Task 5.4 Water Quality Alternatives Assessment

CSO Post Construction Monitoring and Performance Assessment

MWRA Contract No. 7572

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1. Introduction

1.1 Background

Hydrodynamic and water quality models of the Charles River and Alewife Brook/Upper Mystic River were developed, calibrated and utilized to assess the impacts of various sources of bacteria on attainment of Water Quality Standards. These rivers were selected for evaluation with water quality models because they are the subject of Water Quality Variances. The variances allow limited departures from the Water Quality Standards due to CSO discharges, but require periodic reassessment.

The development and calibration of the water quality models are described in the December 2020 *Task 5.2 Receiving Water Quality Model Development and Calibration Report* (AECOM, 2020). The calibrated models were used to assess existing conditions (as of 2019) following the completion of the thirty-five (35) wastewater system projects that comprise the Long Term Control Plan (LTCP). The results of that assessment are presented in the August 2021 *Task 5.3 Water Quality Assessment Report* (AECOM, 2021). That assessment concentrated on *E. coli* counts in the rivers in comparison with the Massachusetts Surface Water Quality Standards for *E. coli*, specifically the "Single Sample Maximum" criterion of 235 #/100mL. The Water Quality Standards also include a criterion on geometric means of bacterial counts, but this was not used as it relates to monitoring data rather than model results. Also, the single sample maximum was the metric used in the LTCP to assess water quality conditions and a goal of the current modeling was to compare existing conditions with LTCP predictions. Differences in the approach to assessing attainment with Water Quality Standards between the LTCP and the current evaluations, including the change in indicator bacteria from fecal coliform to *E. coli* and *Enterococcus*, are summarized in the August 2021 *Task 5.3 Water Quality Assessment Report* (AECOM 2021). While *Enterococcus* was also evaluated in the new modeling, it was considered a secondary parameter as *Enterococcus* is more relevant to saline waters.

The Charles River model is two-dimensional (horizontally), based on the Delft3D software, while the Alewife Brook/Upper Mystic River Model is one-dimensional, based on the InfoWorks-ICM software. The extents of the two models are shown in Figure 1.1.

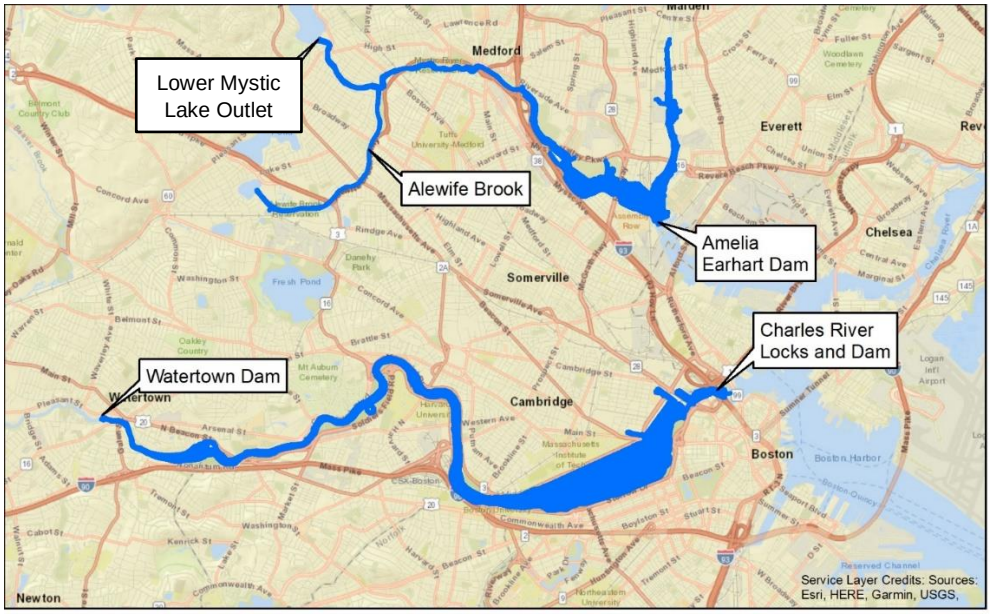

Figure 1-1. Extent of the Charles River and Alewife Brook/Upper Mystic River Models

The models were calibrated by comparison of model predictions with the measurements from the extensive receiving water quality monitoring conducted by MWRA. The calibration was conducted for the year 2018.

The sources of pollution that were considered were CSOs (treated and untreated), stormwater, dry weather discharges and boundary inflows (water flowing into the model domain from upstream). The models were applied to the "Typical Year" defined during the LTCP based on a review of long-term rainfall records. The Typical Year consists of 93 storms with a total precipitation of 46.8 inches; the largest storm has an approximately 2-year return period.

The model results, in terms of exceedance of the *E. coli* single-sample maximum criterion, were presented in several different ways. The simplest presentation was the number of hours that the criterion was exceeded anywhere in the rivers. From the numbers of hours of exceedance, the percent of time in compliance with the criterion was assessed. This assessment is very conservative as the locations where the criterion is exceeded move with time so that a stationary receptor would only experience the exceedance for a fraction of the total time. Nevertheless, the total exceedance time has the advantage of being a single number that can be compared with LTCP predictions.

More refined assessments were provided through plots of *E. coli* count contours (for the Charles River) and longitudinal profiles (for the Alewife Brook/Upper Mystic River) for the entire Typical Year and at different times during the 1-year, 24-hour storm, which was also included in the Typical Year.

1.2 Alternatives Assessments

Following model development/calibration and establishment of water quality conditions based on the 2019 collection system conditions, the next step in the water quality modeling assessment was to evaluate alternatives and conduct sensitivity analyses for various bacterial load reduction scenarios. These alternatives included updated collection system conditions (Q1-2021 conditions), which became the new baseline to which other alternatives were compared, as well as other alternatives covering further potential improvements to the wastewater collection system and to the stormwater systems. The alternatives were consistent with the intent of the May 24, 2019 AECOM Receiving Water Model Work Plan (MWRA 2019), and included suggested alternatives from DEP, EPA and other stakeholders.

The performance of the alternatives was assessed primarily in terms of the percent compliance with the *E. coli* single sample maximum criterion over the entire rivers, which can be easily compared to the baseline conditions. The presentation of the alternatives below in Section 2 includes a description/intent of the alternative, how the alternative was represented in the model, a summary of the results, and qualitative comments on the general feasibility of implementation of the alternative. Some alternatives suggested by stakeholders were not assessed in detail for different reasons. These alternatives are discussed in Section 3. The following is a list of the alternatives presented in Sections 2 and 3:

<u>Section 2: Alternatives Simulated</u>

Alternative 1. Q1-2021 Collection System Conditions

Alternative 2. Non-CSO Sources Capped at 100% of Water Quality Criterion

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Alternative O1. Simulate conditions when the design capacities of Cottage Farm and Somerville Marginal are exceeded

Alternative O2. Simulate CSO elimination by sewer separation

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Alternative O5. Simulate CSO variability

2. Alternatives Simulated

Alternative 1. Q1-2021 Collection System Conditions

Description/Intent. The purpose of this alternative was to incorporate collection system modifications and model improvements that were implemented between 2019, which was the basis for the previous assessment (MWRA, 2021), and the first quarter of 2021 (Q1-2021). The main collection system and model improvements implemented from 2019 to Q1-2021 relevant to the Charles River and Alewife Brook/Upper Mystic River models are summarized below.

For the Charles River:

- Completion of the Cambridgeport partial sewer separation project. This project reduced the treated discharge activation frequency and volume at the Cottage Farm CSO Facility.
- Update of the model configuration of MWR018-020 based on inspection data. These changes slightly reduced the total volume at those outfalls, with no change to activation frequency.

