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April 30, 2019

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Todd J. Borci
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US EPA New England
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Boston, MA 02109-3912

Subject: CSO Discharge Estimates and Rainfall Analyses for Calendar Year 2018

Dear Mr. Brander and Mr. Borci:

The following information documents the Massachusetts Water Resources Authority's (MWRA) estimates of combined sewer overflow (CSO) discharges in its service area during calendar year 2018. MWRA is required to submit estimates of CSO activations and volumes for the previous calendar year for the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin. These submittals are to be done in accordance with conditions in the Variance Extensions for the CSO Discharges to these waters, issued by the Massachusetts Department of Environmental Protection in 2016 pursuant to the Massachusetts Surface Water Quality Standards at 314 CMR 4.00. The Variance Extensions authorize limited CSO discharges to the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin in conjunction with National Pollutant Discharge Elimination System (NPDES) permits MA0103284, MA0101982 and MA0101974 issued to MWRA, the City of Cambridge and the City of Somerville, respectively.

In this report, MWRA is providing its estimates of calendar year 2018 CSO activation frequency and total discharge duration from each of the outfalls addressed in MWRA's approved CSO Long-Term Control Plan (LTCP), including but not limited to the outfalls discharging to the Alewife Brook/Upper Mystic River and the Lower Charles River/Charles Basin. For the majority of locations, representing the most significant overflows, MWRA is reporting discharge volumes as described below and presented in "Table 10," attached. The information contained in this submittal has also been provided to MWRA's member communities with CSOs: Boston Water and Sewer Commission (BWSC) and the cities of Cambridge, Chelsea and Somerville.

For several regulator locations, MWRA is unable to provide discharge volume estimates at this time because meter measurements are not available and MWRA is in the process of improving the calibration of its hydraulic model to incorporate new information and data obtained during the court ordered performance assessment it commenced in November 2017. In particular, with respect to the CSO outfalls that discharge to the variance waters, MWRA currently does not have volume estimates for Outfall SOM 007A/MWR205A, which discharges to the Upper Mystic River, and for outfalls MWR018, MWR019, MWR020, and MWR023 (at certain regulators only), which discharge to the Lower Charles River/Charles Basin. For this submittal, MWRA is using the City of Cambridge's hydraulic model results for estimated volumes at outfalls CAM001, CAM002, and CAM401A.

Upon completion of the ongoing calibration of the hydraulic model of MWRA's wastewater collection system, MWRA will resubmit these annual discharge estimates, supplemented by data, including discharge volumes, generated from that model effort.

CSO Post-Construction Monitoring and Performance Assessment

In compliance with the Federal District Court Order in the Boston Harbor Case (U.S. v. M.D.C. et al, No. 85-0489 MA) and milestones in the Court's Schedule Seven, MWRA is undertaking an extensive program of CSO inspections, overflow metering, rainfall analyses, hydraulic model upgrades and calibration, site-specific CSO performance investigations and water quality impact assessments. These activities, which MWRA commenced in November 2017, will culminate in a report to the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (DEP) in December 2020 as required by Schedule Seven.

On April 15, 2018, MWRA installed and began collecting data from temporary overflow monitoring equipment at 57 potentially active CSO regulators. The instrumentation includes 81 meters collecting data from 106 depth and velocity sensors, 20 level sensors and 16 tide gate inclinometers. All of this instrumentation remained in place and operational at the 57 regulators through calendar year 2018, and MWRA currently plans to maintain the monitoring equipment and continue to collect data at 36 of the 57 regulators to June 2020. At outfalls permitted to the cities of Cambridge, Chelsea and Somerville, and at several CSO outfalls permitted to BWSC, the MWRA's temporary meters supplement permanent or long-term overflow meters maintained by the community.

For all storms prior to implementation of the temporary metering program on April 15, 2018, MWRA collected overflow data where it has permanent meters and reviewed operational records from its facilities. MWRA also performed hydraulic model simulations for all storms January 1, 2018 – April 14, 2018, to estimate activations and volumes where metering was unavailable, even though the model is now undergoing improved calibration (see the Table 10 discussion, below). For all storms occurring in the period April 15, 2018 - December 31, 2018, MWRA collected or obtained data from its temporary meters at the 57 regulators, from the communities' meters, and from permanent meters or other operational records at MWRA's four CSO treatment facilities, the

South Boston CSO Storage Tunnel and dewatering pump station, the BOS019 Storage Conduit and dewatering pump station, and at Outfall MWR003 at Alewife Brook. For the period April 15, 2018 - December 31, 2018, this equipment together provided data for all potential sources of CSO (treated or untreated) in MWRA's service area.

The MWRA's temporary metering program had the primary objectives of providing extensive overflow and system data to support improved calibration of MWRA's hydraulic model and measuring CSO activations and volumes at outfalls that MWRA's model had previously predicted would activate in the Typical Year. Both objectives would then support the goal of validating MWRA's model for CSO predictions and for verifying attainment of the LTCP levels of control.

