AECOM

CSO Annual Report – January 1 to December 31, 2023:
CSO Discharge Estimates and Rainfall Analyses

April 30, 2024

Prepared for the:
Massachusetts Water Resources Authority

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Table of Contents

Figures

Tables

1. Introduction

On December 30, 2021, the Massachusetts Water Resources Authority (MWRA) submitted the Final Combined Sewer Overflow *Post Construction Monitoring Program and Performance Assessment Report ("December 2021 CSO Report")* to the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (MassDEP) documenting the results of the four-year study to measure the performance of its Long Term Control Plan (LTCP). Until the Schedule was amended in February 2022, this was the final court scheduled milestone in Boston Harbor Litigation (U*nited States v. Metro. Distr. Comm'n.*, et al, No. 85-0489 RGS). From 1987 through 2015, MWRA addressed 182 CSO-related court schedule milestones, including completing the construction of the 35 wastewater system projects that comprised the LTCP by December 2015. MWRA's obligations for CSO control under the Court Order are defined in the March 15, 2006, *Second Stipulation of the United States and the Massachusetts Water Resources Authority on Responsibility and Legal Liability for Combined Sewer Overflow Control*, as amended on April 30, 2008 (the "Second Stipulation").

This report is the third of three Annual Reports as required by the Court's compliance order extending until December 2024 the time to complete, among other things, identified projects and additional evaluation of alternatives to further reduce CSOs at the sixteen outfalls that did not meet the LTCP goals by December 31, 2021. As part of this extension, MWRA is required to provide estimates of combined sewer overflow (CSO) discharges in its service area during calendar year 2023. For more information about MWRA's federal court obligations for CSO control, including the LTCP levels of control, see Section 1.3.5 in Semiannual CSO Discharge Report No. 2, May 3, 2019.

Pursuant to the Court's Schedule Seven, as amended, MWRA reports herewith its estimates using hydraulic modeling of calendar year 2023 CSO activation frequency and total discharge volume from each of the CSO outfalls addressed in MWRA's approved LTCP. In addition, MWRA also provides estimates of CSO activation frequency and volume at each of the outfalls calculated using meter data. MWRA has also provided this information to its member communities with CSOs, including Boston Water and Sewer Commission (BWSC) and the cities of Cambridge, Chelsea, and Somerville.

For the MWRA outfalls in the variance waters (Charles River, Alewife Brook, and Upper Mystic River), the activations, volumes, and durations are provided in accordance with the reporting requirements in the Variances for the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin, issued by MassDEP in 2019 pursuant to the Massachusetts Surface Water Quality Standards at 314 CMR 4.00. The Variances authorize limited CSO discharges to the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin in conjunction with National Pollution Discharge Elimination System (NPDES) permits MA0103284, MA0101982 and MA0101974 issued to MWRA, the City of Cambridge and the City of Somerville, respectively.

This report is organized into the following chapters:

Chapter 1: Introduction

Chapter 2: Summary of 2023 Meter[1] Data and Comparison to Model Results. Presents the following:

- a summary of the model changes incorporated into the 2023 system conditions model
- a summary analysis of the 2023 rainfall in comparison to the Typical Year[2]
- a table with the metered CSO activation frequency, duration, and volume for each of the MWRA outfalls tributary to the variance waters for 2023 to meet the reporting requirement as described in section D.4.b.iv of the 2019 Alewife Brook/Upper Mystic River Variance and as described in section D.3.b.iv of the 2019 Lower Charles River/Charles Basin Variance
- the estimated CSO activations and discharge volume during calendar year 2023 using the MWRA collection system model, configured to represent system conditions in 2023
- the estimated CSO activations and discharge volumes calculated from monitoring data from MWRA and the CSO community meters

Chapter 3: Updated System Performance Assessment and Comparison with LTCP Levels of Control. Presents the following:

- a comparison of the CSO activations and discharge volumes for the Typical Year for Q4-2023 (end of 2023) system conditions to the activation frequency and volume goals established for each outfall under the Second Stipulation. Also presented are previously-modeled Typical Year CSO activations and volumes for 1992 system conditions.
- a table with the percent capture of combined sewage for the Typical Year for Q4-2022 and Q4-2023 system conditions.
- a summary of the status of further evaluations of outfalls that did not meet the LTCP goals for activation frequency and/or volume as of the end of 2023.

Appendix A: Rainfall Data Collection and Analyses January 1, 2023 to December 31, 2023. Provides a summary of the rainfall data collected for 2023, characterizes the return period for each storm, and provides a comparison to the Typical Year rainfall.

2. Summary of 2023 Model Results and Comparison to Meter Data

MWRA developed estimated CSO activation frequency and discharge volume at each CSO outfall during calendar year 2023 using the MWRA's Integrated Catchment Model (ICM) of the collection system. The model simulated each of the rainfall events in 2023 with system conditions existing at the time of each storm. In support of these simulations, MWRA updated the model to account for new information and known changes to the system, including system improvements that were completed during the year, new meter data, and results of field inspections. Each system change was incorporated into the 2023 Typical Year simulation, which represents end-of-year conditions. The model updates for 2023 are summarized in section 2.1, and the rainfall analysis is summarized in section 2.2. Section 2.3 presents the meter estimates of MWRA CSO discharges to the variance waters for 2023 and Section 2.4 presents the comparison of meter and modeled estimates of all CSO discharges for the period of January 1, 2023 to December 31, 2023.

[1] Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.

[2] Typical Year Rainfall or Typical Year: The performance objectives of MWRA's approved Long-Term CSO Control Plan include annual frequency and volume of CSO discharge at each outfall based on "Typical Year" rainfall from 40 years of rainfall records at Logan Airport, 1949-1987 plus 1992. The Typical Year was a specifically constructed rainfall series that was based primarily on a single year (1992) that was close to the 40-year average in total rainfall and distribution of rainfall events of different sizes. The rainfall series was adjusted by adding and subtracting certain storms to make the series closer to the actual averages in annual precipitation, number of storms within different ranges of depth and storm intensities. The development of the Typical Year is described in MWRA's System Master Plan Baseline Assessment, June 15, 1994. The Typical Year consists of 93 storms with a total precipitation of 46.8 inches.

2.1 Hydraulic Model Updates

Updates to MWRA's hydraulic model are necessary to refine CSO discharge estimates as improvements are made to the MWRA and community sewer systems or to adjust model parameters or configurations based on updated system information; to compare model predictions against meter data; and to update Typical Year CSO performance for comparison with the LTCP activation and volume goals. The MWRA's Q4-2023 model was updated with the changes listed in Table 2-1 below. The table provides the **Location** of the part of the model that was modified. The **Summary of Change** provides information on what was changed in the model. **Supporting Information** provides additional context on the justification/source of information about the modification that was made to the model. The Q4-2023 system conditions model was used to predict CSO discharges during the storms that occurred in the period of January 1, 2023, through December 31, 2023, and to assess the Typical Year CSO performance for current system conditions.

Table 2-1. Model Changes to reflect Q4-2023 System Conditions

Location	Summary of Change	Supporting Information
CSO Facilities	Updated the Real Time Control (RTC) to include the storm-by-storm operation of the facilities based on facility operation data provided by MWRA.	The updated RTC was added for the January 1 – December 31, 2023 period based on data provided by MWRA
Outfall BOS046, Boston Gate House #1	The model RTC was updated to reflect the actual gate conditions at Gate House #1 during the January 1, 2023 – December 31, 2023 period (the Typical Year version of the model will open the gates in accordance with BWSC's current SOP's).	BWSC opens the gates in Gate House #1 for individual storms based on operator discretion and if the storm is predicted to exceed 80% of a 2-year recurrence interval depth.
Regulator RE046-100	Regulator configuration updates	Updated the regulator RE046-100 influent pipe diameter (increased pipe diameter from 12-inches to 18-inches based on field observations).
Outfall CHE008	CHE008 Dry Weather Flow (DWF) Connection Modification Completed June 30, 2023	MWRA provided field measurements and sketches documenting the new dry weather flow configuration at regulator RE-081. Work was completed on June 30, 2023.
Prison Point Tributary Area	Stormwater Subcatchments	MWRA updated stormwater subcatchment delineations in the Back Bay based on GIS mapping. The updated delineations relocated stormwater from the Stony Brook Conduit to the Old Stony Brook Conduit.
Outfall BOS070	South Boston Sewer Separation Contract 1 Completed August 2023	BWSC completed Contract 1 of the 5-contract South Boston Sewer Separation project in August 2023.

2.2 Rainfall Analyses

Rainfall is a driving factor in the analysis of CSOs, as the occurrence of overflows within the MWRA sewer system is dependent on rainfall intensity and/or depth. The rainfall for the period of January 1, 2023, through December 31, 2023, was analyzed to help support the understanding of the modeled performance for 2023 conditions with respect to the measured activations and volumes at each outfall for the 2023 period, and with respect to the LTCP targets for performance for the Typical Year. As described in the *CSO Annual Report: Discharge Estimates and Rainfall Analyses report for Calendar Year 2021*[3], the MWRA's rainfall recurrence interval calculation methodology was updated from *Technical Paper 40* (TP-40)[4] to *Atlas-14*[5].

[3] CSO Annual Report April 29, 2022: CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2021 https://www.mwra.com/cso/pcmpa-reports/042922-annualcso.pdf

[4] TP 40: https://reduceflooding.com/wp-content/uploads/2018/09/TechnicalPaper_No40.pdf

[5] Atlas 14 Volume 10 report : https://www.weather.gov/media/owp/oh/hdsc/docs/Atlas14_Volume10.pdf

Values for Atlas 14 for Boston were extracted from NOAA's data server[6] on April 12, 2022. The Atlas 14 partial duration curves were used to assign the recurrence intervals. The smallest storm the partial duration curves address is the 1-year storm, so the partial duration intensity-duration-frequency (IDF) curves for the 3-month and 6-month frequencies were extrapolated. The storm recurrence intervals identified in the text and sections below and in Appendix A are based on the 2019 edition of Atlas 14 referenced above.

Appendix A includes the following tables that were prepared in support of this analysis:

- Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2023, to December 31, 2023
- Table A-5. Frequency of Events within Selected Ranges of Total Rainfall for January 1, 2023, through December 31, 2023
- Table A-6. Comparison of Storms Between January 1, 2023, and December 31, 2023, and Typical Year with Greater Than 2 Inches of Total Rainfall
- Table A-7. Comparison of Storms Between January 1, 2023, and December 31, 2023, and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

The findings from those tables are summarized below.

In 2023, Metropolitan Boston experienced a substantially greater volume of rain, more higher-intensity storm events, and about the same number of storms with depth greater than 2 inches compared to the Typical Year. The average depth across the collection system's rain gauges in 2023 of 55.35 inches was 8.55 inches greater than the Typical Year total rainfall depth of 46.80 inches. The exceptional number of high intensity events during the two months of July and August 2023 resulted in 2023 being classified by the National Weather Service as the second wettest summer on record in the Boston region. The impact of higher rainfall (in terms of total rainfall, as well as peak intensity) is evident in the 2023 vs. Typical Year rainfall comparisons in the rainfall summary tables, and in comparing the modeled CSO discharge estimates for 2023 versus the Typical Year. For example, in 2023, the Prison Point modeled discharge volume was 385.49 MG, compared to the Typical Year predicted Prison Point discharge of 250.39 MG, a 135.10 MG difference. Also in 2023 the total modeled CSO discharge was 713 MG compared to the Typical Year predicted total CSO discharge of 397 MG.

In terms of comparing the 2023 rainfall to the Typical Year, the following observations are noted:

- 2023 averaged 93 storm events with an average annual rainfall depth of 55.35 inches across the rain gauges assessed, compared to 93 storm events with an average annual rainfall depth of 46.80 inches for the Typical Year (Table A-5).
- In general, the breakdown of numbers of storms by rainfall depth categories for 2023 skewed towards the larger storms compared to the Typical Year. The 2023 period had eight more storms with depths greater than 0.5 inches and eight fewer storms with depths lower than 0.5 inches. (Table A-5).
- In terms of larger storms, for the four gauges shown in Table A-6 the number of storms with greater than 2 inches of total rainfall in 2023 ranged from four to eight, with 6 storm events recorded to have a depth greater than 2 inches at Ward St (BO-DI-1), 4 storms for Columbus Park (BO-DI-2) and Chelsea Creek (CH-BO-1) respectively, and 8 storms at USGS Fresh Pond. The average of those four gauges came to 6 storms with depth greater than 2 inches, which matched the count from the Typical Year. The largest storm in 2023 among those four gauges had a depth of 3.44 inches, compared to the largest storm in the Typical Year, which has a depth of 3.89 inches (Table A-6). Within the Typical Year, the storms with greater than 2 inches of rainfall were separated from each other by a period of at least one month. In 2023, two

[6] NOAA's Data server for MA: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=ma

December storms recorded at the Ward Street and USGS Fresh Pond rain gauges with greater than 2 inches of rainfall were separated by only one week (Table A-6).

- For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour ranged from ten to fifteen, compared to nine for the Typical Year. The two months of July and August are noted to include eight to ten of these intense storm events. The Typical Year had one storm with a peak intensity of 1.08 inches per hour with the remaining eight storms having peak intensities between 0.42 and 0.75 inches per hour. In 2023, the Fresh Pond gauge measured a storm with a peak intensity of 1.97 inches per hour (determined to equate to a 20-year 1-hour event) and measured a total of seven storms with peak intensities greater than 0.75 inches per hour. The other three gauges represented in Table A-7 had individual storms with peak intensities between 1.14 to 1.69 inches per hour and each measured three storms with peak intensity greater than 0.75 inches per hour. (Table A-7).

Appendix A presents the rainfall data measured during the period of January 1, 2023, through December 31, 2023. It also describes the analysis of the rainfall data used to characterize the return period of each storm event and a comparison of measured rainfall for the 2023 period to the rainfall included in the Typical Year. Further detail regarding the rainfall data collection and processing can be found in Chapter 9 of the *December 2021 CSO Report*.

2.3 Meter Estimates of CSO Discharges to Variance Waters for 2023

Under the CSO Variances for the Alewife/Upper Mystic River and the Lower Charles River/Charles Basin and 314 CMR 16.00: Notification Requirements to Promote Public Awareness of Sewage Pollution, MWRA, Cambridge, and Somerville must provide public notification of CSO activations within two hours and estimate volumes within five business days. In addition, the variances require MWRA, Cambridge and Somerville to report the annual CSO volumes and overflow durations no later than April 30th of each year. MWRA and the CSO communities have been collecting meter data used to report the CSO discharges at each of the outfalls tributary to the variance waters as part of the CSO Notification Program.

Table 2-2 below presents the estimated activation frequency, duration, and volume of CSO to the variance waters for MWRA-owned outfalls based on meter data. These data were collected by MWRA, supplemented by BWSC monitoring of regulators tributary to both outfalls MWR023 and BOS046. Refer to the Cambridge and Somerville annual reports for additional discussion regarding community metering data.

Table 2-2. 2023 MWRA Metered CSO Discharges to Variance Waters

Outfall/Waterbody	MWRA Metered[1] CSO Discharge Estimates[2]		
	Activation Frequency	Volume (MG)	Duration (hr)
Alewife Brook			
MWR003	2	1.3	2.2
Upper Mystic			
SOM007A/MWR205A	15	43.56	29.91
Lower Charles			
MWR010	0	0	0
MWR018	3	0.56	2.93
MWR019	2	0.19	1.09
MWR020	2	0.13	0.91
MWR201 (Cottage Farm) (treated)	8	61.83	19.28
MWR023	6	1.13	4.99

(1) Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.

(2) This table of metered CSO activation frequency, duration, and volume for each of the MWRA outfalls tributary to the variance waters for 2023 is provided to meet the reporting requirement as described in section D.4.b.iv of the 2019 Alewife Brook Variance and as described in section D.3.b.iv of the 2019 Charles River Variance.