For Alewife Brook/Upper Mystic River:

- Removal of sediment downstream of CAM401A. This work, completed by the City of Cambridge, reduced activations and volumes at this CSO.
- Update of the model calibration at SOM001A. The collection system calibration in the vicinity of SOM001A was updated based on newly-available meter data. As a result, the activation frequency and volume increased from 2019 to Q1-2021 conditions.
- Implementation of a revised operating procedure at Alewife Brook Pump Station. This change did not substantially affect CSO volumes or activations.

The Q1-2021 conditions versions of the Charles River and Alewife Brook/Upper Mystic River water quality models as presented below were then used as the new baseline conditions for evaluation of the subsequent alternatives.

Model Simulation Approach. This alternative was simulated by running the Q1-2021 collection system model with a sanitary wastewater tracer (to allow calculation of the CSO *E. coli* counts) and using the model results to specify the CSO inputs to the water quality models. The Q1-2021 CSO activations and volumes for the Typical Year for the Charles River and the Alewife Brook/Upper Mystic River are summarized in Tables 2-1 and 2-2. These tables also include the CSO volume totals for 2019 conditions for comparison. As indicated in the last two rows in Tables 2-1 and 2-2, CSO volumes either decreased or remained unchanged at most of the CSO outfalls between 2019 and Q1-2021 conditions. All other inputs remained the same; for a complete description of the data and assumptions used in deriving volumes and bacteria counts for CSOs, stormwater, and other sources, see *Task 5.2 Receiving Water Quality Model Development and Calibration Report* (AECOM 2020).

Table 2-1. Charles River CSO Activations during Typical Year for Q1-2021 System Conditions

Date	Rainfall		CSO Volume (MG)[1]						
	Peak 15-Min Intensity	Depth	CAM005	CAM007	MWR018	MWR019	MWR020	MWR201 (Cottage Farm)	MWR023[2]
	(in/hr)	(in)							
1/4/1992	0.48	1.15							
1/14/1992	0.52	0.49							
1/23/1992	0.4	1.38							
2/15/1992	0.2	0.87							
2/25/1992	0.24	0.84							
3/7/1992 (3-mo Storm)	0.22	1.89							
3/11/1992	0.48	0.97							
3/19/1992	0.08	0.42							
3/26/1992	0.16	0.67							
3/28/1992	0.08	0.42							
4/11/1992	0.4	0.52							
4/16/1992	0.28	1.02							
4/24/1992	0.24	0.88							
5/2/1992	1.32	1.14	0.06						
6/1/1992	0.48	2.24							
6/6/1992	1	1.34	0.01						
6/20/1992	0.56	0.45							
6/24/1992	0.24	0.56							
7/6/1992	0.36	0.38							
7/15/1992	0.32	0.5							
7/23/1992	0.28	0.42							
7/31/1992	0.68	0.59							
8/11/1992	1.24	0.87	0.12						
8/18/1992	0.8	2.91	0.06						
9/3/1992	0.68	1.19							
9/9/1992	1.72	0.57	0.09	0.26					
9/11/1992	0.36	0.38							
9/22/1992 (1-yr Storm)	0.65	2.8	0.06		0.71	0.28	0.04	7.23	
9/26/1992	0.36	0.74							
10/10/1992	0.72	2.04							
10/23/1992	1.08	1.18	0.26	0.19	0.43	0.23	0.52	1.72	0.14
10/24/1992	0.16	0.38							
11/3/1992	0.2	0.94							
11/5/1992	0.16	0.31							
11/21/1992	0.36	1.93							
11/23/1992	0.36	1.93							
11/26/1992	0.24	0.51							
12/3/1992	0.2	0.82							
12/12/1992	0.24	3.89							
12/17/1992	0.2	0.58							
12/29/1992	0.16	0.37							
12/30/1992	0.12	0.44							
Total CSO Volume in Typical Year - Q1-2021			**0.66**	**0.45**	**1.14**	**0.51**	**0.57**	**8.95**	**0.14**
Total CSO Volume in Typical Year - 2019			**0.73**	**0.39**	**1.92**	**0.56**	**0.32**	**12.36**	**0.14**

Notes:

(1) CAM017 and MWR010 do not activate during the Typical Year. CAM009 and CAM011 were closed by the City of Cambridge in 2007 on an interim basis. The City of Cambridge maintains CAM009 and CAM011 in a closed condition while it continues to evaluate hydraulic conditions in the local sewer system before making a decision to close them permanently.

(2) For the receiving water quality modeling, all CSO discharge from BOS046 regulators was represented as discharging out of MWR023.

Table 2-2. Alewife Brook and Upper Mystic River CSO Activations during Typical Year for Q1-2021 System Conditions

Date	Rainfall		CSO Volume (MG)[1]					
	Peak 15-Min Intensity (in/hr)	Depth (in)	CAM001	MWR003	CAM401A	CAM401B	SOM001A	SOM007A/ MWR205A (Somerville Marginal Relief)
1/4/1992	0.48	1.15						
1/14/1992	0.52	0.49						
1/23/1992	0.4	1.38						
2/15/1992	0.2	0.87						
2/25/1992	0.24	0.84						
3/7/1992 (3-mo Storm)	0.22	1.89						0.04
3/11/1992	0.48	0.97						
3/19/1992	0.08	0.42						
3/26/1992	0.16	0.67						
3/28/1992	0.08	0.42						
4/11/1992	0.4	0.52						
4/16/1992	0.28	1.02						
4/24/1992	0.24	0.88						
5/2/1992	1.32	1.14			0.02	0.01	0.37	3.46
6/1/1992	0.48	2.24						
6/6/1992	1	1.34			0.02		0.08	
6/20/1992	0.56	0.45						
6/24/1992	0.24	0.56						
7/6/1992	0.36	0.38						
7/15/1992	0.32	0.5						
7/23/1992	0.28	0.42						
7/31/1992	0.68	0.59						
8/11/1992	1.24	0.87					0.61	
8/18/1992	0.8	2.91		0.05	0.18	0.07	0.66	
9/3/1992	0.68	1.19					0.07	
9/9/1992	1.72	0.57					0.24	
9/11/1992	0.36	0.38						
9/22/1992 (1-yr Storm)	0.65	2.8		0.26	0.20	0.26	0.91	
9/26/1992	0.36	0.74						
10/10/1992	0.72	2.04						
10/23/1992	1.08	1.18	0.02	0.30	0.23	0.16	1.52	0.49
10/24/1992	0.16	0.38						
11/3/1992	0.2	0.94						
11/5/1992	0.16	0.31						
11/21/1992	0.36	1.93						
11/23/1992	0.36	1.93						
11/26/1992	0.24	0.51						
12/3/1992	0.2	0.82						0.37
12/12/1992	0.24	3.89						0.14
12/17/1992	0.2	0.58						
12/29/1992	0.16	0.37						
12/30/1992	0.12	0.44						
Total CSO Volume in Typical Year - Q1-2021			**0.02**	**0.61**	**0.66**	**0.50**	**4.47**	**4.50**
Total CSO Volume in Typical Year - 2019			**0.02**	**1.60**	**3.59**	**0.73**	**3.60**	**4.95**

Notes:

(1) CAM002 does not activate during the Typical Year.