For most CSO outfalls, MWRA's temporary meters, together with the community meters, provided data sufficient to quantify CSO activation start and stop times, discharge durations and discharge volumes. At several outfalls where MWRA had predicted no activation in the Typical Year, MWRA's original metering plan did not include monitoring equipment at associated regulators. However, MWRA elected to install additional monitoring equipment at each of these regulators, typically a level sensor, to confirm prior model results, which showed that the regulator rarely activates. At some of these locations, level sensor data were used to quantify discharge volume in addition to indicating activation. At other regulators, discharge volume could not be reasonably quantified from level sensor data alone. At these locations, MWRA's hydraulic model, once it is calibrated with the depth sensor and other collected data, should provide reasonable estimates of activations and volumes. MWRA anticipates that the calibration will be completed in August 2019, and, as noted above, MWRA will then submit updated annual discharge estimates for 2018, supplemented with the calibrated model results.

Early in the metering program, it became evident that the hydraulic model was in need of improved calibration. For storms in the period April 15, 2018 – June 30, 2018, MWRA performed simulations using its existing model and compared the modeled CSO predictions to the measured CSO discharges. The comparison indicated that, based on the data collected, the existing MWRA model is underestimating discharges at approximately 15 regulators. MWRA is currently calibrating its hydraulic model with the data collected at all regulators and facilities during dry weather and all storms in the metering period April 15, 2018 – December 31, 2018, and, as noted above, anticipates completing model calibration in August 2019. Until then, in order to prevent the potential mischaracterization of CSO discharges, MWRA will not report discharge volumes in its 2018 Table 10 at regulators where volume was not measured by MWRA.[1] Most of these locations are BWSC regulators where MWRA metering was limited to a level sensor and no measured or modeled volume is currently available.

[1] For Cambridge outfalls CAM001, CAM002 and CAM401B to Alewife Brook, Table 10 includes the discharge volumes estimated and reported by Cambridge from its hydraulic model results.

Table 10: Summary of 2018 and Typical Year CSO Discharge Estimates and Comparison to Typical Year Long Term CSO Control Plan

Table 10 presents estimated CSO activations, discharge duration and discharge volume at each CSO outfall and regulator during calendar year 2018, except where discharge volume could not be reasonably estimated, as discussed above.

- At the outfalls associated with MWRA's four CSO treatment facilities, the discharge estimates (activation frequency, duration and volume) presented in Table 10 are from recorded measurements at the facilities for the entire year. These outfalls are MWR201 (Cottage Farm), MWR203 (Prison Point), MWR205 (Somerville Marginal) and MWR215 (Union Park).

- For outfalls where MWRA had temporary meters from April 15, 2018 - December 31, 2018, **Table 10 reports a combination of the meter measurements for the storms of that period and the predictions of MWRA's existing model (not recalibrated) for the storms in the period January 1-April 14, 2018**. While the model predictions may not be accurate because the current model is now undergoing improved calibration, its predictions are the best available estimates for this three and a half month period.

Table 10 also compares the results of the Typical Year simulation for **end-of-year 2017 system conditions** (as presented in last year's annual report) to the activation frequencies and annual volumes in the approved Long-Term Control Plan as defined in Exhibit B to the Second Stipulation of the United States and the Massachusetts Water Resources Authority on Responsibility and Legal Liability for Combined Sewer Overflow Control in the Federal District Court Order in the Boston Harbor Case as amended in May 2008. While this comparison has been used to track the progress towards meeting the LTCP levels, an updated and accurate Typical Year simulation will not be available until August 2019, when MWRA anticipates completing the calibration of its hydraulic model.

Physical and Operational Conditions in 2018

MWRA's collection and treatment systems had no significant operational or performance problems in 2018. The year saw a significantly higher number of storms and many storms with short, but high, peak rainfall intensities. In response to those peak intensity thunderstorms in 2018, MWRA facility operations at times opened the influent gates at an elevation below standard operating levels at the CSO treatment facilities to prevent upstream flooding and control untreated CSO discharges due to the sudden rise in the influent chamber caused by the peak intensity thunderstorm. Although this may have contributed to nominally higher treated discharge volumes, MWRA feels that the unpredictability of these events and the attendant potential for upstream flooding or higher untreated CSO discharges justifies an earlier response when a thunderstorm warning is issued.

MWRA's 2017 CSO discharge report, submitted April 30, 2018, discussed the significant impact sediments can have in reducing interceptor conveyance capacity and increasing CSO discharges.

MWRA inspected all of its interceptors in the combined sewer service areas ahead of the temporary metering program and determined sediment to be minimal, or removed sediment where it had the potential to affect interceptor performance.

2018 Rainfall Analyses

Table R-1: Comparison of Frequency of Rain Events within Selected Ranges of Total Rainfall, Typical Year Versus 2018

Table R-2: Comparison of Storms with Greater than 2 Inches of Total Rainfall, Typical Year Versus 2018

Table R-3: Comparison of Storms with Peak Intensities Greater than 0.40 Inch/Hour, Typical Year Versus 2018

Figure R-1: Rainfall Intensity Comparison: 2018 Versus Typical Year

These rainfall summaries (attached) were developed primarily to help explain the magnitude of the estimated CSO discharges caused by 2018 rainfall relative to the LTCP levels of control, which are based on Typical Year Rainfall.

