	42.68		1	0.05	0.03																															
5/6/2019	34.93	39.33																																			
5/7/2019	35.21	48.24		1	0.25	0.09		1	1.28	0.79																											
5/8/2019	36.04	48.78						1	4.77	1.79																											
5/9/2019	32.08	37.17																																			
5/10/2019	31.43	37.17		1	0.02	0.01																															
5/11/2019	31.10	37.81																																			
5/12/2019	30.27	37.72		1	0.02	0.01																															
5/13/2019	37.50	79.86		1	0.52	0.14		1	4.13	5.57																											
5/14/2019	37.53	69.22		1	0.20	0.05		1	3.17	2.85																											

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Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
5/15/2019	30.85	34.98																																			
5/16/2019	30.43	33.99																																			
5/17/2019	30.68	38.51		1	0.12	0.07																															
5/18/2019	31.16	35.55																																			
5/19/2019	30.14	46.32		1	0.12	0.12		1	5.47	1.74																											
5/20/2019	30.85	36.06		1	0.02	0.01																															
5/21/2019	30.29	35.79																																			
5/22/2019	28.38	32.34																																			
5/23/2019	27.48	31.85		1	0.10	0.10																															
5/24/2019	28.58	38.46																																			
5/25/2019	26.75	33.38																																			
5/26/2019	28.48	57.27		1	0.13	0.12		1	1.38	1.19																											
5/27/2019	25.51	34.06																																			
5/28/2019	33.99	52.18		1	0.47	0.08		1	9.27	6.28																											
5/29/2019	28.70	42.89		1	0.01	0.01		1	3.02	1.11																											
5/30/2019	26.47	31.56		1	0.07	0.03																															
5/31/2019	26.06	31.50		1	0.01	0.01																															
6/1/2019	25.44	31.59																																			
6/2/2019	33.94	75.37	75.37	1	1.03	0.37	0.37	1	5.55	8.05	1	1.78	0.90	1	0.85	0.72	1	2.30	4.19	1	0.25	0.02	1	1.10	1.26	1	0.67	2.27	1	0.83	6.75	1	3.63	8.90	1	3.63	25.01
6/3/2019	36.40	76.61	76.61	1	0.02	0.02	0.02	1	4.07	6.79							1	0.02	0.02																1	0.02	0.02
6/4/2019	28.08	32.57																																			
6/5/2019	27.40	36.47		1	0.16	0.16																															
6/6/2019	44.41	85.35	85.35	1	1.14	0.67	0.67	1	9.27	12.99	1	1.95	1.08	1	1.55	0.98	1	1.70	4.50	1	0.08	0.02	1	1.78	2.88	1	1.43	0.92	1	1.67	5.50	1	2.52	8.10	1	2.52	23.98
6/7/2019	29.28	32.48																																			
6/8/2019	29.07	31.97																																			
6/9/2019	29.20	31.78																																			
6/10/2019	29.84	37.22																																			
6/11/2019	49.74	82.96	82.96	1	0.83	0.27	0.27	1	11.02	17.40							1	0.67	0.75																1	0.67	0.75
6/12/2019	27.88	33.50																																			
6/13/2019	38.31	70.63		1	0.46	0.14		1	8.53	9.84																											
6/14/2019	29.75	33.22																																			
6/15/2019	27.85	33.10																																			
6/16/2019	39.38	67.89		1	0.58	0.11		1	10.17	11.73																											
6/17/2019	29.03	34.84						1	0.22	0.02																											
6/18/2019	28.43	32.88		1	0.04	0.02																															
6/19/2019	27.79	33.68																																			
6/20/2019	41.54	75.75	75.75	1	0.60	0.23	0.23	1	11.20	11.73							1	0.42	0.48										1	0.28	0.34				1	0.42	0.82
6/21/2019	29.16	45.13		1	0.04	0.02		1	1.68	0.44																											
6/22/2019	29.82	35.19																																			
6/23/2019	29.79	35.42																																			
6/24/2019	30.74	33.88																																			
6/25/2019	30.24	37.76		1	0.12	0.03																															
6/26/2019	29.05	33.93																																			
6/27/2019	30.49	33.70																																			
6/28/2019	31.09	34.11																																			
6/29/2019	35.57	62.53	62.53	1	0.72	0.66	0.66	1	6.60	6.71	1	1.40	0.38	1	0.58	0.25	1	1.00	2.29	1	0.07	0.01	1	0.82	1.25	1	0.22	0.02	1	0.55	2.92	1	0.95	1.10	1	1.40	8.22
6/30/2019	34.30	64.21		1	0.14	0.08		1	3.77	4.56																											
7/1/2019	30.11	33.49																																			
7/2/2019	29.32	33.17																																			
7/3/2019	28.24	32.67																																			
7/4/2019	27.90	32.38																																			
7/5/2019	26.88	31.76																																			
7/6/2019	27.76	45.65		1	0.12	0.08		1	1.33	0.79																											
7/7/2019	27.78	33.69																																			
7/8/2019	26.76	30.64																																			
7/9/2019	26.86	32.05																																			
7/10/2019	26.08	30.36																																			
7/11/2019	33.57	67.29	67.29	1	0.37	0.34	0.34	1	5.78	6.27				1	0.77	0.70							1	0.75	1.10	1	0.38	0.10				1	0.95	1.50	1	0.95	3.40
7/12/2019	41.08	78.02	78.02	1	0.71	0.30	0.30	1	13.42	11.43				1	0.75	0.14	1	0.45	0.40				1	0.87	0.28				1	0.93	2.00	1	0.97	1.20	1	0.97	4.02
7/13/2019	25.74	30.81																																			
7/14/2019	24.82	30.51																																			
7/15/2019	24.93	29.85																																			
7/16/2019	24.52	28.96																																			
7/17/2019	32.54	66.62	66.62	1	0.31	0.19	0.19	1	5.95	6.32				1	0.60	0.32							1	0.35	0.07							1	0.80	2.50	1	0.80	2.89
7/18/2019	25.22	29.86																																			
7/19/2019	25.36	30.19																																			
7/20/2019	24.31	30.29																																			

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Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
7/21/2019	24.24	30.16																																			
7/22/2019	35.53	73.76		1	0.83	0.23		1	7.17	9.64																											
7/23/2019	62.47	82.46	82.46	1	1.32	0.28	0.28	1	15.92	27.18	1	1.05	0.41	1	0.45	0.02	1	2.95	4.43				1	0.95	0.31				1	0.37	0.44	1	5.08	7.40	1	5.08	13.01
7/24/2019	31.71	53.12																																			
7/25/2019	32.51	50.12																																			
7/26/2019	26.37	30.83																																			
7/27/2019	26.52	32.82																																			
7/28/2019	26.12	31.87																																			
7/29/2019	25.94	30.48																																			
7/30/2019	25.24	32.91																																			
7/31/2019	27.26	50.74		1	0.13	0.12		1	1.43	0.48																											
8/1/2019	24.47	28.64																																			
8/2/2019	24.28	39.64																																			
8/3/2019	23.71	32.52		1	0.04	0.03																															
8/4/2019	23.56	28.71																																			
8/5/2019	23.89	28.25																																			
8/6/2019	24.15	28.61																																			
8/7/2019	36.68	70.57	70.57	1	1.53	0.57	0.57	1	8.90	9.43	1	1.73	1.93	1	1.67	0.63	1	1.52	4.19	1	0.07	0.03	1	2.10	2.21	1	0.80	0.27	1	1.83	8.11	1	1.90	5.72	1	2.10	23.09
8/8/2019	39.13	68.79	68.79	1	0.25	0.14	0.14	1	7.27	7.83	1	3.02	0.47				1	1.90	2.10													1	2.78	2.00	1	3.02	4.57
8/9/2019	25.40	29.69																																			
8/10/2019	24.85	30.81		1	0.01	0.01																															
8/11/2019	24.26	30.36																																			
8/12/2019	24.41	28.29																																			
8/13/2019	24.06	28.30																																			
8/14/2019	24.31	28.42																																			
8/15/2019	24.14	28.53																																			
8/16/2019	24.28	28.40																																			
8/17/2019	25.28	66.46		1	0.24	0.20		1	0.47	1.00																											
8/18/2019	24.11	69.06		1	0.20	0.18		1	4.37	4.11																											
8/19/2019	15.61	27.86																																			
8/20/2019	33.28	30.23																																			
8/21/2019	25.78	56.40		1	0.08	0.04		1	1.87	0.90																											
8/22/2019	23.78	27.82		1	0.01	0.01																															
8/23/2019	22.56	26.59																																			
8/24/2019	22.67	28.41																																			
8/25/2019	22.47	28.95																																			
8/26/2019	22.65	27.92																																			
8/27/2019	21.65	26.39																																			
8/28/2019	36.29	82.32	82.32	1	1.22	0.36	0.36	1	7.27	10.84				1	0.43	0.50							1	0.33	0.52	1	0.40	0.33	1	0.35	1.12	1	0.20	2.20	1	0.43	4.67
8/29/2019	33.06	77.12	77.12	1	0.10	0.10	0.10	1	5.43	5.65	1	1.42	0.20	1	0.68	0.36	1	0.87	1.62				1	0.45	0.27	1	0.25	0.03	1	0.25	0.09	1	2.32	3.40	1	2.32	5.97
8/30/2019	22.61	26.43																																			
8/31/2019	23.21	29.06																																			
9/1/2019	22.24	28.60																																			
9/2/2019	23.51	30.52		1	0.03	0.02																															
9/3/2019	23.17	28.61																																			
9/4/2019	23.71	32.82		1	0.05	0.04																															
9/5/2019	22.02	26.53		1	0.01	0.01																															
9/6/2019	22.09	26.47		1	0.01	0.01																															
9/7/2019	21.53	28.19																																			
9/8/2019	21.75	28.60																																			
9/9/2019	21.39	34.96																																			
9/10/2019	21.59	27.11																																			
9/11/2019	22.17	27.74																																			
9/12/2019	21.41	26.37																																			
9/13/2019	21.23	25.61																																			
9/14/2019	23.48	42.45		1	0.19	0.09																															
9/15/2019	21.75	28.39		1	0.01	0.01																															
9/16/2019	21.38	27.63																																			
9/17/2019	21.86	27.24																																			
9/18/2019	23.32	31.00																																			
9/19/2019	21.50	26.25																																			
9/20/2019	20.90	32.52																																			
9/21/2019	20.77	27.21																																			
9/22/2019	21.08	27.33																																			
9/23/2019	21.07	26.40		1	0.04	0.04																															
9/24/2019	21.32	25.92																																			
9/25/2019	21.81	27.02						1	0.42	0.21																											
9/26/2019	24.75	36.22		1	0.30	0.16																															

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Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
9/27/2019	26.13	34.39																																			
9/28/2019	21.60																																				
9/29/2019	22.10																																				
9/30/2019	25.29	29.39																																			
10/1/2019	23.02	28.00		1	0.09	0.05																															
10/2/2019	28.65	45.89		1	0.30	0.11		1	7.77	4.22																											
10/3/2019	22.04	30.54		1	0.06	0.04		1	0.45	0.07																											
10/4/2019	25.18	28.90		1	0.17	0.08																															
10/5/2019	23.92	28.83																																			
10/6/2019	21.96	28.05																																			
10/7/2019	28.18	69.40	69.40	1	0.61	0.20	0.20	1	3.50	3.62																							1	0.48	0.30	1	0.48	0.30
10/8/2019	30.16	65.37		1	0.10	0.03		1	4.10	3.41																											
10/9/2019	22.14	31.64		1	0.08	0.04																															
10/10/2019	21.55	25.87																																			
10/11/2019	21.62	25.08		1	0.01	0.01																															
10/12/2019	21.39	27.39		1	0.04	0.02																															
10/13/2019	21.26	27.63																																			
10/14/2019	22.75	27.60																																			
10/15/2019	21.11	25.53																																			
10/16/2019	23.11	54.99		1	0.26	0.10		1	1.00	0.86																											
10/17/2019	46.50	79.40	79.40	1	1.69	0.77	0.77	1	11.62	14.79	1	2.90	2.89	1	2.32	1.70	1	3.02	11.23				1	3.05	3.22	1	3.05	2.88	1	2.72	10.18	1	4.13	11.60	1	4.13	43.70
10/18/2019	23.57	28.05																																			
10/19/2019	24.60	30.03																																			
10/20/2019	23.49	29.60																																			
10/21/2019	22.86	27.45																																			
10/22/2019	22.88	27.79		1	0.09	0.04																															
10/23/2019	36.91	68.79		1	0.53	0.25		1	5.90	5.49																											
10/24/2019	23.07	27.16																																			
10/25/2019	22.61	25.74		1	0.01	0.01																															
10/26/2019	23.19	28.88		1	0.04	0.02																															
10/27/2019	42.95	78.66	78.66	1	1.25	0.26	0.26	1	10.73	18.04	1	4.18	0.92				1	2.78	4.00				1	0.08	0.03							1	2.70	3.50	1	4.18	8.45
10/28/2019	27.69	54.31						1	1.52	1.03																											
10/29/2019	24.97	29.95		1	0.10	0.05																															
10/30/2019	26.42	34.52		1	0.16	0.07																															
10/31/2019	31.72	46.79		1	0.27	0.09		1	0.83	0.93																											
11/1/2019	27.49	32.02		1	0.08	0.03																															
11/2/2019	27.01	32.38																																			
11/3/2019	26.65	31.91																																			
11/4/2019	25.14	28.63																																			
11/5/2019	24.26	40.31		1	0.02	0.01																															
11/6/2019	23.88	28.21																																			
11/7/2019	32.26	68.13		1	0.48	0.12		1	8.22	5.81																											
11/8/2019	24.79	32.71																																			
11/9/2019	24.19	30.34																																			
11/10/2019	23.94	30.08																																			
11/11/2019	23.72	28.08																																			
11/12/2019	23.48	27.27		1	0.08	0.04																															
11/13/2019	23.27	27.53																																			
11/14/2019	23.09	26.96																																			
11/15/2019	22.61	26.20																																			
11/16/2019	22.72	29.30																																			
11/17/2019	23.11	29.37																																			
11/18/2019	23.68	32.80		1	0.14	0.03																															
11/19/2019	28.78	61.28		1	0.30	0.11		1	3.37	2.31																											
11/20/2019	25.53	30.65		1	0.11	0.02																															
11/21/2019	23.96	27.91																																			
11/22/2019	24.59	37.81		1	0.09	0.07																															
11/23/2019	23.92	30.21																																			
11/24/2019	44.77	72.56	72.56	1	0.96	0.19	0.19	1	10.90	9.89	1	0.48	0.05				1	0.62	1.01													1	1.15	2.50	1	1.15	3.56
11/25/2019	26.54	33.75																																			
11/26/2019	26.01	29.67																																			
11/27/2019	29.83	56.04		1	0.22	0.15		1	3.25	2.63																											
11/28/2019	32.50	51.34		1	0.23	0.10		1	5.30	2.13																											
11/29/2019	25.27	30.68																																			
11/30/2019	25.50	31.74																																			
12/1/2019	25.37	31.07																																			
12/2/2019	25.22	30.03																																			

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01/01/19 12/31/19	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
12/3/2019	25.87	30.56																																						
12/4/2019	25.37	29.64																																						
12/5/2019	25.28	28.70		1	0.16	0.07																																		
12/6/2019	24.72	28.02																																						
12/7/2019	24.76	30.59		1	0.10	0.05																																		
12/8/2019	25.04	31.12		1	0.02	0.01																																		
12/9/2019	45.56	73.06		1	1.05	0.19		1	11.40	15.43																														
12/10/2019	50.50	67.61		1	0.12	0.04		1	24.00	14.44																														
12/11/2019	39.48	47.03		1	0.04	0.02		1	22.42	4.66																														
12/12/2019	32.71	36.73						1	2.68	0.42																														
12/13/2019	35.17	46.09		1	0.20	0.04		1	6.62	2.38																														
12/14/2019	67.17	88.14	88.14	1	1.28	0.27	0.27	1	19.87	34.33	1	3.35	1.19				1	3.93	6.02				1	1.37	0.29	1	1.12	0.53				1	10.60	14.37	1	10.60	22.40
12/15/2019	43.87	49.32																																						
12/16/2019	41.94	47.00																																						
12/17/2019	39.18	43.80																																						
12/18/2019	38.38	47.89																																						
12/19/2019	35.83	40.30																																						
12/20/2019	34.09	37.67																																						
12/21/2019	33.39	39.82																																						
12/22/2019	32.59	39.13		1	0.11	0.04																																		
12/23/2019	32.14	39.34		1	0.18	0.06																																		
12/24/2019	31.31	37.71																																						
12/25/2019	28.84	35.55																																						
12/26/2019	29.02	34.15																																						
12/27/2019	28.64	33.42		1	0.01	0.01																																		
12/28/2019	28.21	34.56																																						
12/29/2019	28.44	38.66		1	0.09	0.05																																		
12/30/2019	42.57	68.46		1	0.42	0.09		1	4.52	2.95																														
12/31/2019	41.77	55.44		1	0.66	0.07		1	6.58	1.08																														
Date	Clean Water Discharge			Warren Station Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
No. Days 365	Flow (MG)	Peak Hour (MGD)	Event Peak (MGD)	Precip Days (No.)	Daily Total (Inches)	Peak Hour (Inches)	Event Peak hour (Inches)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)	Event (No.)	Duration (Hours)	Volume (MG)
Total/Max	10,983.24	104.62	104.62	158	43.25	0.77	0.77	88	566.80	537.18	19	46.45	21.57	14	15.03	7.11	23	41.33	67.54	4	0.47	0.08	17	18.62	14.07	10	8.90	7.43	15	16.22	45.62	24	70.98	120.86	27	75.10	284.28
Avg/Percent	30.09	41.32	78.59	43.3	0.27	0.11	0.30	55.7	6.44	6.10	12.0	2.44	1.14	8.9	1.07	0.51	14.6	1.80	2.94	2.5	0.12	0.02	10.8	1.10	0.83	6.3	0.89	0.74	9.5	1.08	3.04	15.2	2.96	5.04	17.1	2.78	10.53

2.5 CSO Records Certification

All data from High-Flow Treatment and CSO events are reviewed by Lowell Water staff during the 10-day validation period following the event. This review process is critical to ensuring accurate representation to the public regarding collection system and treatment plant performance during such events. Electronic instruments are installed at key points throughout the collection system and calculations are automated via Lowell's SCADA system to streamline this process, but these instruments and the SCADA system itself are prone to both machine and human error at times – most notably during storm events, when communications may be lost due to atmospheric interference, high river levels may invalidate the assumptions of some of the automated calculations, and instruments may become impaired by debris or other malfunctions may occur.

