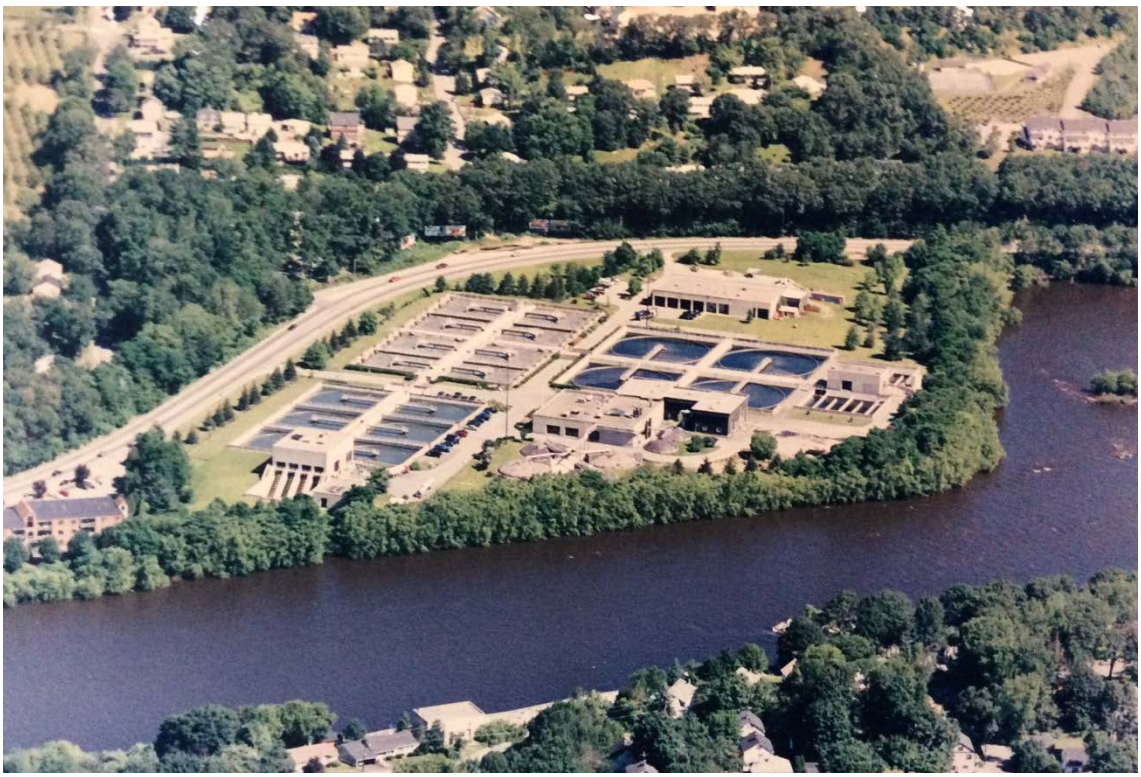
Annual Clean Water Report

Reporting Year 2018



NPDES Permit Number: MA0100633

Report Date: May 23, 2019

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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.

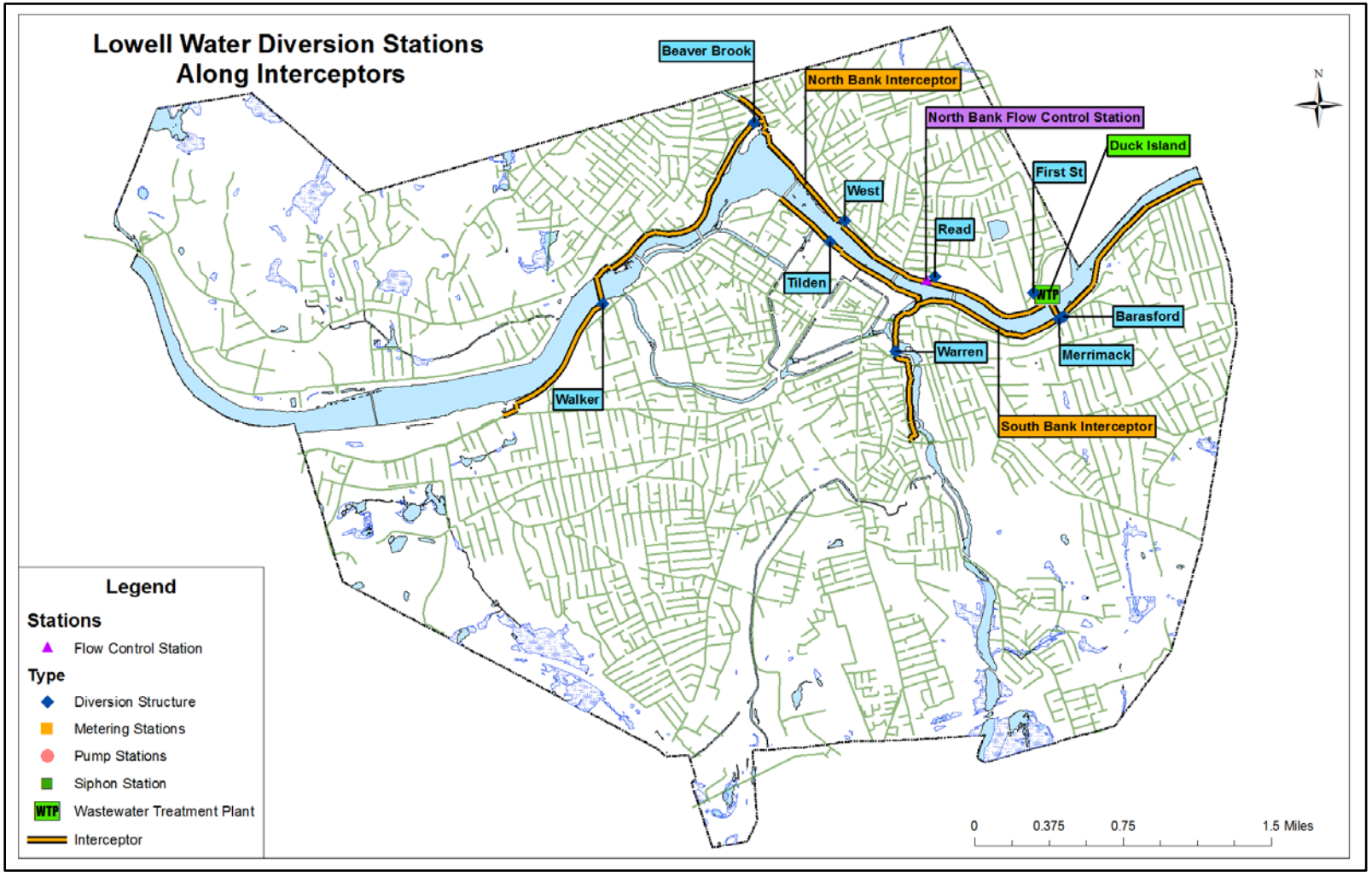
Lowell Water's sewer system consists of approximately 220 miles of gravity sewers and 12 sewage pumping stations. Ten miles of large-diameter (48-inch to 120-inch) interceptors located along the banks of the Merrimack and Concord Rivers collect wastewater from the sewer system and convey it to Duck Island. 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 2018 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.

1.2 Report Requirements

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

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.

Funding allocated to Lowell Water in fiscal year 2018 totaled $18.9 million. This included funds for operation and maintenance of the Duck Island Clean Water Facility at $13.97 million, and collection system funding at $4.93 million. Each of these figures includes 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 are provided for fiscal year 2019. Currently, Lowell Water is seeking approval from the City 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 includes critical infrastructure improvements to Lowell's drinking water system.

The primary areas of activity in 2018 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 is under development and has resulted in significant progress toward identifying new system-level improvements that are expected to significantly reduce CSOs and improve high-flow treatment performance in the coming years. The Integrated Planning framework includes a project ranking decision matrix which considers the impacts of each proposed project on the environment, public health and safety, infrastructure resilience, and other similar parameters of importance. Each design alternative will be assessed through this decision matrix in order to rank and prioritize projects. These ranked alternatives will be finalized and submitted in a report to EPA and MassDEP in December 2019.

Meanwhile, Lowell has continued to construct Phase 2 LTCP projects. In 2018, several of these projects were 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 ¾ 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 high and prevent flooding in the upstream catchment areas.

- Bar-racks were previously installed in several of Lowell's CSO diversion structures to restrict solids transport 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. The bar-racks at Merrimack and Walker stations were recently removed for this reason; and in late 2018 and early 2019, the bar-racks at Warren 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, which will increase the reliability and capacity of these treatment processes. Additionally, automation of the chlorine dosing to the high-flow treatment line will be implemented to help 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 2018

Detailed descriptions of Lowell's High-Flow Management Program development and current practices are provided in Section 2.2, and detailed annual records for 2018 are presented for review in Section 2.4. Brief summary statistics for the year are provided here.

Lowell experienced a wet year in 2018, with 177 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 2018 was 47.8 inches.

This precipitation required activation of Lowell's High-Flow Treatment mode 99 times throughout the year, resulting in the successful capture and treatment of 908 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 293 MG in 2018. The 'capture rate', a key performance indicator defined as the ratio of total CSO discharge volume to total treated high-flow, was 68 percent for the year.

1.3.3 Infiltration and Inflow Reduction in 2018

Section 2.7 of this report 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 2018.

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 our 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 new pilot project 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.

1.3.4 Capacity, Maintenance, Operation and Management (CMOM) in 2018

Lowell Water continued to fund its collection system CMOM program at a rate of roughly one-quarter of its total operating budget in 2018. This investment involved $0.93 million of cleaning, inspection and repair work performed in 2018, which included:

- Replacement of 654 feet of sewer line ($232,000)
- Repair of 1,735 feet of sewer line through cured-in-place-pipe (CIPP) projects ($161,500)
- Repair and replacement of 85 catch basins ($153,000)
- Repair and replacement of 5 sewer manholes ($29,000)
- Repair and replacement of 940 feet of drainage lines and manholes ($312,000)
- Associated paving, test pits, and sidewalk repairs
- Cleaning of 6.2 miles (32,537 feet) of sewer and drain lines
- Video inspection of 15.5 miles (81,904 feet) of sewer and drain lines
- Handling of 729 collection-system work-order requests
- Handling of 720 catch basin, residential sewer-backup and street-flooding reports
- Bi-annual street sweeping yielding removal of 99 tons of sediment and debris prior to entering the collection system
- Cleaning of more than 300 catch basins yielding 253 tons of sediment and debris captured in these basins

Section 3.6 includes a detailed presentation of sewer rehabilitation work performed in 2018.

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 in light of 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 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 2018.