2018 - A Very Wet Year

In 2018, Metropolitan Boston experienced a significantly greater number of storms, significantly greater volume of rain, and many storms with relatively high peak intensity. The impact of these many storms is evident in the Table 10 comparison of the metered and modeled discharge estimates for 2018 rainfall with the model predicted discharges for Typical Year 2017 system conditions and the LTCP and in the 2018 vs. Typical Year rainfall comparisons in the rainfall summary tables. Table R-1 shows that area rain gauges recorded an average of 103 storms in 2018 with total rainfall volume of approximately 54.3 inches compared to 93 storms and rainfall volume of 46.8 inches in the Typical Year. Tables R-1 and R-2 also show that many of a greater number of storms in 2018 had rainfall volumes of 0.5 to 2.0 inches (37 storms in 2018 vs. 24 storms in the Typical Year), while there were fewer storms of greater than 2.0 inches (3 storms in 2018 vs. 6 storms in the Typical Year).

Table R-3 shows that area rain gauges recorded more storms in 2018 with peak hourly intensities of greater than 0.4 inch/hour compared with the Typical Year (14 storms in 2018 vs. 9 storms in the Typical Year). At most of the CSO outfalls, activations are caused primarily by peak rainfall intensity that even over a very short duration can cause flows to exceed interceptor capacities or dry weather connection capacity. Peak intensities of greater than 0.4 inch/hour can cause activations at many CSO outfalls. Figure R-1 shows probability distributions of peak intensities from rainfall measurements in 2018 compared with the Typical Year. For nearly all percentiles, 2018 peak intensities were greater than Typical Year peak intensities. For example, 90% of the storms in 2018 had peak intensities of up to approximately 0.45 inch/hour, while 90% of the storms

in the Typical Year had peak intensities of up to 0.35 inch/hour. Looking at it the other way, 10% of the storms in 2018 had peak intensities greater than 0.45 inch/hour compared with 10% greater than 0.35 inch/hour in the Typical Year.

Comparison of CSO Estimates Reported by MWRA and CSO Community

All four CSO communities – BWSC, Cambridge, Chelsea and Somerville – submit annual CSO discharge estimates. MWRA and the communities have worked closely to understand each other's estimates, how the estimates were determined, and the community and MWRA system conditions contributing to CSO discharges. BWSC's metering program is currently based on pilot study locations, and its hydraulic model is still in development; therefore, for its outfalls, BWSC continues to report the discharge estimates reported by MWRA. The other three communities have outfall meters, and Cambridge has a calibrated hydraulic model. Table 1 presents a comparison of the CSO discharge estimates reported by MWRA and by the CSO communities.

Table 1: Comparison of MWRA and Community CSO Discharge Estimates

Outfall	MWRA		Community		Remarks
	Activation Frequency	Volume (MG)	Activation Frequency	Volume (MG)	
Cambridge's estimates are from its hydraulic model simulations, not overflow measurements					
CAM001	3	N/A	1	0.016	Two of the 3 activations measured by MWRA had discharge durations of <10 minutes.
CAM002	4	N/A	4	1.43	
CAM401A	18	N/A	15	5.007	
CAM401B	3	0	3	0.177	
CAM005	15	4.97	8	1.979	MWRA and Cambridge are jointly investigating regulator conditions, meter configuration and data.
CAM007	2	0.14	2	0.053	
CAM017	0	0	3	2.72	MWRA and Cambridge are jointly investigating regulator conditions, meter configuration and data.
Chelsea's estimates are from its meter data					
CHE003	0	0	0	0	
CHE004	17	1.79	8	1.80	Ten of the 17 MWRA metered discharges had volumes <0.005MG. Volumes for all of the other (7) MWRA measured discharges are nearly identical to Chelsea's measured volumes. MWRA's model did not predict the small (0.01MG) discharge measured by Chelsea on 1/13/18. Model calibration is underway.
CHE008	19	3.46	19	3.54	Four of the MWRA measured activations had discharge volumes of <0.005 MG.
Somerville's estimates are from its meter data at SOM01A and from MWRA meter data at SOM007A					
SOM01A	14	14.64	22	19.58	In early 2019, MWRA removed an obstruction and an orifice plate that had restricted flows from Somerville's Tannery Brook Conduit to MWRA's Alewife Brook Conduit, with the expectation of significantly lowering CSO discharges at SOM01A.
SOM007A	21	N/A	15	N/A	

N/A: Overflow volumes could not be determined from MWRA meter data.

Should you have questions about MWRA's CSO discharge estimates or MWRA's continuing compliance efforts, please feel free to contact me, at 617-788-4359, or David Kubiak, at 617-570-5460.