2.4 Meter and Modeled Estimates of 2023 System Wide CSO Discharges

The Q4-2023 system conditions model was used to simulate the storm events from January 1, 2023, to December 31, 2023. MWRA and the CSO communities have been collecting meter data at each of the outfalls listed in the LTCP as part of the CSO Notification Program. These meter data were used to tabulate the CSO activation frequency and volume for January 1, 2023, to December 31, 2023 period.

The estimates of CSO activations and volumes based on meter data for non-MWRA-owned outfalls were made available from BWSC, Cambridge, Chelsea and Somerville. Each of the communities utilizes a professional metering firm for the installation and maintenance of flow metering equipment and the assessment of CSO activations, volumes and durations based on the meter data. MWRA has worked closely with BWSC to review the CSO activation frequency and volume reported through the CSO Notification System in order to compare how the metered activations and discharge volumes are tabulated to the methodology used in the model. The BWSC meter data presented below has been adjusted to account for a 12-hour minimum interevent time and a minimum activation volume threshold of 0.01 MG to be consistent with model output. Table 2-3 presents the adjusted CSO activation frequency and volume for BWSC outfalls and a brief description of the changes from the originally reported values. MWRA has not reviewed the meter configurations or the methodologies for computing the CSO activations and volumes for BWSC, Cambridge, Chelsea, or Somerville. Calculating CSO discharges from meter data for the purpose of developing volume estimates, whether by MWRA or by the communities, is inherently difficult and can be inaccurate given complex hydraulics, difficultly in proper calibration given normal dry conditions, etc.

Summary of 2023 Modeled and Metered CSO Discharges

Table 2-3 presents the comparison of metered estimates and modeled CSO discharges from January 1, 2023, to December 31, 2023. As indicated in Table 2-3, the model was able to replicate the storm responses for the majority of storm events in the 2023 period. However, it was not possible to match all of the modeled and metered activations for every meter and storm event. These differences may be attributed to various conditions or combination of conditions, including rainfall data quality and rainfall spatial variation, unknown transient conditions in the collection system, and the reliability of overflow metering data (see Section 4.2 of Semiannual Report No. 5 *Model Calibration and Factors Affecting Model Results*). Table 2-4 provides a list of the locations with notable differences between metered and modeled CSO discharges for the January 1, 2023 to December 31, 2023 period.

Table 2-3. Summary of 2023 Modeled and Metered CSO Discharges

Outfall	January 1, 2023 – Dec 31, 2023				
	Meter[1] [2]		Model		Meter Data Notes[7]
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	
Alewife Brook					
CAM001	0	0.00	4	0.19	Meter data provided by Cambridge.
CAM002	0	0.00	1	0.23	Meter data provided by Cambridge.
MWR003	2	1.3	9	5.32	Meter data provided by MWRA. Refer to Table 2-4 below for discussion regarding meter vs model differences.
CAM401A	20	20.51	10	3.85	Meter data provided by Cambridge. Per the City of Cambridge, due to inconsistencies in flow monitoring data, CSO statistics for CAM401A are based on both metered and model simulated data. Refer to Table 2-4 below for discussion regarding meter vs model differences.
CAM401B	7	1.00	10	2.77	Meter data provided by Cambridge
SOM001A	12	7.02	11	14.17	Meter data provided by Somerville. Refer to Table 2-4 below for discussion regarding meter vs model differences.
TOTAL	**20**	**29.83**	**11**	**26.53**	
Upper Mystic River					
SOM007A/MWR205A[3]	15	43.56	14	40.02	Meter data provided by MWRA.
Mystic/Chelsea Confluence					
MWR205 (Somerville Marginal Facility)	32	130.58	31	134.63	Meter data provided by MWRA.
BOS013	6	0.37	7	0.46	Meter data provided by BWSC. CSO Notification Program Reported: • 8 activations and 0.39 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 2 activations with less than 0.01 MG
BOS014	1	0.04	3	0.58	Meter data provided by BWSC. CSO Notification Program Reported: • 4 activations and 0.04 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 3 activations with less than 0.01 MG
BOS017	4	0.60	7	0.89	Meter data provided by BWSC.
CHE003	0	0.00	0	0.00	Meter data provided by Chelsea.
CHE004	2	0.06	3	0.47	Meter data provided by Chelsea.
CHE008	4	0.94	2	0.70	Meter data provided by Chelsea.
TOTAL	**32**	**132.59**	**31**	**137.73**	
Upper Inner Harbor					
BOS009	13	0.85	11	1.13	Meter data provided by BWSC. CSO Notification Program Reported: • 23 activations and 0.87 MG

Table 2-3. Summary of 2023 Modeled and Metered CSO Discharges, Continued

Outfall	January 1, 2023 – Dec 31, 2023				
	Meter[1] [2]		Model		Meter Data Notes[7]
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	
					Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 8 activations with less than 0.01 MG • Removed 2 activations with less than 12-hour interevent time
BOS010	2	0.03	3	0.45	Meter data provided by BWSC. CSO Notification Program Reported: • 3 activations and 0.04 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 1 activation with less than 0.01 MG
BOS012	1	0.03	2	0.04	Meter data provided by BWSC. CSO Notification Program Reported: • 2 activations and 0.04 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 1 activation with less than 0.01 MG
BOS019	4	1.16	3	0.64	Meter data provided by BWSC. CSO Notification Program Reported: • 5 activations and 1.16 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 1 activation with less than 12-hour interevent time
BOS057	2	6.40	4	2.96	Meter data provided by BWSC.
BOS060	3	1.05	3	2.56	Meter data provided by BWSC.
MWR203 (Prison Point)	16	354.28	18	385.49	Meter data provided by MWRA.
TOTAL	**16**	**363.80**	**18**	**393.27**	
Lower Inner Harbor					
BOS003	20	6.77	5	3.17	Meter data provided by BWSC. Refer to Table 2-4 below for discussion regarding meter vs model differences.
BOS004	1	0.05	4	0.46	Meter data provided by BWSC.
BOS005	Closed	Closed	Closed	Closed	
TOTAL	**20**	**6.82**	**5**	**3.63**	
Fort Point Channel					
BOS062	10	2.99	4	3.83	Meter data provided by BWSC.
BOS064	3	0.20	4	0.49	Meter data provided by BWSC. CSO Notification Program Reported: • 6 activations and 0.21 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 2 activations with less than 0.01 MG

Table 2-3. Summary of 2023 Modeled and Metered CSO Discharges, Continued

Outfall	January 1, 2023 – Dec 31, 2023				
	Meter[1] [2]		Model		Meter Data Notes[7]
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	
					• Removed 1 activation with less than a 12-hour interevent time
BOS065	3	0.06	3	1.98	Meter data provided by BWSC. CSO Notification Program Reported: • 4 activations and 0.07 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 1 activation with less than 12-hour interevent time
BOS068	1	0.38	0	0.00	Meter data provided by BWSC.
BOS070/DBC	10	11.62	5	13.38	Meter data provided by BWSC. CSO Notification Program Reported: • 18 activations and 82.57 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Internal regulators and the Union Park Pump Station removed from the BOS070/DBC calculation
MWR215 (Union Park)	11	42.23	11	50.76	Meter data provided by MWRA.
BOS070/RCC	1	0.85	4	1.33	Meter data provided by BWSC.
BOS073	1	0.12	0	0.00	Meter data provided by BWSC.
TOTAL	**11**	**58.45**	**11**	**71.77**	
Reserved Channel					
BOS076	2	0.32	3	1.84	Meter data provided by BWSC.
BOS078	4	0.42	1	0.08	Meter data provided by BWSC.
BOS079	1	0.03	0	0.00	Meter data provided by BWSC.
BOS080	1	0.10	2	0.12	Meter data provided by BWSC. CSO Notification Program Reported: • 2 activations and 0.11 MG Adjusted meter data to be consistent with modeled reporting of activation and volume[8]: • Removed 1 activation with less than 0.01 MG (0.009 MG)
TOTAL	**4**	**0.87**	**3**	**2.04**	
Upper Charles					
CAM005	9	0.87	12	4.10	Meter data provided by Cambridge.
CAM007	2	1.25	7	8.57	Meter data provided by Cambridge.
TOTAL	**9**	**2.12**	**12**	**12.67**	
Lower Charles					
CAM017	4	5.36	2	0.87	Per the City of Cambridge, due to non-operation of CAM017 meters in the period 8/3/23-9/11/23, model simulation data was used for that period.
MWR010	0	0.00	0	0.00	Meter data provided by MWRA.
MWR018	3	0.56	3	2.33	Meter data provided by MWRA.

Table 2-3. Summary of 2023 Modeled and Metered CSO Discharges, Continued

Outfall	January 1, 2023 – Dec 31, 2023				
	Meter[1] [2]		Model		Meter Data Notes[7]
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	
MWR019	2	0.19	3	1.47	Meter data provided by MWRA.
MWR020	2	0.13	3	4.15	Meter data provided by MWRA.
MWR201 (Cottage Farm)	8	61.83	7	50.92	Meter data provided by MWRA. Refer to Table 2-4 below for discussion regarding meter vs model differences.
MWR023[4]	6	1.13	3	0.63	Meter data provided by MWRA.
TOTAL	**8**	**69.20**	**7**	**60.37**	
Back Bay Fens					
BOS046 (BGH#1)[4]	2	2.34	1	0.44	Volume was computed from MWRA data on 046 regulators and activation frequency from BWSC.
BOS046 (BGH#2)[5][6]	2	N/A[6]	1	4.25	Activation frequency provided by BWSC.
TOTAL	**2**		**1**	**4.69**	
TOTAL UNTREATED		**77.10**		**90.90**	
TOTAL TREATED		**588.92**		**621.80**	
GRAND TOTAL		**666.02**		**712.70**	

(1) Metered data are estimates of outfall discharge calculated using data from sensors, taking into account physical configurations and constraints.
(2) Meter volume reported is calculated from MWRA, Cambridge, Somerville, Chelsea, and BWSC community meters.
(3) Outfall SOM007A/MWR205A is a side-outlet relief off of outfall MWR205, downstream of the Somerville Marginal Facility. This outfall can activate and discharge treated flow during storm events when high tides restrict the discharge from outfall MWR205. The SOM007A/MWR205A volume includes a fraction of the flow treated at Somerville Marginal facility plus separate stormwater that enters the Somerville Marginal Conduit (outfall) downstream of the facility. The volume presented for outfall SOM007A/MWR205A is therefore not included in the "Total Treated" volume at the bottom of the table because the treated CSO fraction of the volume at SOM007A/MWR205A is counted in the volume presented for MWR205.
(4) BOS046 (BGH#1 [Boston Gatehouse #1]) is primarily a stormwater discharge but may discharge CSO if the upstream regulators overflow. The upstream regulators are monitored by BWSC. The gatehouse is normally closed but may be opened for flood mitigation. Flow can discharge at BGH#1 if the gate is opened or if water overtops the closed gate. Based on model tracer studies, when a discharge occurs during model simulations at BOS046 and one or more of the upstream regulators in the Stony Brook system are predicted to activate, it was estimated that 25% of the CSO from the upstream regulators discharges at the MWR023 outfall (Charles River) and 75% discharges through BGH#1 at BOS046 (Back Bay Fens).
(5) BOS046 (BGH#2 [Boston Gatehouse #2]) includes a permanently-closed gate which may also be overtopped in larger storm events; this gate was added to the model after the Q1-2021 system conditions model run per new field information.
(6) N/A = Not available: Depth measurement only at this location.
(7) Indicates the source of the meter data.
(8) MWRA has worked closely with BWSC to review the CSO activation frequency and volume reported through the CSO Notification System in order to compare how the metered activations and discharge volumes are tabulated to the methodology used in the model. The BWSC meter data presented has been adjusted to account for a 12-hour minimum interevent time and a minimum activation volume threshold of 0.01 MG to be consistent with model output.

Table 2-4. Notable Differences Between Metered and Modeled CSO Discharges, January 1, 2023 to December 31, 2023

Location	Meter	Model	Comment
CAM401A	20 discharges 20.51 MG	10 discharges 3.85 MG	• MWRA and the city of Cambridge are working together to further understand and resolve observed differences. Flow meters and level sensors have been installed in the CAM401A system to evaluate possible explanations which include meter configuration/reliability, modeled hydrology and hydraulic accuracy, and returning sediment deposition in the downstream system.
MWR003	2 discharges 1.3 MG	9 discharges 5.32 MG	• Based on level data at RE031 and RE032, the model slightly overpredicted the HGL in the Alewife Brook Branch Sewer (ABBS) and Alewife Brook Conduit (ABC) during the 2023 period. The conservative HGL in the model results in higher activation frequency and volume at MWR003. However, 5 of the modeled activations were less than 0.2 MG. Additionally, the model predicted that the gate would have lowered during the August 8th, 2023 storm event yet the meter indicated that the gate did not drop. During this storm event, USGS Fresh Pond rain gauge recorded a 20-year return interval for the 1-hour duration, well exceeding a Typical Year sized storm event. Based on the rain gauge information available, this storm event possessed high spatial variation. As noted in Section 2.2 above, the USGS Fresh Pond gauge also had a total of seven storms with peak intensity greater than 0.75 inches per hour, while the Columbus Park, Ward Street and Chelsea Creek gauges only had three, indicating spatial variation in some of the other larger storms as well.
BOS003	20 discharges 6.67 MG	5 discharges 3.17 MG	• The model tends to under-predict the overflow frequency and volume at BOS003. MWRA continues to work with BWSC to check that the model is accurately representing constructed field conditions. A level sensor is being added to a manhole near this location to provide additional information.
SOM001A	12 discharges 7.02 MG	11 discharges 14.17 MG	• In general, the model tends to slightly overpredict the overflow volume at SOM001A on a storm-by-storm basis compared to the metered volume. However, for the 7/29/23 and 8/8/23 storm events, the model over predicted the meter by 3.15 MG and 1.34 MG respectively. Each of these storm events produced higher 1-hour and 24-hour intensities than are seen in the Typical Year and possessed high spatial variation (see also the discussion of rainfall variability for MWR003 above).
MWR018	3 discharges 0.56 MG	3 discharges 2.33 MG	• Historically, the water level in the BMC was overpredicted by the model during large storm events. Model versus meter comparisons from recent years have demonstrated that the model does a much better job of predicting the level in the BMC and CSO volumes at MWR018, MWR019 and MWR020 during less-extreme storm events.
MWR019	2 discharges 0.19 MG	3 discharges 1.47 MG	
MWR020	2 discharges 0.13 MG	3 discharges 4.15 MG	
MWR201 (Cottage Farm)	8 discharges 61.83 MG	7 discharges 50.92 MG	• In general, the model tends to slightly overpredict the overflow volume at MWR201 on a storm-by-storm basis compared to the metered volume. However, for the 3/14/23 and 12/17/23 storm events, the model underpredicted the meter by 9.06 MG and 5.86 MG respectively. During the 3/14/23 storm event, the model predicted that the MWR201 influent gates opened and closed twice while the plant operations data reported that the gates were open for longer and did not close for a portion of the storm, resulting in a higher discharge volume. The 12/17/23 storm event had a total depth greater than two inches and a peak intensity greater than 0.4 in/hr at multiple rain gauges tributary to MWR201. However, spatial variation and the potential for frozen ground conditions in December could be driving the meter and model differences for this storm event.
MWR023	6 discharges 1.13 MG	3 discharges 0.63 MG	• Meter data provided by MWRA indicates that two activations had durations less than 15 minutes and discharge volumes less than 0.01 MG.