2. High Flow Management and CSO Control Annual Report

This section of the 2018 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 2018, and discusses planned improvements in 2019.
- **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, which has undergone significant changes in 2018 to address public concerns raised since October 2017.
- **Section 2.5** provides signed certification required under the NPDES permit regarding accuracy of CSO activation records presented in Section 2.5.
- **Section 2.6** provides certified (signed) copies of letters required under the NPDES permit regarding CSO structures inspection and maintenance.
- **Section 2.7** presents a summary of Lowell's infiltration and inflow control plan and actions taken in 2018.

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.

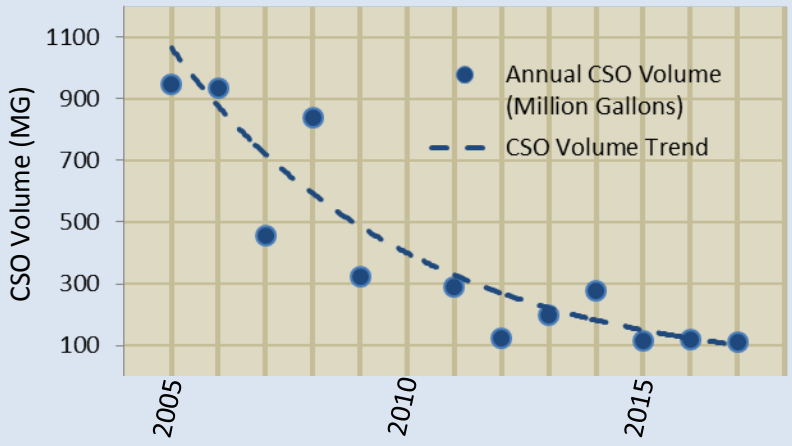
The result of these efforts is best conveyed through the trend presented in Figure 2-1, below, demonstrating a reduction in overall CSO discharge volumes on the order of 80% over the period of LTCP investment.

In 2014 Lowell submitted its Phase II LTCP, and is on schedule to complete these projects in 2019.

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 have 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 is integral to 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 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 (2014-2019)

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 as a means 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 (USACOE) 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 is an improvement priority under the Phase 3 planning process.

The North Bank Flow Control Structure, which allows additional inline wet-weather storage, was designed, constructed, and then 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 ¾ MG was constructed, as well, and the site is under consideration for expansion to a wet-weather treatment facility. This option is discussed in more detail under the Phase 3/Integrated Planning section.

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.
- 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. For example, the bar rack at Warren Station was removed in early 2019 and the impact on CSO diversions is currently under review.
- 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 reliable disinfection of wet-weather flows by modulating chlorine pump speed to maintain constant chlorine residual at the upstream end of the contact chambers. These chlorine pumps will also be replaced to ensure reliable delivery of chlorine to the high-flow treatment line.

2.1.3 Phase 3 LTCP and Integrated Planning

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. A draft proposal of the Integrated Plan is scheduled for submittal to EPA and MassDEP in December 2019.

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 in alignment with meeting the requirements in Lowell's 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 efforts in 2018 on assessing the extent to which these requirements have been maximized, including additional flow metering and collection-system (SWMM 5.1) 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 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 is working in concert with Lowell Water personnel to develop a CSO Control Alternatives Analysis. As this analysis is performed, all reasonable options will be screened for their ability to meet the intended objectives and the leading alternatives will be assessed through more detailed simulation and analysis. These final analyses will be used to select the 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 treatment 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). 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 Nashua wet-weather facility. Throughout these sampling periods, upstream water quality did not violate the single-sample maximum bacteria criteria. The Integrated Planning program is including this option among its CSO control alternatives analysis, presently underway.

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

Lowell Water's High Flow Management program (HFM) has been developed In order 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 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 2018.

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 CSO diversion stations
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).

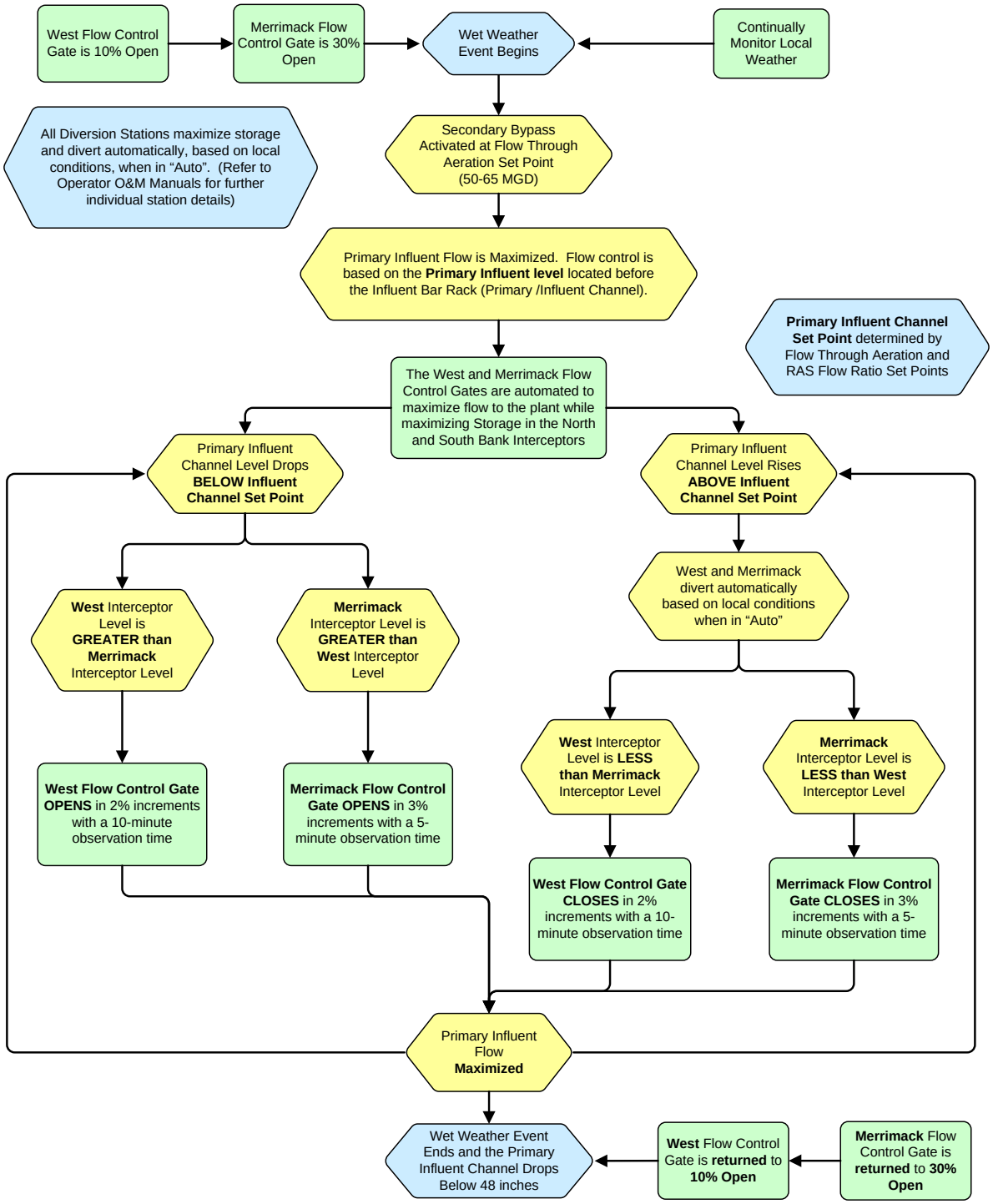
Upon maximization of flow to the biological treatment system, the high-flow treatment line is opened to allow excess primary treatment capacity to be conveyed to the blending well at the outlet of the secondary clarifiers. The hydraulic capacity at Duck Island is currently restricted to an instantaneous 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 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 2018

The following actions have been undertaken to inform improvements to the HFM program in 2018.

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 will be assessed further to develop SCADA control algorithms relating pump speed and chlorine dosage to improve reliability and efficiency of disinfection and de-chlorination.

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 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.

Among the issues identified and corrected in 2018 (and most significant among them all), the Warren Station CSO calculation was found to be incorrect, in that one of the two diversion gates was not accurately represented in the flow calculation employed in SCADA. This resulted in revision of that algorithm to accurately calculate the flow through this station, and a subsequent revision of flow measurements at Warren during CSOs that activated the gate in error. This error is discussed in more detail in **Section 2.5**, and the revised CSO volumes are included in the annual CSO volume report presented in **Section 2.4**.

As this review process continues in 2019, 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 will be included as part of the Integrated Planning 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 Public Notification and Reporting

Lowell has increased the speed of distribution and audience receiving notifications about CSO discharges in 2018. Public concerns over CSO discharges to the Merrimack River, in particular, have grown significantly since 2017. Lowell has responded by providing 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 will continue to engage in this public outreach project through 2019 and onward to ensure that the public understands the frequency, cause and effect of CSO discharges in the Merrimack River.

2.3 Nine Minimum Controls Report

The Nine Minimum Controls (NMC) are stipulated in Lowell's 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 is under revision to provide greater utility to citizens regarding multiple educational components about water quality. Completion is expected in 2019. 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. 50 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 2.3.3**
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 is in the process of preparing a report on this program.

