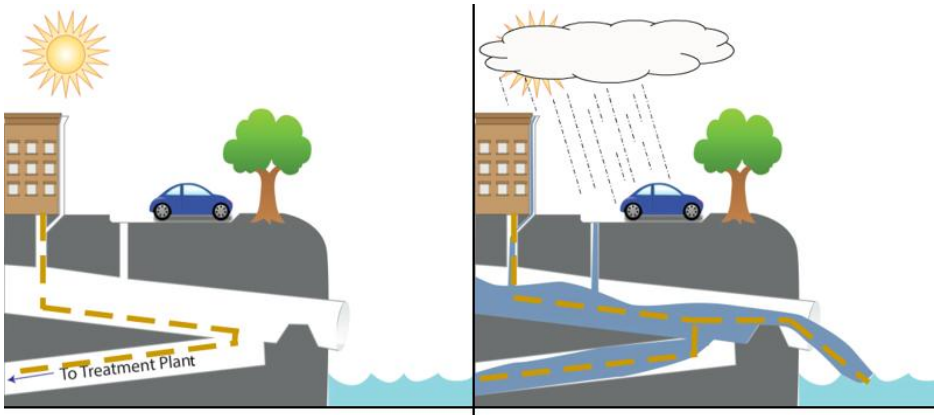
Burlington's Water Quality Journey
(Written by M.Moir, 6/11/18)

Our Water Quality Past:

Despite the fact that sewage treatment in Burlington was discussed as early as 1905, the first large scale sewage treatment plant (Main Wastewater Treatment Plant) was not built until 1953, with North Plant and Riverside Plants built in 1961 and 1963 respectively. Main Plant was reportedly the first large scale sewage treatment plant built in Vermont. Before this time, Burlington was discharging the raw waste from its inhabitants and industries directly into Burlington Bay, Englesby Brook and the Winooski River. Until the 1920s, when gas chlorination was added to the drinking water filtration plants, waterborne illness was a common issue for Burlington's citizens cited in the City's Annual Reports. (See Water Resources History https://www.burlingtonvt.gov/DPW/History;)

The Wastewater Treatment Plants (WWTPs) were all upgraded for additional flow capacity and treatment improvements in the 1970s. Meanwhile, all throughout this time and even after the 1970s upgrade, the City had a number of "sewer relief points" which we now call combined sewer overflows (CSOs). As was typical of older cities, much of Burlington had only one pipe to carry both sanitary waste and stormwater flow away from the buildings and streets. Anytime the volume in the combined sewer system exceed the capacity of the wastewater treatment plant (or in some cases the local pipe network) a mixture of stormwater and untreated sewage would discharge to waterbodies around Burlington (see below). This was to protect the WWTPs and also prevent discharges from the water backing up until people's homes, but obviously had water quality impacts. To this day, there are nearly 860 communities across the United States that still have combined sewer systems (http://bit.ly/EPAcsos).



Under normal conditions, wastewater goes directly to the wastewater treatment plant

When a large rain event occurs, stormwater joins wastewater and excess flows get discharged into nearby streams

Up until the 1990s, as Burlington grew there were on-shore sewage discharges whenever it rained to the Lake and frequent beach closures (http://bit.ly/BacT1990). Burlington voted for a $52 Million Bond[1] to upgrade the WWTPs to improve phosphorus removal, and most importantly to greatly reduce the frequency and volume of untreated CSOs. Based on measurements of what our wet weather system treats now, it is estimated that an average of 170 million gallons of untreated, undisinfected combined

[1] The $52 Million covered 3 plant upgrades, re-piping to capture existing CSOs and convey them to Main Plant and sewer separation where sewer separation was possible. Approximately $30M was spent on the Plant upgrades, with $22M spent on Main Plant upgrades alone. The remainder was spent on sewer separation.

sewer overflows were discharging to the Lake, the Winooski River and Englesby Brook on an annual basis until the upgrade in 1994.[2]