This review process entails a detailed review of SCADA instrument records and, where necessary, recalculation of discharge volumes using external programs developed to consider infrequent but relevant flow conditions such as backwater effects from high river levels.

Following this review process, final reports are issued to the public. Such review processes occasionally uncover a previously unknown error in the calculation of CSO volumes. No significant errors were observed in 2019.

The final record of CSO discharge volumes is presented in *Section 2.4*, and is hereby certified by Lowell Engineering staff as a true and accurate estimation of all CSO discharges from Lowell's permitted outfalls in 2019. These records are stored at Duck Island in Lowell's Water Information Management System (WIMS).

2.6 CSO Station Inspection Certification

CSO structures are inspected regularly by maintenance personnel on the Structures Crew. The Structures Crew visits all remote/satellite stations on a daily basis, and as of late 2018 all inspection records are collected digitally and managed by Lowell Water's engineering staff.

CSO diversion stations are visited weekly by the same personnel. Structures are inspected to verify that the grounds are clear and accessible, including any need for landscaping services; record wet-well conditions (normal, flooded, evidence of flooding, high wet-well level); HVAC systems, lighting, and SCADA systems are functional; and perform basic cleaning tasks.

Following recommendations from EPA's audit of Lowell's CMOM program in June 2019, an additional task was added to each inspection to ensure frequent (weekly) visual inspection of each associated CSO outfall for evidence of dry-weather discharge.

Any issues observed are logged into the MP2 work-order system and/or discussed at the bi-weekly collection system meetings, as necessary.

In 2019, all CSO structures were routinely inspected, and these records are kept on file as discussed above.

Work orders issued as a result of these inspections identified only minor issues in 2019, including:

- Dry-weather flow was observed at the Read Street CSO Station outfall in June 2019; subsequent video investigation of the outfall pipe confirmed that no dry-weather CSO discharge was occurring, but that groundwater was infiltrating through joints in the outfall pipe. These joints are scheduled for repair (re-grouting) in 2020 when the river level subsides enough to allow entry.
- The front gate at Beaver Brook Station was repaired.

2.7 Infiltration/Inflow Control Plan and Annual Report

The following plan was submitted to MassDEP in January 2020 and is now incorporated into the *Annual Clean Water Report* as a fundamental management document. Any changes made to the Infiltration/Inflow (I/I) Control Plan will be updated here in the future.

2.7.1 Introduction

This *Infiltration/Inflow Control Plan* documents and summarizes the strategies employed by Lowell Water to identify, characterize, and where possible eliminate infiltration and inflow to its collection system, in accordance with 314 CMR 12.04(2).

2.7.2 Regulatory Requirements

This section details the regulatory requirements incumbent upon Massachusetts municipalities related to the management of infiltration and inflow (I/I) in public sewerage infrastructure. *Title 314* of the Code of Massachusetts Regulations (CMR) covers the Division of Water Pollution Control. *314 CMR 12.04(2)* specifically addresses the requirement "to develop and implement an ongoing plan to control I/I to the sewer system," and stipulates that the plan shall include:

> (a) An ongoing program to identify and eliminate sources of infiltration and inflow. The program shall include the necessary funding level and the source(s) of funding to implement the program.
>
> (b) An inflow identification and control program that focuses on the disconnection and redirection of public and private sources of illegal inflow. Priority shall be given to removal of public and private inflow sources that are upstream from, and potentially contribute to, known areas of sewer system backups and/or overflows.
>
> (c) A phased evaluation of the sewer system, consistent with the Department's Guidelines for Performing Infiltration/Inflow Analysis and Sewer Systems Evaluation Survey, to determine its existing condition, the presence and quantity of infiltration and inflow into the system, and locations and risks of wet weather sanitary sewer overflows or by-passes in the sewer system. The Infiltration/Inflow Analysis may assess a range of design storms, but shall specifically assess the risk of sewer system overflows for a five-year, 24-hour storm event.
>
> (d) For those sewer system authorities with NPDES discharge permits for combined sewer overflows, and for all sewer systems tributary to such sewer systems, and for other sewer systems which the Department specifically determines are at risk of wet-weather sanitary sewer overflows (SSOs), the infiltration and inflow plan shall also include a program to address impacts from new sewer connections and extensions to the sewer system. All sewer system authorities shall include provisions in their I/I plan for mitigating impacts from any new connections or extensions where proposed flows exceed 15,000 gallons per day. Such mitigation shall require that four gallons of infiltration and/or inflow be removed for each gallon of new flow to be generated by the new sewer connection or extension, unless otherwise approved by the Department. The sewer system authority or the Department may require a higher removal rate per gallon of new flow in sensitive areas such as where overflows have the potential to impact drinking water supplies or nitrogen sensitive areas.

The requirements of 12.04(2) refer directly to a report issued by the Massachusetts Department of Environmental Protection (MassDEP) in May 2017, entitled *Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Surveys* (MassDEP, 2017), hereafter referred to as the Guidelines.

The Guidelines state that:

> Extraneous water from infiltration/inflow (I/I) sources reduces the useful life, and the capacity of sewer systems and treatment facilities to transport and treat domestic and industrial wastewaters.
>
> **Infiltration** enters a sewer system through defective sewer pipe joints, breaks, or manhole defects, and occurs when existing sewer lines and manholes undergo material and joint degradation, as well as when sewer lines are poorly designed and constructed.
>
> **Inflow** normally occurs when rainfall enters the sewer system through direct connections such as roof leaders, yard drains, catch basins, sump pumps, defective manhole covers and frame seals, or indirect connections with storm sewers. The mitigation of I/I by sewer system rehabilitation and inflow source removal, combined with an on-going operation and maintenance program, is essential to protect the environment and the significant capital investment in sewers and wastewater treatment facilities made by cities, towns and the Commonwealth.
>
> While this Guidance sets forth an approach to implement an I/I removal program, MassDEP will consider alternative approaches on a case-by-case basis when reviewing plans under 314 CMR 12.04(2). Any alternative approaches should have the same goal of identifying and removing excessive I/I and the sewer system authority should document the advantages of an alternative approach.

The Guidelines further describe the typical measures taken to comply with these requirements as follows:

> The I/I analyses are typically divided into the following phases or tasks:
> - Infiltration and Inflow Analysis
> - Sewer System Evaluation Survey
> - Sewer System Rehabilitation
> - Follow-up Analysis

The following sections present the status of these phases, as implemented at Lowell Water, which has modified and/or deferred some portions of these tasks in recognition of the particular challenges of implementing an I/I program in a combined sewer system. These particular challenges are addressed directly in the Guidelines, as follows:

> MassDEP also recognizes that many sewer system authorities in Massachusetts have combined sewer systems, and as such, have been designed to collect and convey stormwater flows in addition to sanitary flows. These systems in nearly every case also have combined sewer

> overflow structures included in their NPDES discharge permits. Communities with CSO discharges are subject to a separate regulatory framework, including the state and federal CSO Control Policies and Guidance. In these communities, the I/I control plan should be consistent with the Long-Term CSO Control Plan, which may supplant the I/I control plan in its entirety, and have approaches and recommendations which differ from approaches in separate sewer systems.

Lowell Water recently submitted its first Integrated Capital Plan (ICP), which includes the results of recent sewer-system flow monitoring and model updates, and a comprehensive review of alternative control strategies considered for control of inflow to the combined sewer system with the objectives of minimizing permitted CSO discharges and eliminating prohibited CSO surcharges.

While Lowell Water continues to invest significant resources in its LTCP to mitigate CSO frequency, duration and volume, the LTCP is restricted in scope to the management of otherwise irreducible infiltration and inflow in the combined sewer system. It is not envisioned as a comprehensive framework for I/I control and reduction because Lowell Water is committed to addressing cost-effective measures for the reduction of infiltration and inflow through other ongoing programs, as well.

The following section presents all principal components of I/I control strategies in Lowell in more detail than was provided in the ICP submission, but also refers back to the ICP for specific details relevant to the LTCP.

2.7.3 Elements of Infiltration and Inflow Control in Lowell

This section presents the elements of Lowell Water's I/I Control Plan as currently envisioned. Taken as a whole, these elements seek to satisfy the four distinct requirements of 314 CMR 12.04(2), sub-sections (a—d), as discussed above.

The primary elements of Lowell's Infiltration and Inflow Control Plan are:

1. Phase III CSO Long-Term Control Plan
2. Sewer System Investigation, Evaluation and Repair Program
3. Sewer System Conductance Surveys
4. Site Planning Review Program

These four programs comprise the I/I Control Plan for the City of Lowell as follows:

- The LTCP addresses the overall management of inflow from public and private properties in the City's combined sewer system, wherein it is not cost-effective or feasible to remove inflow, and instead an approach of system optimization followed by storage and treatment at select locations is proposed;
- The sewer system investigation, evaluation and repair program is an integral part of Lowell Water's collection system Capacity, Maintenance, Operations and Management (CMOM) Program and is structured as an ongoing effort to investigate the entirety of the collection system (combined and separated) and evaluate and prioritize repairs needed to ensure system integrity and reduce infiltration, which are then completed through ongoing contracts or

through integration into the City's Integrated Capital Plan (ICP), depending on the scope and cost of repairs or replacements determined to be necessary;

- Sewer system conductance surveys complement the CMOM inspection program and are conducted annually in the spring and summer as part of a long-term effort to characterize the conductance of sewage throughout the collection system during periods representing both high and low groundwater and streamflow for the purpose of determining areas of low relative conductance that may warrant further investigation via video inspection, flow metering, and other subsequent control actions;
- The Site Planning Review Program is an interdepartmental working group of appropriate staff from the Department of Planning and Development, City Engineering and Lowell Water and is convened twice-monthly to review proposed site-development projects to consider how such proposals may be subject to constraints within the City's drinking water, wastewater and stormwater management programs and related ordinances. All such properties are reviewed according to criteria (currently under development) to restrict and, where possible, remove private inflow to the combined sewer system.

The remainder of this section presents each element of the I/I Control Plan in more detail.

Phase 3 CSO Long-Term Control Plan

As discussed in *Section 2.1.3*, Lowell's wastewater collection system is predominantly a combined sewer system with some components dating to the early 19th century. As such, it was explicitly designed to capture stormwater runoff from city streets and neighborhoods and to discharge such runoff and sewage from the city's residents directly into area waterways. This practice continued until passage of the Clean Water Act led to the construction of large-diameter interceptor pipes that were designed to capture and convey this combined sewage and stormwater runoff to the Duck Island Clean Water Facility in 1980.

Combined Sewer Overflow (CSO) discharge stations (a.k.a. regulators) were designed and subsequently permitted by regulatory agencies through the NPDES program in anticipation of runoff events that would exceed the conveyance capacity of the collection system and the treatment capacity of Duck Island. These CSO stations act as relief valves when flows are very high: combined sewage (stormwater and wastewater) is allowed to flow directly to the nearby rivers under these conditions, in order to avoid damaging the treatment facility and to avoid flooding and property damage in city neighborhoods.

Discharges from these CSO stations are commonly referred to as combined sewer overflow (CSO) discharges, denoting that the sewage was discharged from a permitted CSO facility. Street flooding and property damage associated with combined sewer systems are referred to as CSO surcharges, denoting that such overflows from the combined sewer system occurred through non-permitted structures as a result of unintended flooding (surcharging) in the collection system.

CSO surcharges are often similar in root cause and nature to, but are distinct from, (separated) sanitary sewer overflows (SSOs), which are extremely infrequent in Lowell (see *Section 2.7.4 - Sewer Surcharges & Overflows* for details). CSO surcharges, like SSOs, require subsequent investigation, reporting and remedial actions in the short-term. Conversely, CSO discharges are permitted, so long as they are managed according to the City's CSO Long-Term Control Plan (LTCP) and may not require any short-term actions other than public notification and reporting.

Lowell Water recently submitted to MassDEP and the US EPA its first Integrated Capital Plan (ICP) for capital improvements to the City's drinking water, wastewater and stormwater infrastructure (Hazen, 2019). The following sections of the ICP are of direct importance to this I/I Control Plan:

- Sections 3.3 and 3.4 of the ICP present a comprehensive review of the principal components of Lowell's combined sewer system and its High-Flow Management operating policies.
- Section 4 and associated appendices present a detailed review of recent sewer system flow metering work completed to inform validation of Lowell's collection system model and subsequent alternatives analysis. The collection system is modeled in EPA's SWMM 5 software package, and calibration/validation included dry-weather baseline flow monitoring as well as wet-weather flow monitoring.
- Section 6 presents alternatives considered to mitigate known problem areas with respect to sewer system surcharging.
- Section 10 introduces the recommended plan for the City's Phase III LTCP and presents projects and schedules for addressing CSO discharges as well as CSO surcharges at systematic points in the City's combined sewer system.

The reader is referred to that report for consideration of capital projects Lowell is undertaking to address the mitigation of impacts from infiltration and inflow into the City's combined collection system that may contribute to CSO discharges and surcharges.

Specifically, Figure 10-2 in the ICP presents the prioritization for the design and construction of two wet-weather storage projects intended to eliminate long-recurring CSO surcharges in the City's collection system. These projects, presently referred to as the Pevey Wet-Weather Storage Facility and the Douglas Wet-Weather Storage Facility, are also discussed in Section 6 of the ICP, where initial planning-level cost estimates put the total investment needed to eliminate surcharging in these areas at roughly 20 million dollars. This investment is considered warranted due to the fact that nine of the 17 sewer surcharge overflows in Lowell over the past five years have been related to inadequate system capacity in the areas that will be served by these storage projects; nearly all other surcharge overflows in that time have been due to equipment failure, pipe collapse/blockage, or construction oversight error, all of which were quickly and easily repaired upon discovery (see *Section 2.7.4 - Sewer Surcharges & Overflows* for further discussion).

Sewer System Investigation, Evaluation and Repair Program

While the measures discussed above address several of the key elements required of an I/I Control Plan, particularly with respect to inflow, infiltration is not significantly addressed by these measures.

Infiltration to the sewer system (separate or combined) occurs due to pipe deficiencies and failures over time. It is a factor of concern due to the increased risk of pipe failure where infiltration occurs, and due to the potential for infiltration to significantly reduce capacity in some sewer systems, leading to otherwise avoidable surcharging and overflows.

Infiltration is not considered to contribute significantly to combined sewer surcharges in Lowell's system due to the fact that the design of combined sewers accounts for high inflow rates through specification of large-diameter sewer mains and trunk lines (compared to that of separate systems) and specialized geometries (e.g., egg-shaped pipes) to ensure adequate velocity of high-capacity pipes at lower flow rates. Lowell's combined sewer system experiences high dry-weather inflow rates during periods of high river level and high groundwater, due in part to the direct connection of local streams and wetlands to the collection system, which are legacy issues without apparent cost-effective solutions (see *Section 2.7.4*).

Lowell has not invested in efforts to separately quantify infiltration in the combined system because it is expected that reducible infiltration rates during high-groundwater periods are dwarfed by the direct-inflow rates from these intractable problem areas. Management of these inflow issues, as discussed above, is addressed through Lowell's LTCP.

The deterioration of the sewerage system (of which infiltration is a symptom), however, is a factor of critical concern to Lowell and is addressed through Lowell's collection system Capacity, Management, Operation and Maintenance (CMOM) program. The CMOM program is another core regulatory requirement under the NPDES wastewater discharge permit. The implementation of this program is discussed in detail in *Section 3*.