Results. Table 2-3 presents a comparison of the overall percent time compliance with the *E. coli* criterion for 2019 conditions versus Q1-2021 conditions. As a reminder, the values in Table 2-3 represent the percent of time that all the model cells within the waterbody were in compliance with the criterion and represent a very conservative measure of compliance. For example if there were 40 hours in a year in which the bacteria count exceeded the criterion, that would be a percent compliance of [(24 h X 365 d) – 40 h] / (24 h X 365 d) = 99.5%. Comparisons are presented for model evaluations with all sources, non-CSO sources only, stormwater only, dry weather sources only, boundary sources only, and CSOs only.

Table 2-3. Compliance Statistics for 2019 and Q1-2021 Conditions

Alternative	Percent Annual Compliance with *E. coli* Single Sample Maximum Criterion (235#/100mL)					
	All Sources	Non-CSO Sources Only	Stormwater Only	Dry Weather Sources Only	Boundaries Only	CSOs Only
Charles River						
0 - 2019 Conditions	48%	48%	64%	100%	59%	99.6%
1 - Q1-2021 Conditions	48%	48%	64%	100%	59%	99.9%
Alewife Brook						
0 - 2019 Conditions	45%	45%	48%	100%	100%	98.7%
1 - Q1-2021 Conditions	45%	45%	48%	100%	100%	99.6%
Upper Mystic River						
0 - 2019 Conditions	54%	55%	56%	100%	91%	97.0%
1 - Q1-2021 Conditions	54%	55%	56%	100%	91%	97.9%

Salient results are summarized as follows:

- For the Charles River, percent compliance remained unchanged relative to 2019 conditions, except for the CSOs Only case, where the percent compliance increased from 99.6% to 99.9% (a reduction in hours of non-compliance from 35 to 8 over the Typical Year).
- For Alewife Brook, percent compliance remained unchanged relative to 2019 conditions, except for the CSOs Only case, where compliance increased from 98.7% to 99.6% (a reduction in hours of non-compliance from 114 to 35 over the Typical Year).
- For the Upper Mystic River, percent compliance remained unchanged relative to 2019 conditions, except for the CSOs Only case, where the percent compliance increased from 97.0% to 97.9% (a reduction in hours of non-compliance from 263 to 184 over the Typical Year).

The total untreated volume to both the Charles River and Alewife Brook dropped somewhat from 2019 to Q1-2021 conditions; by 15% in the Charles (4.06 MG to 3.47 MG) and by 34% in Alewife/Mystic (9.54 MG to 6.26 MG). Therefore, the slight improvement in attainment in the CSOs only case could be expected. Since no other changes were made to the non-CSO loadings, it similarly makes sense that no change was seen in the other modeled loading conditions.

Contour plots of annual percent compliance and maximum *E. coli* counts for the Charles River based on the Typical Year are presented for Q1-2021 conditions in Figures 2-1 and 2-2. In each figure, contour plots are presented for All Sources and Non-CSO Sources Only. Corresponding linear plots of annual percent compliance and maximum *E. coli* counts for Alewife Brook/Upper Mystic River are presented in Figures 2-3 and 2-4.

As indicated in Figure 2-1, for All Sources, the minimum level of attainment in any one area of the Charles River was in the 60-80% range, which is much higher than the value of 48% for the Charles River as a whole shown in Table 2-3 above. The comparison of the All Sources and Non-CSO Sources Only contour plots in Figure 2-1 indicate that the non-CSO sources are driving the level of attainment in the river (i.e. the plots are essentially identical). Figure 2-2 shows that the maximum *E. coli* counts in the Charles River were similar for the All Sources and Non-CSO Sources Only conditions, indicating that the remaining CSOs do not significantly affect the value of the maximum *E. coli* counts in the Charles River.

Plots of maximum *E. coli* concentrations over the Typical Year for All Sources and Non-CSO Sources are presented to address the issue that percent compliance may be comparable for these two conditions but the bacteria concentrations in the receiving waters may be higher for All Sources than for Non-CSO Sources because CSO concentrations are higher than Non-CSO sources concentrations. Percent compliance can be similar for these two conditions, because they both exceed the criterion by orders of magnitude but the impact of CSOs could be greater than that of Non-CSO sources.

For the Alewife Brook/Upper Mystic River, the percent compliance plots in Figure 2-3 show virtually no difference between the All Sources and the non-CSO Sources Only conditions. Figure 2-4, however, shows that elimination of the CSO sources was predicted to reduce the maximum counts along Alewife Brook and the Upper Mystic River, but the magnitude of the counts remained sufficiently above the *E.coli* single sample maximum criterion such that the percent attainment was not affected.

For the Charles River, the maximum *E. coli* counts shown in Figure 2-2 for All Sources and Non-CSO Sources were very similar because a main contributor of *E. coli* loading was the upstream boundary, which was the same for both cases. For the Alewife Brook/Upper Mystic River, the CSOs had a relatively larger impact on the total *E. coli* loads to the waterbodies and were discharged into a much narrower waterbody (Alewife Brook) compared to the Charles River. As a result, a more substantial difference in maximum *E. coli* counts was seen in Figure 2-4 between the All Sources and the Non-CSO Sources conditions.

Plots for CSOs Only conditions were included in the Task 5.3 report (AECOM 2021) but were omitted in this report because the changes in CSO activations and volumes between the different alternatives were small and, therefore, the plots would not show any visible differences.

Feasibility. This alternative reflects actual conditions as of Q1-2021, and therefore is by definition feasible.