2.4 Precipitation, High Flow Treatment & CSO Data

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Date	Clean Water Discharge			Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/18 12/31/18	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)
1/1/2018	21.87	27.71																																	
1/2/2018	22.28	27.59																																	
1/3/2018	23.00	28.80																																	
1/4/2018	23.24	28.31																																	
1/5/2018	22.35	26.18																																	
1/6/2018	22.21	27.52																																	
1/7/2018	22.35	28.69																																	
1/8/2018	23.44	27.65																																	
1/9/2018	23.63	27.91		1	0.38	0.09																													
1/10/2018	22.84	27.18		1	0.05	0.02																													
1/11/2018	28.34	38.89		1	0.12	0.05																													
1/12/2018	50.30	97.02	97.02	1	0.43	0.12	0.12	1	11.40	17.86							1	0.20	0.28										1	0.40	0.26				1	0.40	0.54
1/13/2018	62.45	100.51	100.51	1	0.24	0.07	0.07	1	17.10	27.51							1	0.18	0.14																1	0.18	0.14
1/14/2018	33.43	38.36																																	
1/15/2018	31.99	37.04																																	
1/16/2018	30.28	34.97																																	
1/17/2018	31.04	38.02		1	0.11	0.04																													
1/18/2018	28.81	32.39		1	0.03	0.01																													
1/19/2018	28.21	31.13		1	0.06	0.02																													
1/20/2018	29.15	36.91		1	0.05	0.02																													
1/21/2018	28.65	36.07		1	0.02	0.02																													
1/22/2018	29.01	38.48		1	0.09	0.02																													
1/23/2018	52.19	108.18	108.18	1	0.61	0.57	0.57	1	12.05	23.05	1	1.78	0.42	1	0.73	0.30	1	1.52	1.82				1	1.18	0.27				1	2.08	3.29	1	0.50	0.53	1	2.08	6.63
1/24/2018	33.70	37.61																																	
1/25/2018	30.23	34.11																																	
1/26/2018	29.25	32.40																																	
1/27/2018	29.71	35.41																																	
1/28/2018	30.43	35.18		1	0.02	0.01																													
1/29/2018	29.87	33.25																																	
1/30/2018	28.21	31.90																																	
1/31/2018	27.94	32.23																																	
2/1/2018	28.20	32.33		1	0.03	0.01																													
2/2/2018	31.84	41.56		1	0.19	0.06																													
2/3/2018	27.63	33.33																																	
2/4/2018	31.01	69.29		1	0.26	0.09		1	0.75	1.23																									
2/5/2018	45.45	102.35	102.35	1	0.12	0.10	0.10	1	5.82	11.42							1	0.73	0.77										1	0.80	0.34				1	0.80	1.11
2/6/2018	28.22	32.24																																	
2/7/2018	34.74	65.71		1	0.31	0.09		1	4.95	6.06																									
2/8/2018	33.06	44.41		1	0.04	0.02		1	1.57	0.49																									
2/9/2018	27.81	30.97																																	
2/10/2018	34.90	91.20	91.20	1	0.44	0.11	0.11	1	1.03	3.16																			1	0.78	0.33				1	0.78	0.33
2/11/2018	78.44	107.25	107.25	1	0.69	0.11	0.11	1	20.92	40.20	1	3.82	3.05				1	3.63	3.96										1	1.07	0.67	1	2.97	2.93	1	3.82	10.61
2/12/2018	39.78	47.29						1	1.65	0.75																									
2/13/2018	33.84	37.74																																	
2/14/2018	33.61	37.84																																	
2/15/2018	32.76	38.70																																	
2/16/2018	33.17	38.42		1	0.06	0.02																													
2/17/2018	31.93	38.53																																	
2/18/2018	33.31	43.25		1	0.54	0.18																													
2/19/2018	33.91	43.19		1	0.04	0.02																													
2/20/2018	35.67	39.13																																	
2/21/2018	33.67	39.76																																	
2/22/2018	33.68	38.03		1	0.05	0.02																													
2/23/2018	34.22	41.90		1	0.09	0.04																													
2/24/2018	33.75	39.75																																	
2/25/2018	43.47	69.85		1	0.39	0.07		1	7.33	5.55																									
2/26/2018	35.66	39.33																																	
2/27/2018	33.85	38.28																																	
2/28/2018	33.18	37.15																																	
3/1/2018	33.02	38.20																																	
3/2/2018	71.52	109.18	109.18	1	1.31	0.17	0.17	1	15.73	42.84	1	1.42	0.39				1	3.53	4.38				1	0.62	0.04				1	1.35	1.21	1	2.18	1.10	1	3.53	7.12
3/3/2018	46.17	60.56						1	22.83	11.44																									
3/4/2018	40.19	43.87																																	
3/5/2018	42.78	44.86		1	0.06	0.05																													
3/6/2018	38.26	41.91																																	
3/7/2018	43.58	72.60		1	0.33	0.09		1	6.22	7.94																									
3/8/2018	41.40	54.03		1	0.34	0.08		1	9.65	4.22																									
3/9/2018	39.86	44.15		1	0.34	0.04		1	1.30	0.14																									
3/10/2018	40.25	47.62		1	0.48	0.09		1	8.73	2.41																									
3/11/2018	39.18	50.13		1	0.06	0.03		1	8.15	2.57																									
3/12/2018	40.22	44.50		1	0.01	0.01		1	0.38	0.09																									
3/13/2018	41.05	44.81		1	0.10	0.05																													
3/14/2018	42.34	48.19		1	0.45	0.11																													

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01/01/18 12/31/18	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)
3/15/2018	43.83	47.21		1	0.05	0.02																													
3/16/2018	40.75	44.20		1	0.02	0.02																													
3/17/2018	38.88	45.72																																	
3/18/2018	37.52	43.80																																	
3/19/2018	36.55	40.75																																	
3/20/2018	36.03	40.67																																	
3/21/2018	34.25	44.79		1	0.58	0.58																													
3/22/2018	40.61	47.73		1	2.29	1.30																													
3/23/2018	37.57	43.24		1	0.05	0.05																													
3/24/2018	39.22	48.39		1	0.02	0.01																													
3/25/2018	39.99	45.36		1	0.05	0.01																													
3/26/2018	38.20	42.46		1	0.80	0.40																													
3/27/2018	38.07	43.23		1	0.31	0.31																													
3/28/2018	38.65	44.35		1	0.57	0.44																													
3/29/2018	38.37	43.35		1	0.02	0.02																													
3/30/2018	38.92	44.33		1	0.04	0.01		1	8.97	3.16																									
3/31/2018	38.46	43.25						1	14.68	5.11																									
4/1/2018	37.33	53.51						1	5.48	3.47																									
4/2/2018	37.22	44.18		1	0.06	0.04		1	7.88	2.86																									
4/3/2018	42.05	72.21		1	0.24	0.07		1	11.15	9.66																									
4/4/2018	44.93	64.39		1	0.16	0.04		1	18.10	11.77																									
4/5/2018	37.15	41.36						1	16.37	3.74																									
4/6/2018	40.15	55.10		1	0.17	0.04		1	13.17	7.31																									
4/7/2018	43.95	53.99		1	0.11	0.05		1	24.00	10.56																									
4/8/2018	37.50	43.55						1	14.43	4.82																									
4/9/2018	35.69	39.87						1	0.65	0.06																									
4/10/2018	34.83	38.94				0.01																													
4/11/2018	34.11	38.58																																	
4/12/2018	33.04	39.19		1	0.09	0.09																													
4/13/2018	35.61	40.51																																	
4/14/2018	32.60	37.31																																	
4/15/2018	32.11	38.21		1	0.01	0.01																													
4/16/2018	80.46	117.17	117.17	1	1.62	0.25	0.25	1	21.03	48.20	1	7.07	4.05	1	3.73	2.43	1	6.45	12.26				1	3.65	1.66	1	0.70	1.79	1	4.72	11.92	1	3.55	6.86	1	7.07	40.97
4/17/2018	61.89	85.15						1	23.75	32.38																									
4/18/2018	51.66	56.38						1	24.00	19.16																									
4/19/2018	50.99	66.42		1	0.14	0.06		1	24.00	15.90																									
4/20/2018	44.86	49.40		1	0.05	0.05		1	16.77	6.46																									
4/21/2018	42.75	48.80						1	16.23	5.37																									
4/22/2018	40.82	49.35						1	12.12	4.91																									
4/23/2018	37.18	41.27						1	0.35	0.10																									
4/24/2018	36.97	40.30																																	
4/25/2018	46.77	79.16		1	0.46	0.10		1	6.45	12.46																									
4/26/2018	47.89	88.41	88.41	1	0.20	0.15	0.15	1	7.63	10.48													1	0.12	0.01				1	0.33	0.33				1	0.33	0.34
4/27/2018	49.10	87.04		1	0.31	0.13		1	7.65	13.57																									
4/28/2018	41.11	48.48		1	0.01	0.01		1	13.82	3.97																									
4/29/2018	43.23	66.59		1	0.16	0.06		1	9.08	5.76																									
4/30/2018	38.42	43.72		1	0.08	0.03																													
5/1/2018	37.45	44.29																																	
5/2/2018	35.12	37.84																																	
5/3/2018	33.18	37.72		1	0.03	0.03																													
5/4/2018	33.94	37.22																																	
5/5/2018	32.73	37.53						1	0.02	0.47																									
5/6/2018	42.74	82.83		1	0.62	0.14		1	13.07	11.26																									
5/7/2018	40.16	80.89		1	0.01	0.01		1	3.65	6.10																									
5/8/2018	33.74	38.29																																	
5/9/2018	31.22	36.49																																	
5/10/2018	33.50	38.69																																	
5/11/2018	30.14	34.55																																	
5/12/2018	30.77	37.30		1	0.08	0.02																													
5/13/2018	29.87	35.98																																	
5/14/2018	29.62	33.99																																	
5/15/2018	41.39	85.71	85.71	1	0.45	0.21	0.21	1	6.62	13.50																			1	0.25	0.13				1	0.25	0.13
5/16/2018	30.29	38.67						1	0.20	0.01																									
5/17/2018	28.82	32.86																																	
5/18/2018	28.03	31.01																																	
5/19/2018	31.54	41.54		1	0.17	0.03																													
5/20/2018	31.52	39.52		1	0.07	0.02																													
5/21/2018	27.23	31.39																																	