As discussed in that section, a principal component of Lowell's CMOM Program is an ongoing sewer system inspection and rehabilitation program that is managed in collaboration with the City Engineers' road-maintenance program. This collaboration is necessary due to a five-year moratorium imposed by the City on any street openings following repaving. In order to ensure compliance with this policy, Lowell Water employs a video truck and vacuum truck to first clean and then inspect wastewater and stormwater drainage systems in coordination with the paving list issued annually by the City Engineers.

In this manner, approximately 14 miles of the sewerage and drainage systems are inspected every year. Point repairs, replacements and lining projects are carried out through ongoing annual contracts. Larger replacement projects that require significant engineering design and construction costs are reviewed in the context of Lowell's ICP and prioritized for completion accordingly. The benefits realized through this program include reduction of infiltration to the sewerage system as deteriorating components are continually repaired, replaced, or lined to restore structural integrity.

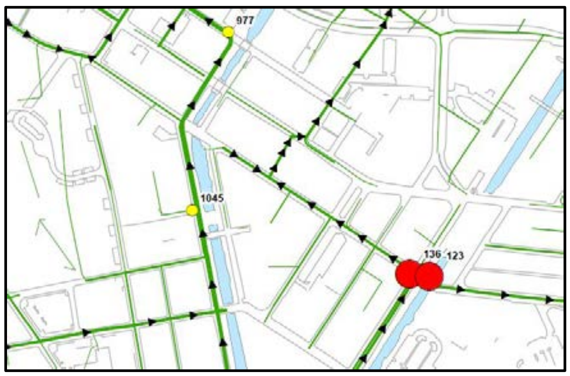
It should be noted that the EPA and MassDEP audited Lowell's CMOM program in 2019, and a concern was raised regarding the degree to which inspection, cleaning and repair has been driven by the City's paving program (US EPA, 2019). In response, Lowell intends to create a second vacuum-truck crew to increase cleaning, while revisions to Lowell's GIS-management plan are in progress to improve the City's ability to broaden the prioritization of inspections to include vulnerability factors not presently in standard use (e.g., cross-country lines, time since last inspection, pipe material and age, et cetera).

For more detailed information on this program, please refer to *Section 3.4* and onward.

Sewer System Conductance Surveys

Lowell Water established sewer system conductance surveys as a pilot project in 2018. Conductance is a measure of electrical conductivity (or dissolved ions) in water, and sewage generally has a high specific conductivity in the range of 1000 micro-Siemens per centimeter (µS/cm). Sections of the collection system with high I/I tend to dilute the sewage and lower the conductance, offering a low-effort screening tool to identify areas of the system in need of further inspection and repair. Such a low-effort screening tool was sought after several years of video inspections (totaling approximately 35% of the interceptors since 2012, when the GraniteNet database was implemented, and much more prior to that time) failed to turn up visual evidence of these suspected interceptor pipe deficiencies.

Figure 2-3. Conductance Survey Pilot Results



For example, above illustrates one significant inflow source to the collection system in downtown Lowell where a drainage connection to the Upper Pawtucket Canal contributed inflow to the South Bank interceptor. The two red dots indicate, respectively: a manhole in which very low conductance readings were observed (136 µS/cm), and the conductivity of the canal water adjacent to the manhole (123 µS/cm). These values can be contrasted to the yellow markers indicating the expected range of conductance in Lowell's sewage (977-1045 µS/cm). The connection inferred was later confirmed by video inspection and sealed in the fall of 2018 shortly after discovery.

The pilot project was initially intended to help identify potential hot spots of suspected infiltration in the riverbank interceptors. While one major drop in conductivity observed in the Tilden interceptor was successfully traced several blocks upstream to the canal inflow point discussed above, no such hot spots of interceptor infiltration have since been found.

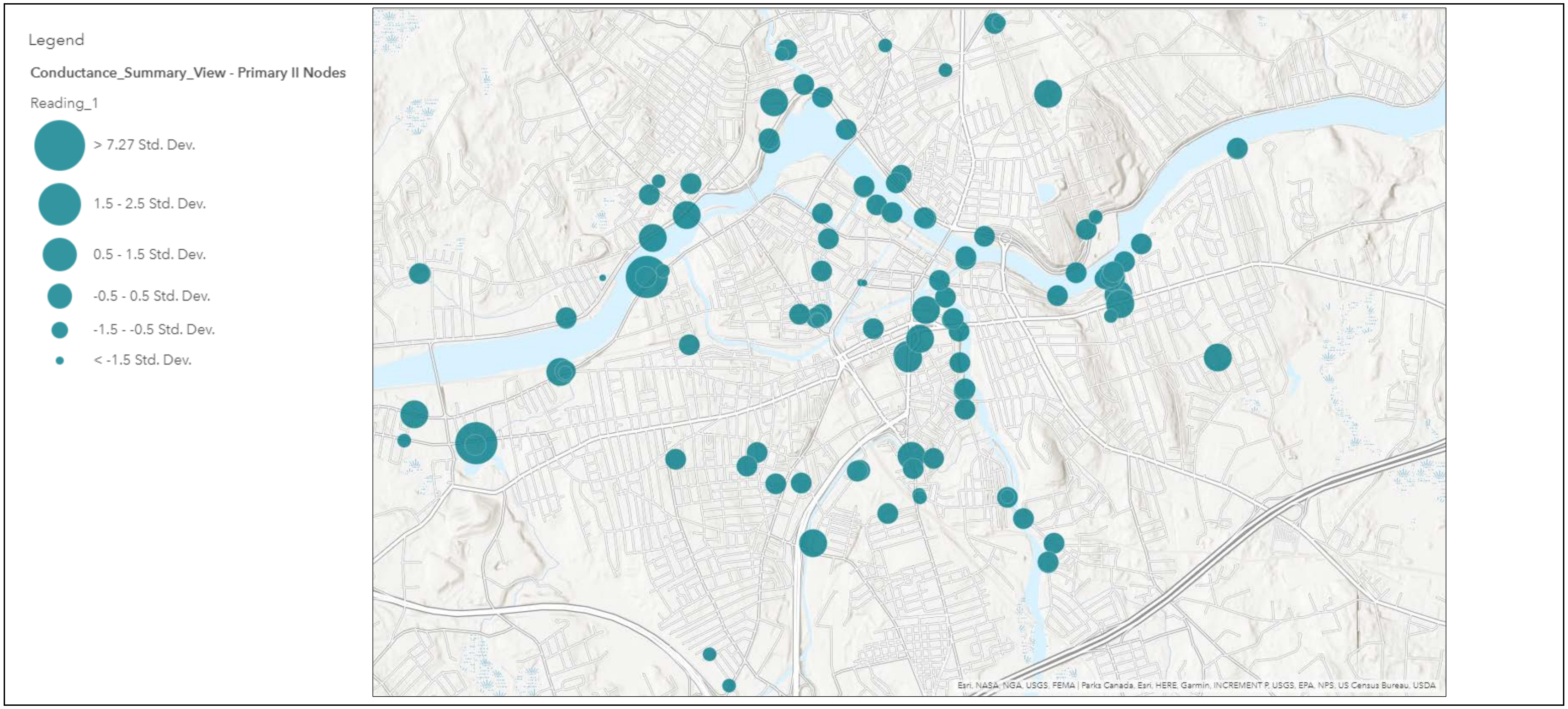
However, the success of the pilot project in quickly identifying, tracing and resolving a previously unknown inflow source has led to an expanded, ongoing program. This program is specifically designed to identify primary points of entry for I/I by utilizing specific conductance probes to screen the collection system at 77 major junctions and other vulnerable points near wetlands and river crossings. Readings are entered into Collector for ArcGIS so that they can be easily reviewed in online management dashboards for follow-up actions, which may include flow metering at specific targeted areas, and/or dispatching the video truck to areas of interest for visual assessment of pipe condition and repair needs.

A full high-water baseline survey of the collection system was completed in the spring of 2019. The results of this survey are summarized in Figure 2-4, below, in which the size of each point corresponds to the value of the reading as described in the legend at left. Both high and low outliers are visible in this figure and may warrant further investigation. High conductivity may be due to discharges to the sewer system warranting investigation for reasons outside the scope of I/I control, or due to high-conductivity wetland waters entering the system.

In essence, this twice-annual survey will serve as a screening tool to prioritize targeted I/I control actions that would otherwise need to be implemented on a system-wide basis at significantly greater expense. Future work will include collection of 'control' measurements from surrounding waterbodies in order to provide a better context of the values that are observed in the sewer system.

As more information is developed through this program, Lowell will include summaries of the work performed, presentation and discussion of any new findings, and review of any follow-up inspections performed by video inspection, dye-testing, metering or other means in *Section 2.7.5*.

Figure 2-4. 2019 Sewer System Conductance Survey (High Water Table Baseline)



The figure above shows the results of the baseline high-water table survey conducted in the spring of 2019. Values are scaled against the standard deviation of the full data set in order to clearly characterize outliers in this summary figure, which demonstrates the utility of the data in identifying both uncommonly high (large dots) and low (small dots) levels of conductivity in the sewer system. Both high and low levels may warrant further investigation, if for different reasons, while medium-sized points may be considered to represent 'normal' conductivity levels for Lowell's system. Storing the survey data in ArcGIS Online facilitates generation of multiple views of the same dataset in a readily accessible format.

Site Planning Review Program

Lowell Water actively participates with the City Engineer's office and the Department of Planning and Development (DPD) in the review and approval of new and redevelopment projects within the City of Lowell. Lowell Water's Engineering Manager and Stormwater Program Manager review all proposed site plans to ensure that impacts from new construction are properly managed to protect the City's infrastructure and meet overall objectives of environmental protection. The City Ordinances provide Lowell Water with the authority to reject or approve these plans and provide standards and specifications for developers to follow.

All proposed site plans are first considered in the context of whether they are within a combined or separated sewer service area. In separated service areas, the following conditions apply:

- Both private and public inflow is prohibited from entering into a separated sewer system, and all stormwater runoff from private development to Lowell's municipal drainage system is managed in accordance with Lowell's Stormwater Management Program (SWMP).
- New sewer connections are evaluated to ensure that the expected flows do not contribute to exceedance of the design flow of downstream sewer systems.

For projects that are proposed in combined service areas, the following considerations are made:

- New sewer connections are evaluated to ensure that the expected flows do not contribute to exceedance of the design flow of downstream sewer systems.
- No new impervious area may be directly connected to the combined sewer system. At a minimum, new impervious area must drain first to a leaching catch basin that is fitted with an overflow to the combined system, and more rigorous detention or retention measures may be required on a site-specific basis where feasible.
- The site grading and drainage is evaluated to determine whether onsite stormwater management controls may be feasible. Commercial properties with high percentage of impervious area are prioritized for inflow removal, while residential properties are given greater flexibility, which is consistent with the Massachusetts Stormwater Standards.

The intent of the site-planning review program is to gradually reduce the acreage of existing impervious area that is directly connected to the combined sewer system, and to restrict the introduction of inflow from newly created impervious areas to the combined sewer system through consistent application of the policies described above. In certain situations where onsite controls are infeasible or insufficient, newly created impervious areas may be directly connected to the combined system to protect Lowell's citizens against risk of injury or loss of property. In these cases, a connection fee will be required, and this fee will be applied to the design and implementation of other inflow-removal projects.

314 CMR 12.04(2)(d), previously cited, requires specifically that "All sewer system authorities shall include provisions in their I/I plan for mitigating impacts from any new connections or extensions where proposed flows exceed 15,000 gallons per day. Such mitigation shall require that four gallons of infiltration and/or inflow be removed for each gallon of new flow to be generated by the new sewer connection or extension, unless otherwise approved by the Department."

While new connections of this size are relatively rare in Lowell, they have been known to occur in recent years. As stated above, new connections are reviewed to ensure that they do not lead to exceedances of downstream conveyance-system capacity. As has also been previously discussed, Lowell's combined sewers are designed for flows far greater than dry-weather sanitary sewage base-flows, such that daily flow to the wastewater facility ranges from an average near 25 MGD at base-flow to 120 MGD at peak hourly flow during wet weather, even when CSO discharges are not necessary. Thus, it would require on the order of 100 such new connections (totaling 1.5 MGD additional base-flow) before the increase in base-flow begins to approach the same order of magnitude as that of daily wet-weather flow variations which lead to High-Flow Treatment and potential CSO surcharges or discharges. At the current rate of occurrence (1 in 3-5 years), this number of new connections may be anticipated in two to three centuries, which is well beyond the useful life of all current sewerage infrastructure.

Consequently, Lowell Water considers the holistic approach to long-term management of I/I in its combined sewer system—as described above with respect to incremental removal of private inflow to the maximum extent practicable (regardless of whether or not new connections are above the stated regulatory threshold), and in particular in the LTCP with respect to storage and treatment of inflow to prevent surcharges and minimize discharges—to be a sufficient provision for "mitigating impacts from any new connections or extensions." Lowell respectfully requests consideration and approval of this approach, in lieu of project-specific I/I removal criteria as suggested in 314 CMR 12.

2.7.4 Characterization of Infiltration and Inflow in Lowell

Aggregate I/I rates are estimated annually using monthly average flows from treatment-plant-influent flow meters, CSO discharge records, inter-municipal metering records and water consumption records. This allows a common metric for assessment of system I/I on a year-by-year basis. Table 2-1 below presents this information as the median of monthly values for the period 2013—2018.

The right-most column in Table 2-1 reports the median dry-weather I/I for each month, calculated over the years 2013—2018, the period for which automated HFM practices have been applied fairly consistently. A clear increase in dry-weather I/I is evident in the spring during snowmelt and associated high river levels.

Figure 2-4 on the following page presents this same information graphically and alongside rainfall and CSO discharge data, for comparison. In this figure, the bars are associated with the left-hand vertical axis representing volume in million gallons of dry-weather I/I, high-flow treatment volume (wastewater treated utilizing excess primary capacity), and CSO discharge volume. Each bar is calculated as the median value of the series of total monthly volumes. For example, the January high-flow treatment value of 29.60 is the median value of the series of the total monthly volume of high-flow treatment in each January from 2013—2018:

Ranked Series of High Flow Treatment Volume: [4.16, 26.67, 26.98, 32.22, 32.74, 68.42]

The line-plots are associated with the right-hand vertical axis representing rainfall in inches. The solid line is the median monthly rainfall total, and the dashed line is the median of the maximum hourly rainfall intensity observed in each month.

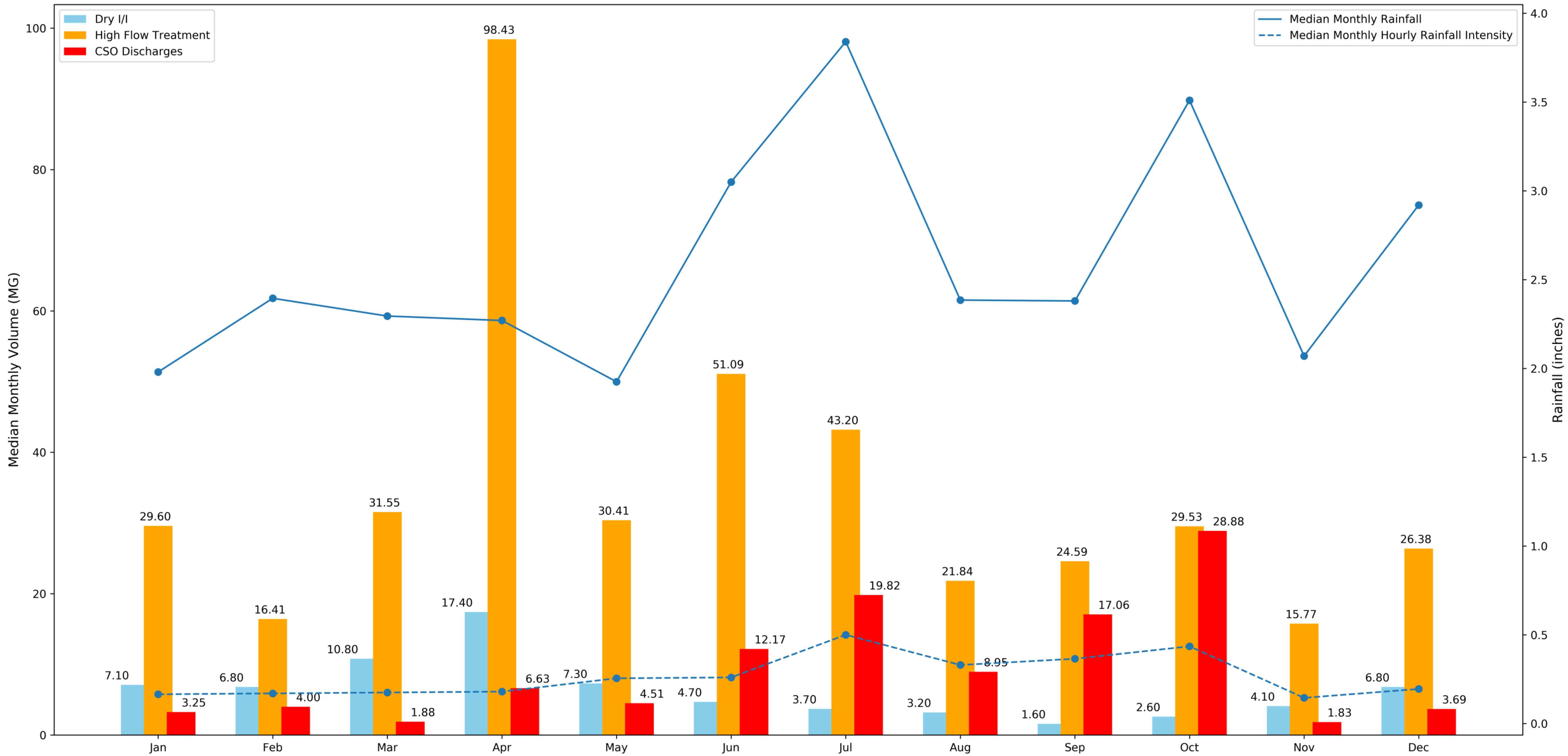
While this figure helps demonstrate the lack of strong correlation between dry-weather I/I and CSO discharges, and the close correlation between total rainfall, rainfall intensity, and CSO discharges, it is also helpful to view these relationships in a regression plot, as shown in Figure 2-5 on the subsequent page.