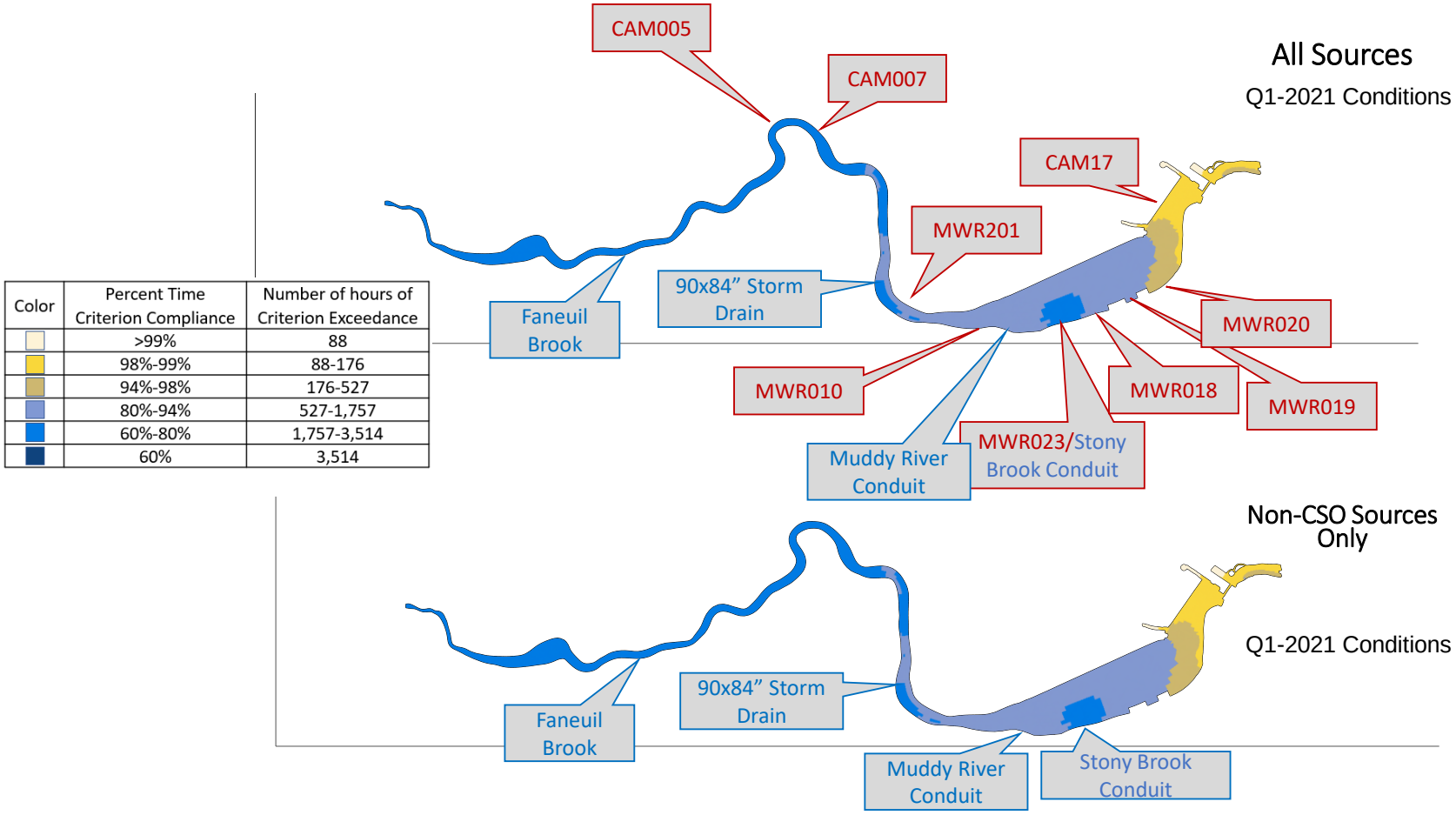

Figure 2-1. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Charles River – Alternative 1: Q1-2021 Conditions

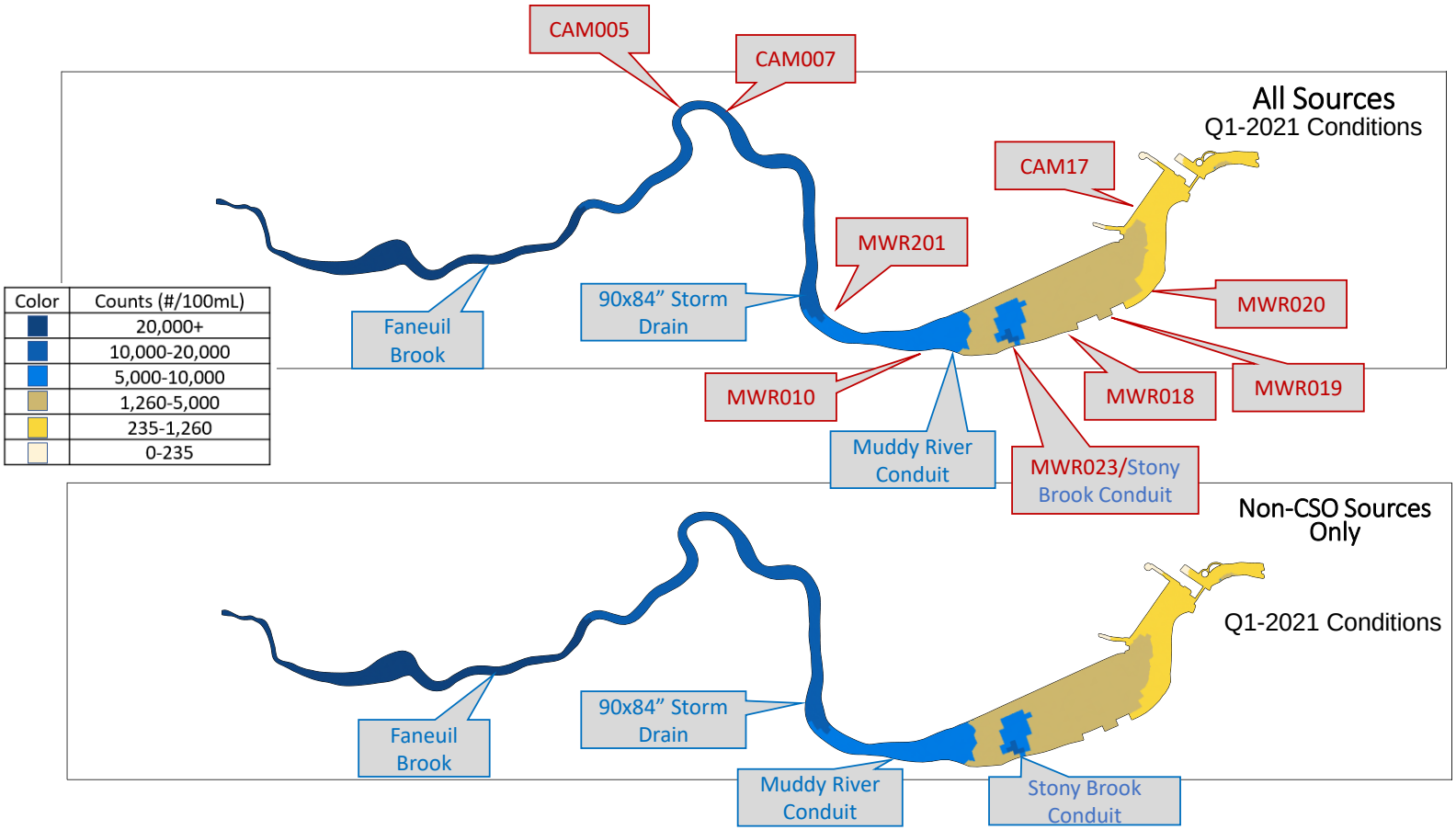

Figure 2-2. Maximum *E. coli* Counts during Typical Year in the Charles River – Alternative 1: Q1-2021 Conditions

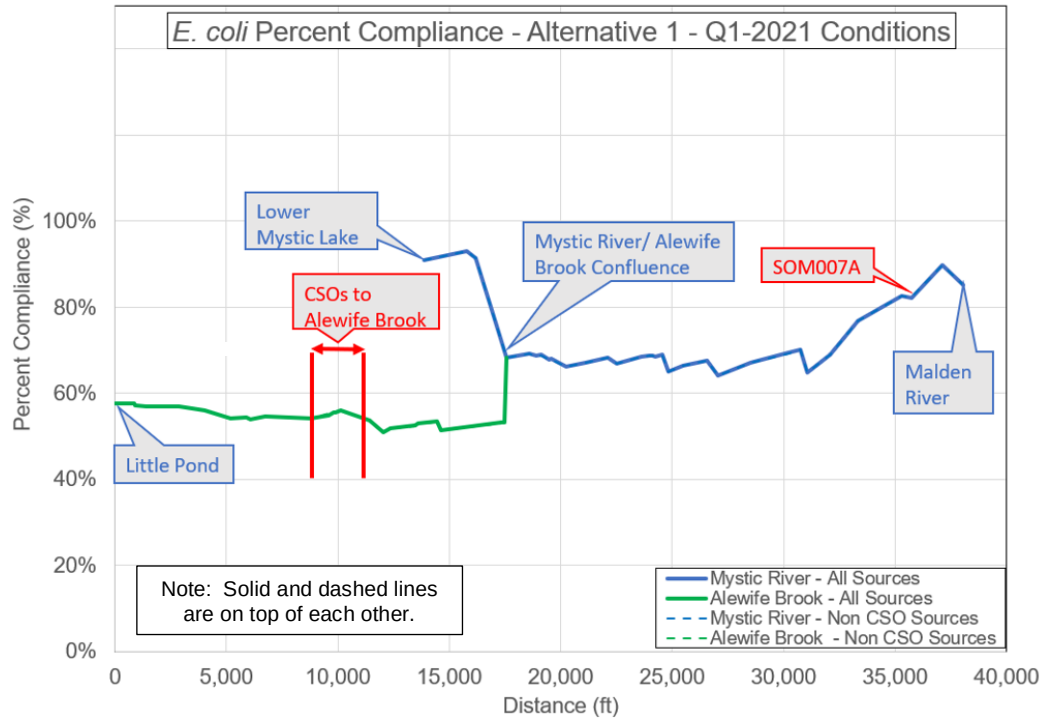

Figure 2-3. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Alewife Brook / Upper Mystic River – Alternative 1: Q1-2021 Conditions

