2021 LONG TERM CONTROL PLAN

CITY OF BURLINGTON
VERMONT

Prepared for the:

City of Burlington
149 Church Street
Burlington, VT 05401

Prepared by:

AECOM

250 Apollo Drive
Chelmsford, MA 01824

STATE OF VERMONT
TENNILLE C. MIGNONE
018.0118510
CIVIL
LICENSED
PROFESSIONAL ENGINEER

June 2022

2021 LONG TERM CONTROL PLAN

CITY OF BURLINGTON
VERMONT

Prepared for the:

City of Burlington
149 Church Street
Burlington, VT 05401

Prepared by:

AECOM

250 Apollo Drive
Chelmsford, MA 01824

July 2022

Table of Contents

List of Appendices

List of Tables

List of Figures

1.0 Introduction

This section presents the background and purpose of this Long-Term Control Plan (LTCP) prepared by the City of Burlington, Vermont ("Burlington" or the "City"). It also presents a section-by-section overview of the content and format of this report.

While this LTCP provides definition of certain terms, please see also the Glossary of Terms, which is provided following the Table of Contents, for definitions of various acronyms.

1.1 Background

The City of Burlington is located on the eastern shore of Lake Champlain in Chittenden County, Vermont (**Figure 1-1**. City of Burlington Location Map). With a 2018 estimated population of 42,899[1], Burlington is the largest city in the State of Vermont. The City is served by three wastewater treatment plants (WWTPs):

- Main WWTP, located on Lavalley Lane, with an annual average permitted flow of 5.3 million gallons per day (MGD)
- East WWTP, located on Riverside Avenue, with an annual average permitted flow of 1.2 MGD
- North WWTP, located on North Avenue Extension, with an annual average permitted flow of 2.0 MGD

As with other older cities and towns throughout Vermont and New England, Burlington's wastewater collection system contains what are referred to as combined sewers, a pipe network designed to convey not only sanitary and industrial wastes but also stormwater runoff during rainfall and snowmelt conditions. Combined sewer overflows (CSOs), or hydraulic relief points, are key features of combined sewers. Burlington's CSOs are designed to regulate the amount of flow that can be intercepted and conveyed to the City's three WWTPs for treatment prior to discharge to Lake Champlain and the Winooski River, a tributary of the Lake. Burlington's WWTPs and CSO discharges are subject to laws and regulations promulgated by the United States Environmental Protection Agency (EPA) and the State of Vermont Department of Environmental Conservation (DEC) pursuant to the Clean Water Act (CWA) as well as EPA and DEC rules, standards, orders, policies, and guidance documents.[2]

In addition to the City's CSO obligations, the City is also facing compliance requirements related to the Lake Champlain Phosphorus Total Maximum Daily Load (TMDL) allocation. Phosphorus concentrations in Lake Champlain typically exceed Vermont Water Quality Standards (VWQS). In 2016, the EPA developed phosphorus TMDLs for Vermont Segments of Lake Champlain[3]. As a result of the Lake Champlain phosphorus TMDLs, the City is currently faced with implementing a 25 percent reduction in phosphorus loading to the Lake from the separate stormwater system (SSS) and reductions in the phosphorus load from the combined sewer wet weather treatment system (i.e., through volume and/or concentration reductions), and attaining wastewater effluent phosphorus concentrations of 0.2 milligrams per liter (mg/L) at the three WWTPs. Specifically, the Lake Champlain phosphorus TMDLs calculate the following annual total phosphorus waste load allocations:

- Main WWTP – 1.464 metric tons

---

[1] United States Census Bureau. 2019. Annual Estimates of the Residential Population: April 1, 2010 to July 1, 2018. Released May 2019.

[2] For the purposes of this LTCP, it is understood that Burlington must comply with the federal CWA as well as applicable Vermont regulations.

[3] EPA. 2016. Phosphorus TMDLs for Vermont Segments of Lake Champlain. Region 1, June 17, 2016.

- Secondary Bypass and Vortex Separator CSO at the Main WWTP – 0.77 metric tons
- East WWTP – 0.331 metric tons
- North WWTP – 0.552 metric tons

In 2016, Burlington began the development of an Integrated Water Quality Management Plan in order to identify and prioritize the most effective strategies to meet federal and state regulatory obligations including, but not limited to, the Lake Champlain TMDL, Vermont's 2016 CSO Rule, Stormwater TMDLs, and other community water resource goals. The Integrated Plan considers, among other things, improved phosphorus removal at the three WWTP, stormwater best management practices (BMPs), continued mitigation of runoff from impervious surfaces in the combined sewer systems (CSSs), and sewer and roof drain separation projects throughout the city. The plan models several scenarios in order to identify the most cost-effective scenario that meets all the City's clean water obligations, including reaching the phosphorus reductions required by the Lake Champlain TMDL as expeditiously as possible.

This LTCP specifically addresses the regulatory requirements related to the mitigation of CSOs. The LTCP affords Burlington an opportunity to assess its progress to date and the additional steps that may be taken to further reduce the City's CSO discharges. It is presented here as a separate document for the purposes of complying with the City's 1272 Order, but its analyses are also incorporated into the larger, more holistic Integrated Plan. Given the numerous regulatory requirements that Burlington must meet, review and updates to the LTCP must be considered within that larger context.

1.2 Purpose

The final order issued by the Secretary of the Vermont Agency of Natural Resources (Secretary) on February 19, 2019, under Title 10 Vermont Statutes Annotated (VSA) Section 1272 (final 1272 Order), requires that the City of Burlington create a LTCP and submit the plan to the Secretary within 24 months of the date of the order. The purpose of this LTCP is to meet the LTCP requirements of the final 1272 Order, which are summarized as follows:

- Alternatives analysis that evaluates the costs and performance of multiple CSO control alternatives.

- Detailed list of the selected CSO control projects necessary to bring the CSOs into compliance with the VWQS and a timeline for implementing the projects.

- Documentation that Burlington Main WWTP wet weather treatment system meets the combined discharge points Main S/N 001 and Main S/N 002 permit limits, the VWQS, or the dry weather permit with 80:1 dilution for total suspended solids, total residual oxidant, *Escherichia coli* (*E. coli*), biological oxygen demand, pH, and settleable solids.

- Documentation of the historical pounds of total phosphorous discharged from the combined Main S/N 001 and Main S/N 002 outfall.

- Strategy to prevent new sources of stormwater and wastewater to the CSS increasing the volume, frequency, or duration of CSO events through implementation of control measures.

- Measures to address and prevent any documented, recurrent instances of sewage backup or discharges of raw sewage onto the ground surface.

- Financing plan to design and implement the CSO control projects identified pursuant to Subsection (11)(2) of the final 1272 Order.

- Proposed schedule to bring Burlington's CSOs into compliance with the VWQS.

Source: Vermont GIS, 2020.

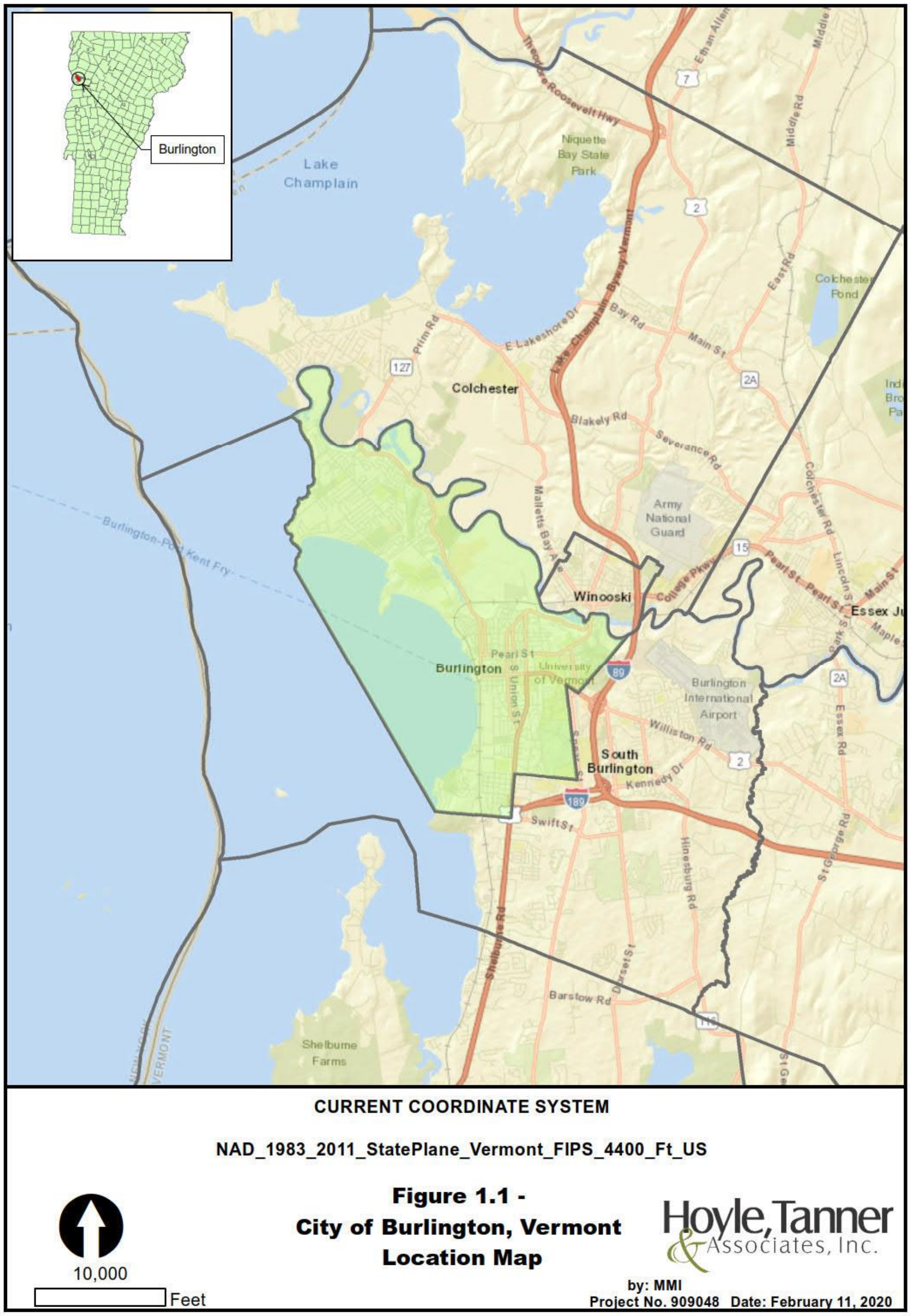

Figure 1-1. City of Burlington Location Map

1.3 Report Format

The LTCP is structured as follows:

Executive Summary.

Section 1: Background information, the purposes of the LTCP, and report format.

Section 2: Overview of the regulatory framework for CSO planning and control.

Section 3: Description of Burlington's wastewater infrastructure, including the collection and treatment systems and CSOs.

Section 4: Summary of previous CSO planning efforts.

Section 5: Description of baseline CSS conditions

Section 6: Presentation of alternatives for further CSO reductions, including the initial screening steps up through the selection of the preferred plan, and development of the targeted level of control for the LTCP.

Section 7: Description of the preferred plan.

Section 8: Description of project financing and an implementation schedule (developed in accordance with the Financial Capability and Affordability Assessment submitted under separate cover).

Section 9: Status of the water quality sampling plan to meet the final 1272 Order.

2.0 Regulatory Framework

This section of the LTCP describes the history of DEC and EPA actions and the overall regulatory framework applicable to CSO control in the City of Burlington. Current DEC and EPA CSO control policies are briefly described below. Appendix D contains a listing of these and other applicable supporting documents.

2.1 1989 Consent Order

On June 1, 1989, Burlington and the DEC entered into Consent Order (CO) #722-89CNC. The CO established timetables for Burlington to complete sewer separation projects to alleviate overflows at the two Manhattan Drive CSOs (Main S/N 003 and Main S/N 004). The first deadline was March 1, 1991. Nearly half of the combined sewer area was separated ahead of schedule. In January 2006, Burlington verified that the work completed in early 1990 was effective in reducing overflows at Main S/N 003 and Main S/N 004. During this time period, the City committed over $52M into CSO control through sewer separation, 105,000-gallon storage tank in Englesby Brook Flood Plain, new conveyance piping to the upgraded WWTP, and a wet weather treatment system at the Main WWTP. Five CSOs, plus additional CSOs along Englesby Brook were eliminated as a result of these projects

Since 2006, Burlington has installed thirteen infiltration systems to remove stormwater input to the combined system upstream of Main S/N 003 and Main S/N 004 using both American Recovery and Reinvestment Act funds and City of Burlington funding. Burlington completed projects on the following streets: Archibald Street, Bright Street, Cedar Street, Luck Street, Manhattan Drive, North Willard Street, North Winooski Avenue, Riverside Avenue, St. Mary's Street, Elmwood Avenue and Walnut Street. Work completed between 1994 and 2020 is discussed in Section 4.2.

2.2 DEC Permit

The City of Burlington owns and operates the following three WWTPs under the indicated DEC-issued National Pollutant Discharge Elimination System (NPDES) permits and discharging to the indicated waterbodies:

- Burlington Main WWTP under Direct Discharge Permit No. 3-1331, issued by DEC on April 28, 2005 and effective on July 1, 2005, which authorizes the discharge of treated and disinfected wastewater into Lake Champlain through discharge point Main S/N 001.NPDES Permit No. 3-1331 also lists S/N 002 as the discharge point from the combined sewer overflow treatment process with the Burlington Main WWTP, referred to as the Wet Weather Treatment System. Discharge Permit No. 3-1331 requires that Burlington' s Wet Weather Treatment System meet Vermont Water Quality Standards (VWQS) or permit limits with the allowable 80:1 dilution for Total Suspended Solids, Total Residual Oxidant, and E. coli.

- Burlington East WWTP under Direct Discharge Permit No. 3-1247 issued by DEC on June 21, 2004 and effective on October 1, 2004, which authorizes the discharge of treated and disinfected wastewater into the Winooski River through discharge point East S/N 001.

- Burlington North WWTP under Direct Discharge Permit No. 3-1245, issued by DEC on July 29, 2004 and effective on October 1, 2004, which authorizes the discharge of treated and disinfected wastewater into the Winooski River through discharge point North S/N 001.

Each WWTP collects and treats both sewage and stormwater. The DEC permits not only regulate the operation and performance of the City's secondary WWTPs, but also the three permitted CSO discharges to the Winooski River and Lake Champlain. These three permitted CSO outfalls, as well as two additional CSO outfalls that are not listed under a discharge permit, are listed in **Table 2-1.** Burlington's Permitted and Non-Permitted CSO Outfalls and their locations are shown in **Figure 2-1**.

All five existing CSOs in the collection systems of Burlington's three WWTPs are equipped with Mission Communications manhole monitoring systems, which record the start and stop times of CSO events and send alarms to Department of Public Works personnel at the start of each event.

Table 2-1. Burlington's Permitted and Non-Permitted CSO Outfalls

CSO Outfall	Location	Receiving Water / Classification
Permitted CSO Outfalls		
Burlington Main WWTP		
Main S/N 003	Manhattan Drive/Park Street	Winooski River / Class B(2) via Class 2 Intervale Wetlands
Main S/N 004	Manhattan Drive/North Champlain Street	Winooski River / Class B(2) via Class 2 Intervale Wetlands
Burlington North WWTP		
North S/N 002	Gazo Avenue	Winooski River / Class B(2)
Non-Permitted CSO Outfalls[1]		
Burlington Main WWTP		
Main S/N 005	Pine Street	Lake Champlain / via Pine Street Barge Canal/ Class B(2)
Burlington East WWTP		
East S/N 002	Colchester Avenue	Winooski River / Class B(2)

Note 1: These CSOs were discovered after the issuance of the WWTP permits, as part of mapping updates and Illicit Discharge Detection and Elimination efforts under the City's MS4 permit. Colchester Ave CSO was located in 2010 and Pine Street Barge Canal CSO in 2015. They were not able to be closed without causing up-stream surcharge of manholes.

2.2.1 Main WWTP Discharge Permit No. 3-1331

Discharge Permit No. 3-1331 lists combined sewer overflow treatment processes Main S/N 002—i.e., the wet weather treatment system—within the Burlington Main WWTP. In the early 1990s, Burlington and Hoyle, Tanner & Associates, Inc. proposed, and the DEC approved, the expansion of the hydraulic capacity of the Main WWTP to treat a portion of peak storm flows (peak flow up to 13 MGD) and the building of the wet weather primary treatment and disinfection system based on the 1987 EPA CSO policy in order to treat flows above the 13 MGD plant capacity. These improvements were constructed in 1994. Flows from most of the City's remaining CSOs were directed into an 8-foot by 10-foot box culvert that is now treated by the wet weather treatment system. It is estimated that an annual average, based on the period between 1994 and present, of 170 million gallons that used to be discharged as untreated CSOs are now being treated.

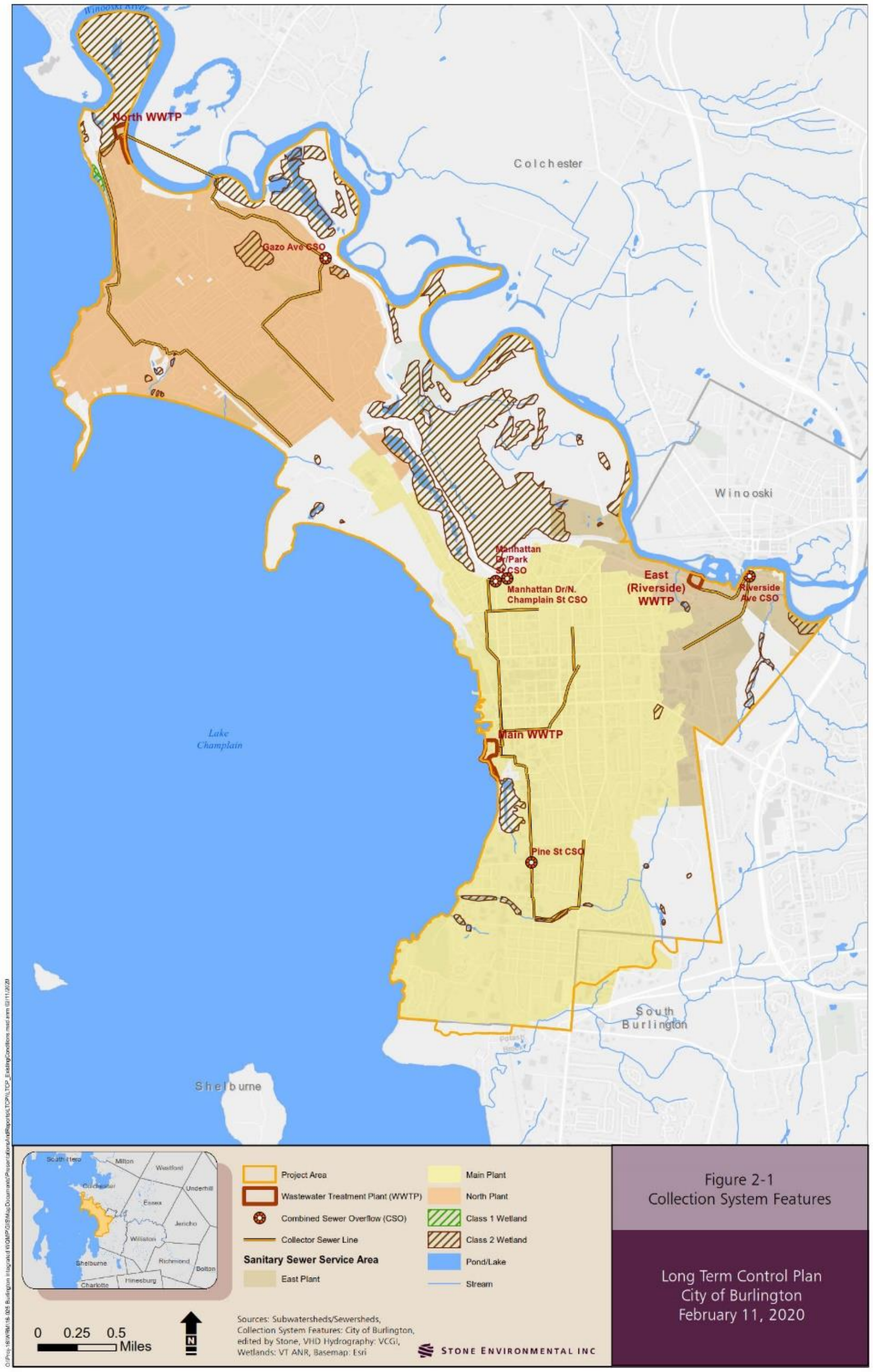

Figure 2- 1. Cit

Numerous additional combined sewer flow reduction projects have been completed since that time, both above CSOs as well as below. See Section 4.2 for a complete discussion of all stormwater mitigation efforts completed to

[4] Note: This figure depicts the service area as of 2018 used in the baseline model, which included the Hadley Road service area in South Burlington. Baseline model modification 1 included removing this service area from the model once it was disconnected in the real world.

date. While there has been a focus on projects above CSO points, these and projects below the CSO work to reduce stormwater flow that reaches the WWTP. Every gallon of stormwater that is removed (through infiltration) or detained results in additional combined sewer flow to be conveyed to the WWTP and fully treated rather than activating the wet weather treatment system.