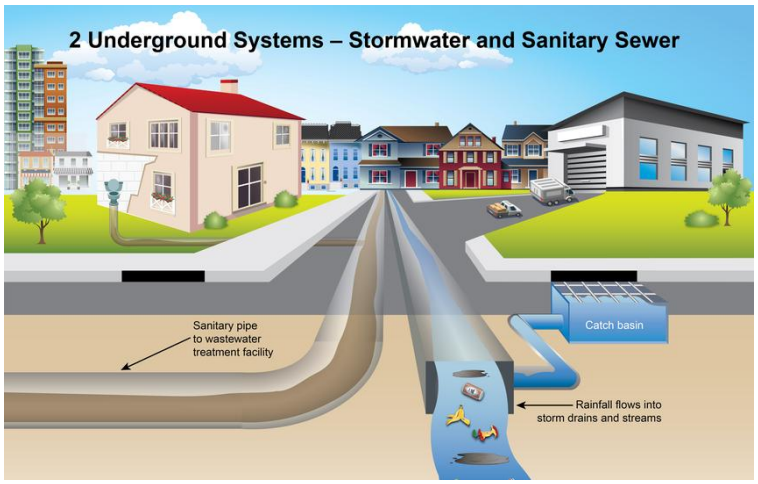
Untreated CSOs eliminated as part of upgrade:

- Bottom of Maple Street
- Marble Avenue
- Howard Street
- Bottom of College Street
- Main WWTP CSO (on-shore with no treatment or disinfection)
- Englesby Brook (various)*

Untreated CSOs still remaining after upgrade (see "Recent Improvements" for additional information on these CSOs)

- Gazo Avenue (frequency reduced due to sewer separation)
- Manhattan at Park Street
- Manhattan at North Champlain
- Colchester Avenue (discovered in 2010 during field visits of stormwater outfalls)
- Pine Street (discovered un 2015 due to mapping updates)

The strategy in the 1990s design for CSO abatement (either elimination or reduction of frequency) was two-fold. Sewer separation and CSO treatment. In areas where it was feasible, a separate storm sewer was installed so that the stormwater flow would not commingle with the sewage.



In other areas where this was more challenging, combined sewer flow was intercepted and conveyed to Burlington's Main Wastewater Treatment Plant where it could be treated (solids removal) and disinfected to mitigate its water quality impacts (the New England region's first Vortex treatment and disinfection system – see http://bit.ly/2JsaCao). Main Plant's overall average daily dry weather capacity

[2] This estimate is based on the amount of Combined Sewer Wet Weather Flow that the current Main WWTP treats in its Vortex screening and wet weather disinfection system. 2001 – 2017 time period, average gallons treated = 170 MG, with 315 MG and 270 MG treated in 2011 (Hurricane Irene Year) and 2013 (frequent intense rain storms).

was increased to 5.3 million gallons per day (MGD), and it was also designed to be able to handle and provide the full range of treatment processes (primary clarification/settling, biological treatment, secondary clarification/settling and disinfection) for smaller storm events and for the slug of waste concentrated by the Wet Weather Vortex solids separator, up to 13 million gallons. This is substantially more treatment than typical separated stormwater receives. The CSOs that remain are all related to downstream pipe capacity.

Table 1: Volume of Combined Sewer Wet Weather Flow Treated and Disinfected in the Vortex System (Does not include volume treated by WWTP)

Year	Millions of Gallons	Notes
2001	58	drought year
2002	146	
2003	140	
2004	154	
2005	170	
2006	272	
2007	124	
2008	167	
2009	161	
2010	194	
2011	315	Hurricane Irene
2012	128	
2013	270	Intense Summer Rains
2014	163	
2015	176	
2016	98	very dry
2017	167	
Average	170.7647	
Median	163	
Max	315	
Min	58	

While the storm events that are conveyed to Main Plant can present additional operational challenges, this design does greatly reduce the water quality impacts presented by our combined sewer design and keeps a great deal of untreated combined sewer volume out of our waterbodies. Sewer separation is not without its water quality impacts since we now know stormwater also contains many pollutants (including bacteria from wildlife and pet waste) and discharging stormwater to water bodies over the long term can cause chronic pollution due to nutrients, sedimentation and other pollutants (see: http://bit.ly/BacT1990). Again, without the installation of the Vortex, Burlington would either still be having massive volumes of untreated combined sewer overflows or would have had to borrow millions more to fully separate. Rough estimates for complete sewer separation (putting in a new storm pipe on streets where only combined sewers exist) would likely be well over $100 million, and that would not include the installation of stormwater treatment necessary to manage long term stormwater pollution.