Very truly yours,

David W. Coppes
Chief Operating Officer

TABLE 10. SUMMARY OF 2018 AND TYPICAL YEAR CSO DISCHARGE ESTIMATES AND COMPARISON TO TYPICAL YEAR LONG TERM CSO CONTROL PLAN

		2018 RAINFALL EXISTING SYSTEM CONDITIONS [1]			TYPICAL-YEAR RAINFALL EXISTING SYSTEM CONDITIONS[2]		TYPICAL-YEAR RAINFALL LONG TERM CSO CONTROL PLAN	
Outfall	**Regulator**	**Activation Frequency**	**Duration (hrs)**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**
ALEWIFE BROOK								
CAM001	RE-011	3	0.75	**0.02**	1	0.02	5	0.19
CAM002	RE-021	4	1.25	**1.43**	1	0.21	4	0.69
MWR003	RE-031	0	0.00	0.00	2	0.38	5	0.98
CAM004	Closed	-	-	-	-	-	Closed	-
CAM400	Closed	-	-	-	-	-	Closed	-
CAM401A	RE-401	18	20.75	**5.01**	2	0.44	5	1.61
CAM401B	RE-401B	3	2.25	0.00	2	0.18	7	2.15
SOM001A	RE-01A	14	9.25	14.64	5	3.90	3	1.67
SOM001	Closed	-	-	-	-	-	Closed	-
SOM002A	Closed	-	-	-	-	-	Closed	-
SOM003	Closed	-	-	-	-	-	Closed	-
SOM004	Closed	-	-	-	-	-	Closed	-
TOTAL				**21.10**		**5.12**		**7.29**
UPPER MYSTIC RIVER								
SOM007A/MWR205A [3]		21	48.87	N/A	2	1.82	3	3.48
SOM007	Closed	-	-	-	-	-	Closed	-
TOTAL				**N/A**		**1.82**		**3.48**
MYSTIC / CHELSEA CONFLUENCE								
MWR205 (Somerville Marginal Facility) [4]		35	131.33	121.44	22	67.33	39	60.58
BOS013	RE013-1	14	6.75	0.51	4	0.13	4	0.54
BOS014	RE014-2	11	9.00	2.25	4	0.45	0	0.00
BOS015	Closed	-	-	-	-	-	Closed	-
BOS017 [5]	RE017-3	8	5.60	1.15	0	0.00	1	0.02
CHE002	Closed	-	-	-	-	-	4	0.22
CHE003	RE-031	0	0.00	0.00	0	0.00	3	0.04
CHE004	RE-041	17	12.50	1.79	1	0.10	3	0.32
CHE008	RE-081	19	32.25	3.46	7	1.83	0	0.00
TOTAL				**130.60**		**69.84**		**61.72**
UPPER INNER HARBOR								
BOS009	RE009-2	14	18.50	0.40	3	0.10	5	0.59
BOS010	RE010-2	7	7.75	1.35	6	0.46	4	0.72
BOS012	RE012-2	12	4.00	1.15	7	0.55	5	0.72
BOS019	RE019-2	5	22.91	N/A	1	0.21	2	0.58
BOS050	Closed	-	-	-	-	-	Closed	-
BOS052	Closed	-	-	-	-	-	Closed	-
BOS057	RE057-6	4	4.25	2.98	2	0.58	1	0.43
BOS058	Closed	-	-	-	-	-	Closed	-
BOS060	RE060-7	9	11.00	1.33	1	0.02	0	0.00
	RE060-20	4	1.25	N/A				
MWR203 (Prison Point) [6]		21	90.09	343.13	17	237.76	17	243
TOTAL				**>350.34**		**239.67**		**246.04**
LOWER INNER HARBOR								
BOS003	RE003-2	3	0.75	0.00	18	11.80	4	2.87
	RE003-7	6	6.50	0.52				
	RE003-12	34	130.02	20.87				
BOS004	RE004-6	6	5.25	0.10	5	0.28	5	1.84
BOS005	RE005-1	0	0.00	0.00	0	0.00	1	0.01
BOS006 [7]	Closed	-	-	-	-	-	4	0.24
BOS007 [7]	Closed	-	-	-	-	-	6	1.05
TOTAL				**21.49**		**12.08**		**6.01**
CONSTITUTION BEACH								
MWR207	Closed	-	-	-	-	-	Closed	-
TOTAL								

TABLE 10. SUMMARY OF 2018 AND TYPICAL YEAR CSO DISCHARGE ESTIMATES AND COMPARISON TO TYPICAL YEAR LONG TERM CSO CONTROL PLAN