Discharge Permit No. 3-1331 requires that Burlington's wet weather treatment system meet VWQS or permit limits with the allowable 80:1 dilution for total suspended solids (TSS), total residual oxidant, and *E. coli*. While permit limits were not set for the wet weather system, monitoring was also required for biochemical oxygen demand, pH, and settleable solids.   See Section 3.2.1.3 for a discussion of the wet weather system's performance.

The 2016 Phosphorus TMDLs for Vermont Segments of Lake Champlain calculate an annual total phosphorus waste load allocation of 0.77 metric tons (4.65 lbs/day) for the wet weather treatment system.

Discharge Permit No. 3-1331 lists S/N 003 and 004 (Manhattan outfalls at Park and North Champlain). S/N 005 (Pine Barge Canal) was identified as part of mapping updates in 2015. Staff did not know it was active and closed it off. Storm events shortly thereafter caused upstream manholes to surcharge. After notifying DEC, the closure was removed, and monitoring added to track CSO events at this location.

2.2.2 East WWTP Discharge Permit No. 3-1247

Discharge Permit No. 3-1247 does *not* list CSO East S/N 002 within the East WWTP collection system. The Colchester Avenue CSO was discovered during outfall inspections and updating mapping completed in the early 2010. The collection system for the WWTP consists primarily of separate sewers.

2.2.3 North WWTP Discharge Permit No. 3-1245

Discharge Permit No. 3-1245 lists CSO North S/N 002 within the North WWTP collection system. Over the past several years, Burlington has redirected roof drains at two public schools from the CSS to a separate storm sewer. This has reduced the frequency of CSS overflow events at the CSO outfall.

2.3 CSO Control Policies and VTDEC CSO Rule (2016)

Both DEC and EPA have promulgated CSO control policies and guidance documents that first began appearing in the late 1980s. The most significant and far reaching of these documents is the EPA CSO Control Policy which was published in the Federal Register in 1994. Section 402(q)(1) of the CWA codified the CSO Control Policy in 2001. Both DEC and EPA have established minimum treatment requirements for CSO discharges and have set goals for their ultimate elimination. The requirements for LTCP development are outlined in the EPA CSO Control Policy and in the VTDEC CSO Rule. LTCP requirements have also been the subject of a series of EPA and DEC guidance documents.

The EPA CSO Control Policy established the minimum technology-based requirements for the control of CSO discharges, known as the Nine Minimum Controls (NMC). NMC are considered low-cost source-control measures to address CSO reduction through BMPs. These BMPs include such measures as street and catch basin cleaning, litter control, and proper operation and maintenance (O&M) of the collection system. A key control for CSO communities is to maximize use of the wet weather capacities in their existing conveyance and treatment systems.

The VTDEC CSO Rule (2016) requires signage of the CSOs, reporting of CSOs within 12 hours of an overflow to the Agency, CSO abatement to meet VWQS, and a Long-Term Control Plan (LTCP) that addresses the requirements within the Rule, as well as the 1272 Order unique to each community.

3.0 Wastewater Infrastructure

Burlington's wastewater infrastructure includes a network of collector and interceptor sewers, pump stations, siphons, and three secondary treatment WWTPs. The collection system includes two components: a Combined Sewer System (CSS) and a Sanitary Sewer System (SSS). The key features of the wastewater collection and treatment system were shown on **Figure 2-1**. City of Burlington Collection System Features and are described below.

3.1 Collection System and Pump Stations

The Burlington SSS services an area of approximately 10.8 square miles, with an estimated 98 percent of the City being serviced by the system. In addition, some, but not all, of the stormwater within the Main WWTP watershed is collected and treated at the Main WWTP, which includes a Secondary Bypass and Vortex Separator for wet weather flows prior to discharge into Lake Champlain. In total, there are approximately 145 miles of gravity pipe systems in the City, including the following:

- 44 miles of sanitary sewer
- 54 miles of storm sewer
- 47 miles of combined storm and sanitary sewers
-
- 2 river siphon crossings

There are 5 miles of sewage force main and 25 public pump stations within Burlington's sanitary sewer collection system, as listed in **Table 3-** 1. Wastewater Pump Stations. Of the 25 pump stations, 15 are in the Main WWTP drainage area, 4 are in the East WWTP drainage area, and 6 are in the North WWTP drainage area.

Table 3- 1. Wastewater Pump Stations

Station Name	Pumping Capacity (gpd)	Average Daily Flow (gpd)
Appletree Point	91,187	57,828
Birch Court	52,128	4,849
Brook Drive	14,544	1,526
Chase Street	27,072	1,109
College Street	92,571	53,782
Crescent Beach	43,499	35,120
Fletcher Place	29,117	8,738
Flynn Avenue	54,171	27,176
Burlington High School	36,923	10,820
Lake Street	29,520	3,667
Lakeside Avenue	15,840	824
Landfill	86,400	43,067
Leddy Beach	32,571	7,009
Lori Lane	32,400	5,526
North Beach Lower	43,200	1,891
North Beach Upper	43,200	9,028
McNeil	57,888	8,210
Mill Street	50,688	7,442
Perkins Pier	23,616	1,538
Pine Street	30,960	6,811
Proctor Place	74,111	52,224
Queen City	85,050	65,480
South Cove	38,647	20,233
Van Patten	43,251	11,106
Water Plant	23,616	5,130

3.2 WWTPs

As stated previously, Burlington owns and operates three wastewater plants (WWTP); Main WWTP located on Lavalley Lane, East WWTP located on Riverside Avenue (sometimes referred to as the Riverside Plant), and North WWTP located on North Avenue. A process overview for each WWTP is presented in the text that follows.

3.2.1 Main WWTP

3.2.1.1 Process Overview

The original Main WWTP was built in 1951 as a primary treatment plant and was upgraded in 1974 to a 4.0-MGD secondary treatment facility. Larger flows bypassed the plant and discharged directly into Lake Champlain or were discharged through CSOs in other areas of the collection system. In 1994, the treatment plant received a major upgrade to provide first flush facilities to manage storm flows up to 88 MGD, and the dry weather flow treatment process was upgraded to an average daily flow 5.3MGD and a peak flow of 13 MGD. For additional information on the vortex, see Sections 3.2.1.1.1 and 3.2.1.4 below.

Modifications have been made over the years to the existing secondary treatment process. Currently, the Main WWTP is operating as a contact stabilization process, with return activated sludge entering Cell #4 of the aeration tanks prior to blending with primary clarifier effluent in Cell #1, which is a biological nutrient removal cell that is not aerated but mixed to keep solids in suspension. Flow then travels to aerated tanks Cells #2, #3, #6, and #5 before exiting to the secondary clarifiers.

Both ferric chloride and alum are added at the aeration tank effluent prior to the secondary clarifiers for phosphorus control and sludge conditioning.

A 40-foot-diameter vortex separator was included in the 1994 upgrade to treat CSO flows from the Main WWTP drainage area. While three upstream outfalls still exist, the vortex treats the majority of the CSO flow in the Main WWTP drainage area. Designed and constructed ahead of the EPA CSO Control Policy issued in 1994, the goal of the vortex was to provide the equivalent of primary treatment followed by disinfection.

The wet weather treatment system, CSO treatment process Main S/N 002, consists of mechanical screening, vortex separation for solids removal, and disinfection using a chlorine activated bromine disinfection process. The system is designed to treat 75 MGD of combined sewage (stormwater and wastewater).

A total of 70% of the collection system for the Burlington Main WWTP consists of combined sewers. There are two combined wastewater inflows to the Main WWTP, the 30-inch diameter line conveying normal combined wastewater flows to the full treatment process, and the 8-ft x 10-ft box culvert conveying wet weather flows. There is an array of manholes in the Main WWTP collection system that contain weirs or other flow diversion structures. Collectively these structures control the proportion of combined wastewater entering the plant via the 30-inch sewer main and the proportion (excess flow typically overtopping the weirs) that is diverted to wet weather combined sewers and reaching the plant via the large capacity box culvert. Some of the more significant structures in the lower portions of the collection system near the plant are: M1.03 on the 72-inch diameter Maple Street combined sewer; M2.01 on the 30-inch by 42-inch diameter brick Battery Street combined sewer; M2.04, a junction manhole at the intersection of Battery and College Streets; and M3.03 and M303.01 behind Curtis Lumber near the southern end of South Champlain Street.

3.2.1.1.1 Secondary Bypass/Vortex

A 40-ft. diameter Vortex Separator was included in the 1994 upgrade as a means to provide equivalent primary treatment to combined sewer flows from the Main WWTP drainage area. While three upstream outfalls still exist (refer to **Table 2-1** above), the wet weather capacity of the plant plus the Vortex treats the majority of the combined sewer flow in the Main WWTP drainage area.

Designed and constructed ahead of the U.S. EPA CSO Control Policy issued in 1994, the goal of the Vortex is to provide the equivalent of primary treatment followed by disinfection. It should be noted that one of the provisions of the CSO Control Policy is that flow entering a WWTP site in excess of the capacity of the secondary treatment facilities needs to be treated to an equivalent of primary treatment, plus disinfection if so required. Two other aspects of the CSO Control Policy need to be noted: (1) it was formally incorporated into the Federal Register in 1994 as an EPA regulation, and (2) the new Vermont DEC CSO Rule, issued in 2016, was based on the EPA policy. It should be noted, as discussed in Section 2-3, that the VT DEC CSO Rule is more stringent than the EPA policy.

The Main WWTP process flow diagram, included as **Figure 3-1**, shows the Vortex and its relationship to the other processes. The operation of the Vortex is as follows:

- Combined sewer flow enters the WWTP in an 8 ft. by 10 ft. conduit, separately from the 36-inch diameter dry-weather influent sewer.
- Following screening, flow is pumped into the Vortex.
- The Vortex is designed to treat up to 75 MGD.
- The Vortex underflow (foul sewer) is pumped and combined with the influent line; the 2 MGD of underflow and 11 MGD of peak wet-weather secondary influent make up the 13 MGD of peak secondary treatment flow.
- In order to maximize contact time, bromine currently is added upstream of the vortex. The system has an ability to also add disinfection chemicals immediately after the Vortex or in the wet weather disinfection chamber.
- Flow in excess of 88 MGD (75 MGD treated through the Vortex plus 13 MGD treated through the main plant) can be bypassed around the Vortex directly into the Disinfection Chamber. When this happens, the bromine dosage being delivered above the Vortex is increased correspondingly.
- Flows can also be bypassed around all wet weather treatment processes (screens, Vortex, and disinfection) during extreme flows, and elevated Lake levels.
- The surface overflow rate (SOR) for the Vortex at 75 MGD is 60,000 gal/day/sf.
- The disinfected Vortex effluent and the disinfected secondary effluent are combined and discharged to the Lake in a common 2,620-foot long, 120" diameter outfall with 118 8" diffusers in the last 990 feet providing significant additional disinfection contact time before discharge to the Lake.
- The outfall discharges into a 200-ft radius mixing zone (Waste Management Zone) where the quality of the diluted effluent at the outer boundary of the zone is required to meet ambient water quality standards. An 80:1 dilution ratio was calculated using dye testing and a CORMIX model.

A schematic of the wet weather side of the Main WWTP is shown as **Figure 3-1**. City of Burlington Main WWTP Schematic. The key conditions of the NPDES permit for the WWTP outfall (Main S/N 001), and secondary treatment process and CSO treatment process (combined Main S/N 001 and Main S/N 002) are summarized in **Table 3-2** and **Table 3-3**, respectively. Discharge from the CSO treatment process is permitted only at times when the combined sanitary and storm influent flow exceeds a rate of 13 MGD as a result of storm induced runoff or snowmelt.

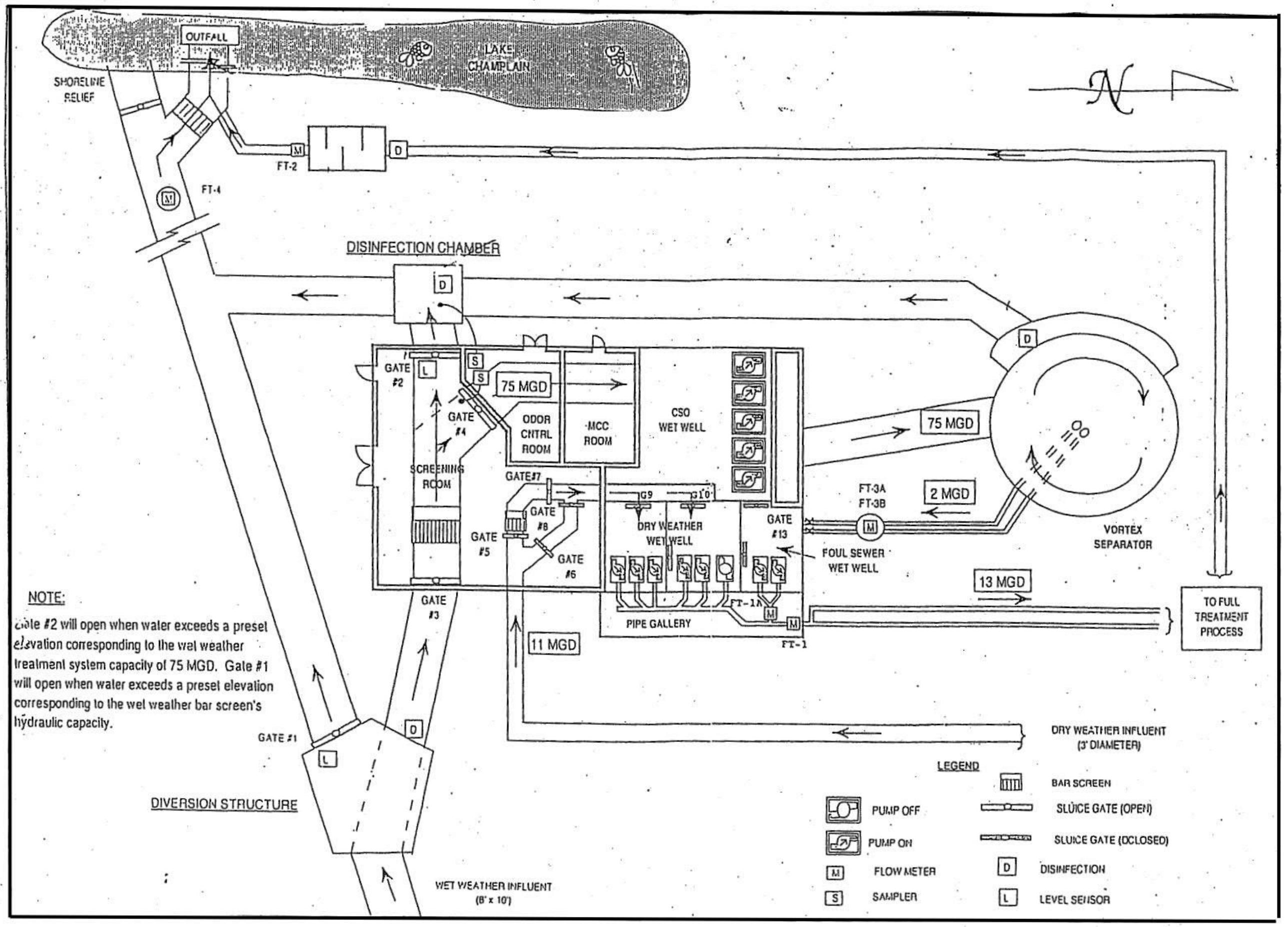

Figure 3-1. City of Burlington Main WWTP Schematic

3.2.1.2 High Flow Management Procedures

The Main WWTP has a design and permitted average daily flow of 5.3 MGD and an average annual daily flow of 3.5MGD. Under wet weather conditions, the plant is designed to provide a secondary level of treatment with phosphorus removal for a flow rate up to 13 MGD of combined dry and wet weather wastewaters during storm events, including 11 MGD influent and 2 MGD of concentrated underflow from the CSO treatment system.

Wet weather instantaneous flows greater than 11 MGD, up to 86 MGD, receive treatment and disinfection by the CSO treatment facility. The vortex separation process, combined with the hydraulic capacity of the secondary treatment plant, is designed to provide a relatively high level of treatment for “first flush” flows generated during the early, rising flow stages of storm events.

Approximately 2 MGD of highly concentrated underflow from the vortex separator is diverted to the secondary treatment process. A storm event’s instantaneous flow above the 75 MGD CSO system treatment capacity, which bypasses the vortex separator, is treated with screening, and is mixed with the disinfected discharge from the vortex separator.

Table 3-2. Key Parameters and Limits from Main WWTP NPDES Permit, S/N 001

Parameter	Loading				Concentration			
	Annual Limit	Monthly Avg	Weekly Avg	Daily Max	Monthly Avg	Weekly Avg	Daily Max	Instant. Max
BOD_5/TSS [a]	—	1,000 lbs/day	1,500 lbs/day	—	30 mg/L	45 mg/L	50 mg/L	—
Total Phosphorus [b]	9,682 lbs/year	—	—	—	0.8 mg/L	—	—	—
Total Ammonia - Nitrogen	—	—	—	—	Monitor only			
Settleable Solids	—	—	—	—	—	—	—	1.0 ml/L
Total Residual Chlorine	—	—	—	—	—	0.44 mg/L	—	0.76 mg/L
E. coli	—	—	—	—	—	—	—	77/100 ml
Whole Effluent Toxicity, NOEL-A [c]	—	—	—	>15%	—	—	—	—
pH	—	—	—	—	Between 6.0 and 8.5 Standard Units			—

(a) The quantity of BOD and TSS discharged shall be limited such that the effluent does not exceed either the BOD and TSS concentration or mass (lbs) limits specified.