Burlington does continue to pursue sewer separation where it makes sense, such as when we determine that a roof drain is connected to the combined sewer system (as roof water adds volume but is not as

dirty as pavement surfaces), but overall, recently we have been focusing on managing the stormwater in the combined sewer system at its source – that is, either reducing the inputs through allowing the stormwater to infiltrate into the ground (reconnecting it to its natural hydrologic cycle) or storing the stormwater and releasing it slowly to the system in a flow rate that the WWTP can fully treat in its full treatment train. Where possible, Burlington prefers implementation of green wet-weather infrastructure to maximize benefits to the community, since green infrastructure not only manages stormwater runoff, but also adds more green space, shading, pedestrian/biking, and property value improvements than typical "grey" infrastructure (storage tanks).

Managing untreated CSOs -- Recent History

As mentioned above, Burlington does still have a few remaining untreated CSOs, including two discovered as part of the City's outfall inspection and mapping efforts in 2010 and 2015.

- Gazo Avenue
- Manhattan at Park Street
- Manhattan at North Champlain
- Colchester Avenue (discovered in 2010 during field visits of stormwater outfalls)
- Pine Street (discovered un 2015 due to mapping updates)

Map of WWTP and CSO locations (http://bit.ly/CSOloc).

Monitoring of these untreated CSOs has advanced over the years, from the early monitoring with a "fish bobber" on a string that would have to be checked after each large storm event, to the CSO alarm technology installed around 2008 (to our knowledge well before any other CSO communities) which sends out emails and text messages letting staff know that the CSO has activated and when the CSO has ended. In 2018 we have purchased and are in the process of installing permanent flow meters in these locations so that we can quantify the amount of combined sewer overflow that occurs in each event. Currently, we have to estimate the volume based on pipe size and duration of event.

Untreated CSO and Sewage Release Reporting

CSO reporting and public notification has also advanced over the years. In accordance with policies at the time, prior to approximately 2013, untreated CSO events were only reported directly to the Department of Environmental Conservation on our monthly Wastewater Discharge reports. Between 2013 and 2016, only untreated CSOs that were considered non-compliant (i.e. occurred during a storm event that did not meet the criteria of the 2.5", 24-hour storm) were reported for publishing in the ANR public database. With the advent of the Act 86 public notification law(http://bit.ly/2t3tW30), all untreated CSOs since 2016 (regardless of the size/nature of the storm event which caused them) are reported to the ANR public notification database.

All volumes and measurements for Burlington's treated combined sewer flows are and have been reported monthly on the Wastewater Discharge report. Per Burlington Main Plant's permit, upsets of any portion of the disinfection system (whether the daily disinfection system or the wet weather) were required to be publically noticed within 12 hours via notification to "two radio stations and one print media" entities as well as to nearby towns, the DEC, Burlington Water and Champlain Water. More recently Act 86 added the public alert/notification system and also required the posting of beaches within 1 mile. These later requirements also apply to any situations such as a sewer back up (in the

sewer system, not the WWTP) that causes a discharge of sewage to nearby waters (usually nearby separate stormwater systems where those exist)

Managing CSOs -- Continued Implementation

As shown in the tables above, while the overall volume was greatly reduced, CSOs were still occurring. Though it was recognized that Burlington had made significant gains in CSO reduction and had greatly reduced the overall volume of discharge, there were still CSOs occurring.

Table 2: Estimated Annual Frequency of CSO events since 2005

Year	N. Champlain	Park	Gazo	Colchester	Pine Street	Notes
2005	3	12	1	UNK	UNK	
2006	1	11	3	UNK	UNK	
2007	3	8	2	UNK	UNK	
2008	2	13	?	UNK	UNK	
2009	4	8-9	?	UNK	UNK	
2010	0	5	?	2	UNK	Colchester Ave CSO discovered through mapping/outfall visits
2011	1	9	1	3	UNK	
2012	1	6	1	9	UNK	
2013	4	6	2	10 - 13	UNK	
2014	0	1	1	2	UNK	Colchester CSO improved through pipe cleaning downstream
2015	0	3	1	0	8	Pine Street Discovered through mapping
2016	0	1	0	0	5	
2017	0	1	1	0	8	
2018 YTD	0	0	0	0	1	Late 2017 conducted significant cleaning of downstream section
Note: Does not demonstrate decrease in duration or volume, particularly for Park and Gazo, nor adjust for the impact of wet/intense rainfall years such as 2011 and 2013.						
UNK =	Previously unidentified CSO point, no data available					
? =	data not easily available, still researching					
Range provided when unclear or multiple events on one day						

Even though some of the events listed above in Table 2 were considered compliant with the 1990 State CSO Policy (which allowed CSOs to occur if the storm event had characteristics related to the 2.5", 24-hour storm, and did not require reporting), non-compliant CSOs were still occurring. Moreover, it was recognized that while the Vortex was treating wet-weather flow appropriately, any opportunity to remove or slow down stormwater in the combined sewer system would improve our overall Water Quality portfolio. As seen in Table 2, the efforts below have made gains in our CSO reduction journey.