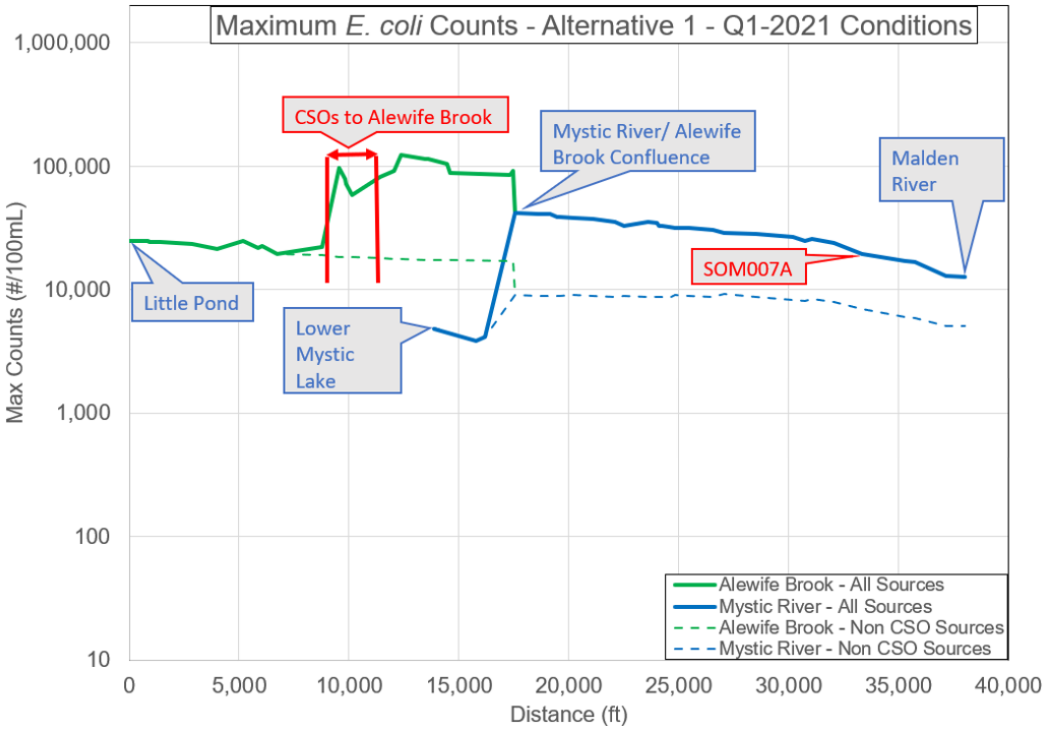

Figure 2-4. Maximum *E. coli* count during the Typical Year in the Alewife Brook / Upper Mystic River– Alternative 1: Q1-2021 Conditions

Alternative 2. Non-CSO Sources Capped at 100% of Water Quality Criterion

Description/Intent. This alternative was intended to reflect an ideal condition where the concentration of *E. coli* in stormwater discharges and other non-CSO sources were capped at the single-sample maximum criterion of 235#/100mL through implementation of Best Management Practices and other measures designed to improve stormwater quality. With non-CSO sources capped at the *E-coli* single-sample maximum criterion, this alternative would be expected to perform similar to the CSOs Only case for the baseline alternative.

Model Simulation Approach. The starting point for this alternative was the Q1-2021 conditions model. For this alternative, the CSO loads remained as they were in the Q1-2021 conditions model, but where the *E. coli* counts in the other, non-CSO inputs were above 235#/100mL, they were set to a constant value of 235#/100mL. Stormwater discharges all had *E. coli* counts larger than 235#/100mL, so they were all set to 235#/100mL. Boundary sources had variable counts with values greater than 235#/100mL during wet weather. The wet weather counts were adjusted to 235#/100mL but the dry weather counts that were below 235#/100mL were not changed.

Results. The percent compliance for this alternative compared to the baseline case of Q1-2021 Conditions are presented for the Charles River, Alewife Brook, and Upper Mystic River in Table 2-4.

For this alternative, the Non-CSO Sources Only, Stormwater Only, Dry Weather Sources and Boundaries Only compliance is 100% as these discharges are capped at the *E. coli* criterion of 235 #/100 mL and have no CSO inputs. For both the Charles River and the Alewife Brook/Upper Mystic River the percent compliance for All Sources is slightly less than the CSOs Only percentage. For the All-Sources case, the CSOs still discharge into ambient waters that contain *E. coli* from other sources, even though the counts from those sources were capped at 235 #/100mL. For the CSOs Only case, the discharge is into theoretically pristine waters with no other *E. coli* sources. Therefore, for this alternative, the *E. coli* counts due to CSOs decline to below the criterion more slowly in the All-Sources case than in the CSOs Only case.

Contour plots of compliance and maximum *E. coli* counts for this alternative for the Charles River are presented in Figures 2-5 and 2-6. Corresponding linear plots for the Alewife Brook / Upper Mystic River are presented in Figures 2-7 and 2-8.

Feasibility. This alternative represents an aspirational target for controlling *E. coli* counts in stormwater and other sources, but the level of stormwater controls needed to achieve these *E. coli* levels in stormwater discharges is not realistically implementable in the foreseeable future.

Table 2-4. Compliance Statistics for Non-CSO Sources Capped at 100% of Water Quality Criterion, Compared to Q1-2021 Baseline Conditions

Alternative	Percent Annual Compliance with *E. coli* Single Sample Maximum Criterion (235#/100mL)					
	All Sources	Non-CSO Sources Only	Stormwater Only	Dry Weather Sources Only	Boundaries Only	CSOs Only
Charles River						
1 - Q1-2021 Conditions	48%	48%	64%	100%	59%	99.9%
2 - Non-CSO Sources Capped at 100% of WQ Criterion	98%	100%	100%	100%	100%	99.9%
Alewife Brook						
1- Q1-2021 Conditions	45%	45%	48%	100%	100%	99.6%
2- Non-CSO Sources Capped at 100% of WQ Criterion	99.2%	100%	100%	100%	100%	99.6%
Upper Mystic River						
1 - Q1-2021 Conditions	54%	55%	56%	100%	91%	97.9%
2 - Non-CSO Sources Capped at 100% of WQ Criterion	97.1%	100%	100%	100%	100%	97.9%