(b) Total Annual Pounds of Phosphorus discharged shall be defined as the sum of all the Total Monthly Pounds of Phosphorus discharged for the calendar year. Total Monthly Pounds of Phosphorus discharged shall be calculated as follows: (Monthly Average Phosphorus Concentration) x (Total Monthly Flow) x 8.34.

(c) NOEL-A is the concentration of effluent in a sample that causes No Observed (acute) Effect (i.e., mortality not to exceed 10% of the test organisms) to the test population at the 48-hour exposure interval of observation.

Table 3-3. Key Parameters and Limits from Main WWTP NPDES Permit, Combined S/N 001 and S/N 002

Parameter	Loading				Concentration			
	Annual Limit	Monthly Avg	Weekly Avg	Daily Max	Monthly Avg	Weekly Avg	Daily Max	Instant. Max
TSS	—	—	—	—	—	—	—	800 mg/L
Total Residual Chlorine (a, b)	—	—	—	—	—	—	—	0.83 mg/L
Total Residual Chlorine (a, c)	—	—	—	—	—	—	—	0.97 mg/L
E. coli	—	—	—	—	—	—	—	6,160/100 ml

(a) When Total Residual Oxidant measured as chlorine may include chlorine plus bromine, or bromine.

(b) The discharge limitation applies during the period from January 1 through March 31 annually.

(c) The discharge limitation applies during the period from April 1 through December 31 annually.

3.2.1.3 Vortex Performance

Wet weather flows in excess of plant secondary capacity receive primary treatment through the Vortex and disinfection through the outfall. In conformance with Section II.3. of the 1272 Order, the City monitors and records treated wet weather events at the Vortex at the Main WWTP on their daily monitoring reports (DMRs). Recorded information includes amount of precipitation, total by-pass flow associated with the wet weather bypass, total residual of disinfectant, E. coli concentration, total phosphorus (TP), as well as other water quality parameters.

The following section presents documentation of historical pounds of total phosphorous discharged from Combined S/N 001 and S/N 002 outfall, as well as documentation showing that the Burlington Main Wet Weather Treatment System meets the following:

- Combined S/N 001 and S/N 002 wet weather permit limits for: Total Suspended Solids, Total Residual Oxidant, E. coli.
- Dry weather permit with the 80: 1 dilution for: Total Suspended Solids, Biological Oxygen Demand, pH, and Settleable Solids; and the dry weather permit limits for E. coli.

A summary of wet weather bypass flows and monitored parameters in the discharge from the combined S/N 001 and S/N 002 outfall from Vortex at the Main WWTP from the facility's Monthly Operating Reports for the years 2015 through 2019 is presented in Appendix B.

Phosphorus

An annual summary of wet weather bypass events and the associated total phosphorus discharged to Lake Champlain is presented **Table 3-4**.

Table 3-4. Vortex Discharge Events

Year	Total Annual Treated CSO Q (Mgal)	Total Annual Rainfall (in)	Total Annual Phosphorus (lbs)	Pounds of Phosphorus per treated CSO Q (lbs/Mgal)
2012	128.37	21.49	1,361	10.60
2013	270.83	31.59	**2,701**	9.97
2014	163.36	22.95	1,649	10.09
2015	176.98	28.4	1,456	8.23
2016	97.76	15.52	1,292	13.22
2017	166.81	25.10	1,467	8.79
2018	150.04	23.53	2,015	13.43
2019	221.48	29.93	2,074	9.45
Average				10.47

From this summary, approximately 2,700 lbs of phosphorus were released to the lake during wet weather bypass events at the Main WWTP in 2013, a particularly wet year. This amount is more than double the amount of total phosphorus released to the lake during wet weather bypass events at the Main WWTP in 2016, a relatively dry year, which highlights the seasonal and precipitation-based variations observed at the Main WWTP.

The existing NPDES permit for the Main WWTP does not currently have an annual phosphorus limit for discharges from the Vortex, however the published phosphorus waste load allocation (WLA) for the Vortex unit based on The Vermont Lake Champlain Phosphorous TMDL Phase 1 Implementation Plan is 0.77 metric tons per year, or 1,694 pounds per year. Based on this anticipated permit limit, discharges from the Vortex unit would have exceeded this anticipated phosphorus limit in 2013, 2018, and 2019. A graphical representation of the total annual pounds of phosphorus discharged versus the total annual rainfall is presented in **Figure 3-2.**

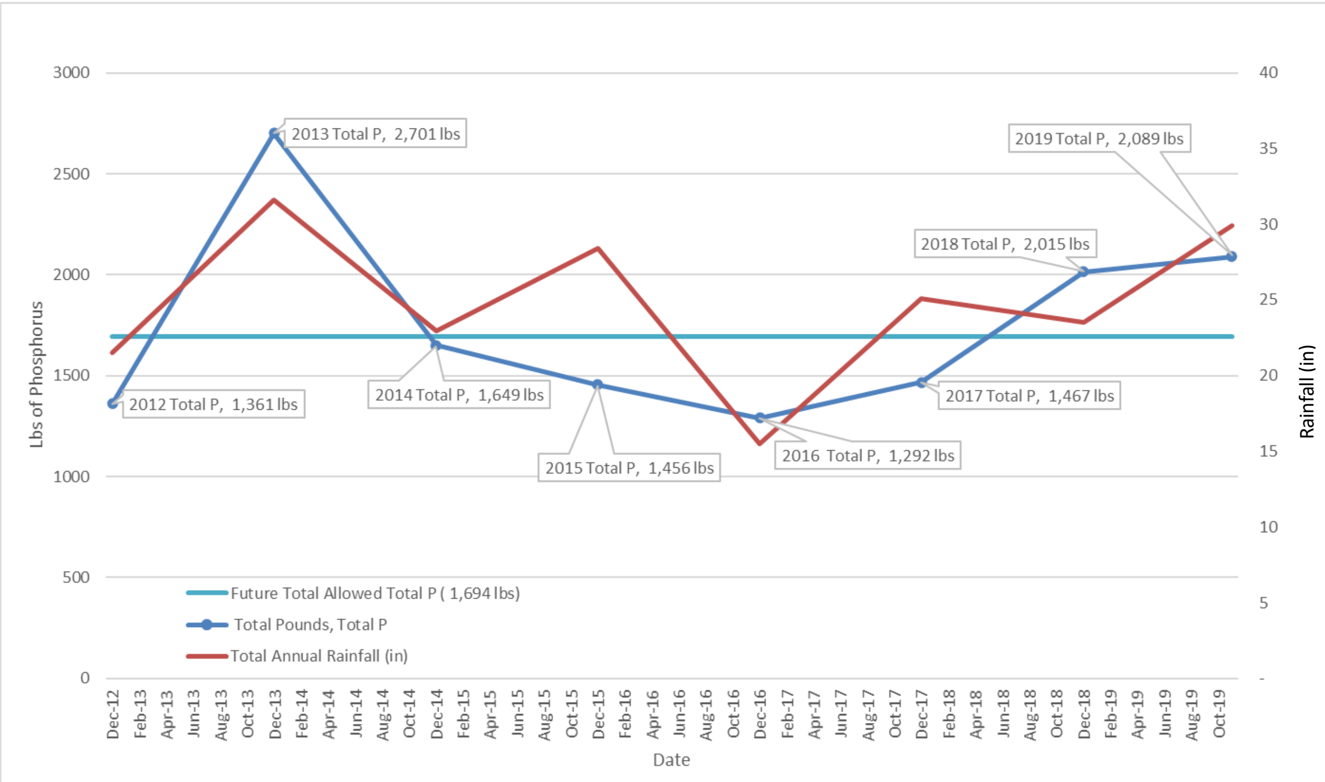

Figure 3-2. Vortex Total Annual Phosphorus Discharge vs. Annual Rainfall

Other Monitored Parameters and Conformance to Limitations

A summary of monitored parameters and conformance to NPDES Permit limitations for the discharge from the combined S/N 001 and S/N 002 outfall from Secondary Bypass/Vortex at the Main WWTP is presented in Appendix B. Historic compliance monitoring data from 2015 through 2019 shows that the discharge from the Burlington Main Wet Weather Treatment System meets the Combined S/N 001 and SIN 002 wet weather permit limits and the dry weather permit limits with the 80: 1 dilution with the following few exceptions:

E. Coli Performance

As per the 2005 Main WWTP NPDES Permit, the instantaneous maximum E. coli count for the combined effluent (outfalls S/N 001 and S/N 002) is **6,160/100 ml**, whereas the limit for the secondary effluent (S/N 001) is 77/ml. Using an 80:1 dilution factor on the secondary effluent (S/N 001) as per the 1272 Order, the corresponding limitation is also 6,160/100 ml. Historic compliance monitoring data shows that the combined discharge has exceeded this limitation twice in the last five years on the following dates:

Date	Concentration
April 16, 2018	28,000/100 ml
June 1, 2018	13,714/100 ml

Discussions with the Main Plant Chief Operator indicate that the April 16, 2018 exceedance was due to a valve failure in the disinfection chemical feed system, which was corrected.

The June 1, 2018 exceedance was due to an issue on the dry weather treatment train, and as the CSO sample is taken at a point where the discharges from the dry weather train and wet weather train combine, the CSO grab sample was influenced by the dry weather process upset.

Total Residual Oxidant

As per the 2005 Main WWTP NPDES Permit, the instantaneous maximum concentration for total residual oxidant in the combined effluent (outfalls S/N 001 and S/N 002) is **0.83 mg/l** from January 1st through March 31st, and **0.97 mg/l** from April 1st through December 31st. Historic compliance monitoring data shows that the combined discharge has exceeded this limitation once in the last five years on the following date:

Date	Concentration
June 5, 2019	1.05 mg/l

Total Suspended Solids

As per the 2005 Main WWTP NPDES Permit, the instantaneous maximum concentration for total suspended solids for the combined effluent (outfalls S/N 001 and S/N 002) is **800 mg/l**, whereas the average monthly limitation for the secondary effluent (S/N 001) is 30 mg/l. Using an 80:1 dilution factor on the secondary effluent (S/N 001) as per the 1272 Order, the corresponding limitation is 2,400 mg/l. Historic compliance monitoring data shows that the combined discharge has exceeded this limitation once in the last five years on the following date:

Date	Concentration
April 15, 2019	915 mg/l

Settable Solids

As per the 2005 Main WWTP NPDES Permit, there is no limitation for settable solids for the combined discharge point (outfalls S/N 001 and S/N 002). The instantaneous maximum concentration for settable solids for the secondary effluent (S/N 001) is 1 ml/l. Using an 80:1 dilution factor on the secondary effluent (S/N 001) as per the 1272 Order, the corresponding limitation is **80 ml/l**. Historic compliance monitoring data shows that the combined discharge has exceeded the dry weather permit with the 80: 1 dilution for settleable solids once in the last five years on the following date:

Date	Concentration
January 11, 2018	81 ml/l

3.2.2 East WWTP

3.2.2.1 Process Overview

The East WWTP was originally built in the 1950s as a primary treatment plant and was upgraded in 1974 to a 1.0-MGD secondary treatment facility. The facility was expanded in 1994 to 1.2 MGD of flow capacity and the secondary treatment process was upgraded to achieve phosphorus removal and seasonal nitrification.

Currently, the East WWTP is operating a plug flow activated sludge process. The plant utilizes sodium aluminate at the aeration tank effluent prior to the secondary clarifiers for phosphorus control and to facilitate settling.

A schematic of the East WWTP is shown as **Figure 3-3.**

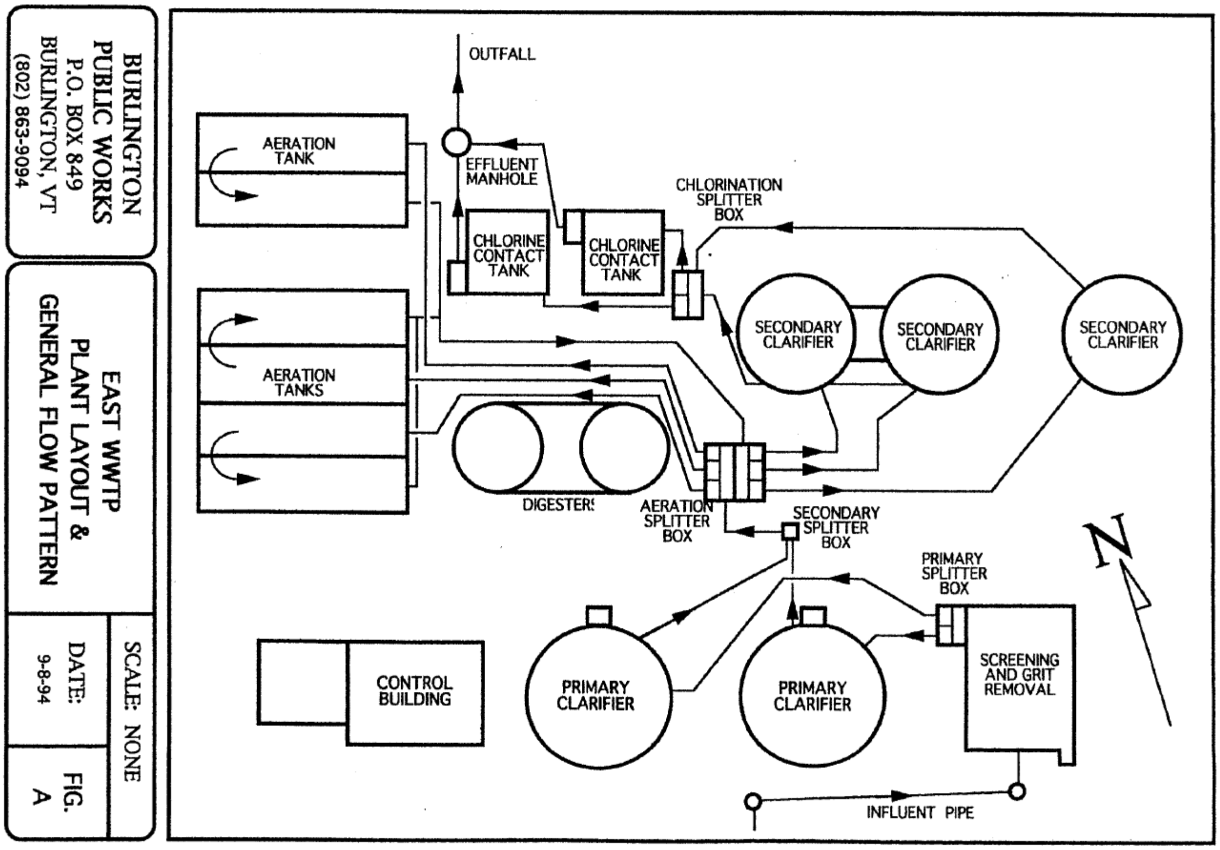

Figure 3-3. City of Burlington East WWTP Schematic

The key permit conditions of the NPDES permit for the WWTP are summarized in **Table 3-5.** The East WWTP has a chlorine disinfection system.

Table 3-5. Key Parameters and Limits from East WWTP NPDES Permit

Parameter	Loading				Concentration			
	Annual Limit	Monthly Avg	Weekly Avg	Daily Max	Monthly Avg	Weekly Avg	Daily Max	Instant. Max
BOD_5/TSS [(a)]	—	250 lbs/day	375 lbs/day	—	30 mg/L	45 mg/L	50 mg/L	—
Total Phosphorus	2,191 lbs/year [(b)]	—	—	—	0.8 mg/L	—	—	—
Ultimate Oxygen Demand (UOD) [(c)]	—	—	—	700 lbs/day	—	—	—	—
Total Kjeldahl Nitrogen (TKN) [(c)]	—	—	—	—	Monitor only			
Total Copper	—	—	—	—	Monitor only			
Total Zinc	—	—	—	—	Monitor only			
Settleable Solids	—	—	—	—	—	—	—	1.0 ml/L
Total Residual Chlorine	—	—	—	—	—	—	—	1.1 mg/L
E. coli	—	—	—	—	—	—	—	77/100 ml
pH	—	—	—	—	Between 6.0 and 8.5 Standard Units			—

(a) The permittee shall operate the facility to meet concentration limitation or the pounds limitation, whichever is more restrictive.

(b) **Total Annual Pounds of Phosphorus** discharged shall be defined as the sum of all the **Total Monthly Pounds of Phosphorus** discharged for the calendar year.

(c) Ultimate Oxygen Demand (UOD is defined by the following equation: UOD lbs/day = 8.34 x [(BOD mg/l x 1.43) + (TKN mg/l x 4.57)]. The quantity of BOD and TKN discharged shall be limited to not exceed the UOD daily maximum limit or the BOD concentration and mass (lbs) as specified above, whichever is more limiting. **The UOD limitation applies from June 1 through October 31 annually**.

3.2.3 North WWTP

3.2.3.1 Process Overview

The North WWTP was originally built in the 1950s as a primary treatment plant and was upgraded in 1974 to a 2.0-MGD secondary treatment facility. The treatment facility was modified in 1994 to upgrade the secondary treatment process to achieve phosphorus removal and seasonal nitrification.

Currently the North WWTP is operating as a contact stabilization process similar to the Main WWTP process with a Biological Nutrient Removal cell. The plant utilizes sodium aluminate at the aeration tank effluent prior to the secondary clarifiers for phosphorus control and to improve settling.

A schematic of the North WWTP is shown as **Figure 3-4**. The key permit conditions of the NPDES permit for the WWTP are summarized in **Table 3-6**. The North WWTP has a chlorine disinfection system.

Table 3-6. Key Parameters and Limits from North WWTP NPDES Permit

Parameter	Loading				Concentration			
	Annual Limit	Monthly Avg	Weekly Avg	Daily Max	Monthly Avg	Weekly Avg	Daily Max	Instant. Max
BOD_5/TSS	—	500 lbs/day	751 lbs/day	—	30 mg/L	45 mg/L	50 mg/L	—
Total Phosphorus	3,653 lbs/year [(a)]	—	—	—	0.8 mg/L	—	—	—
Ultimate Oxygen Demand (UOD) [(b)]	—	—	—	1,400 lbs/day	—	—	—	—
Total Kjeldahl Nitrogen (TKN) [(b)]	—	—	—	—	Monitor only			
Total Copper	—	—	—	—	Monitor only			
Total Zinc	—	—	—	—	Monitor only			
Settleable Solids	—	—	—	—	—	—	—	1.0 ml/L
Total Residual Chlorine	—	—	—	—	—	—	—	1.4 mg/L
E. coli	—	—	—	—	—	—	—	77/100 ml
pH	—	—	—	—	Between 6.0 and 8.5 Standard Units			—

(a) **Total Annual Pounds of Phosphorus** discharged shall be defined as the sum of all the **Total Monthly Pounds of Phosphorus** discharged for the calendar year.

(b) Ultimate Oxygen Demand (UOD is defined by the following equation: UOD lbs/day = 8.34 x [(BOD mg/l x 1.43) + (TKN mg/l x 4.57)]. The quantity of BOD and TKN discharged shall be limited to not exceed the UOD daily maximum limit or the BOD concentration and mass (lbs) as specified above, whichever is more limiting. The **UOD limitation applies from June 1 through October 31 annually**.