- 2000 - A large storage tank was installed on South Prospect in between College and Main Street to attenuate (slow down) stormwater runoff entering the combined sewer system from the redesigned Upper Main Street.
- 2008 -0.5 acre of roof top at the Gosse Court Armory (now Robert Miller Community & Recreation Center) was separated from the combined sewer system (connected to the storm sewer system)
- There are a few examples in this time period (2000s) of development projects in the combined sewer system (which, because they discharge to the combined sewer system did not need a State stormwater permit) that were required to install storage tanks to attenuate their flow, but it appears these tanks were based on minimizing the increase in stormwater, not necessarily improving stormwater runoff situations.

- In 2009, the City of Burlington was the second (after South Burlington) community in Vermont to take the important step of creating a Stormwater Utility to ensure that there would be dedicated funding for continued investments in Water Quality improvements. As part of this creation, the Wastewater ordinance was updated to include stormwater requirements and the authority to require new development and redevelopment projects to more fully manage their stormwater, regardless of state requirements. (See "How Burlington Leverages Development to Improve Water Quality"
- The most recent significant investment in mitigating wet weather runoff to the combined sewer came in 2009-2011, when the City was awarded $1.2 Million in American Recovery & Reinvestment Act funding (50% forgiveness). With this funding, the City implemented the following:
    - In the Manhattan Drive CSO sewersheds:
        - Construction of 13 subsurface infiltration systems (allowing the runoff from more than 3.5 acres of impervious surface to be absorbed and never reach the combined sewer system, approximately 220,000 gallons during a 2.5" storm)
        - Separation of a roof drain from H.O. Wheeler (0.55 acres, 36,600 gallons)
        - Frequency of CSOs at Manhattan/North Champlain has nearly ceased (with the exception of 2013, a very wet year)
        - Frequency and duration of CSOs at Manhattan/Park has greatly decreased.
    - In the Gazo CSO sewershed
        - Separation of roof drain for LC Hunt (1.6 acres, 106,400 gallons)
        - Separation of roof drain for CP Smith (0.7 acres, 46,500 gallons)
        - Frequency of CSOs and duration has stabilized at Gazo CSO.
- Since the ARRA project, Burlington Water Resources has continued annual implementation of smaller scale combined sewer reduction projects throughout the City coordinated with other investments the City is making
    - 2013 – Infiltrating bio-retention system installed in the traffic calming bumpouts on upper North Street
    - 2014- Infiltrating bio-retention system installed in the traffic calming/road cut off project on northern Hyde Street
    - 2015 – Installation of permeable pavers (stormwater friendly sidewalk) and Silva cells to support tree canopy growth as part of redevelopment of South Winooski sidewalk (between Main and King)
    - 2016 – Installation of subsurface infiltration system at Grant Street and infiltrating bio-retention bumpout coordinated with street paving and traffic calming
    - 2017 – Installation of subsurface infiltration system at bottom of King Street.
    - 2018 (mid June completion) – Installation of subsurface infiltration system at Park & Myrtle coordinated with street paving.
- With the discovery of the untreated Colchester Ave CSO in 2010 and monitoring showing very frequent discharge, a private contractor was hired in 2013/2014 to remove significant amounts of sediment downstream of the CSO to restore pipe capacity. Adjustments were also made to the internal weir in the CSO manhole structure. Since this time, Colchester Ave CSO frequencies have been reduced to zero.

- Pine Street Untreated CSO, discovered in 2015, has shown itself to also be easily activated. Recent flow metering and camera work show that there may be some more complexity to what is going on at this location, namely that some events that have been reported as CSOs may have actually been events where the storm sewer was overflowing to the combined sewer. This is our first permanently flow metered CSO point as of 2018. Additionally, significant pipe cleaning occurred downstream of the CSO in late 2017 and staff are monitoring this CSO very closely to determine what level of intervention remains. Abating this CSO is a prime focus of the City's Integrated Water Quality Planning (see below).