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Date	Clean Water Discharge			Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/18 12/31/18	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)
5/22/2018	27.11	31.37		1	0.02	0.01																													
5/23/2018	26.77	30.56																																	
5/24/2018	26.45	30.52																																	
5/25/2018	26.73	29.79																																	
5/26/2018	25.60	30.94																																	
5/27/2018	29.88	46.02		1	0.27	0.13																													
5/28/2018	26.31	31.49		1	0.01	0.01																													
5/29/2018	25.90	29.84																																	
5/30/2018	24.61	29.27																																	
5/31/2018	24.67	28.77																																	
6/1/2018	24.77	27.95		1	0.01	0.01																													
6/2/2018	24.80	29.53																																	
6/3/2018	24.25	29.50																																	
6/4/2018	29.35	63.79		1	0.25	0.10		1	3.00	3.90																									
6/5/2018	26.66	39.37		1	0.15	0.11																													
6/6/2018	24.08	27.36																																	
6/7/2018	23.68	27.98																																	
6/8/2018	23.31	25.93																																	
6/9/2018	23.06	28.10																																	
6/10/2018	22.68	27.68																																	
6/11/2018	22.35	27.01																																	
6/12/2018	22.53	26.81																																	
6/13/2018	22.66	26.97																																	
6/14/2018	22.35	26.10																																	
6/15/2018	21.59	24.75		1	0.01	0.01																													
6/16/2018	21.65	26.60		1	0.01	0.01																													
6/17/2018	21.15	25.90																																	
6/18/2018	25.87	55.98	55.98	1	0.17	0.13	0.13	1	2.52	2.18																			1	1.17	2.41				1	1.17	2.41
6/19/2018	22.74	27.40		1	0.04	0.01																													
6/20/2018	22.13	26.25																																	
6/21/2018	21.90	28.19		1	0.02	0.02																													
6/22/2018	20.57	23.62																																	
6/23/2018	21.41	27.96		1	0.03	0.02																													
6/24/2018	22.84	31.43		1	0.20	0.08																													
6/25/2018	37.24	92.54	92.54	1	0.46	0.19	0.19	1	4.52	13.25				1	0.15	0.01							1	1.00	0.13				1	1.23	2.42	1	1.35	1.09	1	1.35	3.65
6/26/2018	22.19	25.75		1	0.01	0.01																													
6/27/2018	22.52	27.13		1	0.05	0.04																													
6/28/2018	48.18	91.13	91.13	1	0.20	0.08	0.08	1	10.75	20.54							1	0.45	0.53				1	0.08	0.01				1	1.38	1.60				1	1.38	2.14
6/29/2018	23.88	27.55		1	0.02	0.01																													
6/30/2018	22.97	27.98		1	0.01	0.01																													
7/1/2018	22.56	26.80		1	0.01	0.01																													
7/2/2018	22.51	26.76																																	
7/3/2018	26.73	55.92	55.92	1	0.35	0.33	0.33	1	2.75	2.54																			1	0.35	0.92				1	0.35	0.92
7/4/2018	21.48	25.93																																	
7/5/2018	22.13	25.78																																	
7/6/2018	23.48	32.68		1	0.01	0.01																													
7/7/2018	21.50	25.75																																	
7/8/2018	21.79	29.63																																	
7/9/2018	20.37	27.46																																	
7/10/2018	22.04	28.11																																	
7/11/2018	20.82	25.02																																	
7/12/2018	21.59	23.73																																	
7/13/2018	21.58	24.15																																	
7/14/2018	24.77	76.15	76.15	1	0.18	0.08	0.08	1	1.43	4.19										1	0.12	0.01													1	0.12	0.01
7/15/2018	25.95	68.83		1	0.03	0.01		1	1.18	1.83																									
7/16/2018	21.42	25.93																																	
7/17/2018	47.69	97.59	97.59	1	1.98	0.38	0.38	1	9.87	29.75				1	0.90	0.35	1	0.97	1.26				1	1.08	0.54	1	0.52	0.12	1	1.05	3.32	1	2.77	3.94	1	2.77	9.53
7/18/2018	23.35	41.39						1	0.70	0.22																									
7/19/2018	21.22	24.40																																	
7/20/2018	20.96	24.36																																	
7/21/2018	20.56	24.92																																	
7/22/2018	25.18	40.90		1	0.29	0.05		1	0.82	0.24																									
7/23/2018	27.31	40.08		1	0.16	0.08																													
7/24/2018	21.90	25.84		1	0.02	0.01																													
7/25/2018	21.91	25.43																																	
7/26/2018	51.35	98.75	98.75	1	0.96	0.43	0.43	1	9.35	18.23				1	0.92	0.66	1	0.90	1.22	1	0.17	0.08	1	1.42	1.37	1	0.67	1.73	1	0.95	3.66	1	1.05	2.05	1	1.42	10.77
7/27/2018	23.89	28.14		1	0.01	0.01																													
7/28/2018	22.82	27.83		1	0.01	0.01																													

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01/01/18 12/31/18	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)
7/29/2018	22.23	27.02																																	
7/30/2018	22.49	30.86		1	0.01	0.01																													
7/31/2018	22.75	26.83																																	
8/1/2018	22.04	26.01		1	0.01	0.01																													
8/2/2018	32.10	95.51	95.51	1	0.53	0.36	0.36	1	3.25	6.44				1	0.37	0.02	1	0.32	0.35	1	0.18	0.06	1	0.77	0.85	1	0.33	0.05	1	0.62	5.79	1	0.42	0.50	1	0.77	7.62
8/3/2018	22.36	26.09		1	0.01	0.01																													
8/4/2018	30.24	83.15		1	0.20	0.14		1	3.37	3.68																									
8/5/2018	22.85	27.54																																	
8/6/2018	21.87	25.62																																	
8/7/2018	26.53	51.49		1	0.13	0.12																													
8/8/2018	22.15	30.07		1	0.03	0.02																													
8/9/2018	25.70	51.00	51.00	1	0.16	0.09	0.09																1	0.30	0.06				1	0.25	1.50				1	0.30	1.56
8/10/2018	20.61	23.58																																	
8/11/2018	46.13	105.97	105.97	1	1.17	0.50	0.50	1	9.42	17.42	1	3.43	1.57	1	2.67	2.46	1	4.55	1.97				1	3.27	3.16	1	1.48	2.49	1	2.35	10.92	1	3.28	5.30	1	4.55	27.87
8/12/2018	43.97	104.67	104.67	1	0.47	0.17	0.17	1	5.20	10.28	1	1.27	0.22	1	0.37	0.02	1	0.38	0.45				1	0.43	0.22										1	1.27	0.91
8/13/2018	29.59	55.43		1	0.20	0.09		1	0.65	0.61																									
8/14/2018	46.35	97.78	97.78	1	0.46	0.34	0.34	1	8.53	10.76				1	0.68	0.21	1	0.40	0.51				1	0.40	0.07	1	0.32	0.06	1	0.43	2.51	1	0.90	0.60	1	0.90	3.96
8/15/2018	29.96	37.61																																	
8/16/2018	27.36	30.54																																	
8/17/2018	36.81	88.70	88.70	1	0.53	0.48	0.48	1	4.57	6.24			0.04	1	0.95	0.55	1	0.65	1.07	1	0.15	0.02	1	0.77	0.86	1	0.48	0.33	1	0.72	7.33	1	1.18	1.40	1	1.18	11.60
8/18/2018	44.95	81.73	81.73	1	0.36	0.21	0.21	1	7.45	7.57													1	0.10	0.01										1	0.10	0.01
8/19/2018	28.54	32.77																																	
8/20/2018	27.50	31.44																																	
8/21/2018	26.62	30.79		1	0.01	0.01																													
8/22/2018	38.43	73.60	73.60	1	0.52	0.28	0.28	1	4.27	3.79							1	0.33	0.41				1	0.52	0.10				1	0.58	1.62	1	0.67	0.70	1	0.67	2.83
8/23/2018	26.60	30.01																																	
8/24/2018	25.88	29.00																																	
8/25/2018	25.20	30.04																																	
8/26/2018	26.04	33.72																																	
8/27/2018	25.41	29.65																																	
8/28/2018	24.58	29.37																																	
8/29/2018	24.90	29.85																																	
8/30/2018	22.66	26.46																																	
8/31/2018	21.53	25.68																																	
9/1/2018	21.35	26.06																																	
9/2/2018	21.72	26.73																																	
9/3/2018	23.73	32.11																																	
9/4/2018	23.76	28.93																																	
9/5/2018	22.15	25.88																																	
9/6/2018	33.23	93.80	93.80	1	0.59	0.32	0.32	1	3.80	5.38	1	0.75	0.26	1	1.03	0.56	1	0.68	1.42				1	0.95	0.76	1	0.38	0.11	1	0.87	5.80	1	0.35	0.30	1	1.03	9.21
9/7/2018	22.09	25.24																																	
9/8/2018	21.52	26.39																																	
9/9/2018	21.75	26.79																																	
9/10/2018	33.99	97.07	97.07	1	0.75	0.29	0.29	1	4.07	7.15							1	0.73	1.05				1	0.13	0.02				1	0.53	0.98				1	0.73	2.05
9/11/2018	48.90	101.32	101.32	1	0.50	0.15	0.15	1	7.30	16.07	1	2.35	0.32				1	2.58	2.56													1	0.37	0.30	1	2.58	3.18
9/12/2018	25.73	30.30		1	0.04	0.02																													
9/13/2018	24.77	29.28		1	0.05	0.02																													
9/14/2018	24.12	27.02		1	0.01	0.01																													
9/15/2018	24.00	29.62																																	
9/16/2018	23.87	28.85																																	
9/17/2018	23.48	28.44																																	
9/18/2018	67.41	106.22	106.22	1	1.47	0.20	0.20	1	12.87	19.29	1	5.50	2.96	1	2.07	1.73	1	4.90	10.01	1	0.07	0.01	1	2.73	2.19	1	1.15	2.88	1	2.13	10.26	1	6.78	10.20	1	6.78	40.24
9/19/2018	32.47	37.62																																	
9/20/2018	30.48	37.04																																	
9/21/2018	28.04	30.55																																	
9/22/2018	26.46	31.61		1	0.01	0.01																													
9/23/2018	26.28	31.63																																	
9/24/2018	25.51	30.06																																	
9/25/2018	43.02	85.40		1	0.73	0.18		1	7.62	8.44																									
9/26/2018	33.87	93.08	93.08	1	0.56	0.38	0.38	1	1.68	2.24	1	0.52	0.20	1	1.23	0.43	1	0.65	1.28				1	1.22	0.73	1	0.97	0.12	1	1.05	3.31	1	1.03	1.30	1	1.23	7.37
9/27/2018	42.34	91.38	91.38	1	0.03	0.03	0.03	1	4.33	4.35	1	1.18	0.19	1	0.67	0.02	1	0.87	0.71				1	0.67	0.13				1	0.57	0.70	1	1.70	2.00	1	1.70	3.75
9/28/2018	29.65	35.39		1	0.05	0.03																													
9/29/2018	28.60	32.18		1	0.01	0.01																													
9/30/2018	28.02	32.68		1	0.01	0.01																													
10/1/2018	28.08	32.01		1	0.06	0.01																													
10/2/2018	32.62	51.76		1	0.33	0.09		1	0.50	0.11																									
10/3/2018	34.02	47.67		1	0.15	0.09																													
10/4/2018	28.73	32.27																																	