3. Updated System Performance Assessment and Comparison with LTCP Levels of Control

3.1 Performance Assessment

This section summarizes the system performance under Typical Year rainfall based on the Q4-2023 system conditions model, representing conditions as of the end of 2023. As set forth in further detail below, with the completion of the Post Construction Monitoring Program and Performance Assessment and additional work completed at certain outfalls MWRA has demonstrated that 73 of the 86 outfalls listed in Exhibit B of the Second Stipulation have achieved or materially achieved LTCP goals as of the end of 2023, which is one more than reported at the end of 2022. MWRA continues to focus on the 13 (formerly 16) outfalls not yet forecasted to meet LTCP goals. Of the remaining 13 outfalls, seven have projects to meet or materially meet the LTCP goals that are in design or construction and are expected to be completed by the end of 2024 with the exception of two outfalls downstream of the Somerville Marginal CSO Facility where the project is estimated to be completed in 2025 due to construction constraints, given the new chamber installation in a heavily traveled roadway. The six outfalls that remain are particularly challenging and no clear alternatives commensurate to the minimal receiving water quality benefits have been identified.

Hydraulic modeling has historically served as the basis for evaluating performance of the MWRA's CSO system. Table 3-1 presents a full accounting of the status and Typical Year overflow activity as of Q4-2023 System Conditions for all discharge locations addressed by MWRA's CSO planning efforts and projects since MWRA assumed responsibility for system-wide CSO control in the mid-1980s. Table 3-1 also presents previously-modeled CSO discharge levels for 1992 System Conditions for the Typical Year, and the LTCP goals for Typical Year levels of control as defined in the Second Stipulation. In Table 3-1, Q4-2023 System Conditions activations or volumes that are greater than (i.e. do not achieve) the LTCP goals are shaded in grey, and each CSO outfall is color-coded based on status of attainment with the LTCP goals, as follows:

- Dark blue indicates outfalls meet or materially meets the LTCP goals under the Q4-2023 System Conditions.
- Light blue indicates outfalls that have projects in design or construction forecast to meet or materially meet the LTCP goals after December 2023.
- No color indicates outfalls that are particularly challenging with no clear plan yet established to achieve the LTCP goals.

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2023 Conditions and LTCP Goals

Outfall currently achieves LTCP activation and volume goals.	Outfall is forecast to achieve LTCP goals after Dec 2023
Outfall investigations continue for forecast of LTCP attainment potential.	Model prediction is greater than LTCP value.

OUTFALL	1992 SYSTEM CONDITIONS [1]		Q4-2023 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN [2]	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
ALEWIFE BROOK						
CAM001	5	0.15	1	0.02	5	0.19
CAM002	11	2.73	0	0.00	4	0.69
MWR003	6	0.67	3	0.61	5	0.98
CAM004	20	8.19	Closed	N/A	Closed	N/A
CAM400	13	0.93	Closed	N/A	Closed	N/A
CAM401A	18	2.12	5	0.66	5	1.61
CAM401B			4	0.50	7	2.15
SOM001A	10	11.93	8	4.47	3	1.67
SOM001	0	0.00	Closed	N/A	Closed	N/A
SOM002	0	0.00	Closed	N/A	N/I[3]	N/I[3]
SOM002A	0	0.00	Closed	N/A	Closed	N/A
SOM003	0	0.00	Closed	N/A	Closed	N/A
SOM004	5	0.09	Closed	N/A	Closed	N/A
TOTAL		**26.81**		**6.26**		**7.29**
UPPER MYSTIC RIVER						
SOM007A/MWR205A[7] [8]	9	7.61	5	4.50	3	3.48
SOM006	0	0.00	Closed	N/A	N/I[3]	N/I[3]
SOM007	3	0.06	Closed	N/A	Closed	N/A
TOTAL		**7.67**		**4.50**		**3.48**
MYSTIC/CHELSEA CONFLUENCE						
MWR205[7] (Somerville-Marginal CSO Facility)	33	120.37	30	100.41	39	60.58
BOS013*	36	4.40	8	0.27	4	0.54
BOS014	20	4.91	0	0.00	0	0.00
BOS015	76	2.76	Closed	N/A	Closed	N/A
BOS017[7]	49	7.16	6	0.34	1	0.02
CHE002	49	2.51	Closed	N/A	4	0.22
CHE003	39	3.39	0	0.00	3	0.04
CHE004	44	18.11	2	0.08	3	0.32
CHE008	35	22.35	0	0.00	0	0.00
TOTAL		**185.96**		**101.10**		**61.72**
UPPER INNER HARBOR						
BOS009[7]	34	3.60	10	0.73	5	0.59
BOS010	48	11.83	1	0.06	4	0.72
BOS012	41	7.90	0	0.00	5	0.72
BOS019	107	4.48	1	0.07	2	0.58
BOS050	No Data		Closed	N/A	Closed	N/A
BOS052	0	0.00	Closed	N/A	Closed	N/A
BOS057*	33	14.71	2	0.58	1	0.43
BOS058	17	0.29	Closed	N/A	Closed	N/A
BOS060*	64	2.90	2	0.38	0	0.00
MWR203 (Prison Point Facility)*	28	261.85	17	250.39	17	243.00
TOTAL		**307.56**		**252.21**		**246.04**

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2023 Conditions and LTCP Goals, Continued

OUTFALL	1992 SYSTEM CONDITIONS [1]		Q4-2023 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN [2]	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
LOWER INNER HARBOR						
BOS003	28	18.09	4	1.15	4	2.87
BOS004	34	3.43	4	0.29	5	1.84
BOS005	4	10.23	Closed	Closed	1	0.01
BOS006	17	1.21	Closed	N/A	4	0.24
BOS007	34	3.93	Closed	N/A	6	1.05
TOTAL		**36.89**		**1.44**		**6.01**
CONSTITUTION BEACH						
MWR207	24	4.00	Closed	N/A	Closed	N/A
TOTAL		4.00		N/A		N/A
FORT POINT CHANNEL						
BOS062[7]	8	4.15	5	1.23	1	0.01
BOS064	14	0.99	0	0.00	0	0.00
BOS065[7]	11	3.08	1	0.41	1	0.06
BOS068	4	0.62	0	0.00	0	0.00
BOS070/DBC[7]	4	281.62	6	2.59	3	2.19
MWR215 (Union Park Facility)			9	21.65	17	71.37
BOS070/RCC			0	0.00	2	0.26
BOS072	21	3.62	Closed	N/A	0	0.00
BOS073	23	4.73	0	0.00	0	0.00
TOTAL		**298.81**		**25.88**		**73.89**
RESERVED CHANNEL						
BOS076	65	65.94	1	0.09	3	0.91
BOS078	41	14.84	0	0.00	3	0.28
BOS079	18	2.10	0	0.00	1	0.04
BOS080	33	6.21	0	0.00	3	0.25
TOTAL		**89.09**		**0.09**		**1.48**
NORTHERN DORCHESTER BAY						
BOS081	13	0.32	0 / 25 year[9]	N/A	0 / 25 year[9]	N/A
BOS082	28	3.75	0 / 25 year[9]	N/A	0 / 25 year[9]	N/A
BOS083	14	1.05	Closed	N/A	0 / 25 year[9]	N/A
BOS084	15	3.22	0 / 25 year[9]	N/A	0 / 25 year[9]	N/A
BOS085	12	1.31	0 / 25 year[9]	N/A	0 / 25 year[9]	N/A
BOS086	80	3.31	0 / 25 year[9]	N/A	0 / 25 year[9]	N/A
BOS087	9	1.27	Closed	N/A	0 / 25 year[9]	N/A
TOTAL		**14.23**		**0.00**		**0.00**
SOUTHERN DORCHESTER BAY						
BOS088	0	0.00	Closed	N/A	Closed	N/A
BOS089 (Fox Pt.)	31	87.11	Closed	N/A	Closed	N/A
BOS090 (Commercial Pt.)	19	10.16	Closed	N/A	Closed	N/A
TOTAL		**97.27**		**0.00**		**0.00**
UPPER CHARLES						
BOS032	4	3.17	Closed	N/A	Closed	N/A
BOS033	7	0.26	Closed	N/A	Closed	N/A
CAM005	6	41.56	8	0.75	3	0.84
CAM007*	1	0.81	2	0.48	1	0.03
CAM009[4]	19	0.19	Closed	N/A	2	0.01
CAM011[4]	1	0.07	Closed	N/A	0	0.00
TOTAL		**46.06**		**1.23**		**0.88**

Table 3-1. Typical Year Performance: Baseline 1992, Q4-2023 Conditions and LTCP Goals, Continued

OUTFALL	1992 SYSTEM CONDITIONS [1]		Q4-2023 SYSTEM CONDITIONS		LONG TERM CONTROL PLAN [2]	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
LOWER CHARLES						
BOS028	4	0.02	Closed	N/A	Closed	N/A
BOS042	0	0.00	Closed	N/A	Closed	N/A
BOS049	1	0.01	Closed	N/A	Closed	N/A
CAM017	6	4.72	0	0.00	1	0.45
MWR010	16	0.08	0	0.00	0	0.00
MWR018	2	3.18	2	0.44	0	0.00
MWR019	2	1.32	2	0.17	0	0.00
MWR020	2	0.64	2	0.09	0	0.00
MWR021	2	0.50	Closed	N/A	Closed	N/A
MWR022	2	0.43	Closed	N/A	Closed	N/A
MWR201 (Cottage Farm Facility)	18	214.10	2	7.73	2	6.30
MWR023*[5]	39	114.60	2	0.19	2	0.13
SOM010	18	3.38	Closed	N/A	Closed	N/A
TOTAL		**342.98**		**8.62**		**6.88**
NEPONSET RIVER						
BOS093	72	1.61	Closed	N/A	Closed	N/A
BOS095	11	5.37	Closed	N/A	Closed	N/A
TOTAL		**6.98**		**0.00**		**0.00**
BACK BAY FENS						
BOS046 – Boston GH1[5]	2	5.25	2	0.22	2	5.38
BOS046 – Boston GH2[6]			0	0.00		
TOTAL		**5.25**		**0.22**		**5.38**
Total Treated		**698**		**380**		**381**
Total Untreated		**759**		**17**		**23**
GRAND TOTAL		**1457**		**397**		**404**

Notes:

* Model predicted activation and volume for Q4-2023 System Conditions has decreased since 1992 levels to a level believed to achieve anticipated water quality improvements. The inability to precisely meet activation and/or volume goals at these locations is considered immaterial.

(1) 1992 System Conditions include completion of Deer Island Fast-Track Improvements, upgrades to headworks, and new Caruso and DeLauri pumping stations. Estimated 1988 Grand Total Typical Year CSO volume (prior to these improvements) was 3,300 million gallons.

(2) From Exhibit B to Second Stipulation of the United States and the Massachusetts Water Resources Authority on Responsibility and Legal Liability for Combined Sewer Overflows, as amended by the Federal District Court on May 7, 2008 (the "Second CSO Stipulation").

(3) N/I: Outfall is not included in Exhibit B to the Second CSO Stipulation.

(4) Tentatively closed pending additional hydraulic evaluation by City of Cambridge.

(5) BOS046 (Gatehouse 1) is primarily a stormwater discharge but may contain CSO if the upstream regulators overflow. The upstream regulators are monitored directly. Gatehouse 1 is normally closed but may be opened for flood mitigation. Flow can discharge at the Gatehouse if either the gate is opened or if water overtops the gate. Based on model tracer studies, when a discharge occurs it is estimated that 25% of the CSO from the upstream regulators discharges at outfall MWR023 (Charles River) and 75% discharges at outfall BOS046 (Back Bay Fens).

(6) BOS046 (Gatehouse 2) includes a permanently-closed gate which may also be overtopped in extreme wet weather; this gate was added to the model after the Q1-2021 system conditions model run per new field information. Boston GH2 was not included in the 1992 Conditions model, and was not predicted to activate in the Typical Year for the Q42023 Conditions model.

(7) See Table 3-3 below for outfalls with ongoing project forecast to attain LTCP goals.

(8) The SOM007A/MWR205A volume includes a fraction of the flow treated at Somerville Marginal facility plus separate stormwater that enters the Somerville Marginal Conduit (outfall) downstream of the facility. The volume presented for SOM007A/MWR205A is therefore not included in the “Total Treated” volume at the bottom of the table because the treated CSO fraction of the volume at SOM007A/MWR205A is counted in the volume presented for MWR205.

(9) The outfalls do not discharge in a 25-year storm as defined at the time the LTCP was approved.

As indicated in Table 3-1, of the 45 outfalls that remain active (i.e. are not physically closed or associated with the North Dorchester Bay CSO Storage Tunnel), 32 outfalls meet or materially meet the LTCP goals as of Q4-2023 conditions[7]. As of the 2021 annual report, 16 outfalls were not predicted to meet LTCP goals. In 2022, projects were completed to allow the predicted discharge at BOS014 and BOS003 to meet LTCP goals. As of the end of 2023, a project has been completed at CHE008 resulting in predicted discharges meeting LTCP goals for that outfall. Of the remaining 13 outfalls, seven have projects predicted to meet or materially meet the LTCP goals that are in design or construction and are expected to be completed by the end of 2024 with the exception of the Somerville Marginal CSO Facility project which is estimated to be completed in 2025. MWRA has investigated alternatives to further reduce CSOs at the six outfalls that remain closer towards their individual LTCP goals. Additional detail is provided below in Section 3.3. However, as detailed in Section 3.3, with the exception of CAM005, further projects are not recommended to meet the LTCP goals, given the marginal improvements in water quality resulting from further CSO reductions and the expected development of a new CSO control plan, as required under the CSO variance for the Charles River, Alewife Brook and Upper Mystic River. **The total treated and untreated CSO volume of 397 MG is below the LTCP goal of 404 MG and, as noted, above a number of projects are underway that will further reduce the total volume by the end of 2024, with continued reductions into the near future**.

3.1.1 Percent Capture of Combined Sewage

Table 3-2 presents the computed percent capture of combined sewage for the Typical Year for Q4-2023 system conditions, and also presents for comparison the percent capture for the Q4-2022 system conditions that had previously been presented in the 2022 CSO Annual Report. The percent capture was computed by dividing the tributary wet weather volume conveyed to Deer Island and the MWRA's CSO treatment facilities by the total tributary wet weather volume. The total tributary wet weather volume, in turn, was defined as the volume of runoff collected into the combined sewer system, plus sanitary/base flow from the combined sewer areas that occurred for the duration of rain events. Wet weather volume from areas where complete sewer separation has been implemented (such as Dorchester, Constitution Beach, and the former CAM004 area) was not counted, nor was wet weather flow from separate systems outside of the CSO communities of Boston, Cambridge, Somerville and Chelsea. Wet weather volume from partially-separated areas (i.e. areas where active CSOs remain) was counted.

The differences between the Q4-2022 and Q4-2023 percent capture values can be attributed to the model updates summarized above in Table 2-1. The changes included the stormwater subcatchment updates tributary to Prison Point, which slightly increased the treated discharge volume; the South Boston Sewer Separation project, which reduced the wet weather volume captured at Deer Island; and the dry weather flow connection modifications at CHE008, which allowed more flow at CHE008 to enter the interceptor system, reducing the number and volume of CSOs at that location. In Table 3-2 the percent capture for Q4-2022 and Q4-2023 is presented in terms of the wet weather volume tributary to Deer Island, the wet weather volume tributary to Deer Island, Cottage Farm, Prison Point and Union Park, and the wet weather volume at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal. Table 3-2 shows that the percent capture at Deer Island for the Q4-2023 conditions is 93.4% which is down slightly from 93.5% (Q4-2022) due to the slight increase in discharge at Prison Point. The percent capture at Deer Island, Cottage Farm, Prison Point, and Union Park increased from 98.0% to 98.1% due to the slight increase in treated discharge at Prison Point, and the percent capture at Deer Island, Cottage Farm, Prison Point, Union Park, and Somerville Marginal remained at 99.7%.

[7] Outfall BOS005 was closed as part of the East Boston Contract 2 Sewer Separation Work on September 6, 2022 but had been meeting the LTCP goal prior to closure.