How Burlington Leverages Development to Improve Water Quality

As part of the update to the Chapter 26 Ordinance, projects that disturb more than 400 sq. ft. are reviewed for stormwater impacts. The Burlington Stormwater Program is currently working to more fully codify the below principles which have been applied to commercial and industrial projects in the combined sewer system in recent years, regardless of whether or not a State Stormwater Permit is needed:

- 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 our 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. Example 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.

Future Water Quality Improvement Planning

The City of Burlington, having already invested millions of dollars into water quality improvements, is still not done. There are numerous Clean Water Act regulations (Lake Champlain Phosphorus TMDL, Updated 2016 Vermont CSO Policy, Stormwater Impaired Streams TMDL) and clean water concerns (beach closures due to E. coli from stormwater or wastewater issues, beach closures due to algae blooms) that Burlington must address.

In 2014 Burlington was awarded a Technical Assistance Grant from the EPA to begin a process called Integrated Planning, which encourages communities to examine all of their obligations in one holistic planning effort vs. as individual requirements. (See: https://www.burlingtonvt.gov/DPW/Stormwater/IMSWP)

In 2016, the City applied for a planning loan and grant from the State to begin the official Integrated Planning Process. The primary scope items of this work include:

- Evaluating improvements at the WWTPs for enhancing phosphorus removal
- Evaluating improvements at Main WWTP for enhancing wet weather treatment
- Identifying and prioritizing combined sewer wet weather reduction strategies (throughout the City, including small scale infiltration and storage measures as well as large scale storage structures) that will 1) bring CSOs into compliance with the 2016 Vermont CSO Rule 2) reduce stormwater inputs to the Main Plant collection system and result in water quality improvements in wet weather related discharge.
- Identifying and prioritizing separate storm sewer pollution reduction strategies

While this work was originally anticipated to be completed at the end of 2018, early evaluations of our existing Hydraulic/ Hydrologic model revealed that additional model development and calibrations were necessary to fully optimize our water quality capital planning. Permanent flow meters were installed in early 2018 for the Main Plant collection system, and model calibration will be completed over the winter of 2018/2019.

Already, our Water Resources and Integrated Planning team has:

- developed a comprehensive map and analysis of stormwater and wet weather opportunities (http://bit.ly/RunoffOpp) to reduce stormwater pollution and reduce the frequency of combined sewer overflows and volume of stormwater reaching Main WWTP.
- developed an analysis of possible non-structural strategies for reducing runoff pollution (enhanced street sweeping, lawn waste collection programs etc.)
- evaluated our current phosphorus removal optimization efforts (indicating that we are performing excellent phosphorus removal)
- evaluated possible tertiary (enhanced) phosphorus removal technologies

The remaining work and evaluations, including prioritizing the various strategies, will occur (along with more citizen engagement) over 2018-2019, with a final deliverable anticipated in early 2020. From there, Burlington will be pursuing design work and construction funding for the first round of

implementation. Full implementation is likely to take upwards of 20 years, however the goal of Integrated Planning is to implement the projects with the greatest return on investment (most water quality improvement for the money) early on in the implementation cycle.

Meanwhile, while this planning effort is occurring, the Water Resources team continues to work with the rest of the City to coordinate implementation of wet weather improvements with other City investments, such as the street paving program (see Grant, King and Park street infiltration systems above). In particular, Burlington Water Resources has ensured that the upcoming Great Street and City Hall Park projects have significant improvements to stormwater/wet weather management: bio-retention areas that collect and allow stormwater to soak in and slow down before reaching the combined sewer system, permeable pavers that capture and infiltrate stormwater, and the construction of "enhanced soil volume systems" that will support the growth of healthy and robust tree canopies that can capture even more stormwater.

Other Wastewater Infrastructure Needs:

In parallel with planning Burlington's Water Quality future, there are existing systems that need near term investment.

Currently, Burlington Water Resources anticipates a need for $8-10 Million of investment over the next 3-4 years in existing WWTP equipment to avoid future structural or mechanical issues. Additionally, approximately $1 Million of investment is needed each year for the next 5 years in our sanitary sewer/combined sewer pipe infrastructure to ensure that those pipes can continue to safely convey sewage and combined sewer flow to the WWTPs.

Burlington Water Resources will be working in FY19 to advance these projects and plan for likely borrowing through the Clean Water State Revolving Fund Loan program.