		2018 RAINFALL EXISTING SYSTEM CONDITIONS [1]			TYPICAL-YEAR RAINFALL EXISTING SYSTEM CONDITIONS[2]		TYPICAL-YEAR RAINFALL LONG TERM CSO CONTROL PLAN	
Outfall	**Regulator**	**Activation Frequency**	**Duration (hrs)**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**
FORT POINT CHANNEL								
BOS062	RE062-4	11	10.25	0.11	0	0.00	1	0.01
BOS064	RE064-4	2	2.50	0.20	1	0.02	0	0.00
	RE064-5	5	2.25	N/A				
BOS065	RE065-2	10	16.00	N/A	1	0.62	1	0.06
BOS068	RE068-1A	1	0.50	N/A	0	0.00	0	0.00
BOS070								
BOS070/DBC	RE070/8-3	10	8.50	2.14	4	3.30	3	2.19
	RE070/8-6	1	1.00	N/A				
	RE070/8-7	7	4.25	N/A				
	RE070/8-8	1	0.25	N/A				
	RE070/8-13	0	0.00	0.00				
	RE070/8-15	2	1.25	N/A				
	RE070/9-4	12	10.00	2.25				
	RE070/10-5	2	0.50	0.31				
	RE070/7-2	25	23.00	1.81				
MWR215 (Union Park) [6]		10	32.71	34.09	11	33.81	17	71.37
BOS070/RCC	RE070/5-3	2	0.50	N/A	0	0.00	2	0.26
	RE070/6-1	Closed	-	-	-	-		
BOS072	Closed	-	-	-	-	-	0	0.00
BOS073	RE073-4	1	2.50	0.04	0	0.00	0	0.00
TOTAL				**>40.95**		**37.74**		**73.89**
RESERVED CHANNEL								
BOS076	RE076/2-3	0	0.00	0.00	6	1.19	3	0.91
	RE076/4-3	1	2.50	0.12				
BOS078	RE078-1 & RE078-2	1	0.75	0.11	0	0.00	3	0.28
BOS079	RE079-3	0	0.00	0.00	0	0.00	1	0.04
BOS080	RE080-2B	1	0.75	N/A	3	0.08	3	0.25
TOTAL				**>0.23**		**1.27**		**1.48**
NORTHERN DORCHESTER BAY								
BOS081	RE081-2	0	0.00	0.00	0	0.00	0 / 25 year	-
BOS082	RE082-2	0	0.00	0.00	0	0.00	0 / 25 year	-
BOS083 [8]	Closed	-	-	-	-	-	0 / 25 year	-
BOS084	RE084-3 & RE084-6	0	0.00	0.00	0	0.00	0 / 25 year	-
BOS085	RE085-4	0	0.00	0.00	0	0.00	0 / 25 year	-
BOS086	RE086-1	0	0.00	0.00	0	0.00	0 / 25 year	-
BOS087	Closed	-	-	-	-	-	0 / 25 year	-
TOTAL		**0**	**0.00**	**0.00**	**0**	**0.00**		
SOUTHERN DORCHESTER BAY								
BOS088/BOS089 (Fox Point)	Closed	-	-	-	-	-	Closed	-
BOS090 (Commercial Point)	Closed	-	-	-	-	-	Closed	-
TOTAL								
UPPER CHARLES								
BOS032	Closed	-	-	-	-	-	Closed	-
BOS033	Closed	-	-	-	-	-	Closed	-
CAM005	RE-051	15	11.50	4.97	3	1.36	3	0.84
CAM007	RE-071	2	4.50	0.14	2	0.25	1	0.03
CAM009 [9]	Closed	-	-	-	-	-	2	0.01
CAM011 [9]	Closed	-	-	-	-	-	0	0.00
TOTAL				**5.11**		**1.62**		**0.88**

TABLE 10. SUMMARY OF 2018 AND TYPICAL YEAR CSO DISCHARGE ESTIMATES AND COMPARISON TO TYPICAL YEAR LONG TERM CSO CONTROL PLAN

		2018 RAINFALL EXISTING SYSTEM CONDITIONS [1]			TYPICAL-YEAR RAINFALL EXISTING SYSTEM CONDITIONS[2]		TYPICAL-YEAR RAINFALL LONG TERM CSO CONTROL PLAN	
Outfall	**Regulator**	**Activation Frequency**	**Duration (hrs)**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**	**Activation Frequency**	**Volume (MG)**
LOWER CHARLES								
BOS028	Closed	-	-	-	-	-	Closed	-
BOS042	Closed	-	-	-	-	-	Closed	-
BOS049	Closed	-	-	-	-	-	Closed	-
CAM017	CAM017	0	0.00	0.00	1	1.27	1	0.45
MWR010	RE37	0	0.00	0.00	0	0.00	0	0.00
	RE036-9	No meter data available						
MWR018		2	1.75	N/A	0	0.00	0	0.00
MWR019		2	1.75	N/A	0	0.00	0	0.00
MWR020		2	2.00	N/A	0	0.00	0	0.00
MWR021	Closed	-	-	-	-	-	Closed	-
MWR022	Closed	-	-	-	-	-	Closed	-
MWR201 (Cottage Farm) [6]		4	10.26	30.14	3	10.62	2	6.30
MWR023	RE046-19	0	0.00	0.00	1	0.02	2	0.13
	RE046-30	0	0.00	0.00				
	RE046-50	0	0.00	0.00				
	RE046-54	0	0.00	0.00				
	RE046-55	3	15.00	N/A				
	RE046-62A	0	0.00	0.00				
	RE046-90	1	0.25	N/A				
	RE046-100	6	2.00	0.02				
	RE046-105	1	0.50	0.03				
	RE046-381	2	1.00	N/A				
	RE046-192	0	0.00	0.00				
SOM010	Closed	-	-	-	-	-	Closed	-
TOTAL				**>30.19**		**11.91**		**6.88**
NEPONSET RIVER								
BOS093	Closed	-	-	-	-	-	Closed	-
BOS095	Closed	-	-	-	-	-	Closed	-
TOTAL								
BACK BAY FENS								
BOS046[10]	Fens Gatehouse #1	7	16.00	N/A	1	1.57	2	5.38
TOTAL				**N/A**		**1.57**		**5.38**
Total Treated				**528.80**		**350**		**381**
Total Untreated				**>71.21**		**30**		**23**
GRAND TOTAL				**>600.01**		**379**		**404**

N/A: Level sensor, only. No volume measurement.