Table 3-2. Percent Capture of Combined Sewage for the Typical Year for Q4-2023 System Conditions Compared to Q4-2022 System Conditions

	Typical Year Q4-2022	Typical Year Q4-2023	Notes
(A) Total Tributary Wet Weather Volume[1] (MG)	6,073	6,057	Reduction due to South Boston sewer separation (SBSS)
(B) Total volume discharged at untreated CSOs or at CSO Facilities (MG)	396	397	Slight increase at Prison Point attributed to changes in stormwater subcatchments in the Back Bay
(C) = (A - B) Total Wet Weather Volume Captured at Deer Island (MG)	5,677	5,660	Reduction due to SBSS
(D) = (C)/(A) Percent Capture at Deer Island	93.5%	93.4%	Slight increase in treated discharge (Prison Point)
(E) Total volume discharged at untreated CSOs or at Somerville Marginal Screening/Disinfection Facility (MG)	122	117	Decrease in untreated discharge because of SBSS and CHE008
(F) = (A - E) Total Wet Weather Volume Captured at Deer Island, Cottage Farm, Prison Point and Union Park (MG)	5,951	5,940	Reduction due to SBSS
(G) = (F)/(A) Percent Capture at Deer Island, Cottage Farm, Prison Point and Union Park	98.0%	98.1%	Slight increase in treated discharge (Prison Point)
(H) Total volume discharged at untreated CSOs (MG)	21	17	Reduction due to SBSS and CHE008
(I) = (A - H) Total Wet Weather Volume Captured at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal (MG)	6,052	6040	Reduction due to SBSS
(J) = (I)/(A) Percent Capture at Deer Island, Cottage Farm, Prison Point, Union Park and Somerville Marginal	99.7%	99.7%	

Notes:

1. *Wet weather volume defined as volume of runoff collected into the combined sewer system, plus sanitary/base flow that occurs for the duration of rain events. Includes wet weather volume from combined or partially-combined areas in Boston, Cambridge, Chelsea and Somerville.*

3.2 Outfalls Forecast to Attain LTCP Activation and Volume Goals by December 2024

Table 3-3 presents 10 outfalls that did not meet the LTCP goals as of December 2021 but are forecast to meet the LTCP goals by December 2024. Six of these outfalls were originally presented in Table 2-3 of the December 2021 CSO Report. Table 3-3 has been updated to include outfalls BOS062, BOS065, BOS017 and BOS070/DBC, which are now forecast to meet LTCP goals by December 2024. Table 3-3 (below) presents the same information from Table 2-3 of the *December 2021 CSO Report* with updated information. For each outfall, Table 3-3 presents a description and updated status of the system improvement(s) intended to result in attainment of the LTCP goals by 2024, as well as the entity implementing the work and the tentative schedule for completion. As noted above, the construction projects at the regulators tributary to outfalls CHE008, BOS003 and BOS014 are now complete, and these locations are predicted to meet LTCP goals as of the end of 2023.

Table 3-3. Outfalls With Ongoing Projects Forecast to Attain LTCP Goals

OUTFALL	LOCATION	SYSTEM IMPROVEMENT(S)*	TO BE IMPLEMENTED BY	TENTATIVE SCHEDULED COMPLETION
MWR205	Somerville Marginal CSO Facility	Construct new connection chamber with control gate connecting the facility influent conduit to the interceptor. Project bid advertisement expected in May 2024. Project constraints given location of work resulting in extended construction duration. Substantial completion anticipated in December 2025.(1)	MWRA	2025
SOM007A/ MWR205A				
BOS003	East Boston	East Boston Sewer Separation Phase 3 to be completed Summer of 2024. Work has been completed to reduce CSO at BOS003 & BOS014. Work to resume this spring that will bring BOS009 in line with LTCP goals. Further CSO reductions expected beyond LTCP with an additional five sewer separation phases is expected with complete sewer separation of East Boston by 2030.	BWSC	Completed 2023
BOS 009				2024
BOS014				Completed 2023
CHE008	Chelsea Creek	Replace/upgrade interceptor connection. Construction has been completed and was brought online June 30, 2024.	MWRA	Completed 2023
BOS017	Mystic/Chelsea Confluence	Modify existing upstream siphon structure. Final design is complete. The construction contract was awarded in December 2023 and the contractor mobilized on April 1, 2024. Construction is estimated to be completed in 2024.	BWSC	2024
BOS062	Fort Point Channel	Modify existing regulator structure. Final design is complete. The construction contract was awarded in December 2023 and the contractor mobilized on April 1, 2024. Construction is estimated to be completed in 2024.	BWSC	2024
BOS065		Modify existing regulator structure. Final design is complete. The construction contract was awarded in December 2023 and the contractor mobilized on April 1, 2024. Construction is estimated to be completed in 2024.	BWSC	2024
BOS070		Construct a new relief pipe parallel to the BMI. Final design is complete. The construction contract was awarded in December 2023 and the contractor mobilized on April 1, 2024. Construction is estimated to be completed in 2024.	BWSC	2024

(1) A small CSO reduction was achieved at SOM007A/MWR205A by replacement of the tidegate on MWR205 in May 2023

3.3 Outfalls Currently Not Forecast to Attain LTCP Activation and/or Volume Goal

Six locations remain where Typical Year CSO activation and/or volume exceed the LTCP goals and no additional system improvement has yet been recommended. MWRA has continued to track CSO performance at these locations and assess the causes of higher overflow activity. In Table 2-4 of the December 2021 CSO Report, MWRA identified candidate projects or system adjustments that may further mitigate CSO discharges to bring activations and volumes to, or closer to, the LTCP goals. In Chapter 4 of that report, additional information was provided regarding the alternatives being evaluated for these outfalls. The following section of this report presents updates for the remaining six outfalls that present significant challenges. The modeled Typical Year overflow frequency and volume presented below represent the Q1-2023 version of MWRA's model, which was the version used to conduct the evaluations summarized below.

3.3.1 SOM001A

Outfall SOM001A is located on the Alewife Brook Conduit in the Alewife Brook System. This outfall is not

meeting the LTCP goals for activation frequency or volume as shown in Table 3-4. A schematic of the Alewife Brook system including outfall SOM001A is presented in Figure 3-1.

Table 3-4. SOM001A Q1-2023 Conditions and LTCP Goal

OUTFALL	TYPICAL YEAR			
	Q1-2023 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
ALEWIFE BROOK				
SOM001A	8	4.47	3	1.67

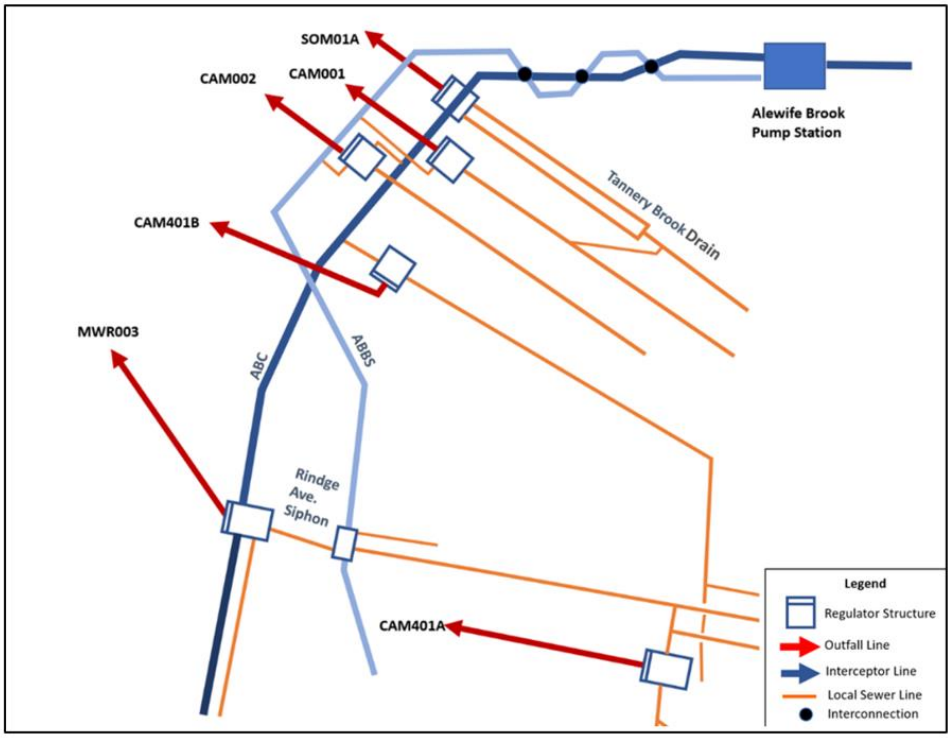

Figure 3-1. Schematic of Alewife Sub-System

Table 3-5 presents a summary of the alternatives that were evaluated with the goal of attaining LTCP goals at outfall SOM001A. The alternatives were evaluated using the Q1-2023 system conditions model with the exception of the green infrastructure alternative which used a model with additional detail that provides similar results to the model used in assessing LTCP goals. This more detailed model was used to assess green infrastructure in the area tributary to outfall SOM001A. For each of the five alternatives evaluated for outfall SOM001A, preliminary conceptual layouts and preliminary estimated construction costs were developed. As shown in Table 3-5, two storage alternatives and one regulator modification/stormwater relocation alternative were identified that could potentially meet the LTCP goals. The feasibility of the regulator modification/stormwater relocation alternative was highly uncertain. As indicated in Table 3-10 of the December 2021 *Task 6: Final CSO Post Construction Monitoring Program and Performance Assessment Report,* with CSO loads only, Alewife Brook would meet the Class B *E. coli* Single Sample Maximum Criterion 98.7% of the time for the Typical Year (2019 system conditions). Further levels of CSO control for outfall SOM001A would be more appropriately assessed in the context of the Updated CSO Control Plans being developed in accordance with the Variance for the Alewife Brook/Upper Mystic River.

Table 3-5. SOM001A Summary of Alternatives Evaluated to Attain LTCP Goals

Alternative	Meets LTCP Goals?	Comments	Preliminary Estimated Construction Cost (2023 dollars)	Benefit[3]			
				Parameter	From	To	Reduction
Regulator modifications[1] and lining the ABC and ABBS between ABPS and SOM001A	No[2]	This alternative would put outfall MWR003 out of compliance with the LTCP goals	$9.5 million	SOM001A Activation Frequency	8	3[2]	5
				SOM001A Vol. (MG)	4.47	1.23	3.24
				Total Volume to Alewife Brook (MG)	6.26	3.75	2.51
Regulator modifications[1] and approximately 115 acres of stormwater relocation from the Tannery Brook drain upstream of SOM001A and new stormwater outfall for relocated stormwater	Yes	Feasibility of relocating 115 acres of stormwater directly to Alewife Brook and water quality impacts/Alewife Brook flood impacts have not been assessed.	$0.5 million + Stormwater Relocation Costs	SOM001A Activation Frequency	8	3[2]	5
				SOM001A Vol. (MG)	4.47	0.77	3.70
				Total Volume to Alewife Brook (MG)	6.26	3.03	3.23
Box Storage Conduit (0.61 MG) to capture overflow from SOM001A to meet LTCP goal	Yes	Feasibility of locating the box storage conduit between the ABC and ABBS needs further evaluation.	$45 million	SOM001A Activation Frequency	8	3	5
				SOM001A Vol. (MG)	4.47	1.26	3.21
				Total Volume to Alewife Brook (MG)	6.26	3.05	3.21
Microtunneled Storage (0.61 MG, 8 ft diameter, 1,800 feet long) to capture overflow from SOM001A to meet LTCP goal	Yes	Feasibility of locating areas for jacking and retrieving shafts needs further evaluation, along with further investigation of utility conflicts	$32 million	SOM001A Activation Frequency	8	3	5
				SOM001A Vol. (MG)	4.47	1.26	3.21
				Total Volume to Alewife Brook (MG)	6.26	3.05	3.21
Green Infrastructure: 41 stormwater infiltration units to capture the first 0.5 inch of rain from 30.25 acres of separate stormwater areas. Infiltration unit dimensions are 10 ft wide by 25 ft long by 4 ft deep each with a hydrodynamic separator.	No	Additional investigations into soil and ground water conditions and potential sanitary connections to storm drain is needed to assess feasibility.	$9 million	SOM001A Activation Frequency[3]	8	7	1
				SOM001A Vol. (MG) [3]	4.46	4.15	0.31

Notes:

(1) Regulator modifications include raising the weir, enlarging the DWF connection, and adding a gate to restrict flow in storms larger than Typical Year storms.

(2) Alternative would meet LTCP goals at outfall SOM001A but would force outfall MWR003 out of compliance.

(3) Model results are representative of the Q1-2023 version of MWRA's model with the exception of the green infrastructure alternative which uses a model with additional detail that provides similar results to the model used in assessing LTCP goals.

3.3.2 Cottage Farm

The Cottage Farm CSO Facility is a CSO treatment facility that detains and treats CSO before it is discharged to the Charles River. The facility provides relief to the North Charles Metropolitan Sewer/Relief Sewer and to the South Charles Relief Sewer. This outfall is not meeting the LTCP goal for annual volume as shown in Table 3-6. A schematic of the interceptor system in the vicinity of the Cottage Farm Facility is presented in Figure 3-2.

Table 3-6. Cottage Farm Q1-2023 Conditions and LTCP Goal

OUTFALL	TYPICAL YEAR			
	Q1-2023 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
CHARLES RIVER				
MWR201 (Cottage Farm)	2	7.74	2	6.30

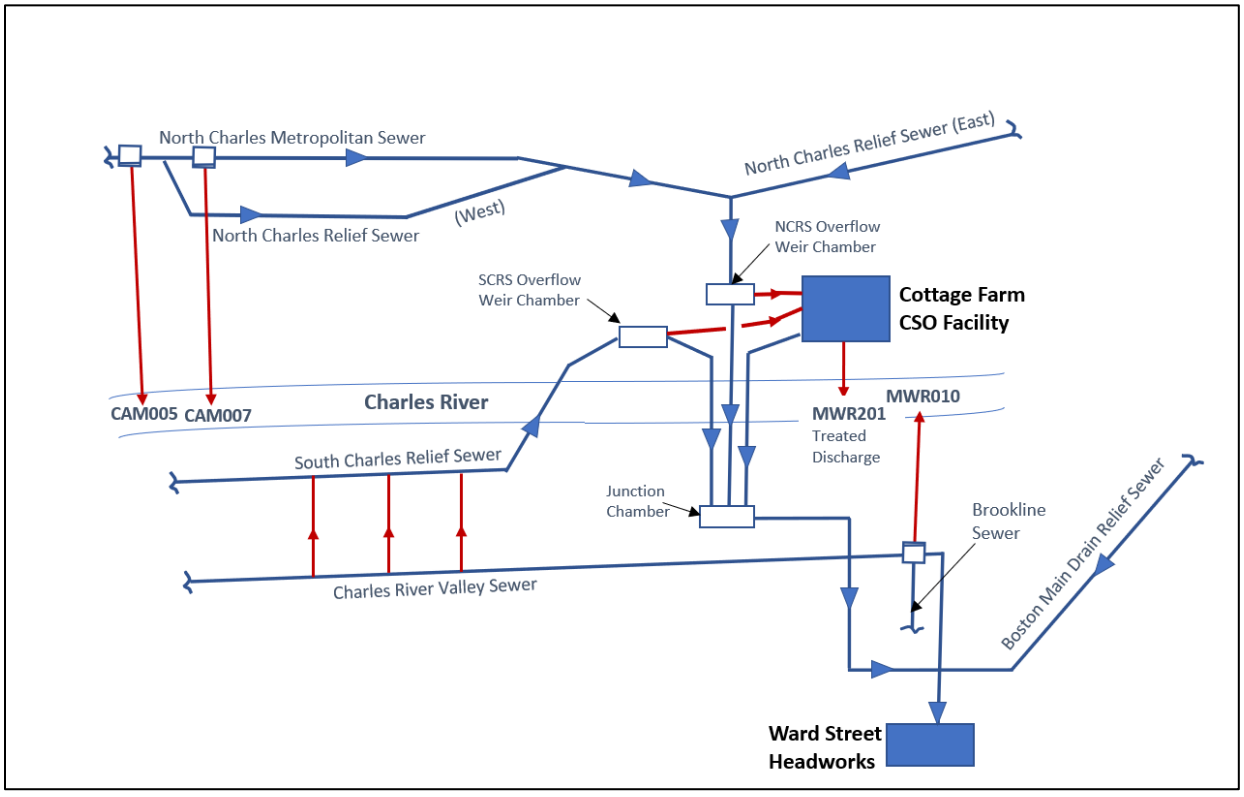

Figure 3-2 Schematic of the Charles River/Cottage Farm Sub-System

Table 3-7 presents a summary of the alternatives that were evaluated with the objective of attaining LTCP goals at the Cottage Farm CSO Facility. The alternatives were evaluated using the Q1-2023 system conditions model. For each of the alternatives evaluated, preliminary conceptual layouts and preliminary estimated construction costs were developed. As shown in Table 3-7, two storage alternatives and one sewer separation alternative were identified that could potentially meet the LTCP goals. As indicated in Table 3-5 of the December 2021 *Task 6: Final CSO Post Construction Monitoring Program and*

Performance Assessment Report, with CSO loads only, the Charles River would meet the Class B *E. coli* Single Sample Maximum Criterion 99.6% of the time for the Typical Year (2019 system conditions). Further levels of CSO control for the treated discharge from the Cottage Farm facility would be more appropriately assessed in the context of the Updated CSO Control Plans being developed in accordance with the Variance for the Charles River.