Table 2-4. Median Monthly Infiltration/Inflow Rates (2013-2018)

Month	Days With Precipitation (Wet Days)	Days W/out Precipitation (Dry Days)	WWTF Avg Daily Flow (All Days) MG	WWTF Avg Daily Flow (Wet Days) MG	WWTF Avg Daily Flow (Dry Days) MG	Avg Rain-Related I/I (Wet I/I) MG	Avg Non-Rain-Related I/I (Dry I/I) MG
Jan	10	21	26.1	30.3	24.2	6.1	7.1
Feb	10	19	25.7	27.9	24.5	3.4	6.8
Mar	12	18	31.1	35.0	29.0	6.1	10.8
Apr	11	18	34.9	37.5	33.3	4.3	17.4
May	13	20	25.7	28.1	24.2	4.0	7.3
Jun	16	16	25.4	29.0	22.5	6.6	4.7
Jul	13	17	22.8	26.1	20.7	5.4	3.7
Aug	11	20	21.6	24.8	19.8	5.0	3.2
Sep	11	20	20.7	25.7	18.7	7.1	1.6
Oct	10	21	21.5	26.2	19.3	6.9	2.6
Nov	9	19	25.6	29.1	23.4	5.7	4.1
Dec	10	20	26.6	30.7	24.2	6.6	6.8
Total/Mean	134	229	25.6	29.2	23.6	5.6	6.3

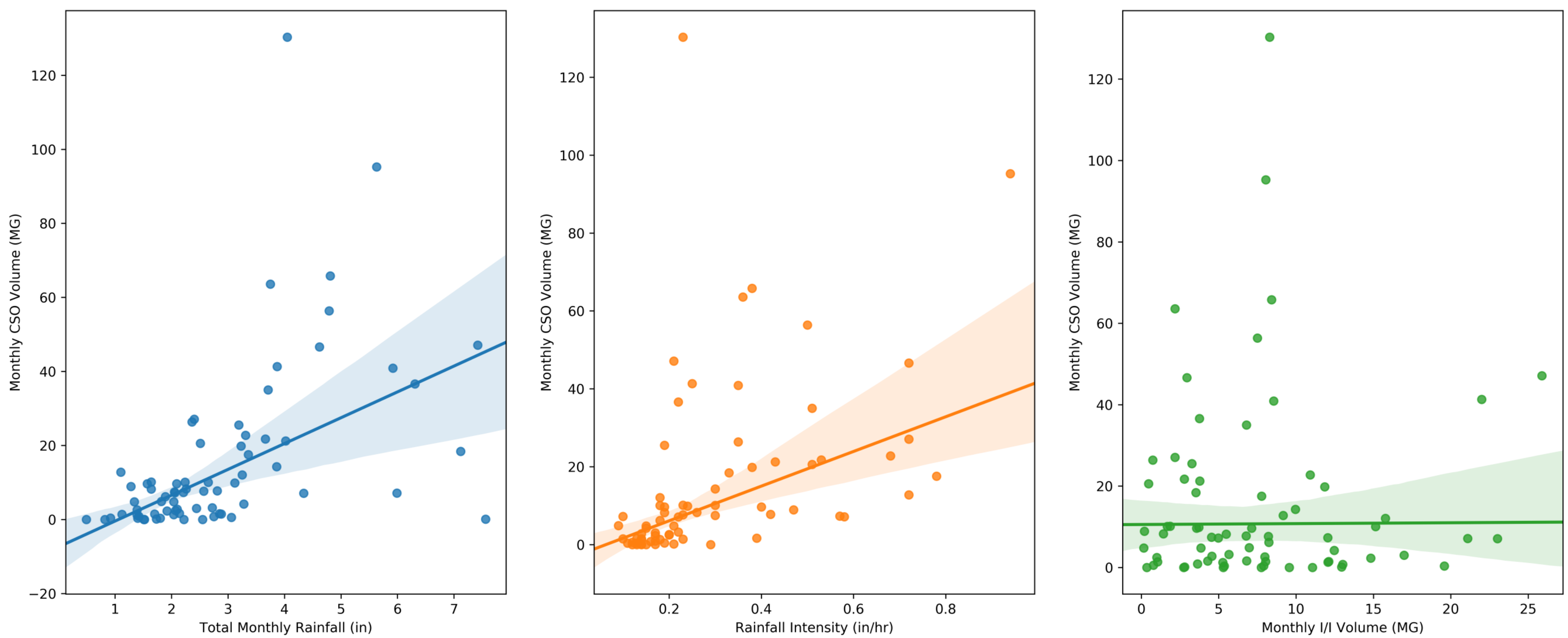
Each column in the table above reports the monthly median across the years 2013—2018.

Figure 2-4. Median Seasonal Flow Trends (2013-2018)



Bars above represent the median value of total monthly volume of I/I, high-flow treatment, and CSO discharges, respectively. The solid line represents the median total monthly rainfall for each month, while the dashed line depicts the median of the maximum hourly rainfall intensity for each month. Medians are all calculated from the monthly series in the period 2013—2018.

Figure 2-5. Regression Plots for Monthly CSO Volume (2013—2018)



The regression plots above summarize the relationships between total monthly CSO discharge volumes and three primary components of interest. At left, a fairly strong relationship between total monthly rainfall and CSO discharge is shown. At center, a similar relationship is presented for maximum monthly rainfall intensity and CSO discharge volume. Conversely, at right the regression shows a lack of strong correlation between total monthly CSO discharge volumes and total monthly I/I volume. The shaded regions around each regression line indicate the 95% confidence interval for the estimate of the regression line. This confidence interval is produced by resampling the data (bootstrapping) 1,000 times for each data pairing and re-calculating the regression.

Summary of Known Infiltration/Inflow Sources

The right-most column of Table 2-1, above, provides an estimate of non-rain-related (dry-weather) I/I by calculating the difference between monthly average dry-weather flow measured at Duck Island and the monthly average contribution of flow from water consumption in Lowell and other contributing co-permittees (Chelmsford, Dracut, Tewksbury and Tyngsborough).

As can be seen from the seasonal trend in these values, much of the dry-weather I/I occurs during months of spring runoff or high river levels in the fall rain season.

Sources of known significant inflow include Humphrey's Brook, Billings Brook and Hovey Field. These sources were characterized in a 2007-2008 flow-monitoring survey, which provided direct observation of an average 1.34 MGD contribution from these sources (report and figures included in **Appendix B**). All of these sources are legacy direct connections of wetlands (Hovey Field) and streams (Humphrey's and Billings) into Lowell's combined sewer system.

It is suspected that much of the remaining seasonal trend may be attributed to infiltration into the riverbank interceptor pipes, which are often located in or near the river bed. However, while the correlation of seasonal dry-weather I/I with high river level and groundwater level is strong, various investigations to date have failed to provide any supporting evidence of this hypothesis. These investigations have included multiple video inspections of the interceptors, flow metering of the interceptors, and now conductance surveys. As discussed above, conductance surveys are a new investigation technique still under development, and Lowell is hopeful that the technique will provide new insight into this problem. This method is a quick and inexpensive *in-situ* analysis that is a reliable indication of I/I.

Meanwhile, it should be noted that the consequence of this seasonal I/I does not directly result in CSO surcharges or discharges, although it does contribute directly to increased use of excess primary treatment capacity and blending at Duck Island.

Determination of Feasibility to Control Known I/I Sources

Control of I/I entering the interceptors directly during high river levels is not financially practical at the present time, nor is it warranted by current understanding of the issue. No evident pipe deficiencies have been identified through the various efforts that have so far been employed, so it is not currently possible to generate a list of specific repairs needed to address a quantifiable amount of I/I in the interceptors; rather, a comprehensive interceptor lining program would be necessary. Complete lining of all interceptors and manholes would be required to eliminate this suspected infiltration. An internal estimate for such a program, based on quotes from a CIPP-lining contractor and GIS records of interceptor diameters, is in excess of $30 million – an extraordinary expense with limited benefit toward reduction of CSO surcharges or discharges. Alternative solutions would have to include replacement of the interceptors, which would entail excavation to depths of a dozen feet or more along sensitive riparian buffer zones, and would also be prohibitively expensive.

Control of I/I attributable to direct connection with streams and wetlands are similarly impractical at present. The primary known inflow sources of this type are tributary to the area served by the West

Street station, and removal of these inflow sources would necessarily entail separation of each respective sub-catchment and construction of a stormwater pumping facility for flood control purposes. Such a facility would be redundant with respect to the West Street Flood Control Station, which was recently rehabilitated at considerable expense, and in coordination with FEMA and the US Army Corps of Engineers.

It is possible that inflow from the Billings wetlands may be controlled to some extent through practical engineering controls designed to increase the local storage capacity in that wetland. Further examination of this source and opportunities to reduce inflow from it may be considered through Lowell's Integrated Planning program, but will necessarily be considered at a later phase once projects with major anticipated benefits to CSO discharge and surcharge mitigation have been completed.

Sewer Surcharges & Overflows in Lowell (2014-2019)

A review of Lowell's SSO Notification reports, used to report both sanitary (separate) sewer overflows and overflows due to combined sewer surcharges, was conducted over the years 2014-2019. Table 2-2, below, presents these events and associated details including type of overflow (combined (CSO) or separate (SSO)), date, estimated volume, where the sewage was discharged to (e.g., residential property/basement, ground/street surface, receiving water), root cause, and corrective actions taken to resolve the cause of the surcharge/overflow. Surcharges assessed to be the result of inadequate system capacity are shaded orange for emphasis.

Figure 2-6 displays these events on a map of Lowell, where red markers represent combined sewer surcharges and green markers represent sanitary (separated) sewer overflows (SSOs). Callout boxes identify those locations associated with capacity issues listed in Table 2-2 and the corresponding corrective action as identified in the table and the ICP.

It should be noted that only one SSO was observed in the years 2014-2019, and this was associated with a construction project and was not caused by I/I. This is important evidence supporting Lowell's position that infiltration is not contributing significantly to such overflows.

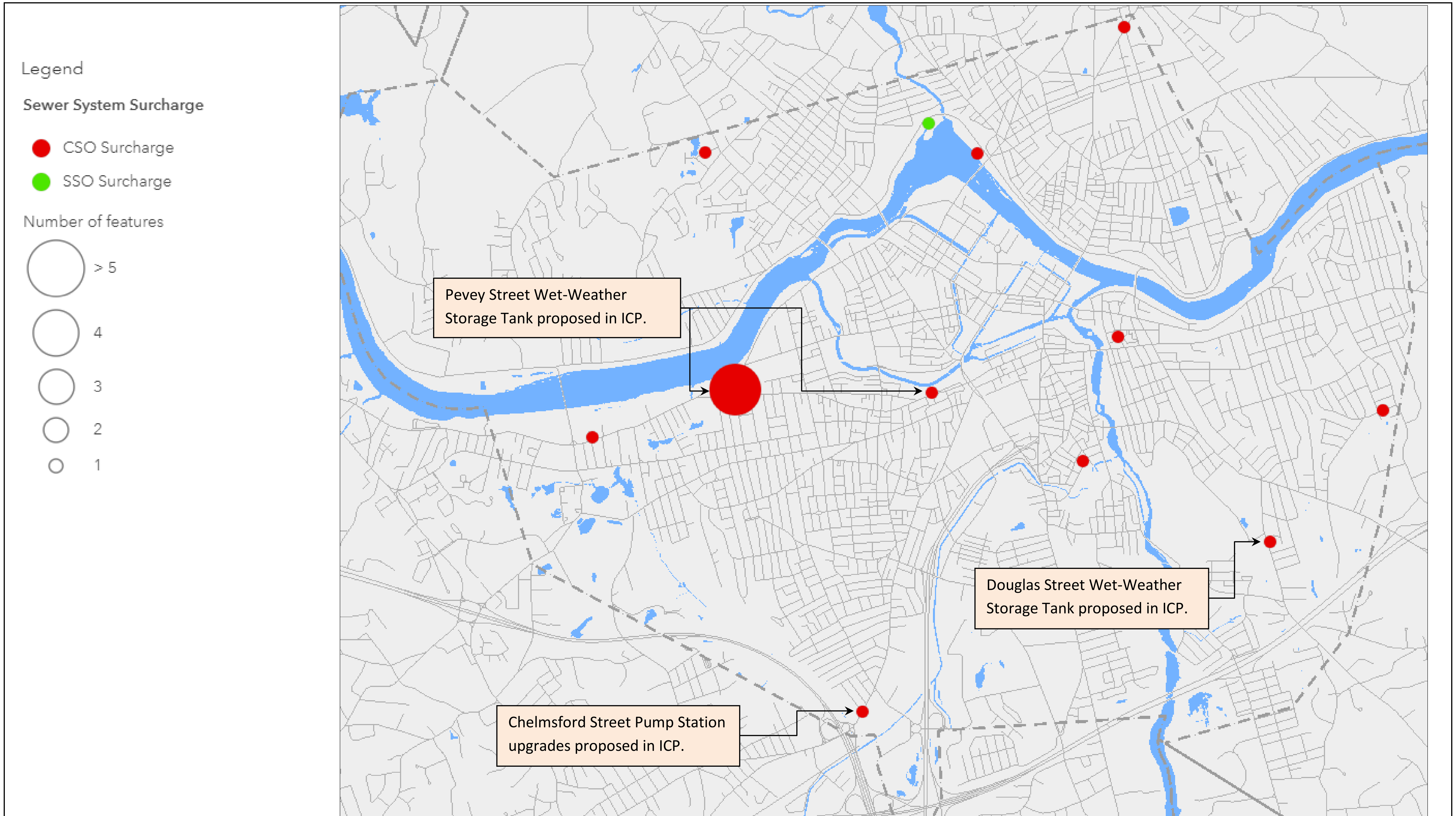
Similarly, 314 CMR 12.04(2)(c) requires an I/I analysis to consider the risk of SSOs in the context of the 5-Year, 24-Hour storm (five-year storm). Lowell's collection system model is currently parameterized to simulate rainfall-runoff dynamics only in the large mains, trunk lines, and interceptors, and so is not an appropriate tool for such an analysis.

However, review of the rainfall records since 2012 identified the storm of October 22, 2014 (35-hour total duration, 3.72-inch total precipitation, 0.70 inches/hour peak intensity) as being the storm of record in the 2012-2019 period that is most similar to the five-year storm (24-hour duration, 4.61-inch total precipitation, 0.73-inches/hour peak intensity). Figure 2-7, below, presents the 2014 observed storm, in comparison to the five-year storm.