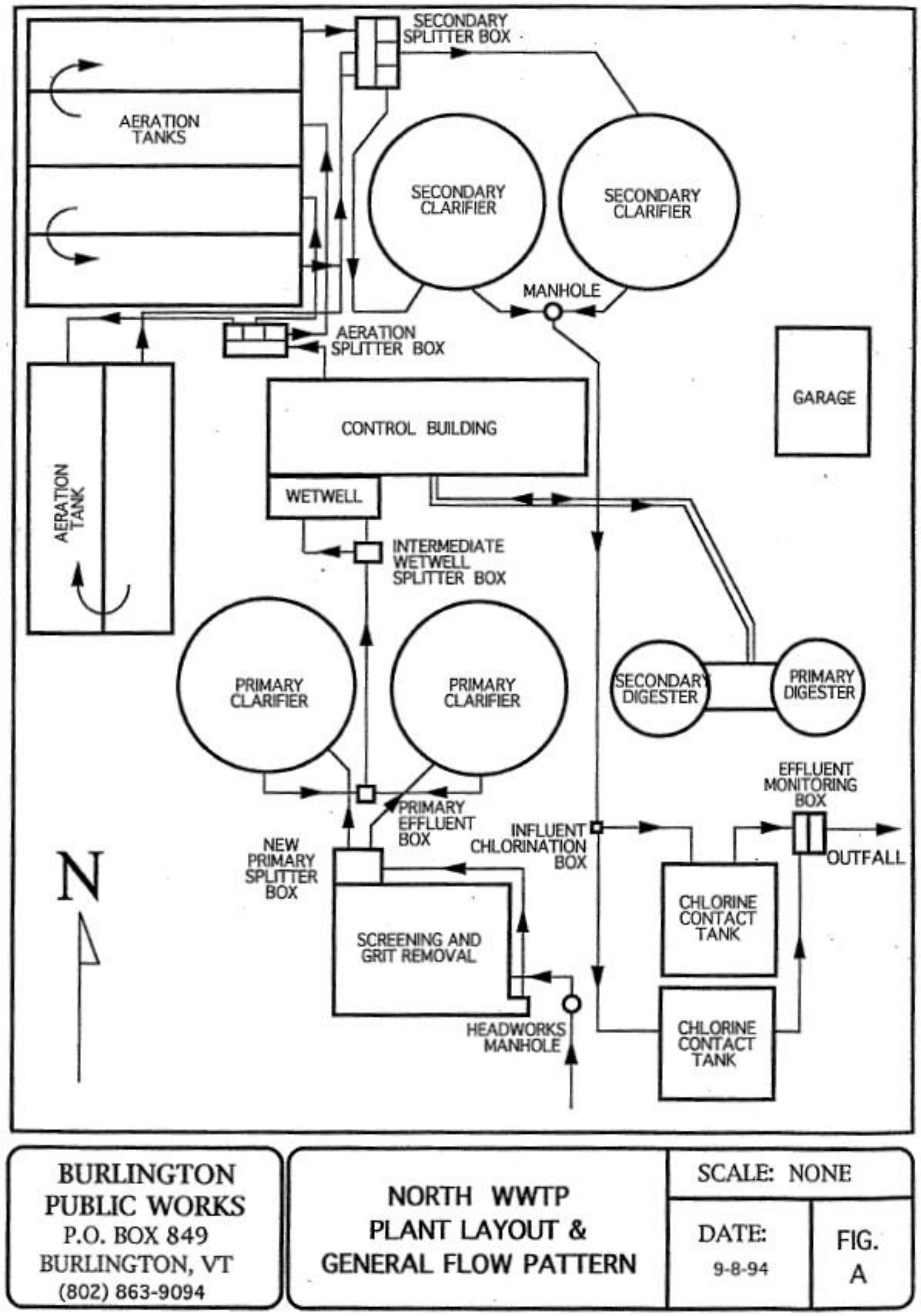

Figure 3-4. City of Burlington North WWTP Schematic

3.3 Collection System

3.3.1 Main WWTP

A significant portion of the collection system for the Burlington Main WWTP is served by combined sewers. The Main WWTP wastewater collection system is divided into sub sewersheds. For the CSS, the subsections coincide with the tributary drainage area to each CSO outfall. In the case of the SSS, the subsections represent defined areas tributary to key connection points along the interceptor sewers.

3.3.1.1 Permitted CSOs

There are three known CSO structures in the Main WWTP collection system. **Table 3-7.** Key Features of Main WWTP Combined Sewer System (CSS) contains the key features of the three permitted CSO outfalls listed in **Table 2-1.** Burlington's Permitted and Non-Permitted CSO Outfalls and shown on **Figure 2-1**. The data include the pipe network and acres of the total and combined portions of the subsection from the model. The tabulated pipe length includes both combined and separated sanitary sewer. Many projects were completed in the Main WWTP collection system between 2000-2020 and are listed in Section 4.2.

Table 3-7. Key Features of Main WWTP Combined Sewer System (CSS)

CSO Outfall			Pipe Network (lf)	Total Area (acres)	Combined Area (acres)
CSO #1	Main S/N 003	Manhattan Drive/Park Street	16,732	104	15.8
CSO #2	Main S/N 004	Manhattan Drive/North Champlain Street	13,788	82	9.0
CSO #3	Main S/N 005	Pine Street	36,422	330	31.4

3.3.1.2 CSO Storage Facilities

There are four storage structures in the Main CSS that were installed by the City to detain combined wastewater to reduce backups and attenuate peak flows in the CSS. Two of the tanks installed on South Prospect were designed to reduce basement surcharge events in homes on the downslope side of that area of South Prospect. **Table 3-8.** Summary of Burlington Main WWTP's Four CSO Storage Facilities presents a summary of the four Main WWTP collection system CSO storage facilities.

Table 3-8. Summary of Burlington Main WWTP's Four CSO Storage Facilities

Facility Location	Capacity (gallons)	Type
South Prospect Street between College Street and Main Street	342,000	Cistern
South Prospect Street near Robinson Parkway	5,500	Off-Line Tank
South Prospect Street near Henderson Parkway	5,500	Off-Line Tank
South End in Englesby Brook Floodplain	105,000	Cistern
Total	**458,000**	—

3.3.2 East WWTP

The collection system for the East WWTP is primarily an SSS. The collection system includes much of the University of Vermont campus as well as areas off Colchester, East, and Riverside Avenues and adjoining streets. There are two gravity sewer mains on Riverside Avenue which convey wastewater to the East WWTP: a 24-inch-diameter combined sewer from the eastern portion of the service area and a 12-inch-diameter sanitary sewer from the western portion of the service area.

The East WWTP wastewater collection system has been divided into sub sewersheds. For the CSS, the single subsection coincides with the tributary drainage area to the only CSO outfall. In the case of the SSS, the subsections represent defined areas tributary to key connection points along the interceptor sewers.

3.3.2.1 Non-Permitted CSO

There is only one known CSO in the East WWTP drainage area. The weir in this structure recently was raised approximately 6 inches and a significant cleaning effort was performed downstream in 2014. Two catch-basins on Thibault parkway were disconnected from the combined sewer system and redirected to the separate storm system. These actions have significantly reduced the frequency of CSO events.

3.3.3 North WWTP

The collection system for the North WWTP is primarily an SSS. The system extends as far south as Burlington High School. There are three gravity sewer mains conveying wastewater to the North WWTP: the 8-inch-diameter North Avenue main, the 18-inch-diameter Western Interceptor, and a 24-inch-diameter sewer main that crosses under the Winooski River through a siphon near the Heineberg Drive bridge and then crosses back under the river through a siphon immediately east of the plant.

The North WWTP wastewater collection system is divided into sub sewersheds. The single CSS subsection coincides with the tributary drainage area to the only CSO outfall. The SSS subsections represent defined areas tributary to key connection points along the interceptor sewers.

3.3.3.1 Permitted CSOs

There is one known CSO in the North WWTP collection system. The incoming pipe to this manhole is 24-inch diameter and the outgoing pipe is 18-inch diameter, with a 24-inch overflow pipe. CSO events occur when the weir in this manhole is overtopped. Disconnection of roof drains from the CSS into the storm drain system for 2.3 acres of rooftops from two public schools has substantially reduced the frequency of overflow events at this CSO.

4.0 Previous CSO Planning Documents and History of Burlington CSOs

This LTCP is the first comprehensive evaluation of Burlington's CSO system. A brief chronology of Burlington's CSO program is presented below.

4.1 1980s through 1994

Burlington had approximately 11 active CSOs in the late 1980s. Between the late1980s and 1994 the City committed over $52M into CSO control through sewer separation, 105,000-gallon storage tank in Englesby Brook Flood Plain, WWTP upgrades, and a wet weather treatment system at the Main WWTP. By 1994, the City of Burlington had three known CSOs remaining. Two CSOs, previously thought to be inactive, Colchester Avenue and Pine Street were later identified as active.

4.2 1994 through the Final 1272 Order (2019)

The City of Burlington completed many additional CSO projects and efforts from the time of the WWTP upgrades through receiving the 1272 Order. **Table 4-1** presents a list of the stormwater and CSO projects undertaken since 2000 to decrease CSOs within Burlington:

Table 4-1. Stormwater and CSO Projects Completed Since 2000

Year	Project	Sewer / Watershed
2000	College Street/ Prospect Street subsurface storage tank-362,000 gallons	Main Plant CSS
2009	Burlington Stormwater utility established	City wide
2009	Decatur Street bioretention bump outs constructed	Main Plant CSS
2010	Subsurface infiltration - Archibald Street	Main Plant CSS - Above Park Street CSO
2010	Subsurface infiltration - North Willard Street	Main Plant CSS - Above Park Street CSOs
2010	Subsurface infiltration - N. Winooski (1)	Main Plant CSS - Above Park Street CSOs
2010	Subsurface infiltration - N. Winooski (2)	Main Plant CSS - Above Park Street CSOs
2010	Subsurface infiltration - Bright Street (1)	Main Plant CSS - Above Park Street CSOs
2010	Subsurface Infiltration - Bright Street (2)	Main Plant CSS - Above Park Street CSOs
2010	Subsurface infiltration - Elmwood Avenue	Main Plant CSS - Above Park Street CSOs
2010	Subsurface infiltration - N. Winooski (3)	Main Plant CSS - Above Park Street CSOs
2010	Rooftop disconnection - H.O. Wheeler	Main Plant CSS - Above Park Street CSOs
2010	Rooftop disconnection - L.C. Hunt	North Plant CSS - Above Gazo CSO
2010	Rooftop disconnection - C.P. Smith	North Plant CSS - Above Gazo CSO
2010	Rooftop disconnection - Miller Center	North Plant CSS – Above Gazo CSO
2010	Vac-Con purchased for SW maintenance	CSS Catch basin/sediment maintenance
2010	Two 5,500 storage tanks to mitigate basement surcharge	Main Plant CSS
2011	Subsurface infiltration - Riverside Avenue	Main Plant CSS - Above Park Street CSOs
2011	Subsurface infiltration - Luck Street	Main Plant CSS - Above Park Street CSOs
2011	Subsurface infiltration - St. Mary's Street	Main Plant CSS - Above Park Street CSOs
2011	Subsurface infiltration - Walnut Street	Main Plant CSS - Above Park Street CSOs
2011	Subsurface infiltration - Manhattan Drive	Main Plant CSS - Above Park Street CSOs
2012	Storm drain redirection from CSS to Separate Storm Sewer – Thibault Parkway	East Plant CSS – Above Colchester Ave CSO
2013	Cherry Street silva cell constructed	Main Plant CSS
2013	North Street bioretention bump outs constructed	Main Plant CSS
2014	Hyde Street bioretention bump outs constructed	Main Plant CSS - Above CSO

Year	Project	Sewer / Watershed
2014	SW Friendly Driveways project completed	City wide
2015	SW Friendly Sidewalks Project completed	Main Plant CSS (Downtown Core)
2015	Pearl Street Beverage permeable pavers installed	Main Plant CSS
2015	South Winooski Avenue permeable pavers installed	Main Plant CSS
2016	Final revised TMDL for Lake Champlain issued	City wide
2016	Grant Street bioretention bump out installed	Main Plant CSS
2016	Grant street subsurface infiltration systems installed (2)	Main Plant CSS
2016	Subsurface stone infiltration trench - Russell Street	Main Plant CSS
2017	Subsurface infiltration - Park Street & Myrtle Street	Main Plant CSS
2017	Subsurface infiltration - King Street	Main Plant CSS
2017	Gazo Avenue outfall repair	Intervale wetlands
2017	BLUE BTV Residential SW Incentive Pilot completed (Lake Champlain Basin Program Grant)	City wide
2018	Pleasant Avenue drywell installation	Lake Direct
2018	Booth Street drywell installation	Main Plant CSS
2018	Booth Street bioretention bump out	Main Plant CSS
2018/9	Hadley Road Disconnection	Main Plant CSS- Above Pine Barge Canal CSO
2019	Mansfield Avenue bioretention swale constructed	Main Plant CSS
2019	North Street @ at Russell bioretention bump out	Main Plant CSS
2019	Subsurface infiltration system - Allen Street	Main Plant CSS
2019	Ward Street bioretention bump out	Main Plant CSS
2019	Railyard Enterprise SW outfall assessment project completed	Lake Direct (from Main Plant CSS)
2019	Great Streets St. Paul construction complete - addition of permeable pavers, bioretention bump outs and stormwater trees on 2 blocks of St. Paul Street	Main Plant CSS
2020	City Hall Park	Main Plant CSS

<u>Reductions of Combined Sewer Stormflow as Part of the Development Process</u>

As part of the update to the Chapter 26 Ordinance in 2009, projects that disturb more than 400 sq. ft. are reviewed for stormwater impacts. As part of this stormwater impact review, projects must demonstrate compliance with the following stormwater management goals in the combined sewer system:

- 100% of stormwater volume from new impervious mitigated for the 1 year, 24-hour storm (2.1”).
- Mitigation of stormwater volume from redevelopment impervious (a parking lot that turns into a roof top) to the maximum extent practicable, but with a minimum management target of 50% of the existing impervious surface.
- Mitigation of any increased stormwater volume from “drainage efficiency” projects (installing drainage inlets, pipes etc.).

Examples of recently constructed redevelopment projects that have greatly contributed to the City’s combined sewer runoff reduction efforts include:

- Redevelopment of ICV building at 180 Battery St (storage tanks and permeable pavers)
- Redevelopment of QTs at 237 North Winooski Ave (infiltration system and permeable pavers)
- Redevelopment of parcels at 258 North Winooski Ave (infiltration system)
- Bright Street Housing Cooperative redevelopment (infiltration system)
- Drainage efficiency project at UVM’s Waterman Building (storage tanks)

Recently, as part of the on-going evolution of Burlington's approach to combined sewer reductions, projects that are significantly increasing their sanitary wastewater flows to our plant have been required to not only manage stormwater in accordance with the framework above, but also to remove additional stormwater, either from their site (if a pure redevelopment project) or through providing funding for implementation of additional runoff reduction projects. Examples include:

- Cambrian Rise: 100% management of new impervious, disconnection of all runoff from the combined sewer system for the redeveloped portion of their project, financial contribution to the design and installation of subsurface infiltration that will reduce stormwater inputs from North Ave runoff to the combined sewer system.
- 85 North Ave (top of Depot St): 100% management of new and redeveloped impervious, financial contribution to the North Ave runoff reduction system.
- City Place Burlington: 100% management of all existing and new impervious; disconnecting roof drains that were directly connected to the combined sewer system.

The efforts above have reduced the frequency and volume of CSOs at the two Manhattan CSOs. North Champlain has only activated once since 2014 and Park's frequency and volume are reduced. Pine Street CSO continues to be the most active CSO with the largest volumes of overflow.

There is one known CSO in the East Plant collection system – the Riverside/Colchester CSO. Around 2014 the Riverside/Colchester CSO weir was raised approximately 6 inches and substantial capacity management activities were completed downstream, including pipe cleaning. These actions significantly reduced the frequency of CSO events, resulting in no CSO activation at the Riverside/Colchester CSO during the October 31, 2019 storm event (3.5" in 14 hours). This October Halloween storm resulted in astronomical flows and multiple days of elevated flow at the Main WWTP, in excess of 8 MGD and a CSO at the Pine Street CSO with a volume of approximately 1 MG.

There is one known CSO in the North Plant collection system – the Gazo Avenue CSO. The City has disconnected approximately 2.3 acres of rooftops through a roof drain disconnection program, which has substantially reduced the frequency of CSOs at Gazo. There have been several years in which Gazo has not activated.

4.3 Annual Reporting

Vermont CSO communities are required to report annually on their CSO volumes and activation frequency. In addition to reporting CSO volumes and activation frequency, Burlington is required to periodically report its progress towards reducing its CSOs.

5.0 System Characteristics

Characteristics of the Burlington, Vermont combined sewer system are represented in the collection system model. Refer to Appendix A: City of Burlington, Stormwater Management Model (SWMM) Update. As described in Appendix A, the model calibration is based on flow metering programs conducted in 2014 and 2017 to 2018.

A model developed by Stantec in 2016 included an extensive water usage study to complete the dry weather analysis. Based on this extensive sanitary study, the sanitary base flows developed by Stantec were used in the 2020 model. Due to the level of detail associated with the dry weather calibration with the 2014 meters, the dry weather flow calibrations were minimally adjusted. The Stantec model was then updated by the City including pipe network and subcatchment areas. The focus of the 2020 model update was wet weather calibration and replacing the RTK parameters with the SWMM groundwater module based on flow metering

The focus of the modeling effort was the Main Plant collection system, due to the volume and frequency of the three CSOs within the Main system. The North and East collection systems both have one CSO. These CSOs overflow infrequently and with low volumes. The updated 2020 model was run for the 5-year level of control (i.e., the CSOs were evaluated to be controlled in up to a 5-year storm event) which is identified as an interim level of control in Burlington's 1272 Order and the VTDEC CSO Rule 2016 (§34-403 (8)). The 5-year event is a 2.7-inch, 24-hour storm, with a 1-hour peak intensity of 1.2 inches. VTDEC CSO Rule 2016 requires CSOs to meet VWQS at all times but recognizes that "financial capability is a significant factor in abating and controlling CSOs and meeting water quality standards." The City will evaluate progress towards meeting VWQS once the interim control target has been met.

The 2020 SWMM model, while an improvement over the 2016 model with regard to the evaluation of wet weather events, relies on calibrations to meters that are lower in the sewersheds. Future upstream metering and re-calibration efforts will ensure that model output for upstream areas is further refined.

5.1 Overview of CSOs

There are five permitted/non-permitted existing combined sewer overflows (CSOs) in the collection systems of Burlington's three wastewater treatment plants (see Table 2-1 for details on all 5 five CSOs). All five are equipped with Mission Communications manhole monitoring systems, which record the start and stop times of CSO events and send alarms to Department of Public Works personnel at the start and end of each event. All CSO locations, except the Manhattan at N. Champlain Street location, are also equipped with BlueSiren flow monitoring equipment that aid in the calculation of overflow volumes.

There are three known CSO structures in the Main WWTP collection system, as follows:

- Pine Street (structure M3.26): Overflow structure located near the intersection of Pine Street and Lakeside Avenue, across from a Department of Public Works facility. Overflows from this structure discharge to the Pine Street Barge Canal. This CSO was discovered as part of sewer system inventory work in 2015. Since discovery, this CSO has historically been the most active of Burlington's five remaining CSOs. There have been 39 overflow events at this structure since 2015.