Table 3-7. Cottage Farm Summary of Alternatives Evaluated to Attain LTCP Goals

Alternative	Meets LTCP Goals?	Comments	Preliminary Estimated Construction Cost (2023 dollars)	Benefit[1]			
				Parameter	From	To	Reduction
Sewer Separation (300 ac.)	Yes	Net Increase in phosphorus loading by approximately 54.9 lbs per year. [2] Net increase in bacteria loading. Extensive construction impacts to residents and businesses.	$155M	Activation Frequency	2	2	0
				Vol. (MG)	7.74	6.01	1.73
Box Conduit Storage (0.72 MG)	Yes	2 location options identified. Construction impacts to passive recreation area, bike path and parking.	Option 1: $35M Option 2: $45M	Activation Frequency	2	2	0
				Vol. (MG)	7.74	6.3	1.44

Notes:

(1) Model results are representative of the Q1-2023 version of MWRA's model.

(2) For perspective on the phosphorus loading, the total phosphorus TMDL for the Lower Charles River is 19,544 kg, or approximately 43,000 lbs. (Final Nutrient TMDL Development for the Lower Charles River Basin, Massachusetts June 2003.) An increase of 54.9 lbs would represent a percent increase of less than 0.1%. Note however that Cambridge and Boston are (or will be soon) subject to municipal stormwater (MS4) permits that require them to reduce the load of phosphorus from stormwater. Under the current MS4 permit, Cambridge needs to eventually reduce its stormwater phosphorus load to the Charles River by 62% to reduce it below 195 kg/yr (488 lb/yr). Boston will likely need to reduce its stormwater phosphorus load to the Charles by 60% so that it is below 2,741 kg/yr (6,030 lb/yr).

3.3.3 CAM005

Outfall CAM005 is located on Mount Auburn Street at Longfellow Road at the entrance to Mount Auburn Hospital and discharges to the Charles River. This outfall is shown in the schematic for the Cottage Farm CSO Facility in Figure 3-2 (above).

Outfall CAM005 is not predicted to meet the LTCP goal for activation frequency as shown in Table 3-8 for the Q1-2023 system conditions. The *Task 8.2-8.3: Alewife Brook and Charles River System Optimization Evaluations* report dated December 22, 2022 recommended raising the weir at regulator RE051 by 1 foot and lengthening it to 10 feet. MWRA has developed a scope of services and will be contracting with its on-call consultant to further evaluate and if feasible, design modifications to the CAM005 regulator structure to increase the weir length and height. In coordination with the City of Cambridge and other impacted stakeholders, MWRA intends to follow this design with a construction contract if the construction is determined to be feasible. This recommendation along with planned sediment removal from the CAM005 overflow pipe and sewer separation in the area of Willard Street were used to create a Future Baseline Condition model for the purposes of further evaluating alternatives for outfall CAM005.

Table 3-8 presents the Typical Year model results for the Q1-2023 system conditions and the Future Baseline Condition. As indicated in Table 3-8, under the Future Baseline Condition, outfall CAM005 was predicted to meet the LTCP goal for annual CSO volume, however, it would not meet the LTCP goal for annual CSO activation frequency.

Table 3-8. CAM005 Q1-2023 Conditions and LTCP Goal

OUTFALL	Q1-2023 SYSTEM CONDITIONS MODEL		FUTURE BASELINE CONDITIONS[1]		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	Activation Frequency (MG)	Volume (MG)
CHARLES RIVER						
CAM005	8	0.73	5	0.64	3	0.84

Note:

(1) Includes raising and lengthening weir at CAM005, removing sediment from the CAM005 outfall, and Willard Street sewer separation.

Table 3-9 presents a summary of the alternatives that were evaluated with the objective of attaining LTCP goals at outfall CAM005. The alternatives were evaluated using the future conditions baseline model as described above. For each of the alternatives evaluated for outfall CAM005, preliminary conceptual layouts and preliminary estimated construction costs were developed. As shown in Table 3-9, one sewer separation and two green infrastructure alternatives were identified that could potentially meet the LTCP goals. As indicated in Table 3-5 of the December 2021 *Task 6: Final CSO Post Construction Monitoring Program and Performance Assessment Report,* with CSO loads only, the Charles River would meet the Class B *E. coli* Single Sample Maximum Criterion 99.6% of the time for the Typical Year (2019 system conditions). Further levels of CSO control for the discharge from outfall CAM005 would be more appropriately assessed in the context of the Updated CSO Control Plans being developed in accordance with the Variance for the Charles River.

Table 3-9. CAM005 Summary of Alternatives Evaluated to Attain LTCP Goals

Alternative	Meets LTCP Goals?	Comments	Preliminary Estimated Construction Cost (2023 dollars)	Benefit[1]			
				Parameter	From	To	Reduction
Sewer Separation and new storm drain tying into existing CAM005 outfall or discharging directly to the Charles River	Yes	Increases phosphorus loading by approximately 4.3 lbs per year[2] and creates net increase in bacteria load.	$12 million	Activation Frequency	5	2	3
				Vol. (MG)	0.64	0.38	0.26
Green Infrastructure: Stormwater Infiltration (14 units) with hydrodynamic separators Green Infrastructure: 14 stormwater infiltration units to capture the first 0.5 inch of rain from 32 acres of separate stormwater area. Infiltration unit dimensions are 10 ft wide by 25 ft long by 4 ft deep each with a hydrodynamic separator.	Yes	Additional investigations into soil and ground water conditions and potential sanitary connections to storm drain are needed to determine feasibility.	$3 million	Activation Frequency	5	3	2
				Vol. (MG)	0.64	0.44	0.20
Green Infrastructure: 60 catchbasin infiltration units to capture the first 0.5 inch of rain from 32 acres of separate stormwater area. Each catch basin unit was assumed to have an estimated storage volume of 200 cubic feet.	Yes	Additional investigations into soil and ground water conditions and potential sanitary connections to storm drain are needed to determine feasibility.	$2 million	Activation Frequency	5	3	2
				Vol. (MG)	0.64	0.44	0.20

Notes:

(1) Model results are representative of the Q1-2023 “Future Baseline Conditions” version of MWRA’s model.

(2) For perspective on the phosphorus loading, the total phosphorus TMDL for the Lower Charles River is 19,544 kg, or approximately 43,000 lbs (Final Nutrient TMDL Development for the Lower Charles River Basin, Massachusetts June 2003.) The additional 4.3 lbs of phosphorus would represent an increase of approximately 0.01%. Note however that Cambridge and Boston are (or will be soon) subject to municipal stormwater (MS4) permits that require them to reduce the load of phosphorus from stormwater. Under the current MS4 permit, Cambridge needs to eventually reduce its stormwater phosphorus load to the Charles River by 62% to reduce it below 195 kg/yr (488 lb/yr). Boston will likely need to reduce its stormwater phosphorus load to the Charles by 60% so that it is below 2,741 kg/yr (6,030 lb/yr).

3.3.4 MWR018/019/020

The regulator structures associated with outfalls MWR018, MWR019 and MWR020, which all discharge to the Charles River, provide relief to the Boston Marginal Conduit along the Esplanade in Boston. These three outfalls are not meeting the LTCP goals for activation frequency and volume as shown in Table 3-10. A schematic of the system associated with outfalls MWR018, MWR019 and MWR020 is presented in Figure 3-3.

Table 3-10. MWR018/019/020 Q1-2023 Conditions and LTCP Goal

OUTFALL	TYPICAL YEAR			
	Q1-2023 SYSTEM CONDITIONS MODEL		LONG TERM CONTROL PLAN	
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)
MWR018	2	0.43	0	0.00
MWR019	2	0.18	0	0.00
MWR020	2	0.04	0	0.00
Total	2	0.65	0	0.00

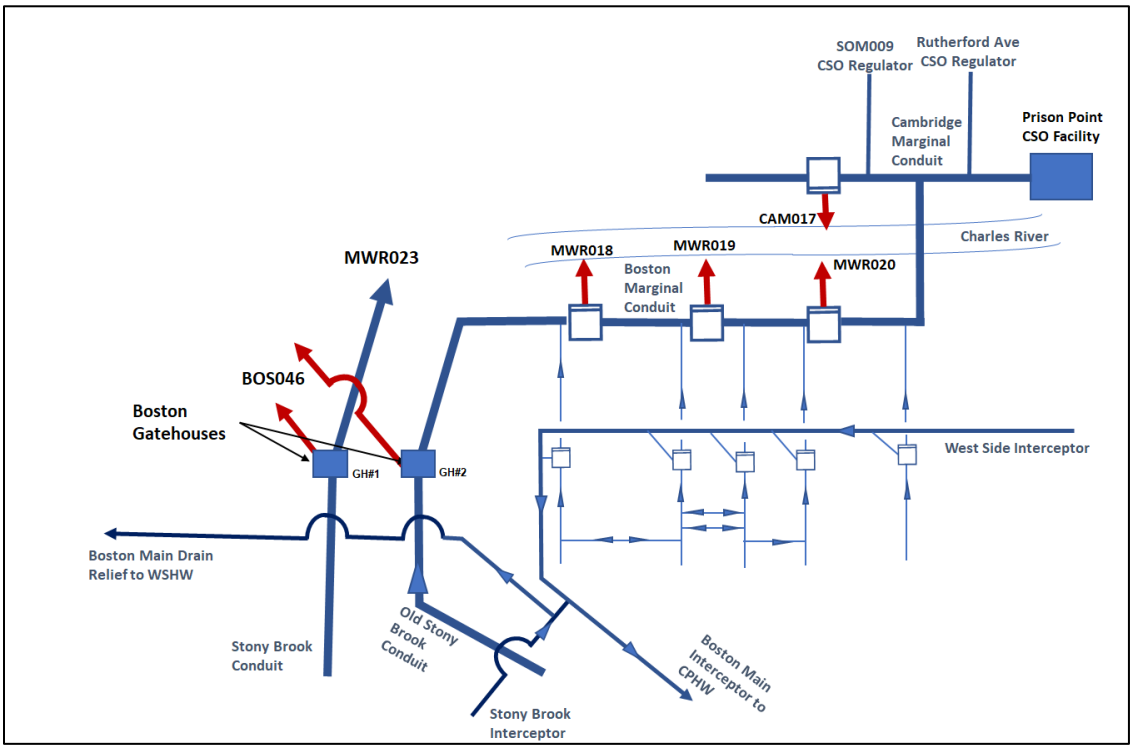

Figure 3-3. Schematic of Charles River/Prison Point Sub-System

Table 3-11 presents a summary of the alternatives that were evaluated with the goal of attaining LTCP goals at outfalls MWR018/MWR019/MWR020. For each of the alternatives evaluated at these locations, preliminary conceptual layouts and preliminary estimated construction costs were developed. As shown in Table 3-11, one sewer separation and two storage alternatives were identified that could potentially meet the LTCP goals. As indicated in Table 3-5 of the December 2021 *Task 6: Final CSO Post Construction Monitoring Program and Performance Assessment Report,* with CSO loads only, the Charles River would meet the Class B *E. coli* Single Sample Maximum Criterion 99.6% of the time for the Typical Year (2019 system conditions). Further levels of CSO control for the discharge from outfall MWR018, 019, 020 would be more appropriately assessed in the context of the Updated CSO Control Plans being developed in accordance with the Variance for the Charles River.

Table 3-11. MWR018/019/020 Summary of Alternatives Evaluated to Attain LTCP Goals

Alternative	Meets LTCP Goals ?	Comments	Preliminary Estimated Construction Cost (2023 dollars)	Benefit[1]			
				Parameter	From	To	Reduction
Remove Restrictions from Roxbury Canal Sewer	No	Alternative deemed infeasible due to projected increase in HGL in the 5-year storm	N/A	Activation Frequency	N/A	N/A	N/A
				Total Vol. for MWR018/ 019/020 (MG)	N/A	N/A	N/A
Sewer Separation and three new storm drains tying into existing outfalls	Yes	Increases phosphorus loading by approximately 49.5 lbs per year.[2] Assumes new storm drains will cross under BMC and tie into existing outfalls. Additional evaluations on the impact to the BMC are needed to assess feasibility.	$62 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 0 MWR019: 0 MWR020: 0	MWR018: 2 MWR019: 2 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.00	0.65
Green Infrastructure: 327 stormwater infiltration units to capture the first 1.5 inches of rain from 61.5 acres of separate stormwater area. Infiltration unit dimensions are 10 ft wide by 25 ft long by 4 ft deep each with a hydrodynamic separator.	No	Additional investigations into soil and ground water conditions and potential sanitary connections to storm drain needed to assess feasibility.	$68 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 2 MWR019: 2 MWR020: 0	MWR018: 0 MWR019: 0 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.23	0.42
Relocate Stormwater from OSBC to SBC with Limited Stormwater Connection to OSBC	No	Results in net increase in bacteria and phosphorus loads to Charles River	$0.7 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 2 MWR019: 2 MWR020: 0	MWR018: 0 MWR019: 0 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.44	0.21
GI + Stormwater Relocation	No	High additional cost with nominal improvement compared to stormwater relocation without GI	$69 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 2 MWR019: 2 MWR020: 0	MWR018: 0 MWR019: 0 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.30	0.52
Box Conduit Storage (0.84 MG)	Yes	Located in park land along the esplanade, potentially Article 97 legislation	$45 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 0 MWR019: 0 MWR020: 0	MWR018: 2 MWR019: 2 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.00	0.65

Table 3-12. MWR018/019/020 Summary of Alternatives Evaluated to Attain LTCP Goals

Alternative	Meets LTCP Goals ?	Comments	Preliminary Estimated Construction Cost (2023 dollars)	Benefit[1]			
				Parameter	From	To	Reduction
Microtunneled Storage (0.84 MG, 7 ft diameter, 2,900 feet long)	Yes	Located in park land along the esplanade, potentially Article 97 legislation	$36 million	Activation Frequency	MWR018: 2 MWR019: 2 MWR020: 2	MWR018: 0 MWR019: 0 MWR020: 0	MWR018: 2 MWR019: 2 MWR020: 2
				Total Vol. for MWR018/ 019/020 (MG)	0.65	0.00	0.65

Notes:

(1) Model results are representative of the Q1-2023 version of MWRA's model.

(2) For perspective on the phosphorus loading, the total phosphorus TMDL for the Lower Charles River is 19,544 kg, or approximately 43,000 lbs (Final Nutrient TMDL Development for the Lower Charles River Basin, Massachusetts June 2003.) The additional 4.3 lbs of phosphorus would represent an increase of approximately 0.01%. Note however that Cambridge and Boston are (or will be soon) subject to municipal stormwater (MS4) permits that require them to reduce the load of phosphorus from stormwater. Under the current MS4 permit, Cambridge needs to eventually reduce its stormwater phosphorus load to the Charles River by 62% to reduce it below 195 kg/yr (488 lb/yr). Boston will likely need to reduce its stormwater phosphorus load to the Charles by 60% so that it is below 2,741 kg/yr (6,030 lb/yr).