Table 2-5. Sewer Surcharges & Overflows (2014-2019)

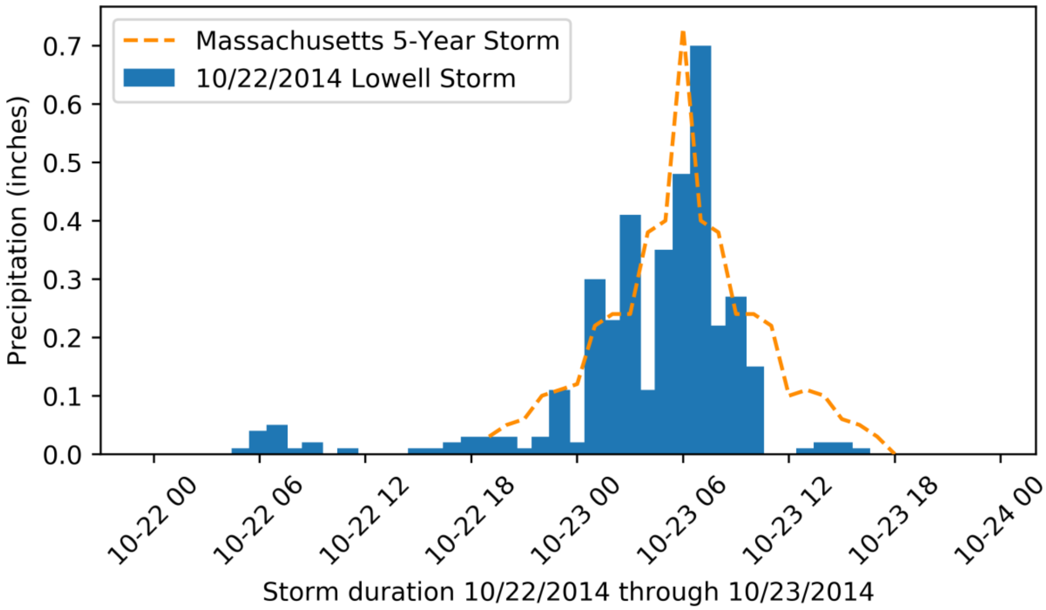
Surcharge Type	Date	Discharge From	Discharge To	Discharge To Other	Estimated Volume (Gal)	Root Cause	Root Cause Comments	Corrective Actions Taken
CSO	9/1/2014	Backup into Property	Property Basement		20	Grease Blockage	Grease blockage was discovered and removed by LRWWU maintenance staff.	The sewer line was inspected and a grease blockage was discovered and removed by LRWWU maintenance staff.
CSO	6/22/2015	Combined Sewer Manhole	Receiving Water	Merrimack River	5000	Treatment Unit Failure	Remote control of downstream gates at West Station did not react quickly enough	LRWWU adjusted its high-flow management protocol in order to prevent repeated issues.
CSO	3/17/2016	Backup into Property	Property Basement		300	Grease Blockage	Caused by property owner	Two vacuum trucks cleared the blockage and cleaned the sewer line. "Enhanced" FOG program to be implemented.
CSO	6/6/2016	Combined Sewer Manhole	Ground		50000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	7/9/2016	Backup into Property	Property Basement		3300	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	7/18/2017	Combined Sewer Manhole	Ground		6000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	7/10/2016	Combined Sewer Manhole	Ground		50000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	8/10/2016	Combined Sewer Manhole	Ground		5000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	6/27/2017	Combined Sewer Manhole	Ground		5000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	7/18/2017	Combined Sewer Manhole	Ground		6000	Inadequate Capacity	Known systemic capacity issue	Marginal Street relief pipe installed 2016, Pevey Street storage tank scheduled in ICP.
CSO	7/18/2017	Backup into Property	Property Basement		500	Treatment Unit Failure	Warren Street Diversion Station bar-rack failure resulted in blinding and back-up	Bar-rack removed from station and replaced with lower risk protective measures.
CSO	7/18/2017	Combined Sewer Manhole	Ground		5000	Inadequate Capacity	Known systemic capacity issue	Douglas Street storage tank scheduled in ICP.
CSO	7/18/2017	Backup into Property	Property Basement		600	Inadequate Capacity	Known systemic capacity issue	Douglas Street storage tank scheduled in ICP.
CSO	7/18/2017	Combined Sewer Manhole	Ground		3000	Inadequate Capacity	Chelmsford Street Pump Station inadequately sized to keep pace with combined flow	Replacement of pumps scheduled with remote station upgrades in ICP.
CSO	4/14/2018	Combined Sewer Manhole	Ground		500	Rags Blockage	Pipe blockage sticks and rags	Sewer line cleaned by jetting.
CSO	5/21/2018	Combined Sewer Manhole	Ground		300	Pipe Collapse	8-inch VCP circa 1930 collapsed	Replaced collapsed pipe segment with new 8-inch PVC.
SSO	8/21/2019	Sanitary Sewer Manhole	Receiving Water	Merrimack River	500000	Other	Construction oversight error led to bypass from SMH to DMH	Bypass redirected; Internal oversight procedures amended to include sign-off by Engineering Manager.

Figure 2-6. Sewer Surcharges & Overflows (2014-2019)



CSO surcharges, defined above to include all surcharge/overflow events from non-permitted structures associated with the combined sewer collection system, are shown in red. SSO surcharges, defined above to include all surcharge/overflow events from structures associated with the separated sanitary sewer collection system, are shown in green. The diameter of the marker indicates the number of discrete locations of surcharge/overflow in the area, even if they occur during the same storm event. Planned corrective actions are noted at all locations where the root cause was determined to be systemic capacity constraints.

Figure 2-7. Comparison of Observed Storm to Five-Year Reference Storm



The hourly hyetograph of the observed storm of 10/22/2014 is plotted in blue bars above. The five-year reference storm is represented by the orange dashed line. While no real storm is likely to match exactly the reference storm's hyetograph, the observed storm is most similar to it over the period of record (2012-2019) at the Warren Station rain gauge in downtown Lowell.

No sewer surcharges or overflows were observed anywhere in Lowell's collection system during this storm. In addition, multiple storms with much greater peak hourly intensity (up to 1.15 inches/hour on 7/18/2018) have occurred over the period in which this review of sewer surcharges and overflows was conducted. None of these high-intensity precipitation events led to sewer surcharges in separated sewer service areas, only in known problem areas that are targeted for early action to increase storage capacity in Lowell's ICP.

2.7.5 Summary and Annual Updates

Lowell's *Infiltration and Inflow Control Plan* has addressed the primary elements required by 13 CMR 12.04(2) in the above sections, including:

(a) An ongoing program to identify and eliminate sources of infiltration and inflow. The program is funded through the collection system operation and maintenance budget as described in *Section 3.3.*
(b) An inflow identification and control program that focuses on the disconnection and redirection of public and private sources of inflow during redevelopment projects, and storage and treatment of existing public and private inflow as described in Lowell's Phase III LTCP submitted under cover of the ICIP in December 2019.
(c) An ongoing program for continual evaluation of the sewer system—modified from the Guidelines in consideration of the unique character of Lowell's combined sewer system and the scope and intensity of capital projects necessary under Lowell's Phase III LTCP—to determine its existing condition, the presence and quantity of infiltration and inflow into the system, and locations and risks of wet weather sanitary sewer overflows or by-passes in the sewer system. The Infiltration/Inflow Analysis specifically assessed the risk of sewer system overflows for an observed storm similar to the five-year, 24-hour storm event.
(d) The infiltration and inflow plan also includes a program to address impacts from new sewer connections and extensions to the sewer system, through consistent application of the principles governing the site-planning review program.

As new information is developed throughout implementation of this *I/I Control Plan*, updates will be provided below.

Table 2-7. 2019 Monthly Infiltration and Inflow Rates

Annual Infiltration-Inflow Rates								
Month	Days With Precipitation (Wet Days)	Days W/out Precipitation (Dry Days)	WWTF Avg Daily Flow (All Days)	WWTF Avg Daily Flow (Wet Days)	WWTF Avg Daily Flow (Dry Days)	Avg Rain-Related I/I (Wet I/I)	Avg Non-Rain-Related I/I (Dry I/I)
			MGD				
Jan '18	13.00	18.00	30.01	34.24	26.96	7.27	9.92
Feb '18	14.00	14.00	35.38	37.81	32.95	4.86	15.85
Mar '18	22.00	9.00	40.50	41.39	38.34	3.05	22.41
Apr '18	16.00	14.00	42.41	44.77	39.72	5.05	23.03
May '18	10.00	21.00	30.87	33.46	29.64	3.82	12.57
Jun '18	16.00	14.00	24.51	25.98	22.83	3.16	4.71
Jul '18	13.00	18.00	24.40	28.16	21.68	6.48	4.07
Aug '18	15.00	16.00	28.89	32.93	25.09	7.84	8.01
Sep '18	14.00	16.00	29.41	35.01	24.51	10.50	9.12
Oct '18	17.00	14.00	28.57	30.64	26.06	4.59	11.66
Nov '18	17.00	13.00	49.79	53.53	44.92	8.61	30.47
Dec '18	10.00	21.00	36.03	41.21	33.57	7.64	17.91
Total/Average	177.00	188.00	33.40	36.59	30.52	6.07	14.14

As discussed in Section 2.7.4, seasonal elevation of non-rain-related I/I is consistently observed in the Spring and late Fall, correlating with high river levels. No cost-effective means of controlling this inflow has been identified in 2019.

3. CMOM Program Plan and Annual Report

Lowell Water has developed and implemented a detailed Capacity, Management, Operations and Maintenance (CMOM) program for its collection system since completing a self-review following EPA's CMOM guidance (US EPA, 2005) in 2011. The CMOM program guidance structure is followed in this report for the convenience of regulatory agency representatives who may be tasked with reviewing Lowell's program.

Lowell's recently re-issued NPDES permit requested submittal of a 'Collection System Operations and Maintenance Plan' that describes collection-system management goals, staffing, information management and legal authorities, and overall condition description and discussion of recent studies and activities. As these requirements have been regularly fulfilled through this section of the annual report, the requested submittal is provided herein. Lowell will review all new requirements for CMOM activities in its recently issued 2019 permit over the duration of 2020 and provide any necessary updates in the next annual report.

3.1 Collection System Management

The purpose of Lowell's collection system is to protect public health and the environment by conveying sewage wastes to the Duck Island CWF for treatment, and to prevent unnecessary property damage from flooding or sewer surcharging. The primary objectives of the CMOM program are to ensure that all work necessary to provide maximum conveyance of wastewater to the treatment plant is performed in a timely manner and to industry standards.

To this end, Lowell's collection system is managed by the Collection System Supervisor, who works in coordination with other Maintenance, Operations and Engineering staff to plan, perform and document the physical and operational states of the assets that make up the collection system: catch basins and manholes; sewer laterals, mains, trunk lines and interceptors; pump stations; communications networks, sensors and associated automated equipment.

The Collection System Supervisor also responds actively to customer requests regarding sewage back-ups and surcharges, and participates in bi-weekly collection-system meetings to identify, discuss and address performance issues related to the CMOM program.

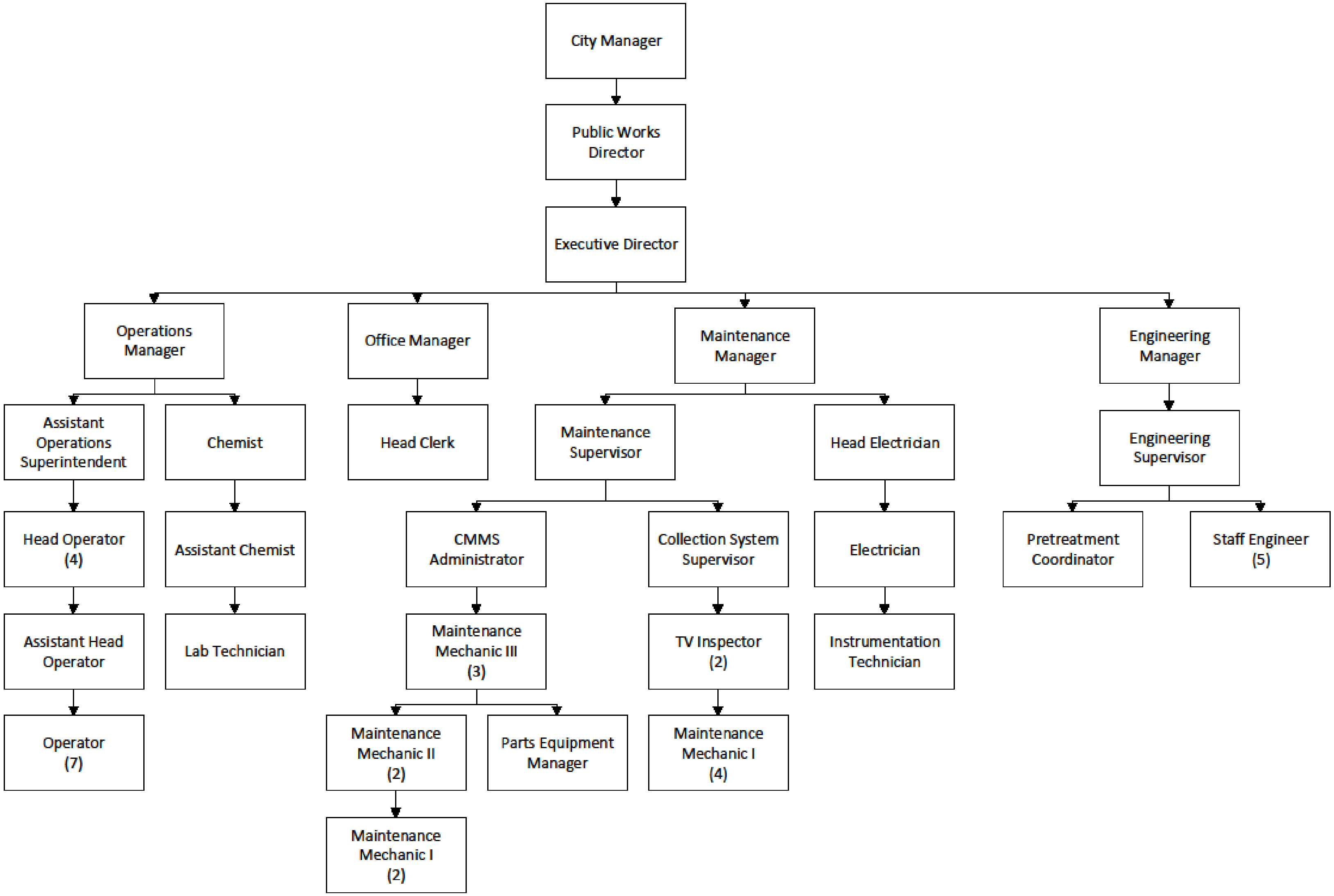
3.1.1 Organizational Structure

An organizational chart depicting authorities and positions of all staff at Lowell Water is provided in *Figure 3-1*, below. Job descriptions are maintained by the Office Manager and include the nature of the work performed, minimum requirements for the position, special qualifications and certifications or licenses that are required. For positions that require licenses with annual training credit hours (TCHs), Lowell provides reimbursement for training and flexibility for staff to attend necessary training during work hours if properly planned. For more on training requirements and tracking, see *Section 3.1.2*, below.

Advancement through the ranks is encouraged through multiple practices, including: educational reimbursement for advanced degrees; annual stipends for certifications achieved and maintained; and preferential notice of and consideration for open positions. Such practices allow Lowell to retain talented workers with critical system knowledge and experience, and to place high-performing individuals in charge of critical programs like CMOM.

In addition to the work conducted by internal staff, many projects in CMOM are contracted out to third-party vendors. Projects implemented by contractors are identified as discussed in the remainder of this section.

Figure 3-1 Lowell Water Organizational Structure



3.1.2 Training

Lowell Water administers a regular training program through its Safety Committee. This program provides several types of training at multiple times throughout the year. Each particular training subject is offered during first shift, when most personnel are onsite, and in the afternoon to allow for second and third shift staff to attend conveniently. Each particular training session is offered twice within a one-month period so that employees with scheduling conflicts have an opportunity to attend at another time. Employees that attend a minimum of eight hours of training each year are rewarded with an annual stipend. While specific trainings are required for certain positions within the utility, these also count toward the stipend.

Training subjects currently offered on a recurring schedule include: First Aid and AED; Work Hazards and Fire Safety; Spill Response, PPE & HAZCOM; Lock-out Tag-out (LOTO) and Regulated Space Entry. Each of these trainings includes drills, demonstrations and testing in a manner appropriate to the subject matter.

The Safety Committee is comprised of representatives from each division and conducts monthly meetings to discuss adequacy of training. When an area of vulnerability or opportunity for improvement is identified, special training sessions may be offered in addition to the standard sessions. In 2018, for example, a special training session was held to review proper trench safety and traffic control practices. In 2019, members of the water-quality monitoring team attended a swift-water rescue training to improve their preparedness for frequent work duties on the river.

Maintenance personnel are provided training that is specific to their regular work duties and requirements through other training contracts, as well. Training covering all material mandatory to maintaining the Commercial Driver's License (CDL) and hydraulics licenses required (pumps, hoisting, and rigging) is provided annually. Training specific to particular equipment is provided by contract with the equipment vendor or an authorized practitioner.

Additional training and license requirements specific to staff positions may be required, as well, but are provided by outside parties and are not coordinated at the utility level. In general, personnel attend trainings at the New England Interstate Water Pollution Control Commission (NEIWPCC) or New England Water Environment Association (NEWEA) seminars to maintain TCHs and/or advance their certification.

All Operations, Maintenance and Engineering personnel are encouraged to get certifications beyond their job requirements in order to develop a more educated and skilled workforce. These additional certifications, if desired by personnel, are paid for by Lowell Water and personnel are granted leave from ordinary work duties provided they have submitted the appropriate requests to management for approval in advance.

3.1.3 Internal Communication

Internal communication at Lowell Water is practiced through both formal and informal arrangements. Divisional staff members meet informally but regularly within their division to discuss work plans, objectives and resource requirements as needed.

More formally, Lowell's ISO 14001 Environmental Management System requires quarterly meetings of an Implementation Team (I-Team) that is composed of staff members from each division to ensure that environmental awareness objectives are discussed between departments. As necessary, each I-Team member communicates with staff in their division regarding EMS updates (e.g., recycling program effectiveness, updates to environmental impacts associated with staff positions, updates to standard operating procedures related to work duties, et cetera).