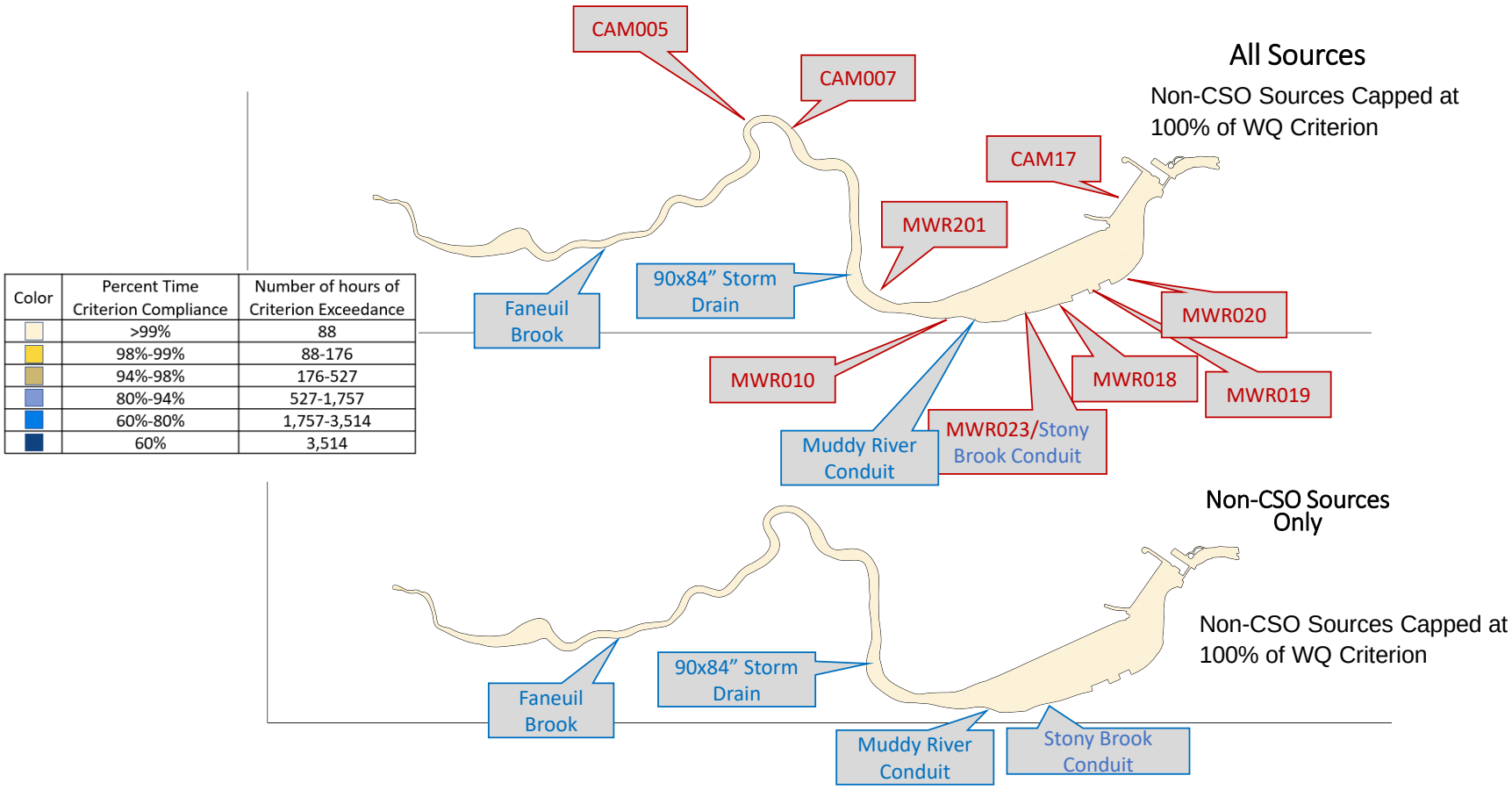

Figure 2-5. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Charles River – Alternative 2: Non-CSO Sources Capped at 100% of WQ Criterion

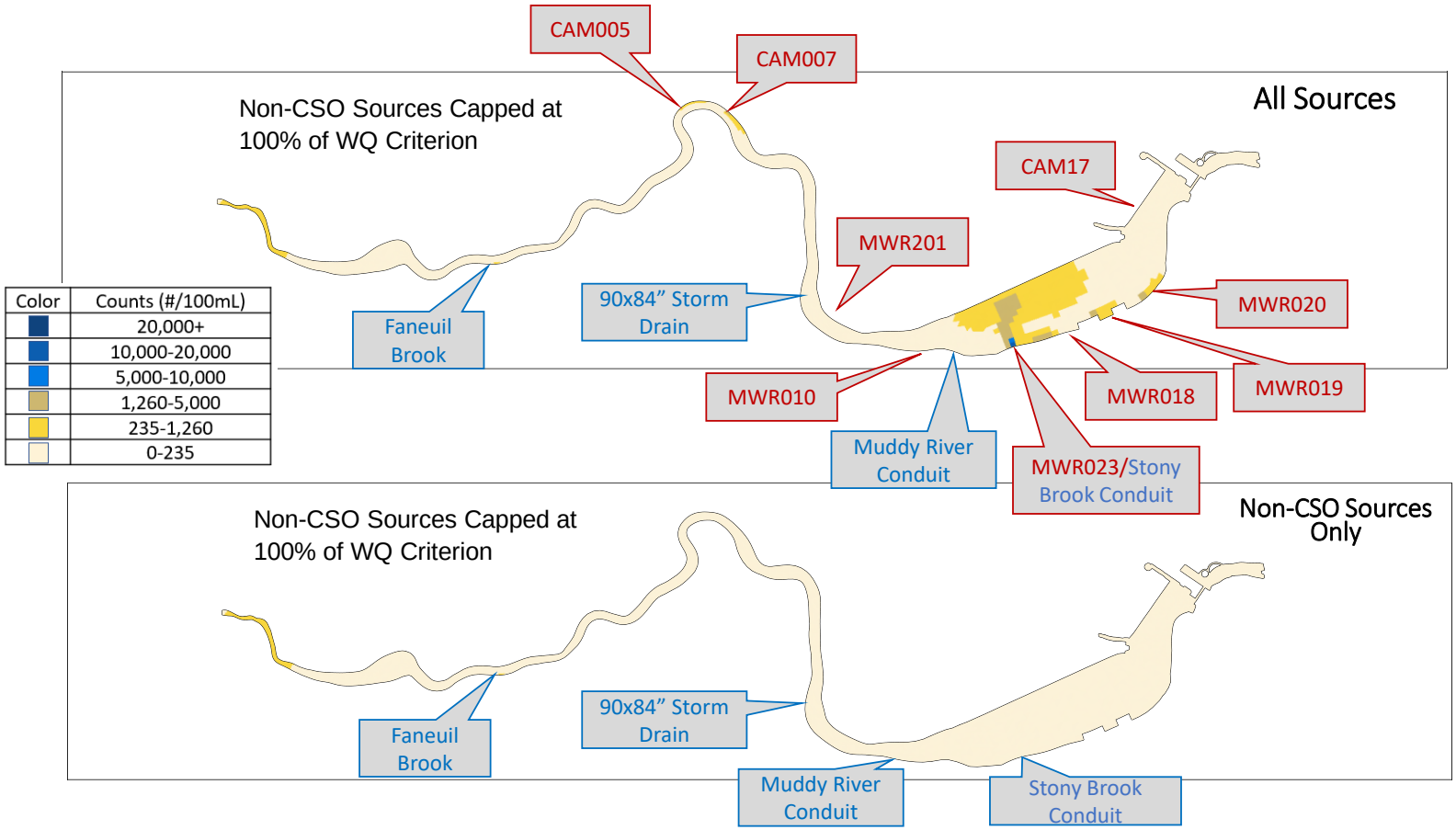

Figure 2-6. Maximum *E. coli* Counts during Typical Year in the Charles River – Alternative 2: Non-CSO Sources Capped at 100% of WQ Criterion