3.4 Summary

As noted in the introduction, the Court extended the time until December 2024 for the MWRA to complete identified projects and further evaluate alternatives to further reduce CSOs at the sixteen outfalls that did not meet the LTCP goals by December 31, 2021. As described above, of the 45 outfalls that remain active (i.e., are not physically closed or associated with the North Dorchester Bay CSO Storage Tunnel), 32 outfalls meet or materially meet the LTCP goals as of Q4-2023 conditions with the completion of the CHE008 modifications. Of the remaining 13 outfalls, seven have projects in design or construction to meet or materially meet the LTCP goals. These projects are expected to be completed by 2024 with the exception of the project upstream of the Somerville Marginal CSO Facility, which has experienced delays and is now expected to be completed in 2025. For the six remaining challenging outfalls, an alternatives analysis was conducted; however, no clear alternatives commensurate to the minimal receiving water quality benefits have been identified. In addition to the tables summarizing the alternatives analysis provided in this report, further detail on the alternatives evaluations will be provided in the December 2024 Supplement to the Updated CSO Control Plan. It is noted that the total Typical Year treated and untreated CSO volume for Q4-2023 conditions of 397 MG is below the overall LTCP goal of 404 MG. As noted above a number of projects are underway that will further reduce the total volume by 2024 and additional reduction will be achieved following completion of a project upstream of the Somerville Marginal CSO Facility in 2025. In addition, all four CSO communities continue to pursue work that will further reduce CSO discharges.

Appendix A Rainfall Processing and Analyses January 1, 2023 – December 31, 2023

A.1 Rainfall Analyses

This section presents the rainfall data measured from 17 gauges within the MWRA wastewater service area during the period of January 1, 2023, through December 31, 2023. It also describes the analysis of the rainfall data used to characterize the return period of each storm event and a comparison of measured rainfall for the 2023 period to the rainfall included in the Typical Year. As described in the *CSO Annual Report: Discharge Estimates and Rainfall Analyses report for Calendar Year 2021*, the MWRA's rainfall recurrence interval calculation methodology was updated from *Technical Paper 40* (TP-40) to *Atlas-14*.

Values for Atlas 14 for Boston were extracted from NOAA's data server on April 12, 2022. The Atlas 14 partial duration curves were used to assign the recurrence intervals. The smallest storm the partial duration curves addresses is the 1-year storm, so the partial duration intensity-duration-frequency (IDF) curves for the 3-month and 6-month frequencies were extrapolated. All of the storm recurrence intervals identified in the text and sections below and in Appendix A are based on the 2019 edition of Atlas 14 referenced above.

A.1.1 Rainfall Data Collection and Processing

Rainfall was quantified for this analysis using 15-minute rainfall data collected at rain gauges distributed over the MWRA system. The rain gauges are listed in Table A-1 and the locations are shown in Figure A-1.

Table A-1. Rain Gauges

Gauge Code	Name	Owner	Gauge Code	Name	Owner
BO-DI-1	Ward St.	MWRA	BWSC006	Dorchester -Talbot	BWSC
BO-DI-2	Columbus Park	MWRA	Rox	Roxbury	BWSC
BWSC001	Union Park Pump Sta.	BWSC	CH-BO-1	Chelsea Ck.	MWRA
BWSC002	Roslindale	BWSC	FRESH_POND	USGS Fresh Pond	USGS
BWSC003	Dorchester Adams St.	BWSC	HF-1C	Hanscom AFB	MWRA
BWSC004	Allston	BWSC	RG-WF-1	Hayes Pump Sta.	MWRA
BWSC007	Charlestown	BWSC	SOM	Somerville Remote	MWRA
EB	East Boston	BWSC	Lex	Lexington Farm	Project (1)
BWSC008	Longwood Medical	BWSC	SP	Spot Pond	Project (1)
BWSC005	Hyde Park	BWSC	WF	Waltham Farm	Project (1)

(1) Project gauges were removed as of July 1, 2020. Project gauge data has been replaced with the nearest rain gauge, following the QA/QC procedures and closest rain gauges substitution table.

Quality assurance and quality control were provided by reviewing the data based on geographic location, comparing total rainfall depth and rainfall intensity values by month and for individual storm events. The shape of rainfall hyetographs was reviewed for irregularities. Rain gauges with significantly higher or lower total rainfall depths than other gauges, and unusual hyetograph shapes, were flagged as suspect and further reviewed.

Suspect or missing rain gauge data were replaced with data from the rain gauge in closest linear proximity. If the closest gauge also had suspect data, the second closest rain gauge was used. Table A-2

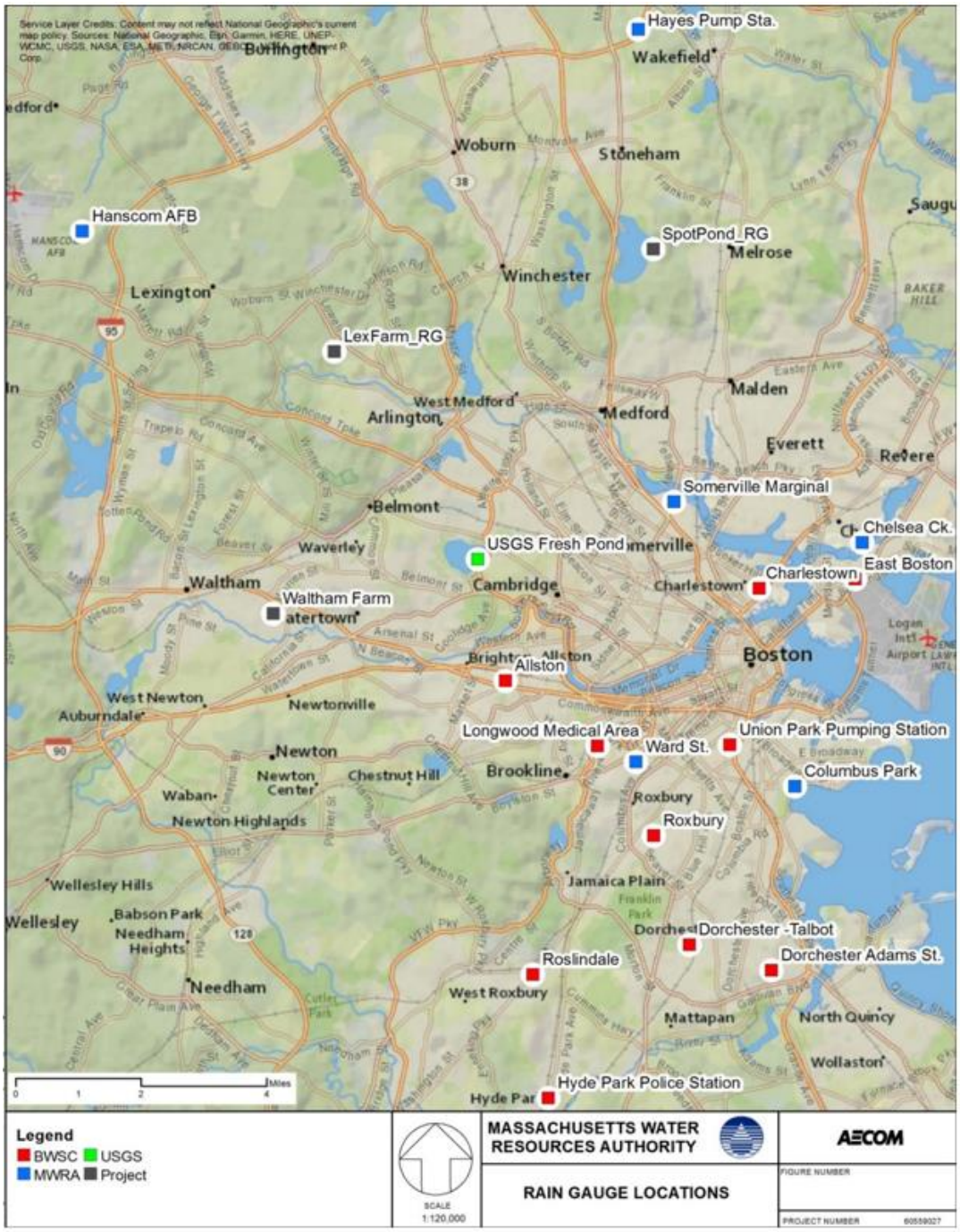

Figure A-1. Rain Gauge Location Plan

identifies the two closest rain gauges to each of the rain gauges. Replacement of suspect data was recorded in Table A-3.

Additional information on the methodologies for rainfall data collection and processing can be found in Semiannual Reports 1 and 2.

Table A-2. Closest Rain Gauges for Data Substitution

Origin Gauge		Closest Gauge		Second Closest Gauge	
Gauge Name	**Gauge Code**	**Gauge Code**	**Distance (mi)**	**Gauge Code**	**Distance (mi)**
Ward Street	BO-DI-1	BWSC008	0.66	Rox	1.23
Columbus Park	BO-DI-2	BWSC001	1.24	Rox	2.39
Union Park Pumping Station	BWSC001	BO-DI-2	1.24	BO-DI-1	1.52
Roslindale	BWSC002	BWSC005	2.02	BWSC006	2.54
Dorchester Adams St.	BWSC003	BWSC006	1.37	Rox	2.88
Allston	BWSC004	BWSC008	1.81	FRESH_POND	2.03
Hyde Park Police Station	BWSC005	BWSC002	2.02	BWSC006	3.36
Dorchester -Talbot	BWSC006	BWSC003	1.37	Rox	1.86
Charlestown	BWSC007	EB	1.53	CH-BO-1	1.80
Longwood Medical Area	BWSC008	BO-DI-1	0.67	Roxbury	1.71
Chelsea Creek	CH-BO-1	EB	0.60	BWSC007	1.80
East Boston	EB	CH-BO-1	0.60	BWSC007	1.53
USGS Fresh Pond	FRESH_POND	BWSC004	2.21	SOM	3.26
Hanscom AFB	HF-1C	Lex	4.47	WF	6.92
Lexington Farm	Lex	FRESH_POND	4.08	WF	4.37
Hayes Pump Sta.	RG-WF-1	SP	3.58	Lex	7.13
Roxbury	Rox	BO-DI-1	1.23	BWSC008	1.71
Somerville	SOM	BWSC007	1.95	CH-BO-1	3.07
Spot Pond	SP	SOM	4.12	Lex	5.34
Waltham Farm	WF	FRESH_POND	3.37	BWSC004	3.86

Table A-3. Summary of Rainfall Data Replacement, January 1, 2023 – December 31, 2023

Rain Gauge	Replacement Data Start Time	Replacement Data End Time	Replacement Rain Gauge
Ward St. (BO-DI-1)	4/6/2023 23:00	4/6/2023 23:15	Union Park Pumping Station (BWSC001)
Roxbury (Rox)	12/31/2022 15:15	10/20/2023 0:00	Ward St. (BO-DI-1)
Roslindale (BWSC002)	1/16/2023 6:00	1/17/2023 13:00	Ward St. (BO-DI-1)
	1/22/2023 6:00	1/25/2023 5:00	Ward St. (BO-DI-1)
	2/22/2023 18:00	2/27/2023 21:00	Ward St. (BO-DI-1)
	6/16/2023 2:15	6/16/2023 12:45	Dorchester-Talbot (BWSC006)
	9/13/2023 9:15	9/13/2023 10:00	Dorchester-Talbot (BWSC006)
	10/23/2023 11:00	10/23/2023 13:00	Dorchester-Talbot (BWSC006)
Longwood Medical Area (BWSC008)	12/31/2022 15:15	12/31/2023 23:45	Roxbury (Rox)
Hyde Park Police Station (BWSC005)	12/31/2022 15:15	12/31/2023 23:45	Roslindale (BWSC002)
Dorchester-Talbot (BWSC006)	1/16/2023 6:00	1/17/2023 13:00	Ward St. (BO-DI-1)
	1/22/2023 6:00	1/25/2023 5:00	Ward St. (BO-DI-1)
	2/22/2023 18:00	2/27/2023 21:00	Ward St. (BO-DI-1)
	6/7/2023 14:45	6/16/2023 12:15	Dorchester-Adams (BWSC003)
	9/27/2023 13:45	9/27/2023 14:00	Dorchester-Adams (BWSC003)
	10/18/2023 12:00	10/18/2023 12:30	Dorchester-Adams (BWSC003)
Columbus Park (BO-DI-2)	12/15/2023 9:00	12/15/2023 10:00	Union Park Pumping Station (BWSC001)
Union Park Pumping Station (BWSC001)	1/16/2023 6:00	1/17/2023 13:00	Columbus Park (BO-DI-2)
	1/22/2023 6:00	1/25/2023 5:00	Columbus Park (BO-DI-2)
	2/22/2023 18:00	2/27/2023 21:00	Columbus Park (BO-DI-2)
	6/20/2023 7:15	6/20/2023 7:45	Columbus Park (BO-DI-2)
	9/7/2023 11:30	9/7/2023 12:00	Columbus Park (BO-DI-2)
	10/16/2023 10:00	10/16/2023 12:00	Columbus Park (BO-DI-2)
Dorchester-Adams (BWSC003)	1/16/2023 6:00	1/17/2023 13:00	Columbus Park (BO-DI-2)
	1/22/2023 6:00	1/25/2023 5:00	Columbus Park (BO-DI-2)
	2/22/2023 18:00	2/27/2023 21:00	Columbus Park (BO-DI-2)
	6/20/2023 7:15	6/20/2023 10:30	Dorchester-Talbot (BWSC006)
	9/27/2023 14:15	9/27/2023 14:30	Dorchester-Talbot (BWSC006)
	10/18/2023 13:00	10/18/2023 13:45	Dorchester-Talbot (BWSC006)
Somerville Marginal (SOM)	2/11/2023 12:45	2/22/2023 13:45	Charlestown (BWSC007)
	5/30/2023 5:00	5/31/2023 8:30	Charlestown (BWSC007)
	8/15/2023 5:30	8/15/2023 8:00	Charlestown (BWSC007)
	11/21/2023 17:15	11/27/2023 11:30	Charlestown (BWSC007)

Table A-3. Summary of Rainfall Data Replacement, January 1, 2023 – December 31, 2023