- Manhattan Drive at Park Street (structure MY2.16): Prior to work completed in 2012, this was the second most active CSO. It discharges to a large wetland in the Burlington Intervale, part of the floodplain of the Winooski River. There have been 7 overflow events at this structure since 2010.

- Manhattan Drive at North Champlain (structure MY2.17): This CSO also discharges to the Burlington Intervale wetland. There have been 3 overflow events at this structure since 2010. It is noted that endangered species and endangered species habitat exists in the vicinity of this CSO. Refer to Appendix C for information on rare, threatened, and endangered species.

Since 2010, various system optimization measures have been completed by the City of Burlington that have decreased overflow events from the numbers presented above. One of those system optimization measures involved installation of 13 subsurface infiltration systems (capturing the 2.5 inch, 24-hour storm runoff from a minimum of 3.5 acres of directly connected impervious surface), in conjunction with the disconnection (sewer separation) of 0.55 acres of rooftop from H.O. Wheeler (IAA) school. This system optimization measure has reduced the frequency and volume of overflows from the Manhattan Drive CSOs. As an example, there was no CSO event from the Manhattan-Park structure during a 3.5 inch, 14-hour storm on 10/31/19.

There is one CSO in Burlington North's collection system, the Gazo Avenue CSO (structure N3.18). The incoming pipe to this manhole is 24-inch diameter and the outgoing pipe is 18-inch diameter, with a 24-inch overflow pipe. CSO events occur when the weir in this manhole is overtopped. Combined wastewater from this CSO structure is released directly to the Winooski River. Approximately 2.3 acres of roof drains that were connected to the combined sewer system have been re-routed into the separate storm sewer. This has reduced the frequency of overflow events at this CSO.

The only known CSO in the collection system tributary to the East Plant discharges to the Winooski River immediately below the Winooski Falls, at the intersection of Colchester Avenue and Riverside Drive (structure R1.12). The weir in this structure was recently raised approximately 6 inches and capacity management activities (pipe cleaning) were completed downstream. These actions have reduced the frequency of CSO events. This CSO did not discharge in the extreme storm event that took place on October 31, 2019 (3.5 inches in 14 hours). Overflow frequency and volumes reported to DEC for the CSOs described above are presented in **Table 5-1**.

City staff have provided a spreadsheet and maps overviewing occurrence locations of State-listed rare, threatened, or endangered (RTE) species within the vicinity of the five CSO outfalls. This information is included in Appendix C. There are no known occurrences of any species with Federal protection status.

It is acknowledged that Gazo and Colchester CSOs discharge to locations with RTE species of concern. However, due to the low discharge frequency, these locations are still not as high a priority as the Pine Street Barge CSO, which has a higher frequency and volume of discharge and possibly more direct recreational impacts. This is also true for Park and North Champlain CSOs, again due to low-frequency, low-volume discharge events. Pine Street CSO has only one plant species listed as rare, which is included in the attached datasets.

Table 5-1. Summary of CSO Events in Collection System

CSO Name	CSO Serial No.	Overflow Location ID	Number of Documented Overflows (2010-2019)	2010-2019 DEC Reporting (1) Volume (gallons)
Gazo Ave. CSO	002	N3.18	6	15,815
Manhattan Dr./Park St. CSO	003	MY2.16	7	35,599
Manhattan Dr./No. Champlain St. CSO	004	MY2.17	3	36,401
Pine Street CSO (2)	N/A	M3.26	39	2,783,645
Riverside/Colchester Ave. CSO	N/A	R1.12	6	219,462

(1) Multiple approximate flows were provided to DEC for each CSO. The larger value was used for the volume in the table.

(2) Pine Street CSO Activations are from 2015-2019 time-period. No volume was recorded for the 9/6/2018 event.

In addition to the CSO events above, there are periodic reports of sewer surcharges from basement plumbing fixtures that are unprotected by back water prevention valves. Per International Plumbing Code sub-grade plumbing fixtures are required to have back water valves. Unfortunately, many homes in Burlington do not appear to have such protection. In many cases, these basement back-ups occur on North-South oriented streets where homes on the western side area are built lower than the street level and/or homes at the bottom of a hill where a steeper sewer enters a flatter sewer. Additionally, there have been some examples in areas of the City where the sewer has a flatter slope. While the City has begun to track these events, the tracking systems to date are not comprehensive enough to get a full picture and also to understand if some of the events are due to private infrastructure issues (lateral condition issues, roof drain or storm drains tied into sanitary sewer laterals). The City is scheduled to implement a robust spatially oriented Computerized Maintenance Management System (CMMS) which will enable improved tracking of basement back-up events. Available information on basement back-ups has been included in Appendix F.

Updates to the Model After 2018 Metering

Following the 2018 metering program, other projects were completed or slated to be completed prior to the review and implementation of the Integrated Planning Projects. The following modifications include the projects that were added to the calibrated 2018 model to create the Baseline model.

Baseline Modification 1

A catch basin located near South Burlington was plugged in April 2016 (see **Figure 5-1**). This area was included in the 2014 model calibration. The South Burlington interconnection flow was disconnected after the model calibration. The entire sewer area from South Burlington was disconnected and directed to South Burlington via a pump station. This reduced the flow tributary to the Pine Street overflow.

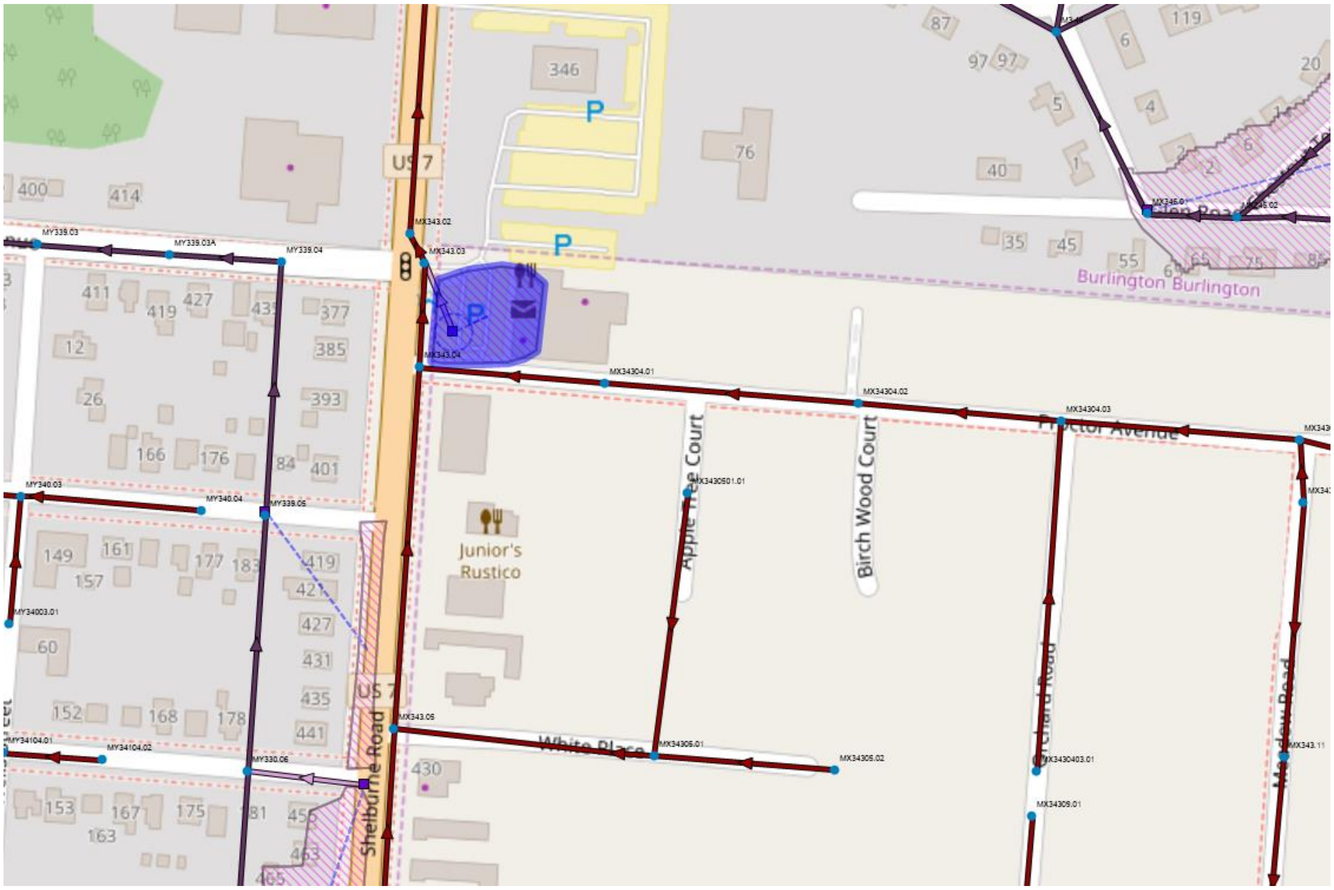

Figure 5-1. South Burlington Catch Basin Disconnection

Baseline Modification 2

The following Green Stormwater Infrastructure BMP projects make up Baseline Modification 2:

- Green Stormwater Infrastructure BMPs built in 2019
- Green Stormwater Infrastructure BMPs that are scheduled to be built

The location of these BMPs is shown in **Figure 5-2**.

Following incorporation of Baseline Modification 2 it was noted that there were possible flow direction fluctuations at the Pine Street CSO regulator due to the dynamic response of the system to flow removal upstream. This will require further investigation with additional metering downstream of the Pine Street regulator.

As noted above, the South Burlington Flow Interconnection and the two phases of Green Stormwater Infrastructure BMPs were incorporated into the calibrated model to create the Baseline Model, which was used for development of CSO control alternatives, as discussed in Chapter 6.

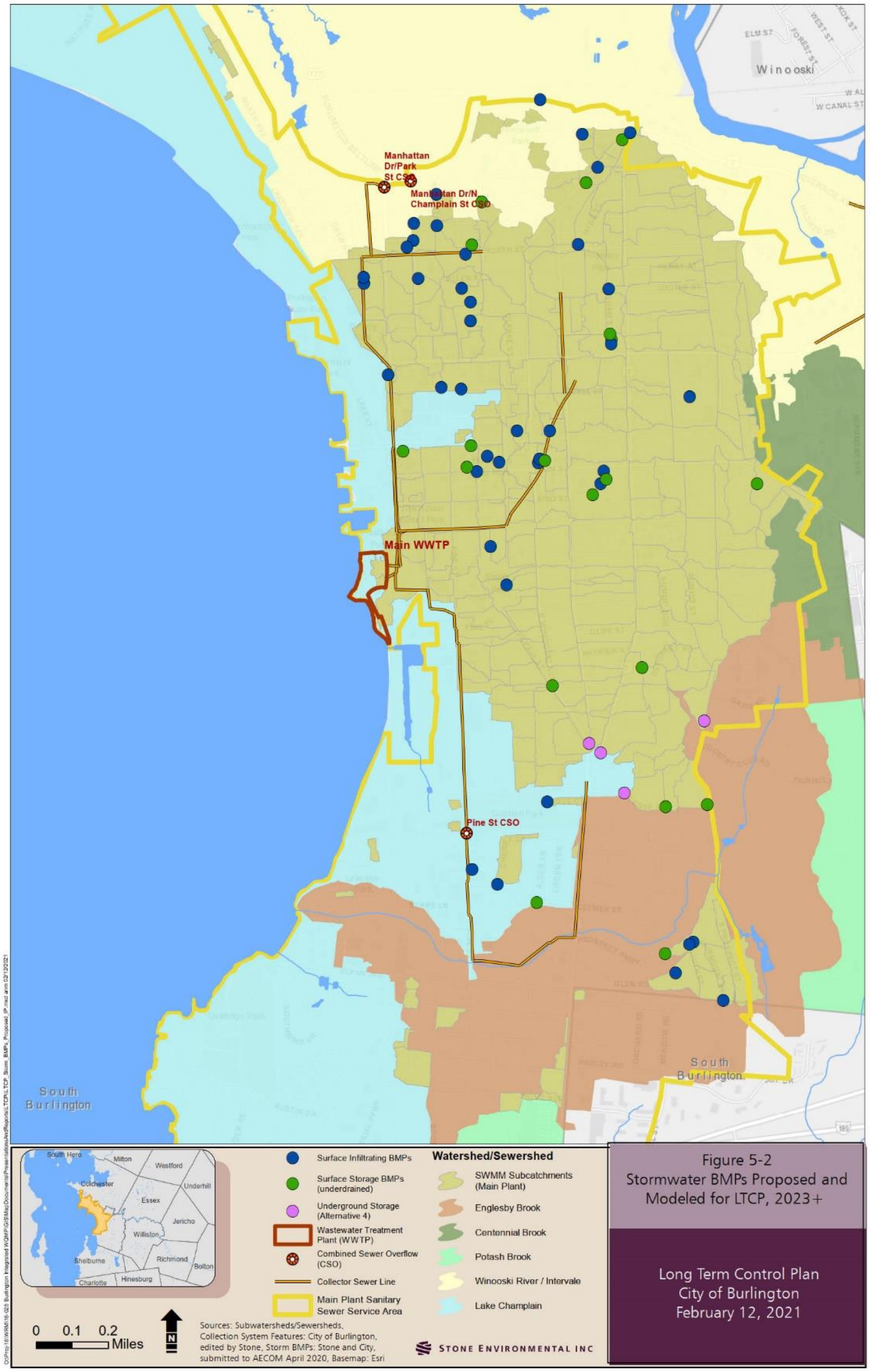

Figure 5-2. Location of Green Stormwater Infrastructure BMPs

6.0 Alternatives for Additional CSO Control

This section of the LTCP describes the process used to develop control measures that are available for consideration with respect to further advancing CSO reduction. This LTCP builds from the foundation of the existing, operational control measures. Also discussed is the multi-step process used to evaluate the measures, starting with a first-level or fatal flaw analysis to screen from consideration those measures that are not suited to Burlington. The remaining controls are then advanced for a more detailed evaluation and screening process. An important part of this process is the establishment of the targeted level of control for the LTCP with respect to reductions in CSO activations and discharge volume.

It is noted that the alternatives analysis discussed in this chapter focuses primarily on the most active CSO in the Main WWTP system, the Pine Street CSO. As noted in **Table 5-1**, the Pine Street CSO overflowed 39 times from 2010 to 2019. The Manhattan Drive at Park Street CSO overflowed seven times and the Manhattan Drive at North Champlain CSO overflowed only three times during the same time period. As discussed in Chapter 7, the North Champlain CSO is not predicted to overflow in the 5-year storm under baseline conditions. An evaluation of the 5-year storm event has been conducted as specified by the VTDEC 1272 Order. The intent for the next 5 years is to evaluate the impact of the remaining proposed projects (Baseline 2) on the Park Street and Champlain CSOs, track overflow volumes and activations, and identify additional projects that may remove storm flow.

6.1 Available CSO Controls

CSO controls are typically grouped into categories that range from simpler, less costly source control measures to more complex and costly treatment and storage facilities. To meet the requirements of the VT DEC, the following specific CSO controls were considered: storage tank/retention basins; expanding WWTP capacity; screening and disinfection at overflow locations; sewer separation, and disinfection at CSOs.

Table 6-1 below contains the currently available measures grouped by the following categories: source controls; system optimization; conveyance enhancements; and treatment and storage.

Table 6-1. Available CSO Control Measures

Source Control
• Best Management Practices/Nine Minimum Controls
• I/I Reduction/Sewer Rehabilitation
• Sewer Separation
• Green Infrastructure
System Optimization
• Weir Adjustment
• Bending Weirs/Control Gates
• Real Time Controls
• Installing flow meters at each CSO outfall
Conveyance Enhancements
• Parallel Relief Interceptors/Pipe Up-sizing
• Pump Station Expansion
Treatment (Satellite and Centralized at WWTP)
• Vortex Separation
• Retention Treatment Basin (RTB)
• High Rate Clarification (HRC)
• WWTP Expansion (Wet Weather Capacity)

• Disinfection in conjunction with treatment technologies
Storage
• In-System/Conduit
• Off-Line Tank
• Tunnel

For the most part, the more complex and costly measures also provide higher levels of volumetric and/or pollutant reduction control and are typically better suited for CSOs where a relatively high level of control is required in order to comply with targeted reduction objectives.

The following are the controls that Burlington has implemented from 1992 to the present:

- All of the Source Control measures
- Weir adjustments
- WWTP expansion
- In-system conduit storage
- On and off-line tank storage

Storage is often more cost-effective than satellite treatment and disinfection when the shape of the overflow hydrograph indicates a high peak flow and relatively small volume, such is the case for Burlington's CSOs. In contrast, satellite treatment is often more cost-effective than storage for hydrographs with lower peak rates of flow that continue for a long duration, resulting in higher overflow volumes. For many owners, storage is preferred over satellite treatment as it is a relatively simple process to operate. The stored volume is drained back to the WWTP following the storm where it receives full secondary treatment and disinfection.

6.2 Evaluation and Screening Methodology

As noted previously, a multi-step process was employed to evaluate the available control measures. The first step is sometimes referred to as a "fatal flaw" analysis. This initial step allows for certain measures to be screened out from further consideration due to a single factor or multiple factors that make them unsuitable for CSO control in Burlington.

6.2.1 Fatal Flaw Analysis

Fatal flaws can include but are not limited to space limitations, complexity of operation, or any other consideration particular to Burlington and the current wastewater system operations. Another reason why certain measures are screened out is that there is no opportunity to implement the measure. **Table 6-2** presents the results of this initial step.

Table 6-2. Results of Fatal Flaw Analysis

	Retained for LTCP Analysis	Remarks
Source Control		
• Best Management Practices/Nine Minimum Controls (BMP/NMC)	Yes	Being implemented on a continuous basis and reported annually to DEC.
• I/I Reduction/Sewer Rehabilitation	No	Sewer rehabilitation for structural integrity purposes, as needed
• Sewer Separation	Yes	To evaluate feasibility and cost of meeting VT DEC closure of CSO requirement

	Retained for LTCP Analysis	Remarks
• Green Infrastructure	Yes	Considered extensively, as noted in the updated 2020 baseline model which included Green Stormwater Infrastructure BMPs.
System Optimization		
• Weir Adjustment	No	Already implemented; however additional beneficial adjustments may be found through future investigations.
• Bending Weirs/Control Gates	No	May be included with other controls (e.g., storage tanks) to optimize operation.
• Real Time Controls	No	For future consideration when additional facilities are under design.
Conveyance Enhancements		
• Parallel Relief Interceptors/Pipe Up-sizing	Yes	Evaluated as possible future need for reduction of collection system surcharging once further model refinement is complete
• Pump Station Expansion	No	
Treatment (Satellite and Centralized at WWTP)		
• Existing Vortex Separator Upgrade	No	Space limitations at the WWTP would make a vortex upgrade difficult.
• Satellite Vortex, Retention Treatment Basin (RTB) and High-Rate Clarification (HRC)	No	As noted above, Satellite treatment is not cost effective for the characteristics of Burlington's remaining CSOs (high peak, short duration, small volume).
• WWTP Expansion (Wet Weather Capacity)	Yes	Wet weather expansion would be considered in conjunction with a dual use (dry and wet weather) treatment system, which is discussed in the Integrated Plan.
• Disinfection with Above Treatment Processes	Yes	As noted above, disinfection with a treatment process is not cost effective for the characteristics of Burlington's remaining CSOs (high peak, short duration, small volume).
Storage		
• In-System Storage	No	Not feasible due to small-size pipes and extent of surcharging in the collection system.
• Off-Line Tank	Yes	For remaining CSOs this is a viable option.
• Tunnel	No	Not suited for a city the size of Burlington.