Divisional management meets regularly to discuss all primary program areas, and personnel involved in these program areas are required to attend these meetings. Such meetings are held on a structured, ongoing basis and include:

- Bi-weekly collection system meetings (sewer system inspection and maintenance actions, problem areas, capacity analysis, contractor activities, safety, review and response to any violations, prior action items)
- Bi-weekly construction meetings (during new construction; construction progress, budget and schedule)
- Bi-weekly high-flow management (HFM) meetings (high-flow treatment performance review and optimization)
- Bi-weekly process control meetings (treatment facility key performance indicators, process modifications and improvements, upgrades, odor complaints, sludge handling, review and response to any violations, prior action items)
- Monthly safety meetings (concerns raised by personnel or citizens, response to concerns, training schedule, seasonal needs, review and response to any safety incidents, prior action items)
- Monthly integrated planning meetings (planning agenda, schedule, consultant progress, data needs, regulatory and stakeholder coordination)

In 2019, a new bi-weekly GIS and Data Management meeting was created to support ongoing improvement of field mapping and data-quality review procedures related to the Utility's collection systems. This working group, led by the Engineering division, is also focused on improving integration of daily work-flow documentation with GIS and making greater use of ArcGIS Online and Field Data Management applications.

Such frequent and recurring meetings between management, personnel, contractors and consultants by program area ensures that all internal and contracted personnel remain informed of overall program activities and objectives. Continual review of each program on a regular basis provides ample opportunity for input from all levels of the organization and proactive response to problems both before and after they may occur. Meeting minutes are maintained by each meeting facilitator to document all issues identified and corresponding responses.

3.1.4 Customer Service

Lowell maintains several lines of communication with its customers to provide opportunities for feedback and notification of problems or concerns:

- Head operators receive phone calls and voice messages (reviewed promptly each day) and maintain a log of complaints and concerns expressed by citizens. If a complaint is received about the collection system, the Collection System Supervisor is notified to investigate; if a complaint is received about odor, the operators investigate potential odor sources and maintain a log of such complaints and actions.
- Front office staff receive calls and forward any concerns or questions to the appropriate staff.
- The City's website, hosted by CivicPlus, provides an online entry point for citizens to file requests or complaints related to each City department. Messages related to the water and wastewater utility are sent to the Executive Director, who then forwards them to appropriate personnel for response.
- Field personnel often receive feedback from concerned citizens while conducting work and convey such concerns to the Collection System Supervisor or other appropriate personnel.
- Engineering staff frequently meet with watershed advocates to increase internal awareness of water-quality issues and concerns and, where possible, provide information related to those concerns; engineering staff also meet as requested with professors from various local institutions to support educational requests.
- The Executive Director regularly attends City Council and other public meetings when wastewater, drinking water or stormwater topics are scheduled for discussion to listen to concerns and provide an appropriate and timely response.

3.1.5 Information Management Systems

Lowell's Management Information Systems (MIS) Department supports many of Lowell Water's needs for standard technology services (general purpose hardware, software, internet service protocol, email, procurement, payroll and financial records, CMMS work-order system, et cetera). The City's Geographical Information Systems (GIS) Department provides specialized technical assistance for support of GIS needs at Lowell Water (ArcMap 10.5.1 and extensions, map development, ArcGIS online tools and services).

MIS services are further summarized as follows:

- Procurement, payroll and financials – the City uses MUNIS, an integrated database management system specifically tailored to the needs of municipal governments. MUNIS supports financial management including a multi-fund accounting system, personnel and payroll, procurement processes, tax billing and collection, city permitting and utility billing.
- CMMS work-order system – the City uses MP2 to organize and track inventory, manage equipment costs and track equipment history, schedule preventive maintenance tasks, maintain labor records, allocate resources, requisition and purchase parts, and generate work orders.

Uses of GIS that are supported by the GIS Department include:

- Sewer system mapping (for more details, see *Section 3.2.6*)
- Municipal drainage system mapping
- Flood protection mapping

- Water-quality monitoring
- ArcGIS online tools supporting field data collection

For support of information systems particular to the wastewater utility, specific technology vendors have been reviewed and selected. These are described below:

- Supervisory Control and Data Acquisition (SCADA) – General Electric's iFix system is used to monitor collection and treatment system information at critical points and relay data back to the Operations Center at Duck Island.
- Hach Water Information Management Systems (WIMS) – An OpsSQL database imports specified treatment process and collection system data at frequencies necessary for analysis, presentation and discussion, long-term planning and regulatory reporting requirements.

Summary of MIS/GIS Updates and Related Issues in 2019

Lowell Water reviewed several CMMS platforms capable of GIS integration in 2017. In prior reports it had been stated that an improved solution would be selected and implemented during the 2018-2020 period to support an integrated asset-management system linking work orders, GIS, asset criticality ranking, and vulnerability factors, among other desired features. Further review of potential programs identified a pre-requisite need to complete a revision of existing piping and instrumentation drawings and to secure adequate funding for this advanced management system. In 2019, Lowell Water continued to work toward these goals to improve its CMMS, but the expected acquisition date remains dependent on work currently in progress.

Several improvements to the GIS program were started in 2018, including a review of field data collection and documentation tools available through ArcGIS online. These initiatives continued in 2019, as ArcGIS Collector and Survey123 were tested for a number of different uses by the Engineering Division, which led to the development of the previously mentioned bi-weekly GIS and Data Management working group.

Continued development and distribution of these field-collection applications to select members of other divisions is underway, and iterative feedback from these users is leading to broader adaptation and acceptance of these applications to capture relevant details of work performed in the collection system.

The end goal of this working group is to develop rigorous and well-documented field-data-management procedures to ensure that all relevant information about work done in the collection system is captured in (or is eventually transferred to) the GIS system. However, the final procedures to be adopted will be contingent upon modification of the current work order system or selection of a new asset management system.

Additional requirements for this data-management program were identified in recent conversations with Esri water-sector representatives, wherein it was made clear that the common ArcMap platform will expire in four years and be supplanted by ArcGIS Pro and the related Utility Network data schema. Lowell's GIS & Data Management team is beginning a 'data-health' inventory in 2020 to develop a roadmap to transitioning to the new geodatabase schema required by Esri's emerging standard platforms, and this will continue at least until successful migration of all Utility data to ArcGIS Pro is achieved.

3.1.6 Sewer Surcharge Notification Program

Lowell Water adheres to all State and Federal regulations requiring notification and reporting of sanitary sewer or combined sewer surcharges. As opposed to combined sewer overflows (CSOs), surcharges of combined sewers result when sewage overflows its conveyance prior to a regulated CSO diversion structure. Lowell very infrequently experiences sanitary sewer surcharges, and has begun commenting specifically on MassDEP reporting forms as to whether a surcharge is in a combined or separate portion of the collection system.

Combined sewer surcharges also occur infrequently, and when they do they are predominantly constrained to known problem areas, such as Marginal Street, which is discussed more below. In the event that a SSO or combined sewer surcharge does occur, the Lowell Water coordinates closely with the Lowell Police and Fire Departments, which then calls the Collection System Supervisor to notify of the surcharge. Citizens may also report any such issue by filing a complaint on the CivicReady system or by calling the Operations Center at Duck Island. Operators will then notify the Collection System Supervisor. The Supervisor and appropriate personnel from Lowell's maintenance division are dispatched to investigate and remedy the problem (e.g., remove any blockage by flushing the affected sewer line).

Following regulatory requirements, notification to MassDEP and EPA will be made upon becoming aware of the overflow (within 24 hours) and written reports will be submitted within 5 days. Written reports include estimates of the amount of sewage, if any, entering a waterway or drainage system. Subsequent investigation of the affected area may be undertaken, if deemed necessary by the Supervisor, using a robotic camera vehicle to identify the cause of the SSO and confirm whether the problem has been resolved (e.g., grease, rags, etc.) or needs further attention (e.g., root removal or line repair). Elements of the sewer system needing further repair will be prioritized in Lowell's CMMS work-order system.

Summary of 2019 Surcharges and Related Actions

Since 2016, Lowell has continued to improve documentation and internal communication about these events. During field inspection of a reported event, the Collection System Supervisor notifies the Collection System Engineer via email with photographic documentation of the surcharge site. Volumes are estimated from witness accounts and photographic evidence, and the Engineer notifies MassDEP and EPA Region 1 through an email and phone call within 24 hours. The Engineer then confirms initial estimates through witness statements and photographic evidence prior to filing an official Notification Form within five days of the event occurrence.

In prior reports, it has been identified that occasional surcharging at Marginal Street still occurs, despite the improvements undertaken in Phase 2 to construct an inter-basin connection to relieve this interceptor of excess flow. The Phase 3 ICIP project list currently under review by regulatory agencies includes a schedule of proposed projects intended to eliminate surcharging at this location.

No weather-induced or maintenance-related combined or sanitary surcharges were observed in Lowell's collection system in 2019. However, a construction-related bypass operation at the Rosemont Pump Station over the summer of 2019 resulted in an unauthorized discharge of sewage to a local waterway (a wetland tributary to the Merrimack River). This incident was reported as a sanitary sewer overflow with comments indicating the root cause and corrective actions taken, as detailed below. The incident resulted in MassDEP filing an administrative consent order with penalty (ACOP), which includes requirements for Lowell to institute a formalized bypass-authorization and -review procedure, as well as identification of specific GIS and records management improvements to ensure that such an incident will be unlikely to occur again. Lowell is cooperating fully with MassDEP in response to these requirements, which are under development and will be submitted to MassDEP on schedule and implemented as standard operating procedures going forward.

Table 3-1 Sewer Overflows and Surcharges in 2019

Location	Date/Time	Notification	Cause	Discharge Volume (MG)	Destination of Discharge	Mitigation Measures
Rosemont Pump Station	8/21/2019	LRWWU Staff	Construction bypass operational error	0.5 (pump log estimate)	Merrimack River	Bypass relocated to sewer upon discovery

3.1.7 Legal Authority

Lowell Water derives its legal authority from Chapter 272 of the City ordinances. These ordinances provide the Utility, through the City, with the authority to:

- regulate the volume of flow entering the collection system, including residential and commercial customers, satellite communities and industrial users
- ensure that new and rehabilitated sewers and connections have been properly designed, constructed, and tested before being put into service
- establish general and specific prohibitions regarding the use of sewers and drains, including grease control requirements
- establish prohibitions on stormwater inflow, infiltration from laterals, and new construction standards
- maintain strict control over the connection of private sewer laterals to sewer mains
- require inspection and approval of new connections

The water and sewer ordinance was revised in June of 2018 to update the annual sewer use charge and metered service water rates, which became effective after July 1, 2018. In July 2018, a stormwater management ordinance was passed to provide Lowell Water, through the City, the authority to regulate, inspect and require proper management of site stormwater systems throughout the City. Also, in July 2018, the industrial waste ordinance was amended to update the maximum allowable industrial loads (MAIL) permissible to the City's collection system following EPA approval of the revised MAIL.

Summary of 2019 Ordinance Revisions and Related Actions

No revisions to water and sewer ordinances were made in 2019. A review of fees is underway in early 2020 and may culminate in changes to improve recovery of costs due to services provided by the wastewater utility.

3.2 Collection System Operation

As discussed in *Section 2.2*, the primary operational procedure governing Lowell's collection system during wet weather is the High-Flow Management plan. General procedures for the operation and maintenance of specific equipment, stations and substations are maintained in the Maintenance and Engineering libraries, as well as on Lowell Water's intranet.

3.2.1 Hydrogen Sulfide Monitoring and Control

The majority of Lowell's collection system is a combined sewer system, and consequently experiences frequent high-velocity flushing due to inflow. Hydrogen sulfide (H2S) corrosion has not been found to be a significant cause of deterioration in the collection system during continual video inspection surveys but does remain a concern for worker safety and equipment in remote stations that have wet wells which may be a source of H2S during dry periods.

Ventilation systems have been installed in these stations in order to protect workers entering the building; structures inspection crews visit each structure daily or weekly (depending on the structure), and so these stations are frequently vented.

3.2.2 Safety

As discussed in the training section (*Section 3.1.2*), Lowell's Safety Committee meets monthly to discuss and address safety incidents, coordinate and update the annual training schedule, and generally identify any opportunities for improvement to the safety program. Lowell Water's Safety Procedures Manual is a comprehensive document that covers all safety procedures specific to hazards encountered during routine work duties (the Emergency Preparedness Manual, discussed below, covers hazards encountered during emergency and/or extraordinary situations).

Other activities managed by the Safety Committee include procurement of safety equipment, inspection of safety equipment, updates to safety documentation and dissemination of new or revised procedures.

3.2.3 Emergency Preparedness and Response

Lowell's Emergency Preparedness and Response Plan (EPRP) serves as a guide for responding to emergency situations to protect employees and the public. Emergencies and disasters can happen at any moment and they occur without warning. When an emergency strikes, our immediate safety response actions and prompt recovery will depend on the levels of preparedness among Lowell Water employees, trained responding personnel, and other emergency departments. This plan provides directions for strategic response to various types of emergencies, including: first aid emergencies, fires or explosions, hazardous material spills, extended power or utility outages, floods, and terrorism or vandalism.

3.2.4 Modeling

Lowell Water has traditionally relied on engineering consultants for technical support in developing its collection system model. At the start of the Phase 1 LTCP, Lowell contracted with Camp-Dresser-McKee (CDM) for initial development of its collection system model. The EPA Stormwater Management Model (SWMM 5.1) was selected by CDM and the model was developed based on review of Lowell as-built records and sewer system maps available at that time. A flow metering program was established to provide a baseline for model calibration and validation. The model included all sewer pipes greater than 24 inches in diameter.

At the start of the Phase 2 LTCP, CDM was still the lead consultant for modeling work, and the model was updated from 2012-2014 to reflect the infrastructure improvements and new knowledge gained over the course of Phase 1 projects. A second flow-metering program was implemented during this revision to re-calibrate the model, particularly with respect to the reduced inflow from sewer catchments that had undergone separation.

Beginning in 2016, Hazen and Sawyer (Hazen) replaced CDM as the consulting LTCP program manager and began reviewing the SWMM model. Hazen made minor modifications to update improved conveyance observed at specific points achieved through collection-system maintenance actions (cleaning, root removal, et cetera) and Phase 2 projects completed at that time (most significantly, the Marginal Street Interceptor Relief structure).

Efforts in 2018 under the Integrated Planning program focused on assessing the extent to which collection system (inline) storage has been maximized, including additional flow metering and collection-system model validation. The collection system model was updated to include logic controls for flow through actuated gates as currently installed and controlled (including the new North Bank Flow Control Station), and the removal of hydraulic restrictions through CMOM and recent upgrades (e.g., the removal of the bar-rack at Warren Station).

Summary of Modeling Improvements and Related Actions in 2019

No updates to Lowell’s collection system model were undertaken in 2019. The next planned model revisions are scheduled to occur as part of the ICIP project schedule, following completion of approved projects that fundamentally change the storage capacity and dynamics of the collection system. The first round of such projects is expected to be completed circa 2025, but this schedule remains dependent on regulatory approval at this time.

As management of Lowell’s utility GIS improves (as discussed in the next section), opportunities for improving the resolution of the collection-system model may be possible. As such opportunities become apparent, Lowell’s engineering staff will consider whether such improvements will substantively improve management of the collection system.

3.2.5 GIS Management

Lowell Water maintains an extensive mapping program that is under continual revision as updates to the collection system are performed. This section details the manner and means by which the GIS resources of the City are leveraged to continually improve the procedures employed at Lowell Water to manage its infrastructure.

GIS Overview

Geographic Information Systems (GIS) technologies are used heavily throughout Lowell Water's programs, as mentioned where relevant in previous sections of this report. GIS is a computer-based system for capture, storage, retrieval, analysis and display of spatially defined or associated data. GIS is one of the basic building blocks of the City's technology services. The goal is to deploy GIS throughout the organization, improving the way services are delivered to residents and businesses. To this end, the GIS department, under MIS, supports databases, develops applications, and provides technical assistance to a growing base of users. The Lowell GIS system was recently updated in April 2019; the current version is Esri software version 10.5.1.

The City of Lowell GIS is based on 2013 aerial photogrammetric mapping at a 1"=100' scale. These maps meet or exceed National Map Accuracy Standards (NMAS). The standards ensure that other data such as municipal parcel maps, compiled using similar specifications, can be overlaid without major discrepancies, and that ground coordinates can be derived from the map to a stated accuracy. Lowell GIS data uses the North American Datum of 1983 (NAD83) Massachusetts State Plane Feet. Lowell GIS parcel and boundary lines are compliant to the MassGIS Level 2 Standard.

Lowell GIS layers relevant to wastewater, drinking water and stormwater infrastructure include: building locations, address information, parcel properties, street centerline network, railroads, waterway/wetlands areas, flood plains, paved roadways, schools, neighborhood boundaries, census data, police and fire stations and sectors, zoning, drainage, sewerage and drinking water infrastructure.

Lowell Water has implemented extensive GIS utilization, and we continue to expand our toolbox to maximize efficiency of managing the large amount of data our day-to-day work generates over the course of any given year.