Rain Gauge	Replacement Data Start Time	Replacement Data End Time	Replacement Rain Gauge
Hayes Pump Station (RG-WF-1)	1/16/2023 6:00	1/17/2023 13:00	Somerville Marginal (SOM)
	1/22/2023 6:00	1/25/2023 5:00	Somerville Marginal (SOM)
	2/22/2023 18:00	2/27/2023 21:00	Somerville Marginal (SOM)
Spot pond (SP)	12/31/2022 15:15	1/1/2023 2:00	Somerville Marginal (SOM)
	1/1/2023 2:15	12/31/2023 23:45	Hayes Pump Station (RG-WF-1)
Charlestown (BWSC007)	1/16/2023 6:00	1/17/2023 13:00	Somerville Marginal (SOM)
	1/22/2023 6:00	1/25/2023 5:00	Somerville Marginal (SOM)
	2/22/2023 18:00	2/27/2023 21:00	Somerville Marginal (SOM)
	6/3/2023 5:45	6/16/2023 14:15	East Boston (EB)
	10/19/2023 9:00	10/20/2023 12:30	East Boston (EB)
East Boston (EB)	1/16/2023 6:00	1/17/2023 13:00	Somerville Marginal (SOM)
	1/22/2023 6:00	1/25/2023 5:00	Somerville Marginal (SOM)
	2/22/2023 18:00	2/27/2023 21:00	Somerville Marginal (SOM)
	6/20/2023 11:15	6/20/2023 11:30	Chelsea Ck. (CH-BO-1)
	8/23/2023 11:15	8/23/2023 11:30	Chelsea Ck. (CH-BO-1)
	10/19/2023 10:00	10/19/2023 12:00	Chelsea Ck. (CH-BO-1)
Chelsea Ck. (CH-BO-1)	1/16/2023 6:00	1/17/2023 13:00	Somerville Marginal (SOM)
	1/22/2023 6:00	1/25/2023 5:00	Somerville Marginal (SOM)
	2/22/2023 18:00	2/27/2023 21:00	Somerville Marginal (SOM)
Allston (BWSC004)	1/16/2023 6:00	1/17/2023 13:00	USGS fresh pond (FRESH_POND)
	1/22/2023 6:00	1/25/2023 5:00	USGS fresh pond (FRESH_POND)
	2/22/2023 18:00	2/27/2023 21:00	USGS fresh pond (FRESH_POND)
	6/20/2023 7:15	6/20/2023 9:00	Ward St. (BO-DI-1)
	9/13/2023 11:15	9/13/2023 12:00	USGS fresh pond (FRESH_POND)
	10/16/2023 13:00	10/16/2023 15:00	USGS fresh pond (FRESH_POND)
USGS fresh pond (FRESH_POND)	5/10/2023 9:00	5/10/2023 12:45	Allston (BWSC004)
	6/2/2023 15:00	8/19/2023 1:00	Allston (BWSC004)
	11/17/2023 11:45	11/17/2023 12:15	Allston (BWSC004)
Waltham Farm (WF)	12/31/2022 15:15	12/31/2023 23:45	USGS fresh pond (FRESH_POND)
Lex-Farm (Lex)	12/31/2022 15:15	12/31/2023 23:45	USGS fresh pond (FRESH_POND)
Hanscom AFB (HF-1C)	12/31/2022 15:15	12/31/2023 23:45	USGS fresh pond (FRESH_POND)

A.1.2 Monitored Storms and Comparison with Typical Year

For the period of January 1, 2023, to December 31, 2023, the rainfall data at each rain gauge were analyzed and summarized, providing the date and time, duration, volume, average intensity, peak 1-hour, 24-hour, and 48-hour intensities and storm recurrence intervals for each storm. The storm recurrence

intervals were assigned values of less than 3 months, 3 months, 3-6 months, 6 months, 1 year, 1-2 year, or the nearest year for recurrence intervals greater than 2-year, based on comparison to the IDF values from Atlas 14. Table A-4 presents the summary of storm events for Ward Street Headworks for the period of January 1, 2023, to December 31, 2023. These data show that 93 storm events occurred in the year long period at the Ward Street Headworks rain gauge (BO-DI-1). The majority of events had less than 3-month recurrence intervals at 1-hour, 24-hour or 48-hour durations.

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2023 to December 31, 2023

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr)	Peak 48-hr intensity (in/hr)	Atlas-14 Recurrence Interval		
								1-hr	24-hr	48-hr
1	12/31/22 16:30	9.25	0.4	0.04	0.10	0.02	0.01	<3m	<3m	N/A
2	1/3/23 8:00	20	0.65	0.03	0.10	0.03	0.01	<3m	<3m	N/A
3	1/4/23 20:30	16.25	0.34	0.02	0.10	0.01	0.01	<3m	<3m	N/A
4	1/6/23 9:15	9	0.22	0.02	0.07	0.01	0.00	<3m	<3m	N/A
5	1/7/23 9:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
6	1/12/23 12:00	52	0.61	0.01	0.16	0.02	0.01	<3m	<3m	<3m
7	1/15/23 20:15	17.5	0.15	0.01	0.06	0.01	0.00	<3m	<3m	N/A
8	1/18/23 8:30	0.5	0.03	0.06	0.03	0.00	0.00	<3m	<3m	N/A
9	1/19/23 14:45	26.25	1.17	0.04	0.31	0.05	0.02	3m	3m	3m
10	1/23/23 11:30	8.5	0.41	0.05	0.11	0.02	0.01	<3m	<3m	N/A
11	1/25/23 20:00	14.75	1.38	0.09	0.27	0.06	0.03	<3m	3m-6m	N/A
12	1/31/23 4:45	2.5	0.07	0.03	0.03	0.00	0.00	<3m	<3m	N/A
13	2/7/23 21:15	1	0.03	0.03	0.03	0.00	0.00	<3m	<3m	N/A
14	2/17/23 10:30	8	0.11	0.01	0.07	0.00	0.00	<3m	<3m	N/A
15	2/21/23 5:45	14.25	0.14	0.01	0.06	0.01	0.00	<3m	<3m	N/A
16	2/22/23 21:00	28.75	1.03	0.04	0.11	0.04	0.02	<3m	<3m	3m
17	2/28/23 5:45	15	0.36	0.02	0.06	0.02	0.01	<3m	<3m	N/A
18	3/2/23 5:00	4.25	0.59	0.14	0.21	0.02	0.01	<3m	<3m	N/A
19	3/4/23 1:15	11	0.83	0.08	0.12	0.03	0.02	<3m	<3m	N/A
20	3/11/23 3:30	9	0.05	0.01	0.04	0.00	0.00	<3m	<3m	N/A
21	3/13/23 17:15	31.75	3.21	0.10	0.28	0.13	0.07	<3m	1-2y	1-2y
22	3/25/23 15:30	10.5	0.11	0.01	0.05	0.00	0.00	<3m	<3m	N/A
23	3/27/23 19:30	16.5	0.65	0.04	0.12	0.03	0.01	<3m	<3m	N/A
24	3/31/23 17:30	18.5	0.54	0.03	0.16	0.02	0.01	<3m	<3m	N/A
25	4/6/23 3:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
26	4/17/23 0:00	13.75	0.16	0.01	0.10	0.01	0.00	<3m	<3m	N/A
27	4/22/23 22:30	24.25	0.74	0.03	0.20	0.03	0.02	<3m	<3m	<3m
28	4/27/23 12:00	5	0.11	0.02	0.06	0.00	0.00	<3m	<3m	N/A
29	4/29/23 19:45	36.5	2	0.05	0.31	0.07	0.04	3m	6m	6m
30	5/2/23 7:00	9.5	0.18	0.02	0.09	0.01	0.00	<3m	<3m	N/A
31	5/3/23 10:30	1	0.11	0.11	0.11	0.00	0.00	<3m	<3m	N/A
32	5/5/23 1:45	7.5	0.02	0.00	0.01	0.00	0.00	<3m	<3m	N/A
33	5/7/23 23:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
34	5/20/23 11:00	13.75	1.81	0.13	0.53	0.08	0.04	3m-6m	6m	N/A

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2023 to December 31, 2023

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr)	Peak 48-hr intensity (in/hr)	Atlas-14 Recurrence Interval		
								1-hr	24-hr	48-hr
35	5/24/23 18:00	2	0.04	0.02	0.03	0.00	0.00	<3m	<3m	N/A
36	6/2/23 18:15	4	1.04	0.26	0.55	0.04	0.02	6m	3m	N/A
37	6/3/23 13:45	4	0.03	0.01	0.01	0.00	0.00	<3m	<3m	N/A
38	6/4/23 15:45	23	0.22	0.01	0.07	0.01	0.00	<3m	<3m	N/A
39	6/9/23 14:30	0.75	0.05	0.07	0.05	0.00	0.00	<3m	<3m	N/A
40	6/10/23 12:45	6.75	0.45	0.07	0.29	0.02	0.01	<3m	<3m	N/A
41	6/12/23 21:00	7.75	0.3	0.04	0.28	0.01	0.01	<3m	<3m	N/A
42	6/14/23 17:45	1.25	0.21	0.17	0.20	0.01	0.00	<3m	<3m	N/A
43	6/17/23 10:45	25.5	1.54	0.06	0.73	0.06	0.03	6m-1y	3m-6m	3m-6m
44	6/24/23 6:30	3.25	0.03	0.01	0.02	0.00	0.00	<3m	<3m	N/A
45	6/25/23 15:30	0.25	0.03	0.12	0.03	0.00	0.00	<3m	<3m	N/A
46	6/27/23 0:15	5.25	0.27	0.05	0.13	0.01	0.01	<3m	<3m	N/A
47	6/28/23 5:30	1.25	0.18	0.14	0.17	0.01	0.00	<3m	<3m	N/A
48	6/28/23 19:30	3	0.06	0.02	0.04	0.00	0.00	<3m	<3m	N/A
49	7/2/23 6:45	20.75	0.81	0.04	0.35	0.03	0.02	3m	<3m	N/A
50	7/4/23 0:00	16.5	0.58	0.04	0.19	0.02	0.01	<3m	<3m	N/A
51	7/10/23 7:00	12.25	0.88	0.07	0.42	0.04	0.02	3m	<3m	N/A
52	7/13/23 23:00	5.75	0.24	0.04	0.12	0.01	0.01	<3m	<3m	N/A
53	7/16/23 4:45	16.25	1.9	0.12	0.43	0.08	0.04	3m	6m	N/A
54	7/21/23 19:15	3.25	1.91	0.59	1.23	0.08	0.04	3y	6m	N/A
55	7/25/23 14:00	5.25	1	0.19	0.53	0.04	0.02	3m-6m	3m	N/A
56	7/27/23 17:00	1.75	0.26	0.15	0.22	0.01	0.01	<3m	<3m	N/A
57	7/29/23 12:00	9.25	3.26	0.35	1.63	0.14	0.07	9y	2y	N/A
58	8/8/23 2:45	11.5	1.59	0.14	0.99	0.07	0.03	1-2y	3m-6m	N/A
59	8/10/23 18:30	6	0.16	0.03	0.11	0.01	0.00	<3m	<3m	N/A
60	8/13/23 4:45	1	0.07	0.07	0.07	0.00	0.00	<3m	<3m	N/A
61	8/15/23 3:45	7.25	0.67	0.09	0.18	0.03	0.01	<3m	<3m	N/A
62	8/18/23 6:45	8.75	0.94	0.11	0.49	0.04	0.02	3m-6m	3m	N/A
63	8/21/23 19:00	2.25	0.52	0.23	0.50	0.02	0.01	3m-6m	<3m	N/A
64	8/24/23 23:30	15.5	1.94	0.13	0.53	0.08	0.04	3m-6m	6m	N/A
65	8/29/23 21:00	12	0.59	0.05	0.20	0.02	0.01	<3m	<3m	N/A
66	9/8/23 8:00	0.25	0.1	0.40	0.10	0.00	0.00	<3m	<3m	N/A
67	9/9/23 15:00	3.25	0.14	0.04	0.13	0.01	0.00	<3m	<3m	N/A
68	9/10/23 11:00	6	0.53	0.09	0.18	0.02	0.01	<3m	<3m	N/A
69	9/11/23 17:15	16.75	0.38	0.02	0.13	0.02	0.01	<3m	<3m	N/A
70	9/13/23 11:45	8.75	0.83	0.09	0.26	0.03	0.02	<3m	<3m	N/A
71	9/16/23 3:30	3.25	0.12	0.04	0.04	0.01	0.00	<3m	<3m	N/A
72	9/18/23 4:45	19	2.29	0.12	0.57	0.10	0.05	6m	6m-1y	N/A

Table A-4. Summary of Storm Events at Ward Street Headworks Rain Gauge (BO-DI-1) for January 1, 2023 to December 31, 2023

Event	Date & Start Time	Duration (hr)	Volume (in)	Average Intensity	Peak 1-hr Intensity (in/hr)	Peak 24-hr Intensity (in/hr)	Peak 48-hr intensity (in/hr)	Atlas-14 Recurrence Interval		
								1-hr	24-hr	48-hr
73	9/23/23 15:30	50.25	0.53	0.01	0.19	0.02	0.01	<3m	<3m	<3m
74	9/29/23 8:30	16.5	0.49	0.03	0.23	0.02	0.01	<3m	<3m	N/A
75	10/7/23 12:15	11.75	0.24	0.02	0.14	0.01	0.01	<3m	<3m	N/A
76	10/16/23 1:00	2.25	0.04	0.02	0.03	0.00	0.00	<3m	<3m	N/A
77	10/16/23 16:00	1.75	0.06	0.03	0.04	0.00	0.00	<3m	<3m	N/A
78	10/17/23 17:45	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
79	10/21/23 0:45	19.5	0.71	0.04	0.20	0.03	0.01	<3m	<3m	N/A
80	10/29/23 10:15	33	0.74	0.02	0.08	0.03	0.02	<3m	<3m	<3m
81	11/7/23 1:30	8.25	0.07	0.01	0.02	0.00	0.00	<3m	<3m	N/A
82	11/9/23 7:30	6.5	0.1	0.02	0.05	0.00	0.00	<3m	<3m	N/A
83	11/10/23 4:15	0.25	0.01	0.04	0.01	0.00	0.00	<3m	<3m	N/A
84	11/18/23 8:15	2	0.16	0.08	0.13	0.01	0.00	<3m	<3m	N/A
85	11/21/23 23:15	16.25	1.23	0.08	0.26	0.05	0.03	<3m	3m	N/A
86	11/26/23 23:15	6	0.48	0.08	0.21	0.02	0.01	<3m	<3m	N/A
87	12/1/23 21:00	3	0.06	0.02	0.04	0.00	0.00	<3m	<3m	N/A
88	12/3/23 7:45	19.25	1.01	0.05	0.15	0.04	0.02	<3m	3m	N/A
89	12/10/23 14:00	19.75	2.83	0.14	0.52	0.12	0.06	3m-6m	1-2y	N/A
90	12/17/23 17:45	23.5	2.96	0.13	0.63	0.12	0.06	6m	1-2y	N/A
91	12/24/23 15:45	11.5	0.03	0.00	0.01	0.00	0.00	<3m	<3m	N/A
92	12/27/23 22:30	39.5	0.86	0.02	0.12	0.03	0.02	<3m	<3m	3m
93	12/30/23 7:30	7.75	0.14	0.02	0.04	0.01	0.00	<3m	<3m	N/A

(1) Recurrence intervals given in ranges of less than 3 months (<3m), 3-months, (3m), 3-6 months (3-6m), 6 months (6m), 6 months-1year (6m-1y), 1 year (1y), 1 to 2 year (1y-2y) or the nearest year for recurrence intervals >2 year, based on Atlas 14.

The characteristics of the rain events that occurred in the January 1, 2023, to December 31, 2023, monitoring period were compared to rainfall characteristics from the Typical Year to help interpret the measured CSO activations and volumes in comparison to Typical Year performance.

The total rainfall and number of storms at each rain gauge were identified for the period January 1, 2023, to December 31, 2023, and the number of storms were categorized by depth. These values were then compared to the values from the Typical Year. Table A-5 presents this comparison. As indicated in Table A-5, during 2023 the rain gauges measured an average total rainfall volume of 55.35 inches, compared with 46.80 inches in the Typical Year, an 8.55-inch increase in precipitation compared to the Typical Year. While the average number of storms in 2023 matches the Typical Year with 93 events, the number of storms within the depth categories in Table A-5 skewed towards the larger storms compared to the Typical Year. The 2023 period had eight more storms with depths more than 0.5 inches and eight fewer storms with depths less than 0.5 inches.