As shown in the table, nearly half of the available control measures were retained for further consideration.

6.2.2 Second Level Screening

The second level of control measure screening builds upon the fatal flaw analysis described above. Due to the size of the collection system, the number of combined sewer overflow locations, the relatively low overflow frequency, and possibility of system surcharging to the ground surface (discussed below) each of the alternatives retained for subsequent screening and evaluation was looked at for the Main Plant collection system as a whole.

The CSOs located within the North and East Plant tributary areas overflow infrequently and with low volumes.

CSO elimination is not considered to be feasible at this time for the Pine Street CSO due to both practical limitations and costs. However, in order to include this level of control in the evaluation process, costs for sewer separation were developed.

During the review of the updated 2020 baseline results, it was noted that the Burlington collection system model predicted surcharging to the ground surface in multiple locations throughout the collection system. Surcharging at these locations were predicted in each of the design storm events evaluated. The City has anecdotal history of possible flooding; however, it has not been clear whether the extent of flooding is related to surcharging of the collection system to the street level or stormwater unable to enter the collection system due to stormwater inlet capacity. In order to develop and plan for a long- term approach which would involve addressing confirmed surcharging, alternatives were developed to mitigate the currently predicted flooding during the storm events by increasing pipe sizes within the collection system. **Table 6-3** below presents a list of the alternatives evaluated for the Pine Street, Champlain, and Manhattan Avenue CSOs.

Table 6-3. List of Alternatives Evaluated

Addition of CSS BMPs • Note that this is part of the baseline used for subsequent alternative assessment. The alternatives listed below include the stormwater IP BMPs. • The baseline also includes the removal of South Burlington flow and the addition of Great Streets BMPs. • The CSS BMPs had a reduction on CSOs at Pine Street
Addition of underground storage • This alternative assessed the impact of stormwater BMPs that would consist of underground storage. This alternative had a minimal impact on CSO discharge volume. • Alternative not pursued further.
Pipes upsized to address predicted surcharging to the ground surface • Successfully eliminated predicted collection system surcharging to the ground surface in design level of control (1-year; 2-year; 5-year) • This alternative will not be designed until further system characterization is completed.
Pine Street CSO storage • Includes a storage tank at Calahan Park with 0.17 MG storage volume for a 1-year level of control, and up to 0.30 MG storage volume for the 5-year level of control • Pipe upsizing would still be required to eliminate predicted flooding in design level of control (1-year; 2-year; 5-year)
Hybrid storage + conveyance • Identified areas with flooding and included storage tanks at strategic locations in the collection system • Extensive pipe up-sizing still required to meet 1-year, 2-year, or 5-year CSO level of control and to address surcharging to the ground surface • Pipe length was decreased by about 1 mile with the addition of 0.5 MG storage • Alternative not pursued further at this time; could be viable based on further characterization of predicted street surcharge areas.

Full sewer separation (performance evaluated based on assuming 70%, 80%, and 90% inflow removal could be achieved) • System-wide inflow reduction commensurate with separation of all combined sewers • 90% inflow removal would be required to eliminate the Pine Street CSO in the 5-year event • Surcharging to the ground surface still predicted to occur; pipe segments would need to be upsized to eliminate surcharging to the ground surface
Partial sewer separation • Targeted inflow reduction to eliminate CSOs up to a certain level of control • Simulated by reducing area of targeted catchments by 300 acres • Would require additional pipe segments to be upsized to eliminate surcharging to the ground surface

Addition of CSS BMPs

This alternative includes the stormwater Integrated Plan (IP) BMPs that are located within the combined sewer system to decrease stormwater flows upstream of the Pine Street CSO. This alternative was effective in decreasing flows to the Pine Street CSO and was included in all of the subsequent CSO alternatives. The details associated with cost of the CSS BMPs is included in the development of the Integrated Plan.

Addition of underground storage

This alternative would include locating several underground storage tanks in upstream locations in the Pine Street and Park Street tributary areas to decrease stormwater flows in the combined sewer system. The intent would be to decrease CSO volume and frequency at Pine and Park Street CSOs. Based on the modeling results for this alternative, the underground storage tanks would not substantially decrease CSO volume or frequency, and the underground storage would be expensive. This alternative was not considered further in the LTCP.

Pipes upsized to address surcharging to the ground surface

This alternative would include upsizing pipes within the combined sewer system to eliminate surcharging to the ground surface, which is widespread in the City, due to relatively small pipe sizes. This upsizing of pipes would eliminate surcharging to the ground surface flooding currently predicted by the SWMM model and would control the Pine Street and Park Street CSOs. Versions of this alternative have been sized/configured to achieve a 1-year, 2-year, and 5-year level of control. More pipes require upsizing, and larger upsized pipes are required in order to achieve higher levels of control.

This alternative needs to be further evaluated following a more targeted metering program and following assessments of the impact of pipe upsizing on both existing CSOs and flows at the Main Plant. Additional flows due to pipe upsizing were preliminarily evaluated using the current version of the PCSWMM model. These results indicated a minimal impact on the magnitude of peak flow at the Main Plant but that elevated flows would be extended over a longer time period, contributing to increased volume to be treated at the Main Plant.

Pine Street CSO storage

This alternative would include controlling the Pine Street CSO through an underground storage tank located at Calahan Park. This CSO storage tank was sized and evaluated for the 1-year, 2-year, and 5-year level of control. This alternative also provides some minimal improvements to the predicted combined sewer system surcharging to the ground surface.

Pine Street CSO storage and Pipes upsized to address surcharging to the ground surface

This alternative would include controlling the Pine Street CSO through an underground storage tank located at Calahan Park and upsizing pipes within the combined sewer system to eliminate predicted surcharging to the ground surface. This upsizing of pipes in conjunction with the underground storage tank eliminated the predicted surcharging to the ground surface and controlled the Pine Street and Park Street CSOs to the 1-year, 2-year, and 5-year level of control.

Hybrid storage plus conveyance

This alternative would include upsizing pipes within the combined sewer system to eliminate surcharging to the ground surface in conjunction with additional distributed storage at select locations within the City. This upsizing of pipes and storage would eliminate predicted collection system surcharging to the ground surface and would control the Park and Pine Street CSOs to the 1-year, 2-year, and 5-year level of control. The amount of storage required would not offset the number (cost) of pipes that would have to be upsized, based on the current model. Accordingly, it was not considered to be a viable alternative, at this time. However, if further characterization of the surcharging areas reveals the surcharge volume to be small, this could become a viable approach in some areas in future LTCP cycles.

Full sewer separation (evaluated at 70%, 80%, and 90% inflow removal)

This alternative is based on modeling the collection system assuming various levels of inflow removal, ranging from 70% to 90%, to simulate the effect of complete sewer separation. In simulating sewer separation, it is important to recognize that 100% removal of inflow is not achievable as certain sources (such as flat roof buildings with internal roof drain piping) cannot feasibly be separated. Experience has shown that inflow removal percentages ranging from 70 to 90% represent the lower and upper limits of feasible inflow removal. The performance of these full sewer separation model runs was determined to assess whether the various levels of inflow removal could eliminate the collection system surcharging to the ground surface and control the Pine Street and Park Street CSOs to the 1-year, 2-year, and 5-year level of control. The full sewer separation alternative assumed that separation was performed throughout the entire combined sewer area. Results from full sewer separation model runs showed that 90% inflow removal (the upper limit of inflow removal considered potentially feasible) would be required to achieve a 5-year level of CSO control at the Pine Street CSO. These model results also showed that sewer surcharging to the ground surface would continue in certain areas.

Partial sewer separation

This alternative is based on modeling the collection system assuming 90% inflow removal (the upper limit of inflow removal considered potentially feasible) but for approximately 1/3 of the total combined sewer area. Results from partial sewer separation modeling showed that the predicted surcharging to ground surface continued in larger storm events.

6.3 Backwater Preventers

As noted above, the collection system model indicated the potential for surcharging to the ground surface. With the hydraulic grade line in the collection system rising to less than six feet of grade there is an increased potential for basement back-ups. One way to mitigate this risk is to install backwater preventers on the service connections of potentially vulnerable properties. The number of backwater preventers potentially required was initially estimated as part of the development of the CSS BMPs, which are included in the baseline condition as discussed above. Collection model output was reviewed to identify locations of “Visible Flooding” predicted within the collection system. Based on the “Visible Flooding” locations, the number of manholes and buildings where the hydraulic grade line could be within six feet of grade was estimated. The results presented below are based on model output and do not account for properties that may have already addressed the need for backwater preventers. The results are not based on current Code requirements and represent a summary of model output.

The number of backwater preventers estimated as described above was reduced to approximately 30% of the total, as previous collection system experience has indicated that:

- Properties may already have backwater preventers installed
- A portion of the properties estimated as described above are more than six feet above the hydraulic grade line (e.g., homes on a hill)
- A portion of the properties estimated as described above may not have basement fixtures

Alternatives that would provide off-line storage of CSOs (e.g., the Pine Street CSO storage alternative) would not appreciably reduce the hydraulic grade line throughout the collection system. The pipe upsizing alternative would reduce the hydraulic grade line, although not universally, to six feet or more below the ground surface. In other words, the number of locations potentially requiring backwater preventers would be somewhat less with the pipe upsizing alternative as compared to the baseline. Based on preliminary estimates made, the difference was not substantial.

Table 6-4 includes the total number of backwater preventers estimated to be required to protect properties that could be impacted by a hydraulic grade line less than six feet below grade. This table also presents an estimated total cost for the installation of the backwater preventers. This table conservatively presents the highest number of backwater preventers and associated cost applicable to all CSO control alternatives under consideration. In general, this corresponded to the baseline condition.

Table 6-4. Alternative Stormwater IP BMPs Backwater Preventer Cost

Design Storm	1 Year, 24-hour	2 Year, 24-hour	5 Year, 24-hour
# Of Manholes with HGL[1] Above Minimum Freeboard Threshold (6 ft.)	277	286	308
# Of Manholes with HGL Exceeding Ground Surface	31	36	91
# Of Houses Requiring Backwater Preventers	757	936	1,179
30% of Houses Requiring Backwater Preventers	227	281	354
Cost of Backwater Preventers ($)	$1,100,000	$1,400,000	$1,800,000

1. HGL = hydraulic grade line

As noted above, the alternative CSO controls under consideration do not lower the hydraulic grade line in the collection system to six feet or more below grade. Therefore, the cost for adding backwater preventers was appropriately / conservatively added to the cost of the CSO control alternatives (e.g., storage, sewer separation, and pipe upsizing).

6.4 Preliminary Costing and Sizing of Control Measures

Preliminary cost estimates were developed for the alternatives. Preliminary costs at this stage of planning do not take into account all of the site-specific cost elements of a potential future project, such as land purchase or contamination mitigation. Preliminary costs are used to compare alternatives and to establish a knee-of-the-curve (KOTC). KOTC curves, presented in Section 6.10, are helpful in determining the cost-effective level of control (e.g., 1-year, 2-year, or 5-year level of control). The estimates developed for each alternative and level of control are based on costs obtained from recent similar CSO abatement projects in New England, and are based on ENR=11440, dated July 2020. The costs are presented as estimated total project costs which include the following components and contingencies:

Opinion of probable construction costs - The costs are planning-level estimates of materials, equipment, and labor.

Estimated total project cost - Opinion of probable construction cost plus allowances for engineering, Owner's contingency, and SRF loan administrative costs.

Estimate contingency (30%) - Includes construction related items (i.e., process piping, electrical conduits, etc.) not yet defined and modifications that would be further defined and quantified between the planning level and completion of bid documents.

Engineering and owner contingency (35%) - Engineering design and construction-related services plus an overall project contingency for items that are unforeseen.

The next step in the alternative development and evaluation process was sizing of the Alternatives over the range of levels of control evaluated in this LTCP. This was performed for the Alternatives noted in **Table 6-3**. The level of control is defined as the number of activations that would result from implementation of the control measure for the storm events analyzed. The 1272 Order and VT DEC CSO rule require that CSO discharges meet VWQS at all times. The CSO rule recommends that CSO control measures sized to achieve CSO control in a 5-year storm be characterized as an interim measure. Due to the high cost of CSO control measures sized to meet VWQS at all times the City focused on the 5-year level of control as an interim target and acknowledges that progress towards meeting VT WQS will be evaluated once the interim target is met. Due to the size and cost of alternatives sized for a 5-year design storm, alternatives were also sized for the 1-year and 2-year design storms. This enabled an assessment of the incremental cost of increasing the level of control from the 1-year to 2-year event and from the 2-year to 5-year event. This is common practice in CSO control planning and is often referred to as the "knee-of-the-curve". For example, if the incremental cost to increase an alternative size from the 1-year to 2-year event was nominal, such an increase could potentially be justified. Conversely, if the incremental cost to increase an alternative size from the 2-year to 5-year event was high, such increase might not be justifiable.

6.5 Pine Street Storage Tank

Storage tanks are sized based on volume to capture a CSO discharge up to tank storage capacity, corresponding to its design level of control. The updated PCSWMM model, described in Section 5, was used to develop volumes to be stored for the 1-year, 2-year, and 5-year events. Storage tank sizes required to capture those volumes are shown in **Table 6-5**. The required storage tank volumes for the 1-year, 2-year and 5-year storm events were physically sized (length, width, and side water depth) based on the following criteria:

- Side water depth assumed to be 18-feet
- Length-to-width ratio of 2:1

Table 6-5. Approximate Pine Street CSO Storage Tank Sizing Over Range Level of Control

Level of Control	1-year	2-year	5-year
Storage Tank Volume (MG)	0.17	0.22	0.30
Storage Tank Volume (ft^3)	22,700	29,400	40,100
Storage Tank Side Water Depth (ft)	18	18	18
Storage Tank Length (ft)	51	59	67
Storage Tank Width (ft)	25	28	33

Footprint sizes for the storage tanks, sized based on the 1-year, 2-year, and 5-year storm events, were developed for the Pine Street CSO off-line storage tank, and are shown on **Figure 6-1**. For planning purposes, it is assumed that the tank would fill by gravity and be emptied by tank dewatering pumps. The influent pipe would be directed into the storage tank from a new diversion structure constructed just downstream of the existing regulator structure. The diversion structure would route flow to the tank, up to the capacity of the diversion piping and/or tank volume. Excess flow would continue to the existing outfall. The dewatering pumps would discharge to a force main which would discharge to the sewer system so stored flows would receive treatment at the WWTP. The storage tanks would also be equipped with an automated flushing mechanism to clean the floor of settled solids and debris. An above-ground Electrical Building, requiring a footprint of about 15 ft. by 20 ft., would be required with this alternative. **Table 6-6** shows the Opinion of Probable Costs for the Pine Street CSO Storage Tank over the range of level controls evaluated. While area for tank expansion is not explicitly shown, Figure 6-1 shows that there is ample room for expansion to the north, east, and south, should expansion be deemed necessary as part of future LTCP cycles.

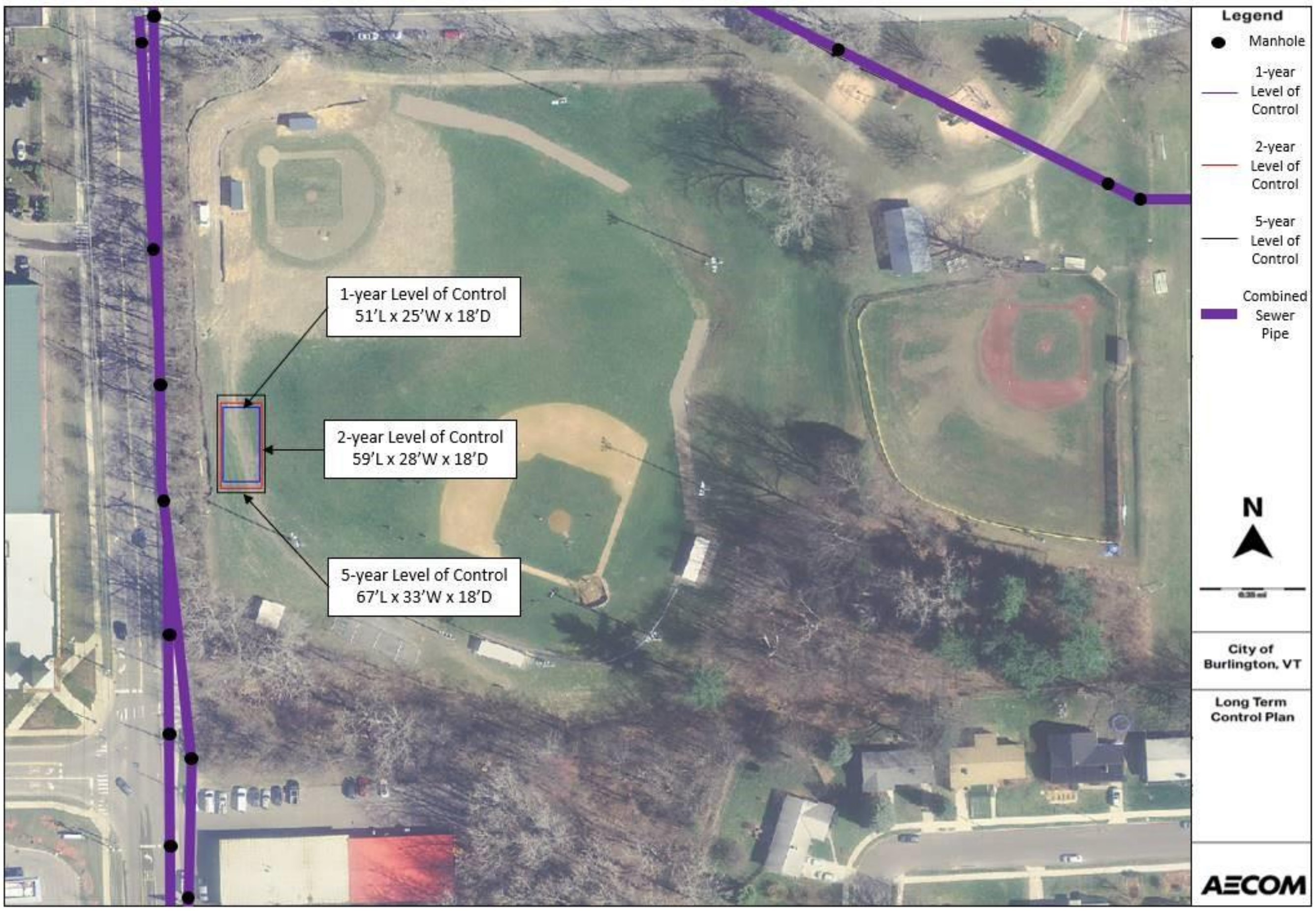

Figure 6-1. Pine Street CSO Storage Tank Layouts for 1, 2, and 5-year Level of Storms

Table 6-6. Opinion of Probable Costs for Pine Street CSO Storage Tank

Opinion of Total Project Costs by Alternative (Cost in Millions)	Design Storm		
	1-year	2-year	5-year
Pine Street CSO Storage	$2.7	$3.5	$4.7

6.6 Upsized Pipes

This alternative included evaluating the upsizing of pipes within the combined sewer system to eliminate the surcharging to the ground surface predicted by the current model due to undersized pipes. While significant additional characterization work remains before construction of this alternative is advanced, this analysis was completed in order to understand the magnitude of possible costs. This upsizing of pipes would eliminate the predicted surcharging to the ground surface during the design storms evaluated.