Where activations occurred and volume is reported as 0.00 MG, volumes are less than 0.005MG.

Alewife Brook: Shaded values are CSO discharge volumes from Cambridge model results.

(1) For the regulators at untreated CSO outfalls, activation frequency, duration and volume for 2018 rainfall are from model results for January 1 - April 14, 2018 period, and are from meter measurements for April 15 - December 31, 2018 period. Only activation frequency and duration are available at level-only meter locations.

(2) From MWRA hydraulic model simulation of 2017 system conditions. The model is currrently undergoing recalibration.

(3) Includes portion of flow treated at Somerville Marginal facility and separate stormwater entering the Somerville Marginal Conduit (outfall) downstream of the facility.

(4) Volume represents all flow through the CSO treatment facility. Activation frequency and volume for 2018 rainfall are from MWRA facility records (measurements).

(5) Activation frequency, duration and volume for 2018 rainfall are from model results for January 1 - April 14, 2018 period, and from meter measurements for July 19 - December 31, 2018 period. No meter measurements were available April 15 - July 18, 2018, the discharge frequency, duration and volumes are from MWRA extrapolation of meter results in the later period.

(6) Activation frequency and volume for 2018 rainfall are from MWRA facility records (measurements).

(7) BWSC has permanently closed outfalls BOS006 and BOS007 in East Boston as part of sewer separation and development plans in the tributary areas. The Long-Term Control Plan assumed these outfalls would remain active.

(8) CSO discharge at Outfall BOS083 was redirected to Outfall BOS084 as part of the construction of the North Dorchester Bay Storage Tunnel. The Long-Term Control Plan assumed BOS083 would have 25-year storm level of control.

(9) The City of Cambridge closed outfalls CAM009 and CAM011 in November 2007. The Long-Term Control Plan assumed these outfalls would remain active.

(10) Volumes represent model predicted total discharge at outfall BOS046, including stormwater and CSO contributions from Stony Brook Conduit.

RAINFALL CHARACTERISTICS

TABLE R-1. COMPARISON OF FREQUENCY OF RAIN EVENTS WITHIN SELECTED RANGES OF TOTAL RAINFALL, TYPICAL YEAR VERSUS 2018

Conditions	Total Rainfall (inches)	Total Number of Storms	Number of Storms by Volume				
			Volume < 0.25 inches	Volume 0.25 to 0.5 inches	Volume 0.5 to 1.0 inches	Volume 1.0 to 2.0 inches	Volume >= 2.0 inches
Typical Year	46.8	93	49	14	16	8	6
MWRA Rain Gauges							
Ward Street	55.81	104	50	13	21	17	3
Columbus Park	56.71	102	48	13	21	16	4
Chelsea Creek	54.54	107	53	16	18	16	4
HF-1C	52.23	108	53	16	21	16	2
RG-WF-1	52.04	97	46	15	17	16	3
BWSC Rain Gauges							
Allston	53.51	103	46	18	20	16	3
Charlestown	50.94	101	44	18	20	16	3
Dorchester - Adam Street	55.91	103	40	21	22	18	2
Roslindale	58.96	103	44	14	26	14	5
Union Park	54.25	105	50	15	21	16	3
USGS Rain Gauge							
Fresh Pond	52.25	103	47	16	21	17	2

TABLE R-2. COMPARISON OF STORMS WITH GREATER THAN 2 INCHES OF TOTAL RAINFALL, TYPICAL YEAR VERSUS 2018

Rain Gauge	Date	Duration (hours)	Total Rainfall (inches)	Average Intensity (inch/hour)	Peak Intensity (inch/hour)	Storm Recurrence Interval (24-hour)
Typical Year	12/11/1992	50	3.89	0.08	0.20	1y
	8/15/1992	72	2.91	0.04	0.66	3m
	9/22/1992	23	2.76	0.12	0.65	1y
	11/21/1992	84	2.39	0.03	0.31	3m
	5/31/1992	30	2.24	0.07	0.37	3m-6m
	10/9/1992	65	2.04	0.03	0.42	<3m
Ward Street Headworks (BO-DI-1)	4/15/2018	22	2.43	0.11	0.47	6m
	7/17/2018	13	2.39	0.18	1.14	6m
	8/11/2018	34.75	2.36	0.07	1.46	3m-6m
Columbus Park Headworks (BO-DI-2)	3/2/2018	21.5	2.64	0.12	0.32	6m-1y
	7/17/2018	13.5	2.44	0.18	0.92	6m
	4/15/2018	22.25	2.15	0.10	0.40	3-6m
	10/27/2018	25.25	2.03	0.08	0.35	3m
Chelsea Creek Headworks (CH-BO-1)	8/11/2018	62.25	2.95	0.05	0.82	3m-6m
	3/2/2018	21.5	2.28	0.11	0.25	6m
	4/15/2018	25.5	2.23	0.09	0.28	3m-6m
	7/17/2018	11.25	2.12	0.19	0.97	3m-6m
Fresh Pond (from USGS)	4/15/2018	22.75	2.06	0.09	0.40	3m-6m
	7/17/2018	17.25	2.03	0.12	0.67	3m