Table A-5. Frequency of Events within Selected Ranges of Total Rainfall for January 1, 2023, to December 31, 2023

Rain Gauge	Total Rainfall (inches)	Total Number of Storms	Number of Storms by Depth				
			Depth < 0.25 inches	Depth 0.25 to 0.5 inches	Depth 0.5 to 1.0 inches	Depth 1.0 to 2.0 inches	Depth ≥2.0 inches
Typical Year	46.80	93	49	14	16	8	6
January - December 2023							
Average of Rain Gauges							
Average	55.35	93	43	12	20	12	6
MWRA Rain Gauges							
Ward Street	57.16	93	43	11	20	13	6
Columbus Park	54.08	94	44	9	23	14	4
Chelsea Creek	52.42	95	44	13	21	13	4
Hanscom AFB	52.60	92	47	11	18	8	8
Somerville	54.65	88	37	16	17	11	7
Hayes PS	52.61	86	41	8	20	10	7
BWSC Rain Gauges							
Allston	57.92	95	46	11	19	11	8
Charlestown	52.84	89	37	16	20	9	7
Dorch-Adams	57.33	97	45	13	20	14	5
Dorch-Talbot	59.58	100	47	14	18	16	5
Hyde Park	60.69	93	42	11	19	16	5
East Boston	53.10	93	41	14	22	11	5
Longwood	57.09	93	43	11	21	12	6
Roslindale	60.69	93	42	11	19	16	5
Roxbury	57.09	93	43	11	21	12	6
Union Park	56.51	94	41	12	22	15	4
USGS Rain Gauge							
Fresh Pond	52.60	92	47	11	18	8	8
MWRA Project Gauges (Removed)							
Lexington Farm	52.60	92	47	11	18	8	8
Spot Pond	52.75	86	41	8	20	10	7
Waltham Farm	52.60	92	47	11	18	8	8

Storms with greater than 2 inches of total rainfall at the Ward Street, Columbus Park, Chelsea Creek Headworks, and USGS Fresh Pond rain gauges were identified and compared to storms with greater than 2 inches of total rainfall in the full Typical Year (Table A-6). Experience has shown that large storms often account for a disproportionate volume of CSO. Also, within the Typical Year, the storms with greater than 2 inches of rainfall were separated from each other by a period of at least one month. In 2023, two December storms recorded at the Ward Street and USGS Fresh Pond rain gauges with greater than 2 inches of rainfall were separated by only one week.

Table A-6. Comparison of Storms Between January 1, 2023 to December 31, 2023 and Typical Year with Greater Than 2 Inches of Total Rainfall

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (24-hr)[1]
Typical Year	12/11/1992	50	3.89	0.08	0.2	1y-2y
	8/15/1992	72	2.91	0.04	0.66	6m
	9/22/1992	23	2.76	0.12	0.65	1y-2y
	11/21/1992	84	2.39	0.03	0.31	6m
	5/31/1992	30	2.24	0.07	0.37	6m-1y
	10/9/1992	65	2.04	0.03	0.42	<3m
January - December 2023 Rain Gauge Data						
Ward Street Headworks (BO-DI-1)	3/13/2023	31.75	3.21	0.10	0.28	1-2y
	4/29/2023	36.5	2	0.05	0.31	6m
	7/29/2023	9.25	3.26	0.35	1.63	2y
	9/18/2023	19	2.29	0.12	0.57	6m-1y
	12/10/2023	19.75	2.83	0.14	0.52	1-2y
	12/17/2023	23.5	2.96	0.13	0.63	1-2y
Columbus Park Headworks (BO-DI-2)	3/13/2023	33.5	3.44	0.10	0.36	2y
	7/16/2023	17	2.03	0.12	0.48	6m
	7/29/2023	9.5	3.32	0.35	1.69	2y
	12/10/2023	19.25	2.27	0.12	0.39	6m-1y
Chelsea Creek Headworks (CH-BO-1)	3/13/2023	30.5	3.05	0.10	0.27	1-2y
	4/29/2023	30.5	2.34	0.08	0.37	6m-1y
	7/29/2023	9.25	2.3	0.25	1.11	6m-1y
	12/10/2023	19.25	2.4	0.12	0.38	6m-1y
Fresh Pond (USGS)	3/13/2023	28.25	2.5	0.09	0.25	1y
	5/20/2023	14	2.27	0.16	0.79	6m-1y
	7/29/2023	9.25	3.05	0.33	1.05	1-2y
	8/8/2023	10	2.85	0.29	1.97	1-2y
	8/25/2023	14.75	2.46	0.17	0.79	1y
	9/18/2023	18.25	2.77	0.15	0.6	1-2y
	12/10/2023	18.75	2.32	0.12	0.55	6m-1y
	12/17/2023	21.75	2.47	0.11	0.53	1y

The largest storm event of the period was recorded at Columbus Park Headworks on March 13, 2023, with 3.44 inches of rainfall over 33.5 hours, which equates to a 2-year, 24-hour duration recurrence interval.

Storms with peak rainfall intensities greater than 0.40 in/hr at the Ward Street, Columbus Park, Chelsea Creek Headworks, and USGS Fresh Pond rain gauges were identified and compared to storms with greater than 0.40 in/hr of peak intensity in the Typical Year (Table A-7). Storms with intensities greater than 0.40 in/hr are of importance because higher intensity storms have been found to produce more CSO activations and volumes than lower intensity storms. The full Typical Year has nine storm events with intensities greater than 0.40 inches per hour. For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour ranged from ten to fifteen. The Fresh Pond gauge recorded a 20-year return interval for the 1-hour duration on August 8, 2023. The peak intensity recorded at the Ward Street and Columbus Park rain gauges on July 29, 2023 had a 9-year and 10-year return intervals, respectively for 1-hour duration. Both the July 29, 2023 and the August 8, 2023 storm events displayed high spatial variability and resulted in CSO activations across the sewershed. In addition, the Fresh Pond gauge had seven storms with peak intensity greater than 0.75 inches per hour, and the other three gauges had at least three storms each, compared to the Typical Year which had only one storm with greater than 0.75 inches per hour peak intensity.

For storms with peak rainfall intensities greater than 0.4 in/hr at Ward Street Headworks, Columbus Park Headworks, and Chelsea Creek Headworks rain gauges, hyetographs were developed. These hyetographs show the 15-minute rainfall intensities and show the distribution of rainfall during the storm. Rainfall distribution during a storm can impact the behavior of system hydraulics due to soil saturation. For example, a storm where the peak rainfall occurs towards the end of the event will generally create more CSO than a storm with similar total rainfall and peak intensity, where the peak occurs at the beginning of the storm. An example hyetograph for the September 18, 2023, storm at the Ward Street gauge is shown in Figure A-2. This hyetograph is a clear example of the peak of the storm occurring towards the end of the event, which could compound the impact of this event (2.29 inches total rainfall at the Ward Street gauge) on CSO volumes.

Table A-7. Comparison of Storms Between January 1, 2023 and December 31, 2023 and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (1-hr)[1]
Typical Year	10/23/1992	4	1.18	0.29	1.08	2y
	8/11/1992	11	0.87	0.08	0.75	6m-1y
	8/15/1992	72	2.91	0.04	0.66	6m-1y
	9/22/1992	23	2.76	0.12	0.65	6m-1y
	5/2/1992	7	1.14	0.16	0.63	6m
	9/9/1992	1	0.57	0.57	0.57	6m
	9/3/1992	13	1.19	0.09	0.51	3m-6m
	6/5/1992	18	1.34	0.07	0.44	3m
	10/9/1992	65	2.04	0.03	0.42	3m
January - December 2023 Rain Gauge Data						
Ward Street Headworks (BO-DI-1)	5/20/2023	13.75	1.81	0.13	0.53	3m-6m
	6/2/2023	4	1.04	0.26	0.55	6m
	6/17/2023	25.5	1.54	0.06	0.73	6m-1y
	7/10/2023	12.25	0.88	0.07	0.42	3m

Table A-7. Comparison of Storms Between January 1, 2023 and December 31, 2023 and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (1-hr)[1]
	7/16/2023	16.25	1.90	0.12	0.43	3m
	7/21/2023	3.25	1.91	0.59	1.23	3y
	7/25/2023	5.25	1.00	0.19	0.53	3m-6m
	7/29/2023	9.25	3.26	0.35	1.63	9y
	8/8/2023	11.5	1.59	0.14	0.99	1-2y
	8/18/2023	8.75	0.94	0.11	0.49	3m-6m
	8/21/2023	2.25	0.52	0.23	0.50	3m-6m
	8/24/2023	15.5	1.94	0.13	0.53	3m-6m
	9/18/2023	19	2.29	0.12	0.57	6m
	12/10/2023	19.75	2.83	0.14	0.52	3m-6m
	12/17/2023	23.5	2.96	0.13	0.63	6m
Columbus Park Headworks (BO-DI-2)	5/20/2023	13.5	1.85	0.14	0.58	6m
	6/10/2023	6.5	0.54	0.08	0.41	3m
	7/2/2023	21	1.24	0.06	0.53	3m-6m
	7/10/2023	12.5	0.73	0.06	0.43	3m
	7/16/2023	17	2.03	0.12	0.48	3m-6m
	7/21/2023	3.5	1.58	0.45	1	1-2y
	7/25/2023	4.5	1.39	0.31	0.87	1y
	7/29/2023	9.5	3.32	0.35	1.69	10y
	8/8/2023	8.5	0.97	0.11	0.54	6m
	8/18/2023	14.25	1.52	0.11	0.78	6m-1y
	8/21/2023	2.75	0.53	0.19	0.48	3m-6m
	8/29/2023	12	0.77	0.06	0.49	3m-6m
Chelsea Creek Headworks (CH-BO-1)	5/20/2023	13.5	1.8	0.13	0.56	6m
	6/14/2023	1.75	0.44	0.25	0.41	3m
	7/2/2023	21.5	1.02	0.05	0.5	3m-6m
	7/10/2023	27.5	0.88	0.03	0.51	3m-6m
	7/21/2023	3.25	1.83	0.56	0.92	1-2y
	7/25/2023	4.75	0.7	0.15	0.47	3m-6m
	7/29/2023	9.25	2.3	0.25	1.11	2y
	8/8/2023	6.5	1.78	0.27	1.14	2y
	8/18/2023	7.5	0.86	0.11	0.48	3m-6m
	8/24/2023	15.5	1.9	0.12	0.58	6m
Fresh Pond (USGS)	5/20/2023	14	2.27	0.16	0.79	6m-1y
	6/17/2023	24.5	1.71	0.07	0.71	6m-1y
	7/2/2023	21.25	1.10	0.05	0.51	3m-6m
	7/10/2023	12.5	1.45	0.12	0.79	6m-1y
	7/21/2023	3	1.59	0.53	1.08	2y
	7/29/2023	9.25	3.05	0.33	1.05	2y

Table A-7. Comparison of Storms Between January 1, 2023 and December 31, 2023 and the Typical Year with Peak Intensities Greater than 0.40 inches/hour

Rain gauge	Date	Duration (hr)	Total Rainfall (inches)	Average Intensity (in/hr)	Peak Intensity (in/hr)	Storm Recurrence Interval (1-hr)[(1)]
	8/8/2023	10	2.85	0.29	1.97	20y
	8/18/2023	13.25	0.70	0.05	0.41	3m
	8/21/2023	13	0.43	0.03	0.41	3m
	8/25/2023	14.75	2.46	0.17	0.79	6m-1y
	9/13/2023	9.5	1.52	0.16	0.77	6m-1y
	9/18/2023	18.25	2.77	0.15	0.60	6m
	12/10/2023	18.75	2.32	0.12	0.55	6m
	12/17/2023	21.75	2.47	0.11	0.53	3m-6m

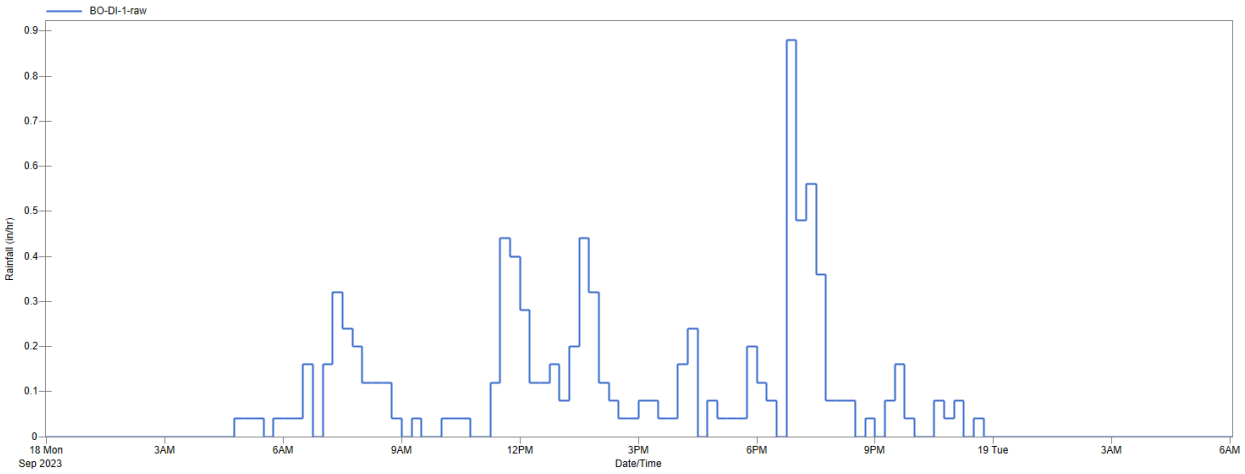

Figure A-0-2. Hyetograph from the Ward Street Headworks Gauge for September 18, 2023

The following is a summary of the rainfall comparison of January 1, 2023, to December 31, 2023, to the Typical Year:

- 2023 averaged 93 storm events with an average annual rainfall depth of 55.35 inches, compared to 93 storm events with an average annual rainfall depth of 46.80 inches for the Typical Year (Table A-5).
- In general, the breakdown of numbers of storms by rainfall depth categories for 2023 skewed towards the larger storms compared to the Typical Year. The 2023 period had eight more storms with depths greater than 0.5 inches and eight fewer storms with depths lower than 0.5 inches. (Table A-5).
- In terms of larger storms, for the four gauges shown in Table A-6 the average number of storms with greater than 2 inches of total rainfall in 2023 ranged from four to eight, an average of six storms, which is same as the Typical Year count of six storms. In 2023, 6 storm events were recorded to have a depth greater than 2 inches at Ward St (BO-DI-1), 4 storms for Columbus

Park (BO-DI-2) and Chelsea Creek (CH-BO-1) respectively, as well as 8 storms at USGS Fresh Pond. The largest storm in 2023 had a depth of 3.44 inches, compared to the largest storm in the Typical Year which has a depth of 3.89 inches (Table A-6). Within the Typical Year, the storms with greater than 2 inches of rainfall were separated from each other by a period of at least one month. In 2023, two December storms recorded at the Ward Street and USGS Fresh Pond rain gauges with greater than 2 inches of rainfall were separated by only one week (Table A-6).

- For the four gauges shown in Table A-7, the number of storms with peak intensities greater than 0.40 inches per hour ranged from ten to fifteen, compared to nine for the Typical Year. The two months of July and August are noted to include eight to ten of these intense storm events. The Typical Year had one storm with a peak intensity of 1.08 inches per hour with the remaining eight storms having peak intensities between 0.42 and 0.75 inches per hour. In 2023, the Fresh Pond gauge measured a storm with a peak intensity of 1.97 inches per hour (determined to equate to a 20-year 1-hour event) and measured a total of seven storms with peak intensities greater than 0.75 inches per hour. The other three gauges represented in Table A-7 had individual storms with peak intensities between 1.14 to 1.69 inches per hour and each measured three storms with peak intensity greater than 0.75 inches per hour. (Table A-7).

In 2023, Metropolitan Boston experienced significantly more volume of rain, higher intensity storm events, and about the same number of large storms in terms of depth greater than 2 inches compared to the Typical Year. The Typical Year total rainfall depth of 46.80 inches was 8.55 inches lower than the average depth across the collection system's rain gauges in 2023 of 55.35 inches. The exceptional number of high intensity events during the two month of July and August 2023 resulted in 2023 being classified by the National Weather Service as the second wettest summer on record in Boston region. The impact of higher rainfall (in terms of total rainfall, as well as peak intensity), is evident in the 2023 vs. Typical Year rainfall comparisons in the rainfall summary tables, and in comparing the modeled CSO discharge estimates for the Typical Year and 2023. For example, in the Typical Year Prison Point is predicted to discharge 250.39 MG, compared to the 2023 Prison Point modeled discharge volume of 385.49 MG, a 135.10 MG difference. Also in 2023 the total modeled CSO discharge was 713 MG compared to the Typical Year predicted total CSO discharge of 397 MG.