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01/01/18 12/31/18	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)
10/5/2018	26.94	29.82																																	
10/6/2018	26.28	30.74																																	
10/7/2018	25.85	31.56		1	0.02	0.02																													
10/8/2018	25.89	31.17		1	0.01	0.01																													
10/9/2018	25.17	29.46																																	
10/10/2018	24.53	29.67																																	
10/11/2018	40.22	93.28	93.28	1	1.09	0.68	0.68	1	5.87	7.17	1	1.28	1.04	1	1.40	1.20	1	1.07	2.68				1	1.42	2.03	1	1.03	1.13	1	2.03	11.83	1	2.27	2.60	1	2.27	22.51
10/12/2018	29.88	38.86																																	
10/13/2018	30.05	38.85		1	0.15	0.04																													
10/14/2018	28.39	33.57																																	
10/15/2018	27.89	33.66		1	0.06	0.04																													
10/16/2018	28.62	36.82		1	0.02	0.01																													
10/17/2018	26.87	30.92		1	0.01	0.01																													
10/18/2018	25.81	30.13		1	0.01	0.01																													
10/19/2018	25.15	28.83																																	
10/20/2018	25.14	31.31																																	
10/21/2018	25.24	31.18																																	
10/22/2018	24.50	29.88																																	
10/23/2018	27.61	50.28	50.28	1	0.16	0.15	0.15																						1	0.18	0.24				1	0.18	0.24
10/24/2018	24.87	29.14		1	0.03	0.01																													
10/25/2018	23.93	28.81																																	
10/26/2018	23.27	26.66																																	
10/27/2018	46.90	99.07		1	0.80	0.12		1	9.28	8.59																									
10/28/2018	29.14	38.32		1	0.05	0.01																													
10/29/2018	40.09	104.97		1	0.35	0.19		1	3.78	6.49																									
10/30/2018	27.65	31.65																																	
10/31/2018	26.39	29.58		1	0.01	0.01																													
11/1/2018	28.99	47.19		1	0.13	0.05																													
11/2/2018	31.40	46.54		1	0.20	0.06																													
11/3/2018	78.75	107.33	107.33	1	1.38	0.21	0.21	1	17.37	27.52	1	2.63	1.15	1	2.53	1.12	1	4.48	4.23				1	4.10	1.06	1	1.48	0.15	1	2.60	4.54	1	8.85	10.00	1	8.85	22.25
11/4/2018	43.44	47.14																																	
11/5/2018	42.57	65.21		1	0.24	0.06		1	1.73	1.07																									
11/6/2018	60.00	95.79		1	0.55	0.19		1	10.82	11.33																									
11/7/2018	43.31	51.40																																	
11/8/2018	40.29	43.93																																	
11/9/2018	45.25	96.92	96.92	1	0.61	0.16	0.16	1	3.45	4.73							1	0.80	0.62															1	0.80	0.62
11/10/2018	62.11	102.49	102.49	1	0.18	0.09	0.09	1	9.52	10.26							1	1.67	3.01															1	1.67	3.01
11/11/2018	42.61	47.96																																	
11/12/2018	40.24	44.15																																	
11/13/2018	75.37	103.84	103.84	1	1.00	0.18	0.18	1	18.87	24.92	1	1.02	0.31				1	2.93	3.06				1	0.23	0.05									1	2.93	3.42
11/14/2018	49.33	54.99						1	0.38	0.01																									
11/15/2018	45.24	49.15																																	
11/16/2018	57.55	85.49		1	0.90	0.19		1	15.87	6.49																									
11/17/2018	51.82	65.12		1	0.04	0.01		1	7.62	1.82																									
11/18/2018	47.73	53.76																																	
11/19/2018	51.73	73.30		1	0.28	0.05		1	3.25	1.67																									
11/20/2018	59.19	70.69		1	0.25	0.03		1	17.05	9.57																									
11/21/2018	47.78	52.64		1	0.12	0.03		1	1.87	0.23																									
11/22/2018	43.72	51.37																																	
11/23/2018	40.49	46.34																																	
11/24/2018	40.19	47.60		1	0.17	0.05																													
11/25/2018	43.29	49.47		1	0.14	0.04																													
11/26/2018	52.46	99.98	99.98	1	0.80	0.14	0.14	1	5.48	9.41							1	0.42	0.48													1	3.60	4.80	1	3.60	5.28
11/27/2018	81.48	101.05	101.05	1	0.43	0.09	0.09	1	24.00	29.57							1	0.35	0.33													1	6.92	12.20	1	6.92	12.53
11/28/2018	53.08	57.64						1	5.25	0.83																									
11/29/2018	49.24	53.06																																	
11/30/2018	45.20	49.13																																	
12/1/2018	42.31	46.18																																	
12/2/2018	68.96	100.01	100.01	1	0.69	0.10	0.10	1	14.03	18.53																						1	1.93	2.30	1	1.93	2.30
12/3/2018	48.23	51.64		1	0.01	0.01																													
12/4/2018	43.59	46.86																																	
12/5/2018	40.96	44.76																																	
12/6/2018	39.49	42.62																																	
12/7/2018	37.34	40.84																																	
12/8/2018	35.21	40.74																																	
12/9/2018	34.84	41.36																																	
12/10/2018	33.62	37.10																																	
12/11/2018	32.23	36.67																																	
12/12/2018	31.66	35.71																																	
12/13/2018	30.24	34.06																																	
12/14/2018	30.36	35.89																																	
12/15/2018	30.46	36.38																																	
12/16/2018	40.59	101.01	101.01	1	0.43	0.16	0.16	1	3.72	6.79																			1	0.55	0.40				1	0.55	0.40

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Date	Clean Water Discharge			Precipitation				Captured Flow (High-Flow Treatment)			Barasford Street			Beaver Brook			Merrimack Street			Read Street			Tilden Street			Walker Street			Warren Street			West Street			All Diversions		
01/01/18	Flow	Peak Hour	Event Peak	Precip Days	Daily Total	Peak Hour	Event Peak hour	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume
12/31/18	(MG)	(MGD)	(MGD)	(No.)	(Inches)	(Inches)	(Inches)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)
12/17/2018	35.68	68.47		1	0.04	0.01		1	0.70	0.51																											
12/18/2018	29.58	33.35		1	0.01	0.01																															
12/19/2018	28.92	32.88																																			
12/20/2018	28.71	32.11																																			
12/21/2018	52.22	98.53	98.53	1	0.71	0.17	0.17	1	10.73	9.66																			1	0.30	0.29				1	0.30	0.29
12/22/2018	36.19	42.82		1	0.04	0.02																															
12/23/2018	32.86	38.65																																			
12/24/2018	33.12	39.81																																			
12/25/2018	30.70	36.90																																			
12/26/2018	30.17	34.98																																			
12/27/2018	29.45	33.26																																			
12/28/2018	39.09	75.74		1	0.30	0.07		1	2.63	2.13																											
12/29/2018	30.81	36.89		1	0.01	0.01																															
12/30/2018	28.71	34.97																																			
12/31/2018	30.74	45.91		1	0.20	0.11																															

Date	Clean Water Discharge			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	Flow	Peak Hour	Event Peak	Precip Days	Daily Total	Peak Hour	Event Peak hour	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume	Event	Duration	Volume
365	(MG)	(MGD)	(MGD)	(No.)	(Inches)	(Inches)	(Inches)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)	(No.)	(Hours)	(MG)
Total/Max	12,172.13	117.17	-	177	47.77	1.30	-	99	827.90	907.50	14	34.02	16.17	16	20.40	12.07	29	47.33	62.82	5	0.68	0.18	24	27.15	16.33	12	9.52	10.96	31	33.68	100.83	22	54.62	73.00	42	81.60	292.36
Avg/Percent	33.35	45.55	93.13	48.5	0.27	0.05	0.03	55.9	8.36	9.17	7.9	2.43	1.16	9.0	1.28	0.75	16.4	1.63	2.17	2.8	0.14	0.04	13.6	1.13	0.68	6.8	0.79	0.91	17.5	1.09	3.25	12.4	2.48	3.32	23.7	1.94	6.96

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. One such error was discovered in 2018 with respect to Warren Station. Validation review demonstrated that the SCADA calculation was failing to account for the back-up (or lag) diversion gate at this station. This programming error led to the underestimation of flows from this station. An external calculation program was written to calculate the diversion flow estimate from each event that would properly consider the second diversion gate opening. A total of 49 MG of additional flow was found to have occurred during such events, bringing Lowell's total CSO discharge up to 293 MG in 2018. The algorithm was repaired in SCADA and has since been validated by the external program during similar events.

The final record with adjusted 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 2018. 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.

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

In 2018, 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 2018, including:

- Heating duct replacement and exterior painting at Warren Station
- Exterior painting at Merrimack Station
- Minor hydraulic unit improvements at Beaver Brook Station

2.7 Infiltration/Inflow Control Annual Report

Infiltration and Inflow (I/I) is estimated annually using monthly average flows from 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. The table below presents this information for 2018.

Table 2-1 Monthly Average Inflow in 2018

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	12.05
Feb '18	14.00	14.00	35.38	37.81	32.95	4.86	15.78
Mar '18	22.00	9.00	40.50	41.39	38.34	3.05	21.09
Apr '18	16.00	14.00	42.41	44.77	39.72	5.05	22.00
May '18	10.00	21.00	30.87	33.46	29.64	3.82	12.94
Jun '18	16.00	14.00	24.51	25.98	22.83	3.16	5.48
Jul '18	13.00	18.00	24.40	28.16	21.68	6.48	3.78
Aug '18	15.00	16.00	28.89	32.93	25.09	7.84	7.51
Sep '18	14.00	16.00	29.41	35.01	24.51	10.50	8.42
Oct '18	17.00	14.00	28.57	30.64	26.06	4.59	10.91
Nov '18	17.00	13.00	49.79	53.53	44.92	8.61	25.88
Dec '18	10.00	21.00	36.03	41.21	33.57	7.64	16.98
Total/ Average	177.00	188.00	33.40	36.59	30.52	6.07	13.57

2.7.1 Summary of Known Inflow Sources

The right-most column of Table 2-4, above, provides an estimate of non-rain-related 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 inflow occurs during months of spring runoff or high river level.

It is expected that much of this seasonal trend is attributable to infiltration into the riverbank interceptors, which are often located in or near the river bed. Other known sources of significant I/I 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. All of these sources are legacy direct connections of wetlands (Hovey Field) and streams (Humphrey's and Billings) into Lowell's combined sewer system.

2.7.2 Determination of Feasibility to Control Known Inflow Sources

Control of I/I entering the interceptors directly during high river levels is not financially practical at the present time. Some sections of these interceptors have been lined with CIPP, but complete lining of all interceptors and manholes would be required to eliminate this source at significant expense. 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.

Control of I/I attributable to direct connection with streams and wetlands are similarly impractical at present, as such control would necessarily entail separation of each respective 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 coordination with FEMA and the US Army Corps of Engineers.

The Billings wetlands may be controlled to some extent through practical engineering controls. Further examination of this source and opportunities to reduce inflow from it may be considered through Lowell's Integrated Planning program.

2.7.3 Ongoing Control Actions

Lowell's CMOM program continues to provide a stable funding source for inspection, identification and scheduling for repair and replacement of sewer lines that may be vulnerable to infiltration and inflow. A summary of 2018 actions in this program is provided in Section 3.6.