TABLE R-3. COMPARISON OF STORMS WITH PEAK INTENSITIES GREATER THAN 0.40 INCHES/HOUR, TYPICAL YEAR VERSUS 2018

Rain Gauge	Date	Duration (hours)	Total Rainfall (inches)	Average Intensity (inch/hour)	Peak Intensity (inch/hour)	Storm Recurrence Interval (1-hour)
Typical Year	10/23/1992	4	1.18	0.29	1.08	1-2y
	8/11/1992	11	0.87	0.08	0.75	6m-1y
	8/15/1992	72	2.91	0.04	0.66	3m-6m
	9/22/1992	23	2.76	0.12	0.65	3m-6m
	5/2/1992	7	1.14	0.16	0.63	3m-6m
	9/9/1992	1	0.57	0.57	0.57	3m
	9/3/1992	13	1.19	0.09	0.51	< 3m
	6/5/1992	18	1.34	0.07	0.44	< 3m
	10/9/1992	65	2.04	0.03	0.42	< 3m
Ward Street Headworks (BO-DI-1)	8/11/2018	34.75	2.36	0.07	1.46	4 yr
	7/17/2018	13.00	2.39	0.18	1.14	1.8 yr
	9/25/2018	18.25	1.82	0.10	0.84	6m-1y
	6/27/2018	15.50	1.21	0.08	0.68	3m-6m
	5/15/2018	3.00	0.98	0.33	0.67	3m-6m
	9/18/2018	12.75	1.18	0.09	0.63	3m-6m
	11/2/2018	33.75	1.91	0.06	0.53	3m
	8/4/2018	2.50	0.66	0.26	0.52	<3m
	4/15/2018	22.00	2.43	0.11	0.47	< 3m
	11/9/2018	19.75	1.60	0.08	0.45	< 3m
	9/12/2018	18.25	0.90	0.05	0.44	< 3m
	10/29/2018	8.50	0.77	0.09	0.41	< 3m
	1/12/2018	17.00	1.82	0.11	0.40	< 3m
Columbus Park Headworks (BO-DI-2)	7/17/2018	13.50	2.44	0.18	0.92	1y
	9/25/2018	19.25	1.42	0.07	0.74	6m-1y
	5/15/2018	3.75	1.06	0.28	0.73	6m
	6/27/2018	15.75	1.22	0.08	0.73	6m
	8/8/2018	16.00	0.94	0.06	0.70	6m
	9/18/2018	13.25	1.29	0.10	0.67	3m-6m
	8/4/2018	3.25	0.88	0.27	0.66	3m-6m
	11/2/2018	35.75	1.98	0.06	0.64	3m-6m
	7/26/2018	1.75	0.64	0.37	0.59	3m
	8/11/2018	37.00	1.43	0.04	0.59	3m
	1/12/2018	17.75	1.73	0.10	0.45	< 3m

Rain Gauge	Date	Duration (hours)	Total Rainfall (inches)	Average Intensity (inch/hour)	Peak Intensity (inch/hour)	Storm Recurrence Interval (1-hour)
	1/22/2018	34.25	1.42	0.04	0.45	< 3m
	11/9/2018	15.75	1.72	0.11	0.45	<3m
	4/15/2018	22.25	2.15	0.10	0.40	< 3m
Chelsea Creek Headworks (CH-BO-1)	9/18/2018	12.75	1.60	0.13	1.05	1.5y
	7/17/2018	11.25	2.12	0.19	0.97	1y
	5/15/2018	4.00	1.29	0.32	0.96	1y
	8/11/2018	62.25	2.95	0.05	0.82	6m-1y
	9/25/2018	13.00	1.52	0.12	0.73	6m
	6/27/2018	15.50	1.15	0.07	0.62	3m-6m
	7/26/2018	1.75	0.56	0.32	0.53	3m
	11/2/2018	33.75	1.87	0.06	0.50	<3m
	11/9/2018	16.00	1.65	0.10	0.47	<3m
	8/4/2018	4.00	0.58	0.15	0.46	<3m
	6/24/2018	14.00	0.81	0.06	0.43	<3m
	8/17/2018	8.75	0.44	0.05	0.42	<3m
Fresh Pond (from USGS)	9/18/2018	14.00	1.75	0.13	1.11	1.5y
	8/11/2018	38.00	1.87	0.05	0.78	6m-1y
	7/17/2018	17.25	2.03	0.12	0.67	3m-6m
	4/27/2018	7.75	0.88	0.11	0.62	3m-6m
	6/27/2018	20.50	1.46	0.07	0.62	3m-6m
	5/15/2018	4.00	0.91	0.23	0.60	3m
	6/24/2018	11.00	1.17	0.11	0.57	3m
	10/29/2018	9.00	0.81	0.09	0.55	3m
	7/6/2018	2.00	0.56	0.28	0.52	<3m
	7/25/2018	37.75	0.75	0.02	0.50	<3m
	1/22/2018	32.50	1.17	0.04	0.49	<3m
	8/22/2018	8.50	0.51	0.06	0.46	<3m
	9/25/2018	21.75	1.61	0.07	0.46	<3m
	8/14/2018	2.50	0.77	0.31	0.45	<3m
	11/2/2018	34.00	1.79	0.05	0.41	<3m
	4/15/2018	22.75	2.06	0.09	0.40	<3m
	6/5/2018	2.50	0.45	0.18	0.40	<3m