Utility Mapping Procedures

Current GIS mapping procedures include:

- **Sewer System O&M** – Lowell's collection-system staff utilize GIS extensively for operation and maintenance (O&M) of the sewerage and drainage systems. The Collection System Supervisor has Lowell's GIS maps available on an iPad. This enables the supervisor to quickly orient to the local sewers and identify all relevant information about the system. Having this information available in the field allows for expeditious resolution of sewer backups and other O&M issues. Several other Lowell Water personnel also have access to the sewer system maps and information via iPads. These GIS tools facilitate the execution of utility mark-outs, system characterization (feature location and metadata updates), and troubleshooting tasks, making all system O&M tasks more efficient. When discrepancies are identified in the field, a GIS mark-up tool enables a correction that is sent via email to the Utility GIS coordinator.

- **Sewer Inspection** – Lowell Water owns and operates a sewer inspection vehicle that records video inspections that are integrated into Lowell's GIS. In 2015, Lowell Water purchased a new video truck to replace its aging vehicle. Through this sewer-inspection program, Lowell Water has identified numerous defects that have led to several miles of sewer rehabilitation and more than $15 million in sewer improvements over the past decade.
    - As new video inspections are performed, the inspections are recorded in the GIS database through integration with GraniteNET technology onboard the video truck.
    - Changes to existing asset locations and metadata observed in these investigations are submitted through a *map-change request* to the Utility GIS coordinator, and these requests are then completed by the coordinator or are assigned to other appropriate staff for completion.

- **Sewer Outfall Abandonment Confirmation** – Lowell Water's Engineering Division is beginning (in 2020) a review of all old sewer outfall locations that were either abandoned or converted to municipal drainage outfalls during the construction of Lowell's interceptor system and several sewer-separation projects that have occurred. This effort will ensure that all upstream features are properly designated as components of the sewer or drain systems and prevent misidentification during any future work.
    - Old interceptor plans are reviewed to identify all outfalls annotated as abandoned, and map annotations in ArcGIS online are made to support field investigation and confirmation of abandonment.
    - A field engineer performs site inspections to confirm the abandonment and/or destruction of outfalls, or to confirm the conversion of old sewer outfalls to separate storm drainage.
    - Field notes are then annotated to the old plans as a corrected version, and are updated in the GIS database.

- **Drainage System Characterization** – Lowell Water uses GIS tools to identify and characterize all drainage outfalls into local waterways within the extents of the City of Lowell. This program is mandated by EPA stormwater regulations and is under development to be implemented through Lowell's MS4 Stormwater Permit. Through this program, the locations of all drainage outfalls will be captured and integrated into Lowell's GIS. Having these assets integrated into GIS will allow Lowell Water to better operate and maintain them. All drainage pipes are also integrated into GIS, including more than five miles of new drains that have been installed in Lowell Water's sewer-separation program. As part of Lowell's MS4 management program, all drainage structures will be investigated and confirmed through GIS in the coming years through an ongoing drainage-system characterization effort, which includes:

  - Drainage system characterization starts with prioritization of outfalls that exhibit dry-weather flow, in order to expedite inspection of these catchments which are at higher risk of conveying illicit discharges to Lowell waterways.
  - Field engineers and interns are deployed to survey and inspect each component of the drainage system upstream of the outfall, utilizing iPads equipped with high-accuracy GNSS receivers (Leica GG04+) and utilizing MassDOT's real-time correction system (MaCORS) to get high three-dimensional accuracy (within ½ foot in all directions, or better) on all drainage-system assets.
  - Upon identification of any illicit connections, cease-and-desist orders will be generated through the City Law department, or appropriate actions will be taken internally if illicit public connections are identified.
  - Lowell's drainage-system characterization (mapping and investigation) program is intended to be an ongoing effort to maintain and improve accuracy of system records.

- **Project Design and Planning** – As part of Lowell Water's Long-Term Control Plan (LTCP) program to control combined sewer overflows (CSOs), more than $50 million has been invested to upgrade Lowell Water's drainage system and separate inflow/infiltration sources from the combined sewer system. Lowell's GIS has been utilized extensively to plan, design and document six sewer-separation projects that have resulted in the installation of more than 20 miles of new drains, sewers, and water mains in the past ten years.
  - A comprehensive review of all projects will be conducted to ensure that all abandonments and/or conversion of sewer to drain (or vice versa) have been accurately recorded in the GIS.
  - New infrastructure projects completed in-house or through Lowell's repair contracts (pipe replacement, new catch basins, et cetera) will be submitted by the Collection System Manager as a map-change request to the Utility GIS Coordinator, who will then update the GIS accordingly.
  - New infrastructure projects completed under large contracts will be asked to submit a GIS project file following Lowell's sewer and drain geodatabase schemas, as part of the final records submittal, and that will be imported into Lowell's GIS after a data-quality review by Lowell's Utility GIS Coordinator.

- **Property Development** – Lowell Water assists property developers when they need information about local utilities. Lowell's GIS has information on water, sewer, drain, and gas utilities, allowing developers to effectively plan their projects.
  - As new properties are developed within the City, and new connections are made to the water infrastructure (potable, sewer and drain), map-change requests are to be submitted with approval of the new connections so that they are incorporated into the GIS.

- **Resident Support** – When residents inquire about local utilities, Lowell Water is able to provide relevant information immediately. Of particular value to home-owners are records of their sewer services. Although these records are not available through the Internet, they are provided upon request.
- **Spill Containment**– Using GIS, Lowell Water is able to provide quick access to information in determining what is affected downstream of the spill and where to set up spill containment.

GIS Online Services

Originally developed as a means to provide access to Lowell GIS data through a website application and as a component for E-government services, Lowell's GIS online services incorporate an internal Intranet alongside an external Internet presence.

Using GIS web services, a user can search by criteria such as parcel address or street name and the Lowell GIS site will return an interactive map of the location requested. This allows users to view GIS data, query databases linked to GIS, view related documents and print maps. A mark-up tool has been developed to aid in the correction of the GIS. This continuous editing of the GIS makes it as accurate as possible, using lines, points, polygons, and text on top of the base map of the GIS. These corrections are then sent to the GIS editors and the base maps are revised.

Wastewater Utility Internal GIS

This GIS Site displays the general GIS layers available as well as Wastewater Utility-specific layers. Examples of Wastewater GIS data layers are the city sanitary sewer and drain networks including sewer and drain pipes and wastewater infrastructures as well as other relevant GIS layers.

Lowell also has developed an ArcGIS server website for retrieval and display of sewer service records. This GIS Site designed for the general public through the city website (www.lowellma.gov). This site displays the general GIS data layers include base mapping (roadways, buildings, property and address locations, elevation model, neighborhood, and zoning boundaries, and assessor tax parcels and property data linked to the parcels).

Summary of GIS Improvements and Planning in 2019

Lowell Water is preparing to use Lowell's GIS to support an asset management program. This program will be implemented after the selection and start-up of a CMMS software program. Lowell Water will track its assets for condition, preventive maintenance, and life-cycle costs. Considering the substantial assets operated and maintained by Lowell Water, the CMMS should prove to be a valuable tool for managing the City of Lowell's assets.

In 2015, Lowell Water purchased a new truck, equipped with hardware and software that will seamlessly transition with the existing technology and have features that enable video editing in the field through real-time updating of GIS attribute tables. What makes this possible is a comprehensive data collection and management software offering flexibility, customization, and ease-of-use. This is currently state-of-the art for the pipeline inspection industry.

Built using contemporary Microsoft Visual Studio™ technologies and designed with an asset-based architecture, a user can navigate to a particular asset (e.g., pipe segment) and view all inspections. Because this is the database structure on which asset management and Geographic Information Systems (GIS) are built, data integration is seamless. Being able to see the pipes below the ground is valuable, but unless that information is shared and distributed, the knowledge gained has limited use. The new system will support video viewing through a hyperlink within the GIS.

In addition, Lowell has begun to redesign field reporting data streams to be GIS-centric. That is, rather than relying on inter-person transfers of information to enter maintenance, repair and replacement records into tracking spreadsheets, Lowell is preparing to use ArcGIS applications like Collector and Survey123 to design reporting forms that capture and store site photographs, work logs, and more, in a manner that can be easily queried and audited by management.

A pilot implementation of this workflow was begun in 2019 for the city's stormwater system. Limitations of the current GIS architecture have been identified, and Lowell Water has entered into planning conversations with the City's MIS department and Esri to develop a plan to upgrade to Esri's new Portal and Utility Network architecture within the next four years. These upgrades are expected to significantly improve the efficiency with which Utility personnel can make observations of data inaccuracies and correct them in the master database.

3.2.6 New Construction

Lowell Water actively participates with the City Engineer's office and the Department of Planning and Development (DPD) in the review and approval of new and redevelopment projects within the City of Lowell. Lowell Water's Engineering Manager and Stormwater Program Manager review site plans to ensure that impacts from new construction impacts are properly managed to protect the City's infrastructure and meet overall environmental protection objectives. The City Ordinances provide Lowell Water with the authority to reject or approve these plans and provide standards and specifications for developers to follow.

Summary of New and Redevelopment Actions and Planning in 2019

Lowell Water, with the City Engineers and DPD, reviewed 47 property improvement projects through the established procedures. The Engineering Manager reviewed all new connections to the sewer and drainage system prior to approval.

Also in 2019, Lowell Water and the City Engineers continued the practice of convening an ordinance revisions working group to meet frequently with the goal of actively identifying opportunities and strategies to improve City ordinances related to its water infrastructure. This process will continue to make certain that standards and specifications meet the needs of the City and Lowell Water.

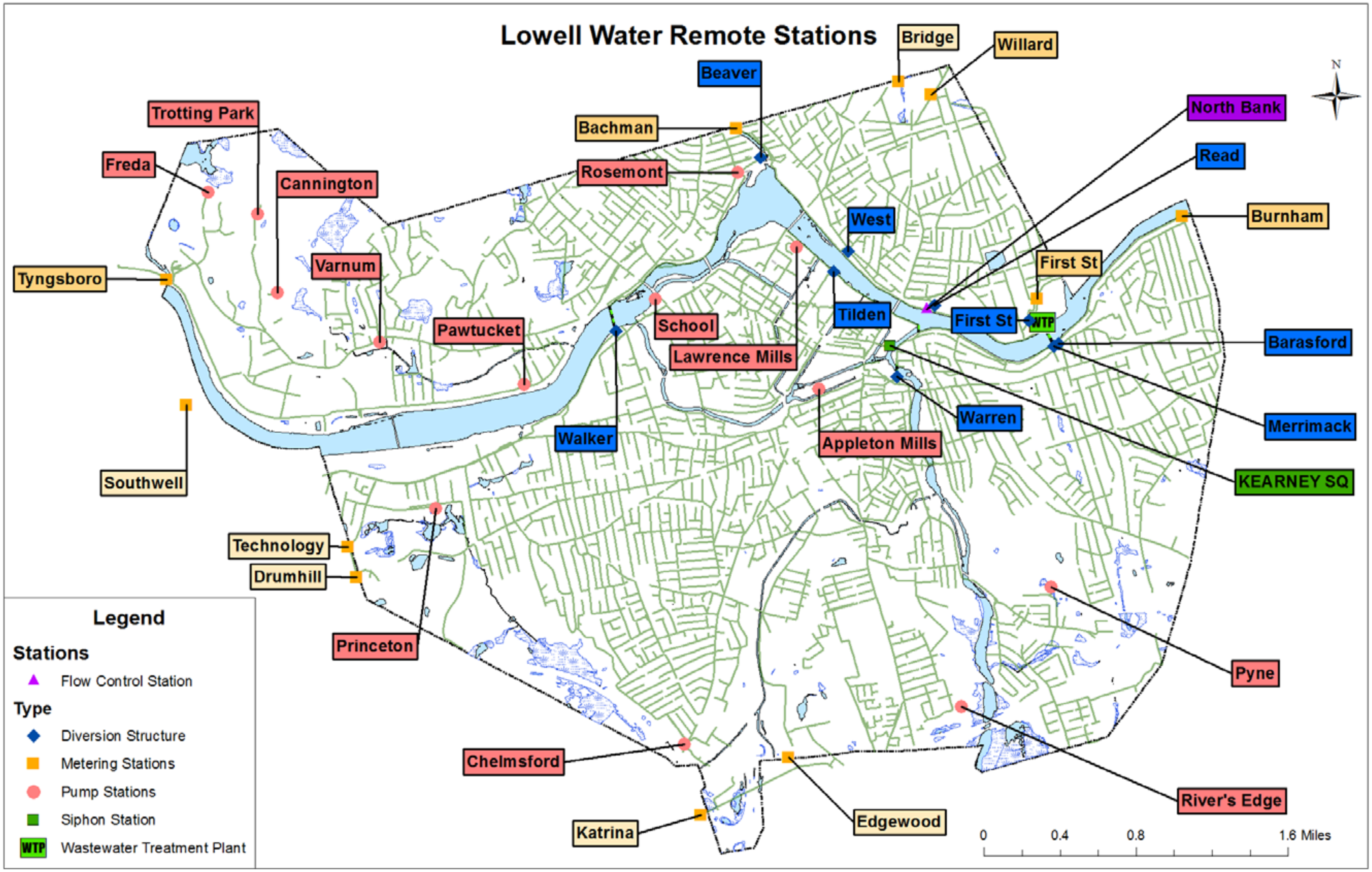
3.2.7 Remote Stations

Lowell Water's collection system includes 34 remote, or satellite, stations which are critical operating components of the collection system. These include CSO diversion stations (DS), pump stations (PS), metering stations (MS), and radio repeater stations (RS). All stations have their own respective operations and maintenance procedures and manual. Remote stations are visited daily by the maintenance structures crew, with the exception of the CSO diversion stations, which are visited on a weekly basis.

Summary of Updates to Remote Stations and Related Actions in 2019

The capital improvement plan currently underway includes renovation and communications improvements at several of the remote stations. Projects are either scheduled or underway for: Beaver Brook DS, Merrimack DS, Tilden DS, Merrimack DS, Warren DS, Walker DS, Cannington PS, Chelmsford PS, Freda PS, Lawrence Mills PS, Pawtucket PS, Princeton PS, Pyne School PS, Rosemont PS, Trotting Park PS , and Varnum PS. These upgrades include improvements to conveyance and storage, mechanical systems, electrical and lighting systems, SCADA and instrumentation, HVAC and plumbing, structural repairs and architectural improvements. Approximate estimates for the total work are on the order of $6M for these upgrades, many of which are now completed and the remainder are expected to be completed by July 2020.

Figure 3-2 Remote Stations Map



3.3 Equipment and Collection System Maintenance

Lowell manages equipment inventories and maintenance needs for the collection system through the MP2 CMMS software package. The MP2 database is populated with an equipment inventory that includes all items requiring maintenance at the Duck Island treatment facility, as well as at the satellite stations. The database features a scheduler that tracks the time from last recorded maintenance to the next scheduled maintenance for every piece of equipment. Work orders are generated through the database and issued to maintenance crews. MP2 does not currently support run-time tracking, so these schedules are time-based. Lowell is aware of the best practice of run-time based maintenance actions and is actively exploring options for improved CMMS software packages. However, current funding is not sufficient to support an upgrade to the CMMS at this time.

Lowell Water also maintains a full-time crew for each of a vacuum truck and a video-inspection truck, which are deployed on a regular schedule for catch-basin cleaning and video inspection of the sewer system. This program is run in close coordination with City Engineers to clean and investigate the sewer and drain systems in advance of the City’s paving schedule in order to identify and complete repair needs prior to new paving projects. Otherwise, the crews are deployed to other priority sections of the collection system to inspect, clean and identify repair needs.

Vehicle and heavy equipment maintenance is performed regularly, as well, and is tracked by the Maintenance Division. Fleet vehicle maintenance is coordinated with the DPW garage.

3.3.1 Maintenance Budgeting

The maintenance budget is coordinated annually by the division managers and the Executive Director. The fiscal year 2019 operating budget for Lowell Water was $19.6M. The maintenance budget comprised 27% of the total, or $5.34M in FY2019. This budget was allocated toward debt service on prior collection system improvements, new sewer repairs, overhead costs, street sweeping and catch-basin cleaning, satellite station maintenance, and GIS support services.

3.3.2 Planned and Unplanned Maintenance

Maintenance actions are planned through the MP2 CMMS, as discussed above. Maintenance personnel actively respond to work-order requests at Duck Island and throughout the collection system. All planned maintenance schedules are designed based on experience operating the particular equipment installed in the collection system. Long-term planning for upgrades includes assessment of critical system equipment nearing its life expectancy and such equipment is upgraded as soon as possible. Unplanned maintenance needs are inevitable, though, and these needs are prioritized as they are identified. Emergency repairs are performed as necessary.

2019 Summary

In 2019 the maintenance division completed 1,285 work orders, including 504 work orders in the collection system. More details are provided in *Section 3.3.3*, Sewer Cleaning; *Section 3.4.3*, Sewer System Inspection; and in *Section 3.5*, Sewer System Rehabilitation.