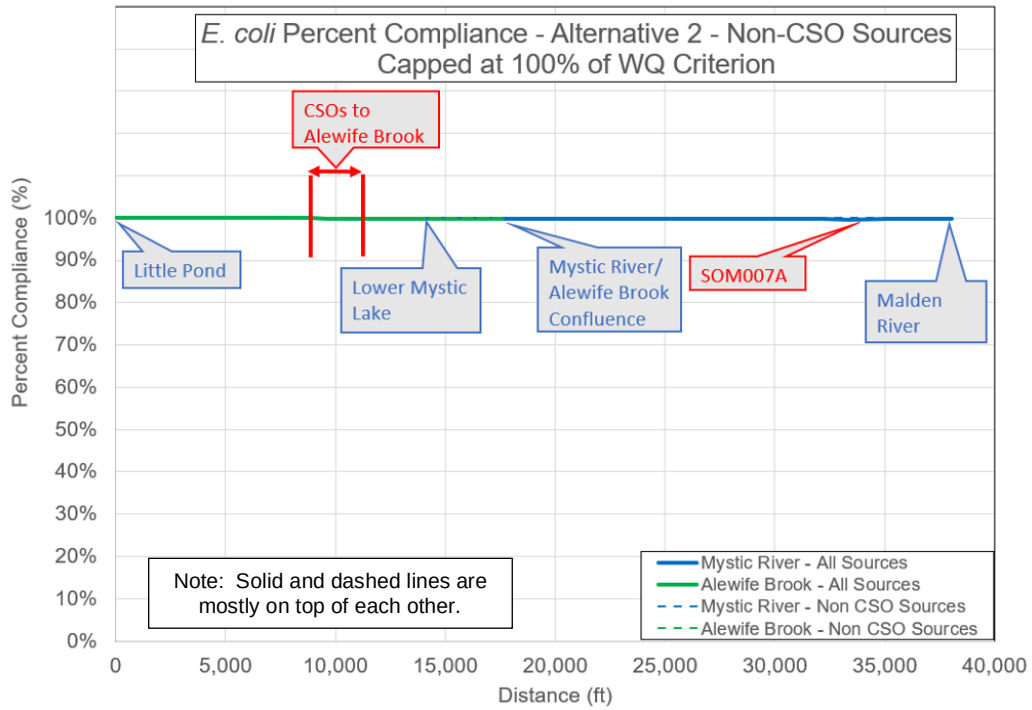

Figure 2-7. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Alewife Brook / Upper Mystic River – Alternative 2: Non-CSO Sources Capped at 100% of WQ Criterion

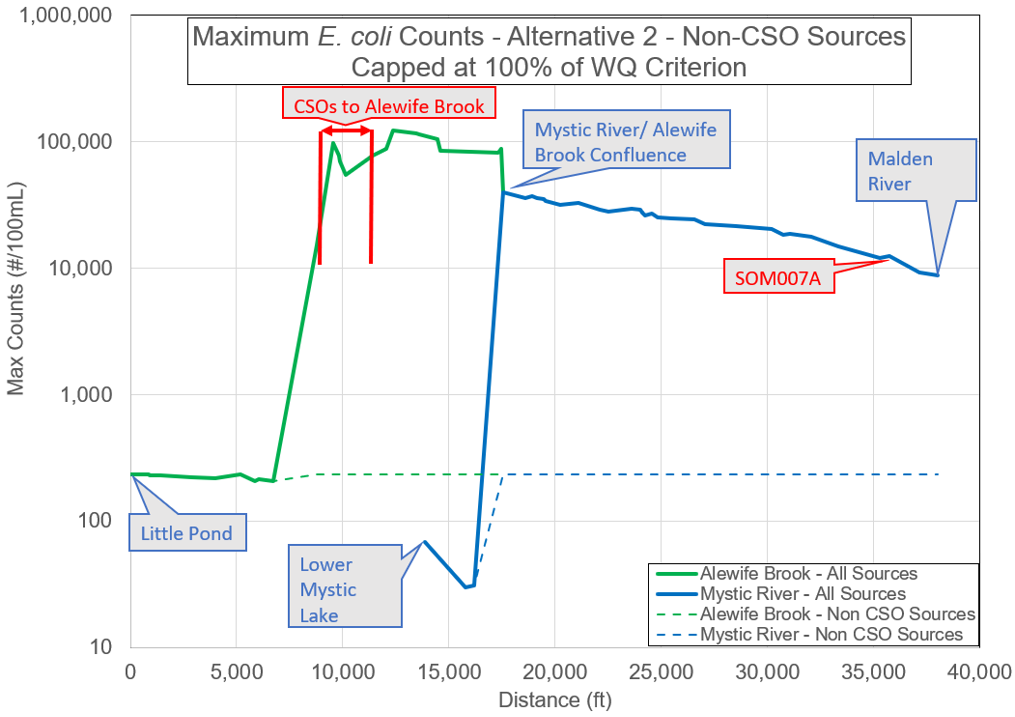

Figure 2-8 Maximum *E. coli* count during the Typical Year in the Alewife Brook / Upper Mystic River– Alternative 2: Non-CSO Sources Capped at 100% of WQ Criterion

Alternative 3. Non-CSO Sources Capped at 50% of Water Quality Criterion

Description/Intent. This alternative assessed the benefits of achieving Non-CSO (stormwater, dry weather and boundary sources) *E. coli* counts that would be capped at a value of half of the current single sample maximum criterion of 235 #/100mL. Alternative 2, which had the Non-CSO *E. coli* counts capped at the criterion, showed that for All Sources, the compliance was less than for the CSOs Only case. Therefore, a lower *E. coli* count was simulated in the Non-CSO discharges to see if the compliance would be improved for the All Sources case.

Model Simulation Approach. This alternative was simulated in a manner similar to Alternative 2 described above, with the Non-CSO sources *E. coli* counts capped at 117 #/100 mL

Results. The percent compliance for this alternative compared to the baseline case of Q1-2021 Conditions is presented for the Charles River, Alewife Brook, and Upper Mystic River in Table 2-5. For both the Charles River and the Alewife Brook/Upper Mystic River, the percent compliance for All Sources is very slightly below the compliance for CSO Sources Only.

Contour plots of compliance and maximum *E. coli* counts for the Charles River for this alternative are presented in Figures 2-9 and 2-10. Corresponding linear plots for the Alewife Brook/Upper Mystic River are presented in Figures 2-11 and 2-12.

Feasibility. As for Alternative 2, this alternative is a hypothetical alternative aimed at assessing the benefits of an extreme level of stormwater quality improvements.

Table 2-5. Compliance Statistics for Non-CSO Sources Capped at 50% of Water Quality Criterion, Compared to Q1-2021 Baseline Conditions

Alternative	Percent Annual Compliance with *E. coli* Single Sample Maximum Criterion (235#/100mL)					
	All Sources	Non-CSO Sources Only	Stormwater Only	Dry Weather Sources Only	Boundaries Only	CSOs Only
Charles River						
1 - Q1-2021 Conditions	48%	48%	64%	100%	59%	99.9%
3 - Non-CSO Sources Capped at 50% of WQ Criterion	99.8%	100%	100%	100%	100%	99.9%
Alewife Brook						
1 - Q1-2021 Conditions	45%	45%	48%	100%	100%	99.6%
3 - Non-CSO Sources Capped at 50% of WQ Criterion	99.2%	100%	100%	100%	100%	99.6%
Upper Mystic River						
1 - Q1-2021 Conditions	54%	55%	56%	100%	91%	97.9%
3 - Non-CSO Sources Capped at 50% of WQ Criterion	97.8%	100%	100%	100%	100%	97.9%