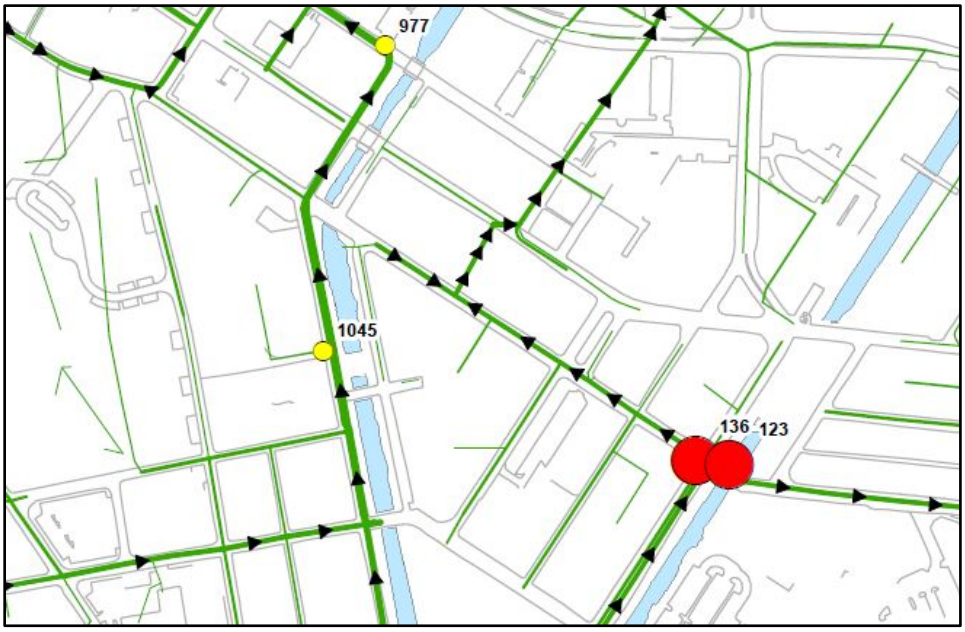
The bulk of Lowell's current I/I control efforts lie within the Site Stormwater Planning Program, which is implemented to reduce private inflow from new development and redevelopment on an ongoing basis. Lowell Water engineers meet bi-weekly with City engineers and the Department of Planning and Development (DPD) to review proposed development projects and provide comment on opportunities to reduce inflow to the combined sewer system where possible. This program is managed as part of Lowell's Stormwater Management Program, and significant efforts are underway to standardize the review process and specifications for new drainage work and connections to both municipal drainage and sewerage systems.

In addition to the conventional metrics used to quantify infiltration and inflow (I/I) in Lowell's system, Lowell Water established a new pilot project specifically designed to survey and identify primary points of entry for I/I utilizing conductance probes to screen the collection system at major junctions. Conductance is a measure of electrical conductivity (or the inverse of resistance) in water, and sewage generally has a high specific conductivity in the range of 1000 micro-siemens per centimeter. Sections of the collection system with high I/I tend to dilute the sewage and lower conductance, offering a low-effort screening tool to identify areas of the system in need of further inspection and repair.

The project identified 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 image below is a captured screenshot from the GIS map created to manage this program, wherein the two red dots shown are very low conductance readings relative to the yellow markers indicating the expected range of conductance in Lowell's sewage.

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.

Figure 2-1 Conductance Survey Mapping (Example)



2.7.4 Projected Control Actions

Lowell will continue to document and characterize newly identified areas of I/I as described in this section. New findings will be added to the following year's annual report and consideration of potential to eliminate or reduce I/I from each identified area will be discussed and prioritized within the context of Lowell's overall Integrated Planning program.

3. CMOM Program 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.

3.1 Collection System Management

The purpose of Lowell's collection system is to protect public health and prevent unnecessary property damage from flooding or sewage 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.

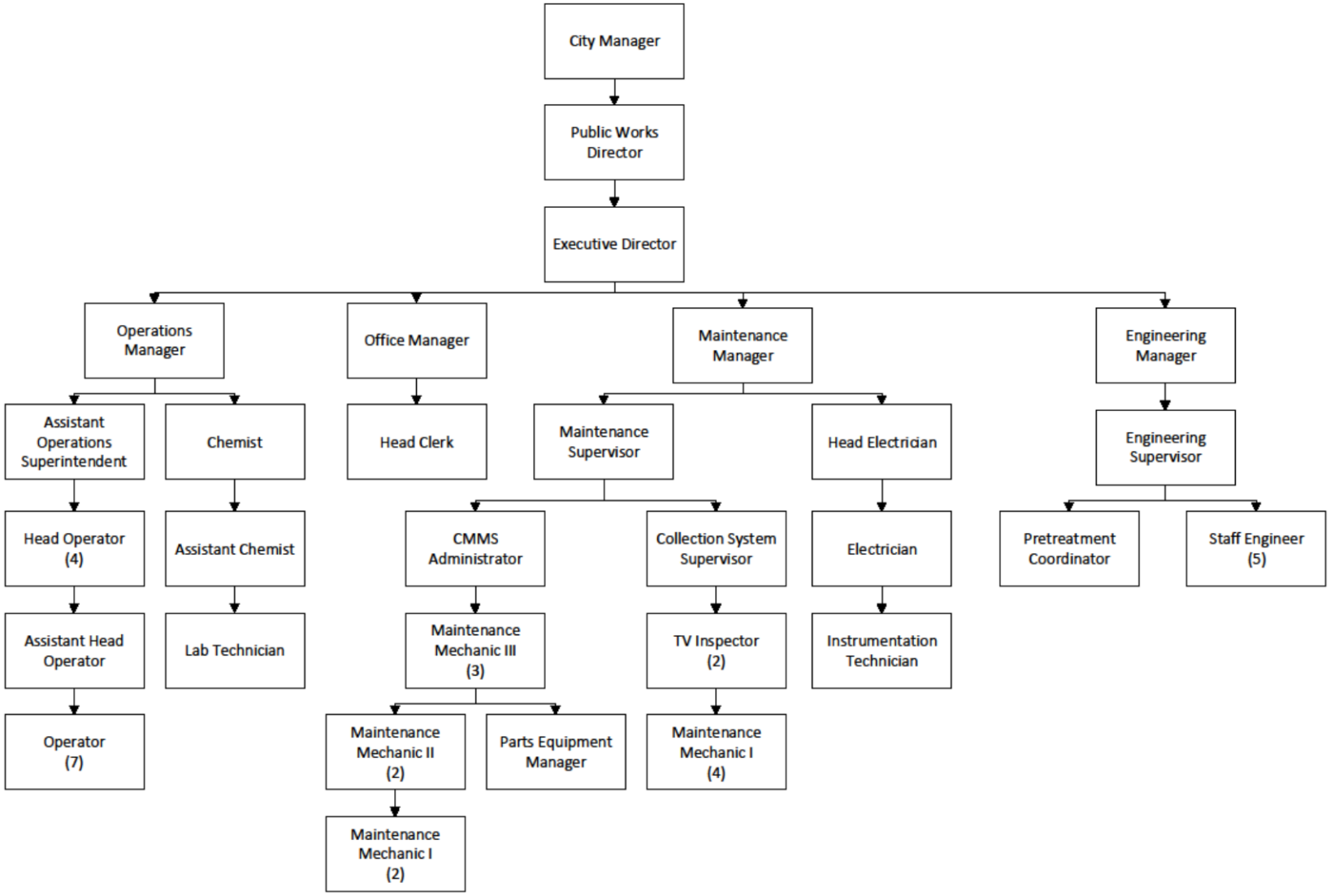
3.1.1 Organizational Structure

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 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.

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)

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 program manager 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 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 Management Information 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 OpSQL 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 2018

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 will continue to work toward these goals to improve its CMMS, but the expected acquisition date will likely be delayed.

Several improvements to the GIS program were started in 2018, including a review of field data collection and documentation tools available through ArcGIS online. ArcGIS Collector and Survey123 are now being tested by the Engineering Division, which will support development and distribution of broader use of these applications to capture relevant details of work performed in the collection system. The end goal will be to develop data management processes 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.

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 from combined sewers are such that 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 2018 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 project list will include assessment of options to completely eliminate surcharging at this location.

All surcharges in 2018 were combined sewer surcharges (no sanitary sewer overflows). Two such events occurred in 2018, as detailed below.

Table 3-1 Combined Sewer Surcharges in 2018

Location	Date/Time	Notification	Cause	Discharge Volume (Gallons)	Destination of Discharge	Mitigation Measures
42 Wellworth Street	04/14/2018 13:30-14:30	Property Owner	Sticks/rags caused initial blockage in sewer line	500 (impacted area estimate)	Flag Meadow Brook	Blockage was removed
Near 174 Willard Street	5/21/2018 16:00-18:30	Lowell Police	Pipe collapsed	300 (impacted area estimate)	Sewage flowed back to combined catch basin downstream	Pipe section replaced promptly

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

Summary of 2018 Ordinance Revisions and Related Actions

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.

3.2 Collection System Operation

Address general operational procedures and refer to HFM program/plan/protocol.

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 is of 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 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 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) 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 through the course of Phase 1. 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 (having replaced CDM as the consulting LTCP program manager) began reviewing the SWMM model and made minor modifications to update improved conveyance observed at specific points achieved through collection system maintenance actions (cleaning, root removal, etc.) and Phase 2 projects completed at that time (most significantly, the Marginal Street Interceptor Relief structure).

Summary of Modeling Improvements and Related Actions in 2018

The Integrated Planning program focused efforts in 2018 on assessing the extent to which collection system (inline) storage has been maximized, including additional flow metering and collection-system (SWMM 5.1) 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).

3.2.5 Mapping

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. GIS is a computer-based system for capture, storage, retrieval, analysis and display of spatially defined data. GIS is one of the basic building blocks of the City's technology offerings. The goal is to deploy GIS throughout the organization, improving the way services are delivered to residents and businesses. To this end, GIS 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 ERSI 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. Current GIS resources include:

- **Sewer System O&M** – Lowell Water'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 (2014 purchase) in his vehicle. This enables the supervisor to quickly familiarize himself with 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. Nine other Lowell Water personnel also have access to the sewer system maps and information via iPads (2014 purchase). The GIS tools facilitate the execution of utility mark-outs, system characterization, 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 in-house GIS editors.

- **Sewer Inspection** – Lowell Water owns and operates a sewer inspection vehicle that records video that is integrated in Lowell's GIS. In 2015, Lowell Water purchased a new video truck to replace its aging vehicle. Through its sewer inspection program, Lowell Water has identified countless defects that have led to several miles of sewer rehabilitation and more than $15 million in sewer improvements in the past decade.
- **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 implemented through the Lowell's MS4 Stormwater Permit. Through this program, the locations of all drainage outfalls are 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.
- **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.
- **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.
- **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 over the years, at significant expense, 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 2018

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. It is expected that this new framework will be implemented initially in 2019 and standardized by 2020.

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 2018

Lowell Water, with the City Engineers and DPD, reviewed 26 property improvement projects of greater than ½ acre formally through the established procedures. The Engineering Manager reviewed all new connections to the sewer and drainage system prior to approval.

Also in 2018, Lowell Water and the City Engineers began the process of establishing 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.