3.3.3 Sewer Cleaning

Sewer cleaning is performed for the purpose of reducing odor issues, maintaining adequate flow rates to convey sewage, and to prevent buildup and blockage of sewer lines from settled solids, rags, grease and detritus. Lowell owns and operates two vacuum (VacCon) trucks, which are equipped with pressure jet hoses used to break up blockages that are then vacuumed into the VacCon's holding tank and later emptied into dumpsters at Duck Island. The drainage from these dumpsters flows to the headworks for treatment, in accordance with the treatment facility Multi-Sector General Permit (MSGP) for stormwater management.

The combined sewer system is frequently flushed clean via rainfall – this was one of the perceived benefits of combined systems by the early sanitary engineers who designed them. With the exception of a few poorly sloped lines that are prone to clogging and are cleaned monthly, Lowell's sewer cleaning program is able to focus on cleaning the sewer and drain lines in coordination with the City paving program.

In the event that cleaning requirements are identified that exceed the equipment capacity, Lowell Water contracts for heavy cleaning services.

Summary of Sewer Cleaning Activities in 2019

Cleaning activities for the year in 2019 included: catch-basin cleaning (294 combined-sewer and 216 municipal drainage catch basins were cleaned, removing 448 tons of debris), sewer line cleaning (12,156 feet of sewer and drain line were cleaned), and street sweeping, which is conducted twice annually (328 tons of debris were prevented from entering the collection systems).

3.3.4 Parts and Equipment Inventory

Lowell Water employs a full-time Parts and Equipment Manager, who works with the CMMS Administrator to track and maintain adequate supplies in the stock room to meet planned maintenance needs, as well as extra stock for unplanned maintenance. This inventory is managed in parallel with the MP2 CMMS system previously discussed.

3.4 Sewer System Capacity Evaluation – Inspection

The capacity of the sewer system is assessed on a recurring basis. Assessment efforts include: video inspection of the sewer system; flow-monitoring programs in support of collection-system model development, conductance surveys throughout the interceptor system to identify and further investigate parts of the system with low conductance suggestive of high inflow; close coordination with the City Engineers and Department of Planning and Development (DPD) to ensure adequate review of all new sewer connections to the collection system and reduce private inflow to the combined system wherever practicable. The remainder of this section discusses each of these methods of capacity evaluation in more detail.

3.4.1 Flow Monitoring

Flow monitoring is conducted in conjunction with two projects. The collection-system model development and maintenance includes relatively infrequent but comprehensive flow monitoring projects throughout the collection system on large-diameter pipes. Extended metering for model development has occurred three times in Lowell's collection system; in 2002, 2012, and most recently in 2018.

In addition, Lowell has installed permanent level sensors at CSO regulators and upstream of interceptor flow-control gates. These sensors are essential to the automated high-flow management (HFM) procedures discussed in *Section 2.3* of this report, and for measurement and reporting of CSO diversion volumes. Regular review of data collected via these sensors occurs in the bi-weekly HFM meetings, providing a regular checkpoint to ascertain system capacity in the context of wet-weather events.

In 2017, Lowell contracted with ADS Environmental through its project manager Hazen and Sawyer to install, maintain and curate data from flow meters at more than 20 locations in the collection system through the monitoring period. Measurements included level and velocity profiles through the deployment period, providing a clear picture of conveyance parameters necessary for validation of the collection system model's prior calibration and information beneficial to overall capacity assessment.

Summary of Flow Monitoring Actions in 2019

No new flow monitoring actions were deemed necessary in 2019.

3.4.2 Sewer System Testing

As discussed in the Infiltration and Inflow Control Report in *Section 2.7*, Lowell has developed an infiltration and inflow (I/I) monitoring program involving regular conductance surveys to identify areas of flow with low conductivity indicative of non-sewage inflows to the collection system. This program was first designed and implemented in 2018, and quickly led to the identification of a significant inflow source at the Tilden Interceptor coming from a drainage connection from the hydropower canals to a sewer manhole at the intersection of Market and Dutton Streets.

The program was continued in 2019 as a low-cost, low-manpower means of identifying major I/I sources in the collection system. The program includes an initial springtime sweep of the collection system in which more than 70 sewer manholes are sampled from, and conductance readings are entered into GIS for review by Lowell Water engineers. During review the engineers consider the relative conductance at points surrounding major junctions of the collection system. If a conductance reading from one incoming line to a junction is significantly lower than the other incoming lines, further surveys are performed to investigate upstream on the line of concern.

3.4.3 Sewer System Inspection

The video inspection crew performs inspection of the collection system lines continuously throughout the year. Inspections are coordinated through the bi-weekly collection system meetings previously discussed, at which City Engineers and Lowell Water program managers coordinate drinking water, drainage system, and sewer system repairs with City paving projects in order to minimize the frequency of construction-related impacts on Lowell citizens. The City imposes a five-year moratorium on issuance of street-opening permits following paving, so it is imperative that Lowell Water investigates and makes the appropriate repairs to all infrastructures within any street that is on the list to be paved.

Video inspection staff are trained and certified through the Pipeline Assessment Certification Program (PACP) for pipe rating standards specified by the National Association of Sewer Service Companies (NASSCO). Pipe conditions are characterized using a scale from one to five, with five being a serious defect that requires immediate attention. This grading system correlates with NASSCO standards.

Inspection reports are generated using software on the video truck, and these reports are reviewed during the bi-weekly collection system meetings to identify all sewers and drains that require rehabilitation. These are added to the prioritized list to be lined, repaired or replaced. Repair and replacement methods are discussed further in the next section.

Summary of Sewer System Inspection Activities in 2019

Approximately 79,000 feet of sewer and drain line were inspected in 2019, which informed the generation of work orders for cleaning, repair and replacement at locations throughout the collection system.

3.5 Sewer System Rehabilitation

Lowell continues to fund rehabilitation of its sewer system at a rate of approximately $1M per year, which equates to roughly 25% of the total annual collection system maintenance budget. As has been discussed above, rehabilitation is by necessity closely coordinated with the City's street paving program due to the City's mandatory 5-year moratorium on issuance of street-opening permits following new paving.

Following inspection and prioritization of rehabilitation needs throughout the collection system, a proper rehabilitation method is determined based on the existing condition of the structures in need of repair. Where possible, a repair method such as lining or grouting is selected over replacement. Where existing conditions are such that lining or grouting would not appreciably extend the life expectancy of the asset, the asset is scheduled for replacement.

3.5.1 Excavation and Replacement

Replacement projects are contracted to a third-party specialist who then conducts the required work at the direction of the Collection System Supervisor. This dig-and-replace alternative is, of course the best option for meeting the objective of improving the overall quality of the repair, but it is also the most expensive. Often, the estimated scope of the repair required changes after exposing the compromised piping, sometimes requiring additional repairs. All such work is performed according to standards and specifications required by the City Engineer.

3.5.2 Cured-In-Place-Pipe Lining

Cured-in-place-pipe (CIPP) lining is an industry-accepted practice for the repair of sewer lines that are not structurally damaged to the point of needing full replacement but suffer from extensive deficiencies leading to infiltration and structural vulnerability. CIPP lining is a relatively inexpensive method of repairing such sewer lines, wherein an epoxy-impregnated tube of fabric is inserted into the damaged pipe (after cleaning the pipe), and the epoxy is then activated with steam. The tube then hardens as the epoxy cures to a structural rigidity similar to poly-vinyl-chloride (PVC) pipe.

3.6 Summary of Collection System Maintenance in 2019

The following table presents a log of typical collection system sewer repairs and replacements undertaken in 2019. In total, $1.05M were invested in the collection system in 2019, including: 313 feet of new sewer pipe installed; 9,261 feet of cured-in-place-pipe repairs; repair and replacement of 46 catch basins; repair and replacement of six manholes. Also included in this total are 532 feet of replaced drainage; 294 sewer catch-basins cleaned; 216 drainage system catch-basins cleaned; and associated miscellaneous items like test pits, paving and sidewalk repairs.

Table 3-2 2019 CMOM Sewer and Drain Work Log

WORK DONE	DIA (in.)	LENGTH (ft.)	STREET	REPAIR COST	MATERIAL	REPAIRED DATE	ENTERED IN GIS
Sewer Service Repair			115 DOUGLAS RD	$ 8,795.92		3/14/2019	Yes
Sewer Service Repair	6	52	115 DOUGLAS RD	$ 19,432.64	PVC	3/13/2019	Yes
CB repair			1255 Middlesex	$ 2,145.00		9/19/2019	Yes
Drain line repair and CB Repair	6	30	137 and 161 Starr Ave	$ 10,769.57	PVC	8/21/2019	Yes
CB Replacement	6	4	142 Carlisle	$ 11,286.76	PVC	9/9/2019	Yes
CB + Drain MH	12	2	15 Nesmith St.	$ 9,879.16	PVC	8/6/2019	Yes
CB Replacement	6	5	1505 Middlesex St	$ 11,590.39	PVC	3/21/2019	Yes
CB Repair and Drain Line Replace	6	30	16 CARMINE ST	$ 9,531.32	PVC	8/13/2019	Yes
CB Replacement	8	15	200 DOUGLAS RD	$ 9,495.91	PVC	9/17/2019	Yes
CB Replacement			209 Summer	$ 9,798.95		9/10/2019	Yes
CB Replacement	6	13.5	216 MANSUR ST	$ 8,612.16	PVC	3/28/2019	Yes
CB Repair	6	4	25 Shattuck St	$ 6,674.56	PVC	7/18/2019	Yes
CB Replacement	8	4	282 FAYETTE ST	$ 9,704.27	PVC	8/28/2019	Yes
CB Rebuild and drain repair			282 FAYETTE ST	$ 8,693.62	PVC	8/29/2019	Yes
CB Repair/Rebuild			346 Boylston St	$ 3,330.14	PVC	9/27/2019	Yes
Cb Rebuild/Drain Repair	8	10	37 WASHINGTON ST	$ 7,135.56	PVC	8/30/2019	Yes
CB Replacement	6	4	474 Beacon St.	$ 9,647.30	PVC	8/14/2019	Yes
CB Replacement	6	4	477 Market St.	$ 7,457.00	PVC	7/19/2019	Yes
DMH Repair			495 Boylston	$ 2,840.00		9/27/2019	Yes
REPAIR SEWER LINE	6	5	50 BERWICK ST	$ 8,821.71	PVC	9/16/2019	Yes
CB Repair	8	2	540 LAWRENCE ST	$ 9,575.00	PVC	8/9/2019	Yes
CB Replacement	6	4	55 Wollaston St.	$ 9,542.52	PVC	8/16/2019	Yes
CB repair			6 Belmont St.	$ 1,430.00		9/19/2019	Yes
CB Replacement	8	5	63 COBURN ST	$ 9,371.86	PVC	9/13/2019	Yes
CB Repair & Sidewalk			67 EXETER ST	$ 5,935.46		9/20/2019	Yes
DRAIN REPAIR	8	2	68 Hally	$ 7,677.45	PVC	10/29/2019	Yes
CB Replacement	6	4.5	83 ROYAL ST	$ 9,620.36	PVC	3/18/2019	Yes
CB Replacement	6	4	86 TANNER ST	$ 8,895.63	PVC	3/25/2019	Yes
REPLACE CB	10	6	BELLEVUE AND THAYER	$ 8,296.07	PVC	10/30/2019	Yes
CB Rebuild and Drain Repairs	6	3	Belmont and Birch St	$ 8,080.43	PVC	8/26/2019	Yes
CB Replacement	6	3	Belmont Av	$ 11,139.60		8/23/2019	Yes
CB Repair			Belmont Ave	$ 9,132.02		8/22/2019	Yes
CB Replacement	6	3.5	BROADWAY AND SUFFOLK	$ 8,404.53	PVC	3/20/2019	Yes
CB Repair			BROADWAY AND WALKER	$ 2,982.38		9/23/2019	Yes

WORK DONE	DIA (in.)	LENGTH (ft.)	STREET	REPAIR COST	MATERIAL	REPAIRED DATE	ENTERED IN GIS
CB Replacement	6	5	CARLISLE ST	$ 9,423.68	PVC	9/6/2019	Yes
CB Repair			CHELMSFORD AND ALBERT	$ 2,280.00		10/21/2019	Yes
DRAIN REPAIR and CB replacement	6	3	CLAUDINE DR	$ 9,617.08	PVC	9/18/2019	Yes
CB Replacement	8	3	COBURN AND JEWLETT ST	$ 9,742.89	PVC	9/12/2019	Yes
DRAIN REPAIR			DELARD ST	$ 7,953.43	PVC	10/28/2019	Yes
DRAIN REPAIR	10	42	DELARD ST	$ 9,349.06	PVC	10/25/2019	Yes
DRAIN REPAIR	10	14	DELARD ST	$ 8,264.29	PVC	10/24/2019	Yes
CB Replacement	6	3	Devine St	$ 9,411.94	PVC	9/5/2019	Yes
CB Replacement	6	2	DOUGLAS RD	$ 8,374.84	PVC	3/27/2019	Yes
CB Replacement	6	4	GREEN @ GEORGE ST	$ 9,571.71	PVC	8/8/2019	Yes
CB Repair	6	3	JOHN ST @ MERRIMACK	$ 6,633.32	PVC	7/17/2019	Yes
CB repair, replace drain line	6	30	Keene St @ Chapel St	$ 10,808.98	PVC	8/12/2019	Yes
CB Repair			LAKEVIEW AND PATRICIA	$ 6,537.11		10/18/2019	Yes
CB Repair			Liberty & School	$ 2,480.97		10/21/2019	Yes
CB Replacement	10	3	Lowell Connector and Thorndike St	$ 10,091.80	PVC	9/11/2019	Yes
DRAIN REPAIR	6	4	LOWES WAY AT INDUSTRIAL AVE	$ 5,641.66	PVC	11/1/2019	Yes
CB Replacement	6	4.3	LYONS AND KINSMAN	$ 8,456.73	PVC	3/19/2019	Yes
CB Repair			MAMMOTH AND MARGINAL AT GLIDDEN	$ 4,560.00		10/22/2019	Yes
CB Replacement	6	6	MANSFIELD AND STAFFORD	$ 8,078.01	PVC	10/31/2019	Yes
Drain Line repair	6	33	Mansur Street and Fairmount	$ 8,748.49	HDPE	8/20/2019	Yes
Drain Line repair	6	23	Mansur Street near 42 Mansur	$ 8,202.64	PVC	8/19/2019	Yes
Drain Line Repair	8	208	MCPHERSON PARK	$ 9,513.50	PVC	9/19/2019	Yes
Drain Line Repair	12	10	MCPHERSON PARK	$ 8,409.50	PVC	9/20/2019	Yes
CB Repair			Middlesex & Grand	$ 2,285.49		9/19/2019	Yes
CB Replacement	6	3	MIDDLESEX AND LIVINGSTON	$ 8,613.80	PVC	12/6/2019	Yes
Drain replacement	6	39	MOORE AT MACKLEY	$ 9,394.85	PVC	9/3/2019	Yes
CB Replacement	6	3	OLD FERRY RD	$ 9,505.18	PVC	9/4/2019	Yes
CB Repair			PAWTUCKET AND BEDFORD AVE	$ 2,840.00		9/26/2019	Yes
CB Repair			Pawtucket Blvd opp 339	$ 3,090.11		9/26/2019	Yes
CB Replacement	6	2	Pawtucket St @ Fox Hall	$ 7,422.49	PVC	11/5/2019	Yes
CB New Install	6	21.75	PHOENIX AV	$ 8,951.87	PVC	3/29/2019	Yes
CB Replacement	6	4	PLAIN AND HOUGHTON	$ 8,129.07	PVC	10/4/2019	Yes
Replace CB	6	3	Princeton & Sayles	$ 8,002.07	PVC	10/3/2019	Yes
CB Replacement	8	6	Princeton Blvd @ Gertrude @ Wood St	$ 11,624.46	PVC	8/15/2019	Yes
CB Replacement	6	3	READ AND SIXTH	$ 7,618.23	PVC	11/6/2019	Yes
CB Repair			School @ Rock	$ 2,840.00		10/2/2019	Yes
CB Repair			SHAWMUT AND FAIRGROVE	$ 2,840.00		10/1/2019	Yes
CB Replacement	6	4	SOMERSET AT QUEEN	$ 7,702.21	PVC	11/4/2019	Yes
CB Repair			WALKER BETWEEN MIDDLESEX AND BRANCH	$ 2,840.00		9/23/2019	Yes
CB Repair/Rebuild	12	4	WANG SCHOOL	$ 9,655.44	PVC	8/7/2019	Yes
CB Rebuild and Drain Repairs	8	9	Wentworth and Andover Streets	$ 9,505.12	PVC	8/27/2019	Yes

WORK DONE	DIA (in.)	LENGTH (ft.)	STREET	REPAIR COST	MATERIAL	REPAIRED DATE	ENTERED IN GIS
CB Repair			WHIPPLE AND MEAD	$ 3,029.00		10/2/2019	Yes

4. References

Hazen. (2019). *Integrated Capital Plan.* Boston, MA.

MassDEP. (2017). *Guidelines for Performing Infiltration/Inflow Analyses and Sewer System Evaluation Surveys.* Wilmington, MA: Commonwealth of Massachusetts.

US EPA. (2019). *Sewer System Compliance Inspection Report.* Boston, MA.