This alternative was evaluated to control the Pine Street and Park Street CSOs to the targeted level of control. In other words, pipe upsizing to eliminate surcharging to the ground surface in the 1-year design storm also controlled the Pine Street and Park Street CSOs in the 1-year design storm. Pipe upsizing to eliminate surcharging to the ground surface in the 2-year and 5-year design storms also controlled the Pine Street and Park Street CSOs to those levels of control. However, it should be noted for the Pine Street CSO, that this portion of the alternative resulted in larger pipes on Pine Street and the surrounding subareas, and that as the level of control was increased from a 1-year storm event to a 5-year storm event, the pipe sizes became so large as to be infeasible to implement. Specifically, for Pine Street, upsizing of pipes was not considered feasible to control the Pine Street CSO due to construction constraints with the large diameter pipes and the overall cost of implementation. Pipe upsizing at Pine Street for CSO control at the regulator structure was not considered further.

Pipe upsizing alternatives were evaluated with and without the Pine Street CSO storage tank in place. The purpose was to assess whether the storage tank would reduce the extent of pipe upsizing required. Model simulations indicated that there would be a decrease in the scope of pipe upsizing required, resulting in a decrease in total project costs when the Pine Street CSO storage tank was considered in conjunction with the pipe upsizing alternative.

Table 6-7 shows the lengths of pipes required for pipe upsizing for the 1-year, 2-year, and 5-year level of control for pipe upsizing with and without the Pine Street storage tank. The length of pipe upsizing required was based on the locations within the collection system that were predicted by the collection system model to surcharge to grade. The collection system model was used to determine the pipe size (diameter) required to eliminate surcharging to grade. Based on sound engineering practice (i.e., the pipe size downstream should be larger than the pipe size upstream) the upsizing of pipes downstream of pipes upsized upstream was also accounted for. While pipe sizing was performed using the collection system model, based on assuming replacement pipe sizes to meet the desired level of control, a spreadsheet was used to evaluate installing a larger replacement pipe versus a secondary, smaller pipe. The spreadsheet was also used for costing. In some instances, an auxiliary pipe (parallel pipe) was recommended in lieu of replacing the existing pipe with a larger pipe.

Table 6-7. Approximate Conveyance Pipe Lengths for Evaluated Alternatives

Level of Control	1-year	2-year	5-year
Pipe upsizing required without Pine Street storage tank (ft)	10,200	15,000	29,000
Pipe upsizing required with Pine Street Storage Tank (ft)	8,000	10,300	25,125

It should be noted that the locations with surcharging to the ground surface were predicted by the collection system model during specific design storms. A list of recommendations that the City should consider prior to design and construction of conveyance piping is provided below:

- Perform temporary flow metering in locations identified to have surcharging to the ground surface; based on flow metering refine the calibration of the model to confirm the volume of surcharge
- Confirm visually (camera/video) locations of potential flooding during actual storm events to the extent possible
- Review previous and on-going results of sewer system inspections and condition assessment reports to compare condition assessment needs with pipe upsizing (conveyance) needs.
  - Complete pipe upsizing in conjunction with condition assessment replacement whenever possible
  - Complete pipe upsizing on pipes that have significant I/I
- Evaluate, on a project-by-project basis, the potential use of green infrastructure, including permeable pavement, to reduce the extent of pipe upsizing required
- Coordinate with other possible City projects as noted below:
  - Champlain Parkway - the catch basins along Briggs Street between Home and Flynn will be removed/disconnected and a separate storm drain will be directed to two water quality/flow control BMPs (one just south of Englesby that will take the south-to-north-flowing runoff, and a sand filter near Lakeside Ave).
  - DPW Streets project in design on Birchcliff Parkway, which may be 2 to 5 years in the future, may redirect flooding catch basins to a separate storm drain and flow to the Pine St. barge canal separate storm outfall.
  - Shelburne Rd. – South Willard – Ledge – Locust intersection is entering construction, which may have a minor impact on flows.
  - Winooski Ave from Riverside Drive almost to the Shelburne Rd. intersection, is part of a transportation corridor study (approved by city council on March 9, 2020). This project will occur in the future along North Winooski between Riverside and North (north end) and/or Adams and St. Paul (south end).

Table 6-8 shows the Opinion of Probable Costs for the Upsized Pipes alternative over the range of level controls evaluated without the Pine Street CSO Storage Tank. The costs are related to pipe upsizing only and are unrelated to the City's maintenance and operation budget or to replacement of pipes that are structurally deficient.

Table 6-8. Opinion of Probable Costs for Upsized Pipes

Opinion of Total Project Costs by Alternative (Cost in Millions)	Design Storm		
	1-year	2-year	5-year
Pipes upsized to address surcharging to the ground surface, without Pine Street Storage Tank	$9.1	$13.4	$25.8

6.7 Full Sewer Separation

As described in Section 6.2.2, above, full sewer separation was evaluated using the collection system model assuming varying levels of inflow removal. Prior studies have shown that 70 to 90% of the inflow from a combined sewer system can cost-effectively be removed, with the actual percentage dependent on factors such as the extent of flat-roofed buildings with internal roof drain piping intertwined with sanitary piping within the building.

Costs for sewer separation were based on average costs per acre of sewer separation of contributing sewershed. Sewer separation would typically include installing new storm lines and drains and replacing sanitary sewers as necessary. Based on other New England sewer separation programs, it can be assumed that approximately 25% of the sanitary sewers would need to be replaced due to their structural condition, presence of excessive I/I, or to maintain minimum velocity. Costs for new storm drains would include new catch basins and new 12" catch basin laterals. The resulting cost estimate is shown in **Table 6-9** and is based on approximately $40,000 per acre, which is a typical cost for sewer separation in comparable New England cities. Below is the opinion of probable construction cost and contractor overhead and profit; the total project cost, with engineering, contingencies, etc, is estimated to be $74M. It should be noted that even if the cost was $20,000 per acre, full sewer separation would represent a large cost for the City of Burlington.

Table 6-9. Opinion of Probable Estimated Sewer Separation Costs

Acres Separated	Sewer Separation Cost Estimate
1,030	$41.2M

Sewer separation and private inflow removal would theoretically denote 100% CSO control. As noted in Section 6.2.2, above, even at 90% inflow removal sewer separation would still result in some sewer surcharging to the ground surface. In other words, overflows would not be completely eliminated. Further work to remove inflow would be required, such as private inflow removal. In other EPA Region 1 CSO communities where private inflow removal was pursued, it accounted for 50% of the sewer separation costs. Therefore, the Opinion of Probable Total Project Costs for CSO closure could exceed $100M.

Furthermore, EPA Region 1 communities that have committed to large-scale sewer separation projects are re-evaluating the benefits of these projects. The following are some of the issues cited by several communities for moving away from large-scale sewer separation projects:

- Sewer separation costs increasing significantly (as much as doubling) between preliminary design and construction.
- Exceeding construction schedule by months or years.
- Neighborhood/business disruption.
- Difficulty in locating and removing private inflow sources, particularly in older, downtown areas.
- Sewer separation causes clogging of the remaining combined sewer line; due to low flow conditions and lack of flushing by stormwater.
- Sewer separation results in all separate stormwater flowing into receiving waters. With combined sewers, contaminated urban stormwater in smaller events is fully captured and treated at the WWTP. In communities such as Burlington, where CSO frequency and volume is relatively low, there can be a net increase in pollutants to receiving waters as a result of sewer separation. Even if there is not a net increase, many communities have recognized that sewer separation, resulting in increased discharges of contaminated urban stormwater, at least partially offsets the water quality benefit associated with CSO reduction.

Full sewer separation is not considered as a viable alternative for the City to meet NPDES and WLA permit requirements for the reasons outlined above. Since CSOs discharge relatively infrequently, sewer separation would result in more frequent bacteria and P-loads being discharged to local waterbodies due to resultant separate stormwater discharges. Accordingly, CSO closure through sewer separation will not be further developed for this LTCP.

6.8 Partial Sewer Separation

As described in Section 6.2.2, above, partial sewer separation was evaluated using the collection system model assuming varying levels of inflow removal. Experience has shown that 90% of the inflow from a combined sewer system can cost-effectively be removed, with the actual percentage dependent on a number of factors such as the extent of flat-roofed buildings with internal roof drain piping intertwined with sanitary piping within the building.

Costs for partial sewer separation were based on average costs per acre of sewer separation. Partial sewer separation would typically include constructing new storm drains and replacing sanitary sewers as necessary. Based on other New England sewer separation programs, it can be assumed that approximately 25% of the sanitary sewers would need to be replaced due to their structural condition, presence of excessive I/I, or to maintain minimum velocity. Costs for new storm drains would include new catch basins and new 12” catch basin laterals. The resulting cost estimate is shown in **Table 6-10** and is based on the same $40,000 per acre cost used for full sewer separation. Below is the opinion of probable construction cost and contractor overhead and profit; the total project cost, with engineering, contingencies, etc, is estimated to be $33M.

Table 6-10. Opinion of Probable Estimated Partial Sewer Separation Costs

Acres Separated	Sewer Separation Cost Estimate
360	$14.4M

As noted in Section 6.2.2, above, even at 90% inflow removal of partial sewer separation would still result in some sewer surcharging to the ground surface.

As described in Section 6.6 (Full Sewer Separation), some EPA Region 1 communities are no longer pursuing large-scale sewer separation projects. Partial sewer separation was not considered as a viable alternative for the City for many of those reasons. Accordingly, partial sewer separation will not be further developed for this LTCP.

6.9 Non-Monetary Evaluation

The alternatives were assessed using non-monetary evaluation criteria. These criteria typically include a wide range of factors that should be considered when planning CSO control projects. For Burlington, the criteria selected are shown in **Table 6-11**. **Table 6-11** also shows how each alternative would rate relative to each criterion. It should be noted that this is a subjective, qualitative evaluation process but can help to show distinctions among the alternatives.

Table 6-11. Non-Monetary Criteria

Criterion	Evaluation Factors	Backwater Preventer Program	Pine Street CSO Storage Tank	Pipe Upsizing	Full Sewer Separation	Partial Sewer Separation
Regulatory Compliance	Compliance with DEC and EPA CSO policies.	Favorable	Favorable	Favorable	Favorable	Neutral

Criterion	Evaluation Factors	Backwater Preventer Program	Pine Street CSO Storage Tank	Pipe Upsizing	Full Sewer Separation	Partial Sewer Separation
Regulatory Uncertainties/ Expandability	Ability to readily expand facility to accommodate possible future stricter effluent limits (e.g., viruses, enterococcus, nitrogen, phosphorus, etc.) and/or higher levels of control (e.g., higher volumetric control and/or lower activation frequency).	Neutral	Favorable	Favorable	Neutral	Neutral
Water Quality Impacts	Degree of pollutant loading reduction to the receiving waters.	Neutral	Favorable	Favorable	Unfavorable	Unfavorable
Constructability	Unique challenges/obstacles associated with the proposed site.	Unfavorable	Neutral	Unfavorable	Unfavorable	Unfavorable
Ease of Operation	Complexity of processes including pre-event preparation and post-event clean-up; also, similarity of the proposed facilities with current facilities so that operators already have requisite experience (i.e., no learning curve).	Neutral	Neutral	Favorable	Favorable	Favorable
Public/ Community Acceptance	Impacts to the immediate and surrounding area and any unique or sensitive resources	Favorable	Neutral	Neutral to Favorable	Unfavorable to Neutral	Unfavorable to Neutral
Ease of Implementation	Available solutions to overcome possible impediments to implementation.	Unfavorable to Neutral	Favorable	Unfavorable to Neutral	Unfavorable to Neutral	Unfavorable to Neutral
Visual/ Aesthetics	Concerns with visual aesthetics and the additional cost necessary to mitigate these concerns.	Neutral	Neutral	Favorable	Favorable	Favorable
Process Reliability	Is the process dependable (e.g., number of moving	Unfavorable to Neutral	Favorable	Favorable	Neutral	Neutral

Criterion	Evaluation Factors	Backwater Preventer Program	Pine Street CSO Storage Tank	Pipe Upsizing	Full Sewer Separation	Partial Sewer Separation
	parts, dependency on human interaction, process control requirements, etc.)					

6.10 Preliminary Costing of Control Measures

The results of this preliminary cost estimating are shown in **Table 6-12**. The costs span the range of control levels (1,2, and 5-year storm events). Total project costs include the following items, as the LTCP is a planning level document:

- Opinion of Probable Construction Cost
- Contractor Overhead and Profit at 22%
- Contingency of 30% during construction
- Engineering and contingencies during design at 35%

Table 6-12. Estimated Ranges of CSO Abatement Costs Expressed as Opinion of Probable Total Project Costs in Million Dollars1 (Based on ENR=11440, dated July 2020)

Opinion of Total Project Costs by Alternative (Cost in Millions)	Design Storm		
	1-year	2-year	5-year
Backwater Preventer	$1.1	$1.4	$1.8
Additional metering/modeling program	$0.75		
Pipes upsized to address surcharging to the ground surface, without Pine Street Storage Tank	$9.1	$13.4	$25.8
Pine Street CSO storage	$2.7	$3.5	$4.7
Partial Sewer Separation	$33	$33	$33
Full Sewer Separation	$74	$74	$74

6.11 Establishment of Level of Control

This section describes the process used to assess the appropriate level of control (e.g., 1-year, 2-year, or 5-year) based on the KOTC.

Since the issuance of the 1994 EPA Policy, associated LTCP guidance documents indicate that in addition to volumetric reductions, a range of levels of control should be considered in LTCP evaluations. For the purpose of this LTCP, the 1-year, 2-year, and 5-year levels of control were considered. These levels of control, while higher than typically considered for other New England agencies and municipalities in their LTCPs, are presented for Burlington for two main reasons:

1. CSO activation frequencies are relatively low. At some outfalls, CSO activation frequency is already less than one event per year.

2. Burlington 1272 Order calls for interim CSO controls to be evaluated and designed based on a 5-year level of control. Accordingly, it is appropriate to consider this relatively high level of control in the KOTC analysis.

The preliminary cost estimates for each CSO control alternative were plotted on the Y-axis with levels of control plotted on the X-axis for the Pine Street CSO storage and pipe upsizing alternatives. Through inspection of these plots (**Figure 6-2**) it was possible to assess whether a cost-effective level of control was evident. The results are shown in **Figure 6-2.**

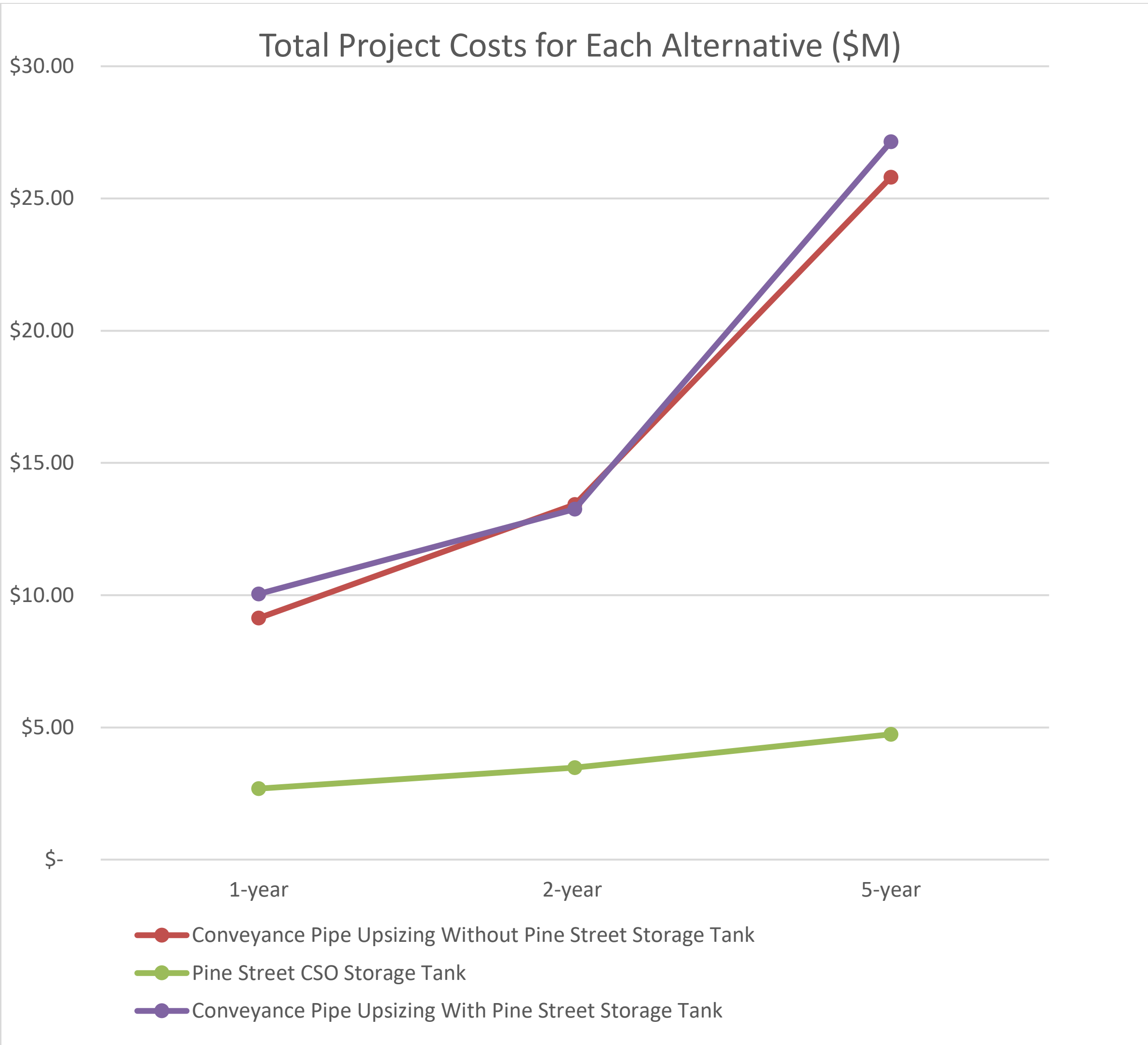

Figure 6-2. Total Project Costs for Each Alternative (excluding Full Sewer Separation)

Figure 6-2 was inspected to determine if an inflection point, or KOTC, was evident for the alternatives. The inflection point, or KOTC, denotes the point where incremental costs associated with moving to the next highest level of control would be both significantly more costly and less cost-effective than the level of control at the inflection point.

For the Pine Street CSO storage tank alternative, there appears to be a slight inflection point at the 2-year level of control, but the 5-year level of control could also be considered reasonable as the plotted line is almost straight. Additionally, the incremental cost to achieve the 5-year level of control is about $1.2 million. While this is a significant additional expenditure it would result in achieving a 5-year level of control.

For the pipe upsizing alternative, there appears to be a clear KOTC at the 2-year level of control. The cost nearly doubles from the 2-year to the 5-year level of control.