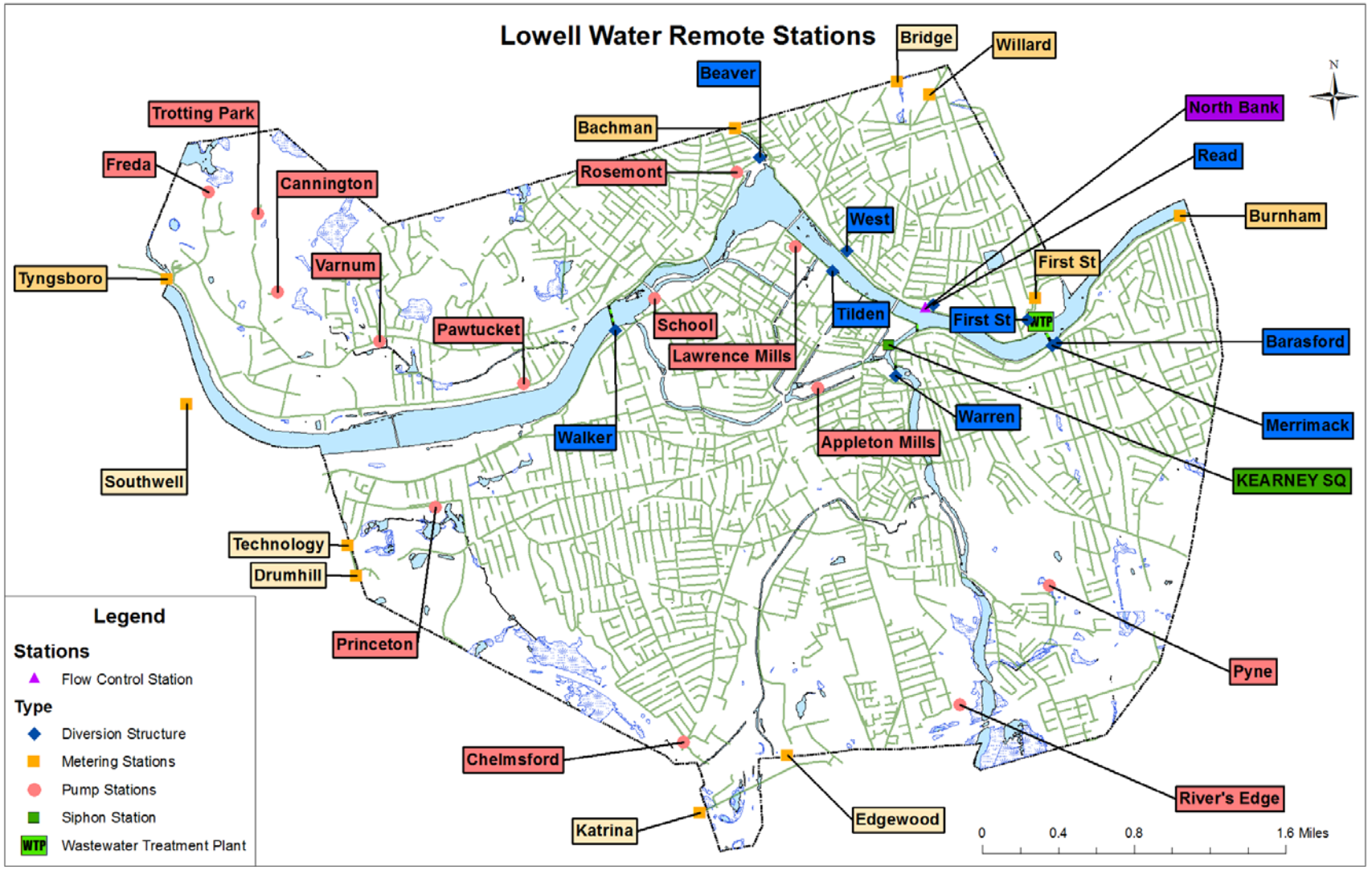
3.2.7 Remote Stations

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 2018

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.

Figure 3-2 Remote/Satellite 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 2018 operating budget for Lowell Water was $18.9M. The maintenance budget comprised 26% of the total, or $4.9M in FY2018. 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.

2018 Summary

In 2018 the maintenance division completed 1,665 work orders, including 729 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 2018

Cleaning activities for the year in 2018 included: catch-basin cleaning (326 catch basins were cleaned, removing 252.7 tons of debris), sewer line cleaning (32,537 feet of sewer were cleaned), and street sweeping, which is conducted twice annually (99 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.

Summary of Flow Monitoring Actions in 2018

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.

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 is continuing 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.

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 2018

The following table presents a log of collection system sewer repairs undertaken in 2018. In total, $928.9K were invested in the collection system in 2018, including: $232.2K on 654 feet of sewer line replacement, $161.5K on 1,735 feet of cured-in-place-pipe repairs, $153.1K on repair and replacement of 85 combined-sewer catch basins, $28.8K on repair and replacement of 5 sewer manholes. Also included in this total are $311.7K invested in repair or replacement of 940 feet of drainage lines and one drain manhole, and $41.5K in associated miscellaneous items like test pits, paving and sidewalk repairs.

Table 3-2 2018 CMOM Sewer and Drain Work Log

2018 SEWER AND DRAIN WORK

WORK DONE	DIA (in.)	LENGTH (ft.)	US MH	DS MH	STREET	REPAIR COST	MATERIAL	INSPECTION DATE	REPAIRED DATE	ENTERED IN GIS
CB REPAIRS					RHINDO PARK DR	$1,618.70			August-18	YES
CB REPAIRS					EDSON CEMETARY	$1,135.06			August-18	YES
CB REPAIRS					GROTON ST	$175.00			August-18	YES
CB REPAIRS					67 PLEASANT ST	$774.14			August-18	YES
CB REPAIRS					50 SUMMER ST	$774.14			August-18	YES
CB REPAIRS					LINDEN AND CHERRY ST	$2,270.12			August-18	YES
CB REPAIRS					46 BURTT ST	$1,135.06			August-18	YES
CB REPAIRS					BELMONT AND PINE ST	$1,012.35			August-18	YES
CB REPAIRS					LPD 50 ARCAND DR	$774.14			August-18	YES
CB REPAIRS					392 E MERRIMACK ST	$984.35			August-18	YES
CB REPAIRS					1ST ST AND READ ST	$651.42			August-18	YES
CB REPAIRS					143 DURANT ST	$1,135.06			August-18	YES
CB REPAIRS					150 UNIVERSITY AVE	$1,135.06			August-18	YES
CB REPAIRS					150 ACROPOLIS RD	$175.00			August-18	YES
CB REPAIRS					73 COBURN DR	$890.85			August-18	YES
CB REPAIRS					ROURKE BRIDGE AND PAWTUCKET	$774.14			August-18	YES
CB REPAIRS					56 FREDA LN	$774.14			August-18	YES
CB REPAIRS					5 MERRIMACK ST	$1,337.31	BRICK		July-18	YES
CB REPAIRS					DECATUR WAY	$1,337.31	BRICK		July-18	YES
CB REPAIRS					SUFFOCK AND FR MORRISETTE	$1,337.31	BRICK		July-18	YES
CB REPAIRS					APPLETON AND CENTRAL ST	$1,337.31	BRICK		July-18	YES
CB REPAIRS					731 SCHOOL ST	$1,337.31	BRICK		July-18	YES
CB REPAIRS					WOOD ST	$1,257.78			May-18	YES
CB REPAIRS					25 JOFFRE ST	$2,217.00			May-18	YES
CB REPAIRS					28 OAKLAND ST	$1,373.27			May-18	YES
CB REPAIRS					102 HIGHLAND ST	$1,618.70			May-18	YES
CB REPAIRS					WESTFORD AND HOWARD	$1,135.06			May-18	YES
CB REPAIRS					31 B ST	$1,734.20			May-18	YES
CB REPAIRS					98 BLODGETT ST	$1,559.20			May-18	YES
CB REPAIRS					25 AVE C	$1,734.20			May-18	YES
CB REPAIRS					177 FOSTER ST	$1,734.20			May-18	YES
CB REPAIRS					CHESTNUT AND FAYETTE ST	$896.85			May-18	YES
CB REPAIRS					6TH AND HOWARD	$1,135.06			May-18	YES
CB REPAIRS					SALEM ST AND ADAMS ST	$1,135.06			May-18	YES
CB REPAIRS					MARKET AND DUTTON ST	$1,373.27			May-18	YES

2018 SEWER AND DRAIN WORK

WORK DONE	DIA (in.)	LENGTH (ft.)	US MH	DS MH	STREET	REPAIR COST	MATERIAL	INSPECTION DATE	REPAIRED DATE	ENTERED IN GIS
CB REPAIRS					BUTLER MIDDLE SCHOOL	$175.00			May-18	YES
CB REPAIRS					MARKET AND WORTHEN ST	$1,373.27			May-18	YES
CB REPAIRS					BRANCH ST	$1,257.78			May-18	YES
CB REPAIRS					STEVENS AND PINE	$2,753.76			May-18	YES
CB REPAIRS					CLITHROE AND WYMAN	$1,135.06			May-18	YES
CB REPAIRS					371 DOUGLAS ST	$175.00			May-18	YES
CB REPAIRS					415 DOUGLAS RD	$2,217.84			May-18	YES
CB REPAIRS					475 DOUGLAS RD	$1,255.78			May-18	YES
CB REPAIRS					35 CEDAR ST	$1,495.99			May-18	YES
CB REPAIRS					286 TROTTING PARK RD	$774.14			May-18	YES
CB REPAIRS					PRINCETON ST	$774.14			May-18	YES
CB REPAIRS					520 PAWTUCKET	$1,865.91			May-18	YES
CB REPAIRS					SARGENT AND CLARE	$3,293.39			May-18	YES
CB REPAIRS					ARLINGTON AND PAWTUCKET	$2,031.91			May-18	YES
CB REPAIRS					VARNUM AND PAWTUCKET	$1,255.61			May-18	YES
CB REPAIRS					47 BEAVER ST	$1,373.27			May-18	YES
CB REPAIRS					268 LAKEVIEW ST	$1,373.27			May-18	YES
CB REPAIRS					MOUNTGROVE ST	$175.00			May-18	YES
CB REPAIRS					SIXTH AND UNIVERSITY	$2,991.00	CONCRETE		April-18	YES
CB REPAIRS					HALLEY RD AND CASTLE RD	$896.00	CONCRETE		April-18	YES
CB REPAIRS					2 FRENCH ST	$1,135.00	CONCRETE		April-18	YES
CB REPAIRS					94 MERRIMACK ST	$1,250.00	CONCRETE		April-18	YES
CB REPAIRS					OPP 1439 GORHAM ST	$1,856.00	CONCRETE		April-18	YES
CB REPAIRS					50 SUMMER ST	$1,192.00	CONCRETE		April-18	YES
CB REPAIRS					147 CAMBRIDGE ST	$175.00	CONCRETE		April-18	YES
CB REPAIRS					12 HUTCHINSON ST	$175.00	CONCRETE		April-18	YES
CB REPAIRS					69 WEST ALBERT	$1,250.00	CONCRETE		April-18	YES
CB REPAIRS					HILLCREST AND MIDDLESEX	$1,676.00	CONCRETE		April-18	YES
CB REPAIRS					179 WENTWORTH	$1,380.00	CONCRETE		April-18	YES
CB REPAIRS					218 DOUGLAS RD	$1,135.00	CONCRETE		April-18	YES
CB REPAIRS					STEVENS AND BOND ST	$2,160.00	CONCRETE		April-18	YES
CB REPAIRS					101 RINDO PARK	$1,856.00	CONCRETE		April-18	YES
CB REPAIRS					STEVENS AND BARTON AVE	$1,736.00	CONCRETE		April-18	YES
CB REPAIRS					115 THORTON ST	$175.00	CONCRETE		April-18	YES
CB REPAIRS					STEVENS AND MIDDLESEX	$1,736.00	CONCRETE		April-18	YES
CB REPAIRS					LONGMEADOW ISLAND	$175.00	BRICK		April-18	YES
CB REPAIRS					E MERRIMACK	$350.00	CONCRETE		March-18	YES
CIPP	12"	150.0	7659	7358	A STREET	$7,000.00	CONCRETE		January-18	YES
CIPP	18" oval	305.0	3311	3308	SOUTH ST	$34,000.00	CONCRETE		January-18	YES
CIPP	16 X 20"	210.0	2458	2457	ADAMS ST	$24,000.00	BRICK		January-18	YES
CIPP	15"	700.0	3809	4105	MERRIMAC	$60,000.00	BRICK		January-18	YES
CIPP	15"	110.0	4110	4105	JOHN ST	$9,500.00	BRICK		January-18	YES
CIPP	18"	260.0	3479	3481	MT VERNON	$27,000.00	CONCRETE		January-18	YES
DMH REPAIR					MARKET AND DUTTON ST	$1,640.09			September-18	YES
DRAIN REPAIRS	6	15			BEAVER ST	$4,525.22			November-18	YES
DRAIN REPAIRS	8	41			120 LAFAYETTE ST	SEE BELOW			November-18	YES