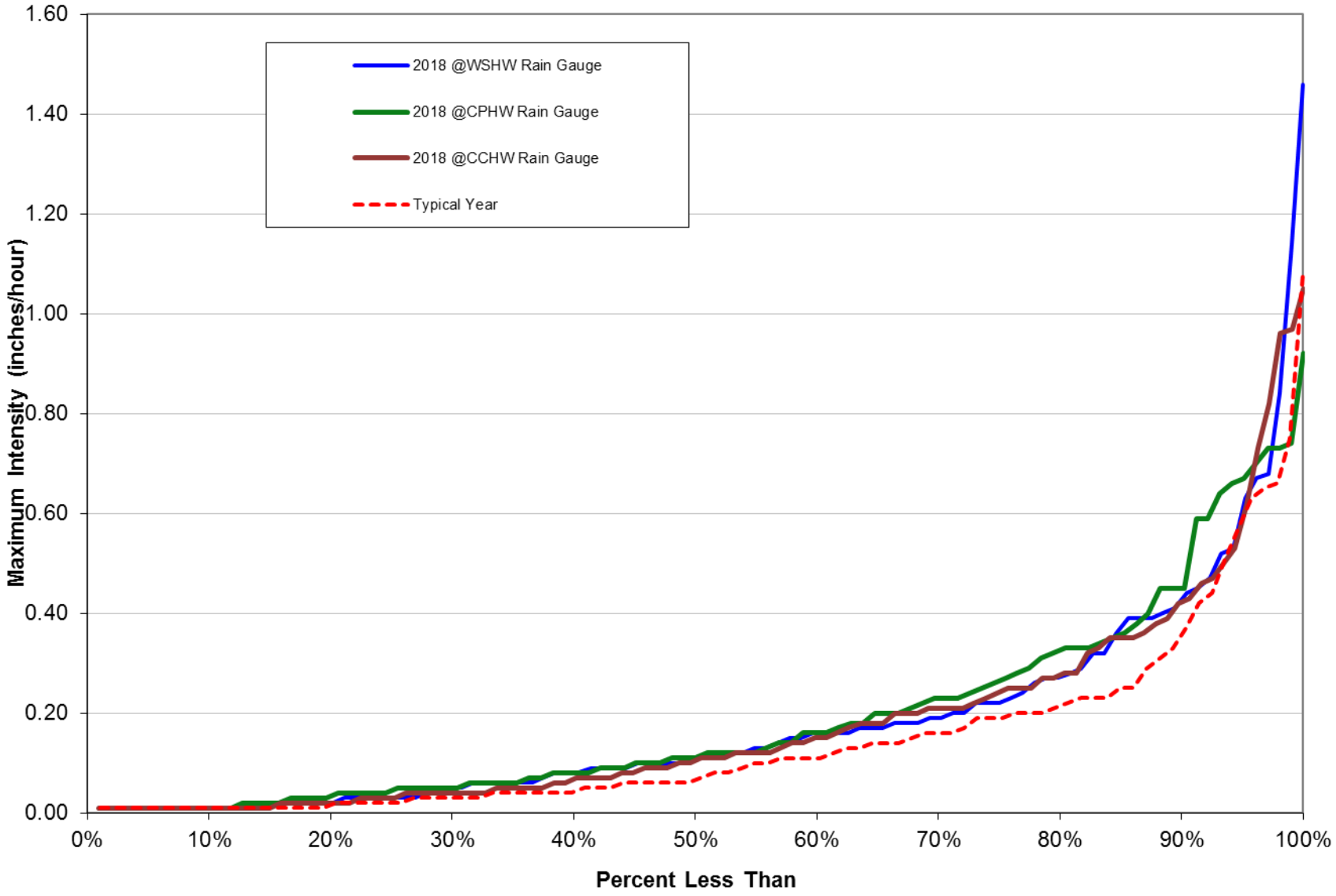

FIGURE R-1. RAINFALL INTENSITY COMPARISON: 2018 VS. TYPICAL YEAR