6.12 Selection of Preferred Control Alternatives

Based upon the results of both the non-monetary and monetary evaluation, preferred control alternatives are as follows:

- CSS Distributed Volume Reduction or Flow Control BMPs within the Pine Street and Park Street CSO locations based on the results provided in Appendix A and Section 5

  Backwater preventer – costs were included in the Financial Capability Analysis (Section 8) for the 2-year and 5-year levels of control. The City would commit to developing a more robust tracking program in 2022 and to conducting a feasibility study regarding implementing backwater prevention by late 2023.

- Pine Street CSO Storage Tank sized for 5-year level of control. Selection of the 5-year level of control is based on the City's input to build out the maximum reasonable storage volume rather than phasing implementation to achieve a 5-year interim level of control, and on the reasonable incremental cost between the 2-year and 5-year levels of control. Prior to final design additional metering will be completed to confirm hydraulics. A CSO storage tank can be designed to be expandable provided space is available for expansion. In the park location envisioned for the tank, expandability would be possible provided that expansion is planned for and incorporated into the design.

- Consideration of Conveyance Pipe Upsizing or Distributed Storage sized for 2-year level of control, after additional characterization. Selection of the 2-year level of control for this alternative was based on the knee-of-the-curve analysis. It is noted that this alternative also controls the Manhattan Drive / Park Street CSO to a 5-year level of control. This alternative over this LTCP period would include:

  - Perform temporary flow metering in select locations that were identified to have surcharging to the ground surface as noted by the SWMM model and by anecdotal history.
  - Re-calibrate model using additional upstream flow metering data
  - Confirm visually (camera/video) locations of potential flooding during actual storm events to the extent possible.

7.0 Description of Preferred Plan

This section of the LTCP describes the preferred control measures. The implementation of these control measures is described in Section 8 along with a phasing plan based on the results of the City's Financial Capability and Affordability Assessment (FCA), also described therein.

It should be recognized that the City implemented previous CSO projects using an adaptive approach. It allowed Burlington to alter some of the recommendations to better suit changing conditions, increased knowledge on certain technologies and other factors such as lessons learned from its completed projects, as well as completed projects from other cities with similar CSO characteristics. That approach should again be used for this plan as the City must be able to adapt to technological changes and possible changes in regulatory requirements.

It is noted that the alternatives analysis discussed in Chapter 6 focused primarily on the most active CSO in the Main WWTP system, the Pine Street CSO. As noted in **Table 5-1**, the Pine Street CSO overflowed 39 times from 2010 to 2019. The Manhattan Drive at Park Street overflowed seven times and the Manhattan Drive at North Champlain overflowed only three times during the same time period. Both Park Street and North Champlain frequencies and volumes (for similar storm events) have been reduced since they implementation of a substantial number of combined sewer stormwater reduction projects.

Based on modeling conducted in support of this LTCP, and as presented in Appendix A, the Manhattan Drive at North Champlain CSO is not predicted to overflow in the 5-year event under baseline conditions. In other words, this CSO will meet the 5-year level of control under baseline conditions. While the presence of endangered species / endangered species habitat in the vicinity of this CSO is noted, the predicted 5-year level of control was judged to be appropriate. The intent for the next 5 years is to evaluate the impact of the previous projects on the Champlain CSO and track overflow volumes, activations, and consider compliance with VT WQS.

Based on modeling conducted in support of this LTCP, and as presented in Appendix A, the Manhattan Drive at Park Street CSO is not predicted to overflow in the 2-year event. The Park Street overflow has a predicted overflow volume of only 23,000 gallons in the 5-year event. The intent for the next 5 years is to evaluate the impact of the previous projects on the Park Street CSO and track overflow volumes and activations.

Each of the preferred alternatives identified at the conclusion of Chapter 6 is described below.

7.1 CSS BMPs

This portion of the preferred plan is the inclusion of stormwater Integrated Plan BMPs as part of the planning baseline. These BMPs will be located within the combined sewer system to decrease stormwater flows upstream of untreated CSOs, particularly in the Pine Street CSO drainage area, and to decrease stormwater flows within the combined sewer system draining to the Vortex treatment unit located at the WWTP. These BMPs will consist of surface green infrastructure with enhanced underground storage and infiltration capacity where subsurface conditions warrant. A total of 65 stormwater BMPs are envisioned, managing runoff from 71 acres of impervious cover, and providing 5.4 acre-feet of storage capacity. Full implementation of the stormwater BMPs in this alternative were predicted to result in appreciable CSO volume reductions in the 1-year and 2-year LTCP design storms, and minimal volume reduction in the 5-year design storm.

7.2 Backwater Preventers

Based on the evaluations discussed in Section 6, the City would work towards the development of a backwater preventer program. The number of backwater preventers potentially required was initially estimated as part of the model evaluation and this program would be implemented by the City by developing a more robust tracking program in its new CMMS and evaluating the best options for addressing basement surcharge. The City will provide an annual update on the ongoing tracking metrics in the annual LTCP progress report. The City will evaluate options for supporting installation of backwater preventers by 2023. This program would need to identify the following:

- All potentially identified buildings located within the model as noted in Section 6.
- Field confirmation and/or flow metering to confirm manhole surcharges during storm events.
- Identify properties that already have backwater preventers installed
- Identify properties that would not be affected by manhole surcharge (e.g., homes on a hill)
- Identify properties that would not be affected by manhole surcharge due to no basement fixtures

For this LTCP, it is assumed that this backwater preventer program will be implemented for between 280-350 affected properties.

7.3 Pine Street Storage Tank

The Pine Street Storage Tank, sized for a 5-year level of control, is the preferred project for controlling the Pine Street CSO. Cost for the project is estimated at $4.7M. As currently envisioned, the 0.3 MG tank, as shown in **Figure 7-1**, will be fed by gravity when the flow reaches a set elevation. Hence, the tank will only receive excess flow during events that exceed the capacity of the existing collection system. Following each event that results in flow into the tank, and when treatment capacity is available at the WWTP, the tank will be dewatered by submersible pumps. The dewatering pumps will discharge to the collection system. In storm events larger than the 5-year design event excess flow will continue to overflow.

A summary of the tank features are as follows:

1. Dimensions:
   - Length – 67 ft.
   - Width – 33 ft.
   - Side water depth – 18 ft.

2. Dewatering:
   - Dewatering pumps

3. Post-event Cleaning:
   - Automated post-event cleaning. Tipping buckets assumed.

The type of dewatering pump type should be selected during preliminary design. A pump capable of handling grit and solids is recommended. Consideration should be given to installation of influent screens with openings sized to protect the dewatering pumps. If influent screening is not provided, selection of a pump capable of macerating solids (i.e., a chopper pump) should be considered. While there are a number of post-dewatering flushing mechanisms available, tipping buckets were assumed as the placeholder as they have proven to be more reliable than flushing gates, and they do not require confined space entry for routine maintenance. As mentioned in Chapter 6, a small above-ground building is recommended to house electrical and control systems equipment for the tank.

7.4 Consideration of Pipe Upsizing or Distributed Storage

Consideration of Conveyance Pipe Upsizing or distributed storage sized for 2-year level of control for this LTCP would be to perform temporary flow metering in select locations that were identified to have possible surcharging to the ground surface as noted by the SWMM model and by anecdotal history. This would be completed in conjunction with visual confirmation of (camera/video) locations of potential flooding during actual storm events to the extent possible. This field program would help the City determine if the surcharging in locations is due to under-sized pipes or if potential street flooding is due to stormwater and the catch basin inlet capacity. Based on the flow metering program, a recalibration of the model will be completed to have a better model to evaluate next steps.

7.4.1 Adaptive Management for Pipe Upsizing or Distributed Storage

Based on the overall needs of the collection system in terms of inflow/infiltration, structural integrity, and surcharging, it is recommended that future LTCPs would incorporate the results from the metering program and field investigations to allow the City to adopt an adaptive management approach for identified pipe upsizing or distributed storage.

The recommendation for pipe upsizing or distributed storage moving forward is adaptive in nature. In other words, these projects would be prioritized and implemented in selected areas based on multiple criteria. An overall pipe upsizing implementation strategy that considers other capital projects in the City is recommended. For example, consideration should be given to pipes that are structurally deficient when deciding on priorities for upsizing.   Those pipes that are identified as needing rehabilitation should be correlated with pipe upsizing needs. This may mean different pipes than those previously identified in the model could be upsized based on rehabilitation needs and capacity, and the other identified CSO projects have been completed. For example, a pipe needing rehabilitation downstream of a bottleneck may be upsized and the result may be that the need to upsize certain upstream pipe segments is eliminated. Following the completion of pipe upsizing or distributed storage projects flow metering should be performed to assess system response and identify next areas for pipe upsizing / other collection system improvements necessary to meet the City’s 1272 Order and infrastructure needs.

7.5 North and East CSOs

This LTCP does not focus on the CSOs in the North and East WWTP tributary areas, as these CSOs overflow infrequently. Accordingly, collection system models have not yet been developed for these CSOs. It is recommended that flow metering be performed in these areas over the next 5 years to more thoroughly understand these CSOs and the types of storms that result in CSO activations. Based on results from the metering program, the City may need to develop a collection system model to further investigate these CSOs in order to comply with its 1272 Order and the VTDEC CSO Rule 2016.

Figure 7-1. Pine Street CSO Storage Tank, 5-year Level of Control

8.0 LTCP IMPLEMENTATION

Section 6 describes the long-term plan to bring Burlington's CSO outfalls to a higher level of control. The current plan encompasses the Park Street and Pine Street CSOs and surcharging of the collection system to the ground surface.

This section of the LTCP outlines the manner in which the preferred alternatives will be implemented with respect to sequencing, financing, and implementation schedule. The key to developing the latter is the Financial Capability and Affordability Assessment (FCA) which takes into account the proposed LTCP-derived CSO abatement facilities for permit compliance.

8.1 Project Sequencing

Section 7 contains a summary of the preferred control alternatives. Based upon a number of factors, including but not limited to annual overflow activations and facility siting, the first CSO projects would be the CSS BMPs in conjunction with the design and construction of the Pine Street CSO Storage Tank.

The upsizing of existing pipes would occur concurrently with associated SSES-related work and other strategic City-wide projects such as green infrastructure installations. Pipe upsizing could be implemented as smaller projects initially, and then as larger-scale projects, using an adaptive management strategy, after the CSS Structural BMPs and the Pine Street CSO Storage Tank projects are completed.

8.2 Financing

The projects described in Section 8 would primarily be financed through the State of Vermont Clean Water State Revolving Fund (CWSRF) which is administered jointly by DEC and the Vermont Bond Bank. CWSRF allows communities to finance wastewater and stormwater infrastructure projects at a reduced interest rate as subsidized by the CWSRF fund. The debt retirement cost, principal, and interest (P&I) payments on the loans, would be paid by the users of the system.

While grants are rarer and more difficult to obtain, with a renewed national emphasis on infrastructure renewal and replacement, it is possible that some level of grant funding could be made available. As such, all sources of potential revenue should be investigated prior to the initiation of the projects contained in Section 7.

Burlington may be able to obtain funding for its CSO and stormwater projects from the Sewer Overflow and Stormwater Reuse Municipal Grants (OSG) program. In February 2021 U.S. EPA published a Federal Register Notice establishing a formula, based on data from the latest Clean Watersheds Needs Survey, population data, and precipitation, for how program funds will be distributed to the states. Information on application requirements for the program were posted to beta.SAM.gov in March 2021. States will provide grants to eligible entities, such as the City of Burlington, for projects that address CSOs, SSOs, and stormwater management. Priority for grant funding is to be given to communities that are financially distressed, have a CSO or SSO control plan in place, or for projects that have requested Clean Water State Revolving Fund (CWSRF) funding. At least 20 percent of the state's allocation must be used for green infrastructure, water and energy efficiency improvements, and other environmentally innovative types of projects. A total of $68 million has been appropriated, with $28 million appropriated in fiscal year 2020 and $40 million in fiscal year 2021.

Considering only CWSRF financing, each million dollars in borrowing will result in a P&I payment of $61,200 per year based on a 20-year bond at 2.0% interest. The resultant increase in P&I payments for the proposed projects are shown in **Table 8-1**.

Table 8-1. Annual Debt Retirement Costs for the Preferred Alternatives

Preferred Alternative	Opinion of Probable Total Project Cost ($M)	Annual P&I Payment ($T)[1]
CSS Structural BMPs	$3.9	$238.5
Pine Street CSO Storage Tank	$4.7	$287.4
Basement Surcharge Program-Backwater Preventer Retrofit Program	$1.8	$110.1
Re-metering Program	$0.75	$45.9
Pipe Upsizing or Distributed Storage	$13.4	$819.5

[1]Payments calculated based on a 20-year bond at 2.0% interest rate, in Thousands.

In addition to these annual P&I payments, there will be additional O&M costs to bear.

8.3 Financial Capability and Affordability Assessment (FCA)

The costs associated with the LTCP, along with other non-CSO wastewater system needs and stormwater program costs under the Clean Water Act (CWA), were evaluated in what is referred to as a FCA in accordance with US EPA's "Combined Sewer Overflows: Final Guidance for Financial Capability Assessment and Schedule Development" (EPA, 1997) (hereafter, the "1997 EPA Guidance"). The complete FCA, based on available data as of February 2021, is included in Appendix D and key findings are summarized in this section. The FCA allows the City to assess its ability to pay for the preferred CSO plan as well as affordability considerations for its customers using metrics established by EPA. The primary metrics include: 1) a Residential Indicator (RI), which examines the average cost of household CWA costs relative to benchmarks of the service area median household income, and 2) a Financial Capabilities Indicators (FCI) score, which reflects a permittee's debt, socioeconomic, and financial conditions compared to national benchmarks.

An overall LTCP cost estimate of $11.15 million was used for this FCA, which is comprised of the following estimated project costs:

- Combined Sewer System (CSS) Structural Best Management Practices (BMPs) – $3.9 million
- Pine Street CSO Storage Tank – $4.7 million
- Basement Surcharge Program-Backwater Preventor Retrofit Program – $1.8 million
- Re-metering Program – $0.75 million

Depending on the results of the metering and investigation work conducted by the City, conveyance pipe upsizing or distributed storage may be required with a cost of up to $13.4 million. If this cost is included, the total overall LTCP cost estimate could be up to $24.55 million. While the City believes additional investigation is needed before committing to this additional project and associated cost, its impact to the City's RI and FCA results was determined to help understand additional affordability considerations associated with this project should it be required in the future.

As part of the FCA, the results of the RI and FCI score were entered into a Financial Capability Matrix to evaluate the level of financial burden the current and future CWA program costs may impose on the service area. The City of Burlington received a "Medium Burden" score based on a RI of 1.96% and a FCI score of 2.5, which indicates notable financial burden and affordability concerns. When accounting for the potential additional cost associated with the conveyance pipe upsizing or distributed storage, the RI value increases to 2.02% and subsequently the City's score changes to a "High Burden", which indicates even greater financial burden and affordability concerns.

In January 2021, US EPA issued 2021 Financial Capability Guidance (2021 FCA Guidance) that incorporates aspects of the 1997 EPA Guidance and is intended to provide options and flexibilities to communities to meet CWA obligations (EPA, 2021). At the time this report was prepared, the 2021 FCA Guidance was pending publication in the Federal Register. The 2021 FCA Guidance includes two alternative approaches for assessing a community's financial capability to implement CWA control measures:

The existing 1997 FCA methodology with expanded consideration of costs, poverty, and impacts on the population in the service area with incomes in the lowest quintile; and development of a dynamic financial and rate model that looks at the impacts of rate increases over time on utility customers, including those with incomes in the lowest quintile.

Alternative 1 was applied in Burlington to evaluate the impact of including two new critical metrics: the Lowest Quintile Residential Indicator (LQRI) and the Poverty Indicator (PI), in addition to the previously assessed RI and FCI score that was determined following the 1997 EPA Guidance. The inclusion of these additional factors resulted in a "High Burden" designation for the City. Based on this result, according to the 2021 FCA Guidance, an implementation schedule of up to 25 years could be considered due to financial capability and affordability concerns. Considering these results, care will need to be taken to evaluate all the City's CWA requirements and to prioritize project implementation in a manner that results in achieving the greatest water quality benefit while still considering affordability. Note that the "High Burden" designation result was reached prior to the City finalizing its comprehensive Wastewater Treatment Plant Renewal Planning. That planning effort, completed in 2022, indicates a much larger ratepayer burden than previously estimated by the 2021 FCA due to the estimated costs of renewing existing Wastewater Plant infrastructure. The FCA will be revisited in advance of the next LTCP cycle to determine if the implementation schedule for remaining future LTCP items should be adjusted to reduce ratepayer burden.

The most immediate major capital CWA projects would be the initial phase of the LTCP: the CSS Structural BMPs and the Pine Street CSO storage tank. While these initial LTCP projects could be considered affordable at this time, the impact of future phases would need to be carefully evaluated while taking into consideration the other identified and yet to be identified WWTP needs of the City and the adoption of the Integrated Plan. The LTCP implementation schedule, described below, took this financial situation into consideration in its development.

8.4 Implementation Schedule

A proposed implementation schedule for the preferred CSO control projects is presented in **Table 8-2**. It is anticipated that this implementation schedule will be adjusted based on updated LTCPs and adaptive management strategies.

Table 8-2. Implementation Schedule

Action	Date	Remarks
1. CSS Structural BMPs	October 2021-March 2030	Will front load bigger impact projects
2. Pine Street CSO Storage Tank		
• Design (18 months)	June 2022–Mar. 2024	Includes additional metering downstream to fully characterize hydraulic behavior
• Bidding/Construction (24 months)	April 2024-April 2026	
• Start-up and Commissioning (3 months)	May 2026-July 2026	
3. Surcharge Prevention	20-year + time period	
A) Basement Surcharge Program-Backwater Preventer Retrofit Program	Develop better tracking by 2022 Evaluate program options by 2023	Develop program including reporting/investigation/ tracking program
B) Re-metering program to fully characterize possible surcharge areas	June 2022 -2025	Program would include field investigations of possible surcharged locations. Re-metering would also include metering in the North and East systems.
C) Pipe upsizing or distributed storage as necessary	Based on results from the re-metering program (3.B, above), update model and use an adaptive management approach to upsizing piping 2025-2040+	Need to implement Action 1 (CSS Structural BMPs) and 3B (Re-metering Program) prior to further consideration of this action item.

It is recommended that future LTCPs evaluate and consider the extent to which implemented CSO control projects are attaining water quality standards, as the City's CSO control program can be considered complete once water quality standards are met. It is also recommended that future LTCPs evaluate and consider whether protective, yet attainable wet weather water quality standards should be proposed, in conjunction with an appropriately protective and cost-effective CSO control program.

9.0 Water Quality Sampling Plan

The City of Burlington was required by the final 1272 Order, issued by the State on February 19, 2019, to submit to the Secretary a proposed two-year monitoring plan to assess the impact of the Pine Street CSO outfall (Main S/N 005) on the Pine Street Barge Canal, which is a tributary to Lake Champlain.

This plan was to include wet weather sampling at the outfall that discharges to the canal, as well as at the point of the canal where it discharges to Lake Champlain. Within three months of completing the monitoring, Burlington was to submit a final monitoring report. The goal of this sampling plan was to better characterize CSO discharges to the Pine Street Barge Canal, and ultimately evaluate whether a modified §1272 Order should be issued for future work at that specific location.

Following the development of this Long-Term Control Plan, the City and DEC have agreed to suspend development of the proposed sampling plan, at least until after installation of the Pine Street storage tank is complete. The City will revisit development of the sampling plan in the next iteration of this LTCP.