2018 SEWER AND DRAIN WORK

WORK DONE	DIA (in.)	LENGTH (ft.)	US MH	DS MH	STREET	REPAIR COST	MATERIAL	INSPECTION DATE	REPAIRED DATE	ENTERED IN GIS
DRAIN REPAIRS	6	16			120 LAFAYETTE ST	$13,837.70			November-18	YES
DRAIN REPAIRS	6	8			39 SPARKS ST	$2,343.00			November-18	YES
DRAIN REPAIRS	8	23			146 ALMA AND 84 LAFAYETTE	SEE BELOW			November-18	YES
DRAIN REPAIRS	6	17			146 ALMA AND 84 LAFAYETTE	$10,715.00			November-18	YES
DRAIN REPAIRS	10	54			118 TO 107 ALMA ST	SEE BELOW			October-18	YES
DRAIN REPAIRS	6	12			118 TO 107 ALMA ST	$16,002.00			October-18	YES
DRAIN REPAIRS	10	26			48 AND 80 ALMA ST	$6,858.00			October-18	YES
DRAIN REPAIRS	6	10			ALMA AND ROSEMONT ST	SEE BELOW			October-18	YES
DRAIN REPAIRS	8	21			ALMA AND ROSEMONT ST	$8,295.00			October-18	YES
DRAIN REPAIRS	10	121			LAFAYETTE ST	SEE BELOW			October-18	YES
DRAIN REPAIRS	6	43			LAFAYETTE ST	$53,398.69			October-18	YES
DRAIN REPAIRS	10	91			LAFAYETTE ST	SEE BELOW			October-18	YES
DRAIN REPAIRS	6	14			LAFAYETTE ST	$48,038.84			October-18	YES
DRAIN REPAIRS	10	65			LAFAYETTE ST	SEE BELOW			October-18	YES
DRAIN REPAIRS	6	42			LAFAYETTE ST	$49,055.73			October-18	YES
DRAIN REPAIRS	10	52			LAFAYETTE ST	$26,869.56			October-18	YES
DRAIN REPAIRS	8	10			20 6TH ST	$4,771.10			October-18	YES
DRAIN REPAIRS	8	25			FOWLER ST	$5,531.00			September-18	YES
DRAIN REPAIRS	6	12			CENTRAL AND HURD STS	$3,662.02			September-18	YES
DRAIN REPAIRS	12	7			786 VARNUM ST	$1,844.57			September-18	YES
DRAIN REPAIRS	12	7			680 VARNUM ST	$1,877.80			September-18	YES
DRAIN REPAIRS	8	18			172 VARNUM AVE	$4,249.10	PVC		August-18	YES
DRAIN REPAIRS	6	6			HUMPHEY AND UTICA	$1,958.00	PVC		April-18	YES
DRAIN REPLACEMENT	12	184			SWAN ST	$46,237.00	PVC		July-18	YES
MISC. PAVING					MISC. LOCATIONS	$37,353.60	HOT MIX			NO
NEW CB	6	4			HIGH ST NEAR 399	$5,178.61			September-18	YES
NEW CB	8	5.5			CARTER ST	$5,313.27			August-18	YES
NEW CB	8	5			547 LAKEVIEW	$4,921.12			August-18	YES
NEW CB	8	2			821 VARNUM AVE	$2,751.00	CONCRETE		August-18	YES
NEW CB	8	5			VARNUM AND MEADOW	SEE BELOW	PVC		SEE BELOW	YES
NEW CB	10	3			PAWTUCKET AND STOCKBRIDGE	$6,076.30	CONCRETE		July-18	YES
NEW CB	10	7			TAUNTON CT	$6,965.80	CONCRETE		July-18	YES
NEW CB	8	6			MOODY ST	$5,589.30	CONCRETE		July-18	YES
NEW CB	10	4			MERRIMACK AND CENTRAL	$6,615.75	CONCRETE		July-18	YES
NEW CB	6	1			DURRANT ST	$4,194.50			May-18	YES
NEW CB	6	5			TROTTING PARK ST	$5,109.00			May-18	YES
NEW CB	6	4			WILDER ST	$5,144.00	CONCRETE		April-18	YES
NEW CB	6	4			C ST AND POWELL	$5,395.00	CONCRETE		April-18	YES
NEW MANHOLE	6	3			4TH ST	$3,798.00			May-18	YES
NEW SMH	15	11			HIGH ST NEAR 399	SEE BELOW			September-18	YES
NEW SMH	8	18.5			HIGH ST NEAR 399	$20,479.75			September-18	YES
SEWER REPLACEMENT	12	12.5			VARNUM AND MEADOW	$7,431.25	PVC		August-18	YES
SEWER REPLACEMENT	6	8			12 RULE ST	SEE BELOW	PVC		July-18	YES
SEWER REPLACEMENT	15	24			WEST 6TH ST AND ENNELL ST	SEE BELOW			6/11-6/12/18	YES
SEWER REPLACEMENT	6	6			WEST 6TH ST AND ENNELL ST	$15,580.00			6/11-6/12/18	YES

2018 SEWER AND DRAIN WORK

WORK DONE	DIA (in.)	LENGTH (ft.)	US MH	DS MH	STREET	REPAIR COST	MATERIAL	INSPECTION DATE	REPAIRED DATE	ENTERED IN GIS
SEWER REPLACEMENT	10	23.5			HUMPHREY AND WILLARD STS	SEE BELOW			May-18	YES
SEWER REPLACEMENT	8	19.5			HUMPHREY AND WILLARD STS	$14,670.50			May-18	YES
SEWER REPLACEMENT	6	5.3			48 ANDERSEN ST	$4,167.58			December-18	YES
SEWER REPLACEMENT	6	19			62 PORTER TERRACE	$8,638.40			December-18	YES
SEWER REPLACEMENT	6	5			27 ALMA ST	SEE BELOW			September-18	YES
SEWER REPLACEMENT	8	12			27 ALMA ST	$4,344.40			September-18	YES
SEWER REPLACEMENT	8	4			PRINCE AND IOWA	SEE BELOW			September-18	YES
SEWER REPLACEMENT	6	35			PRINCE AND IOWA	$10,418.00			September-18	YES
SEWER REPLACEMENT	8	70			PRINCE AND IOWA	SEE BELOW			September-18	YES
SEWER REPLACEMENT	6	5			PRINCE AND IOWA	$21,169.44			September-18	YES
SEWER REPLACEMENT	8	52			PRINCE AND IOWA	SEE BELOW			September-18	YES
SEWER REPLACEMENT	6	4			PRINCE AND IOWA	$20,430.50			September-18	YES
SEWER REPLACEMENT					PRINCE AND IOWA	$2,310.00			September-18	YES
SEWER REPLACEMENT	8	13			12 RULE ST	$5,919.00	PVC		July-18	YES
SEWER REPLACEMENT	6	45			MEADOW DRIVE	$13,240.00	PVC		July-18	YES
SEWER REPLACEMENT	8	155			INA ST	SEE BELOW	PVC		SEE BELOW	YES
SEWER REPLACEMENT	6	24			INA ST	$46,708.67	PVC		7/24-7/26/18	YES
SEWER REPLACEMENT	8	15			76 CAMPAW ST	SEE BELOW	PVC		SEE BELOW	YES
SEWER REPLACEMENT	6	17.5			76 CAMPAW ST	$22,263.50	PVC		July-18	YES
SEWER REPLACEMENT	12	17			AVON ST	SEE BELOW	PVC		SEE BELOW	YES
SEWER REPLACEMENT	6	13			AVON ST	$9,411.50	PVC		June-18	YES
SEWER REPLACEMENT	8	12	6512	6507	HUMPREY AND WILLARD	$8,000.00	PVC	5/22/2018	May-18	YES
SEWER REPLACEMENT	24	15	1705	1722	200 DOUGLAS RD	$10,000.00	PVC	5/14/2018	May-18	YES
SEWER REPLACEMENT	15	10			E MERRIMACK	$3,214.00	PVC	3/28/2018	March-18	YES
SEWER REPLACEMENT	6	13			543 BRIDGE ST	$4,275.00	PVC		March-18	YES
SIDEWALK REPAIR					CENTRAL ST	$777.00			June-18	NO
SMH REPAIRS					NORTHLULLEN ST	$2,340.55			May-18	YES
SMH REPAIRS					CHERRY ST	$2,145.00	BRICK		April-18	YES
TEST PITS					124 BEDFORD ST	$3,522.50			July-18	YES
Totals		**3417.3**				**$928,905.46**			**154**	**153**