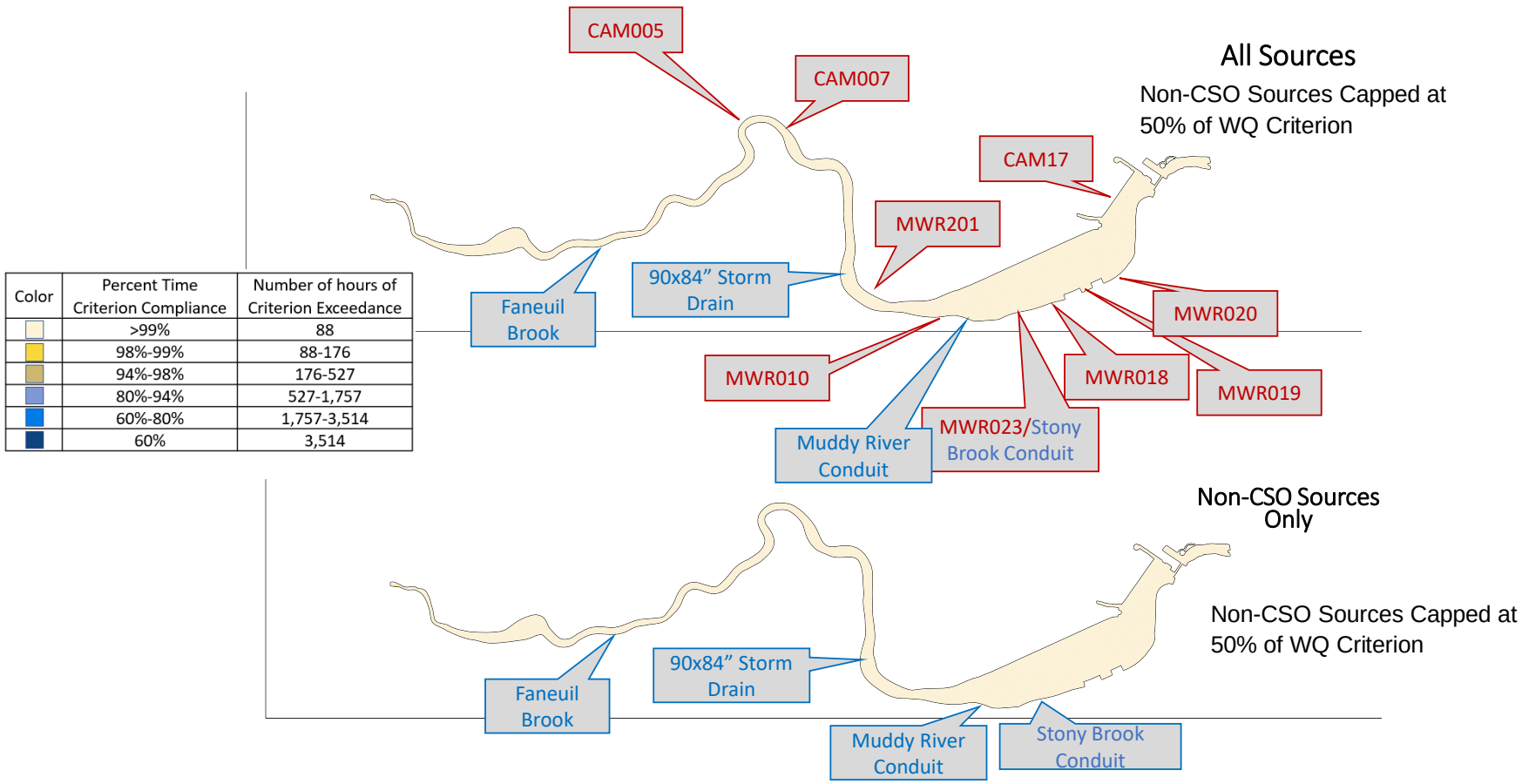

Figure 2-9. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Charles River - Alternative 3: Non-CSO Sources Capped at 50% of WQ Criterion

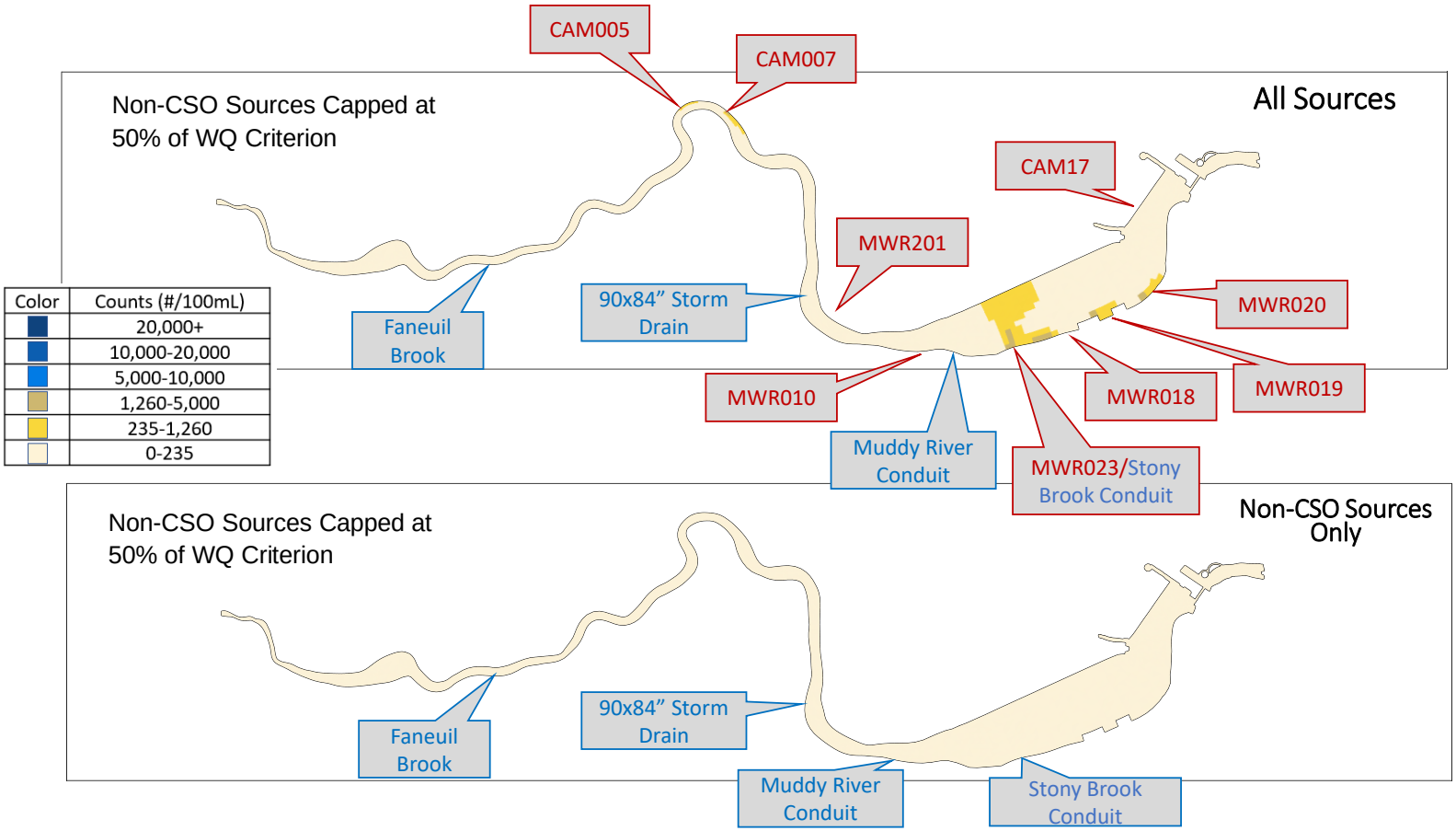

Figure 2-10. Maximum E. Coli Count during Typical Year in the Charles River - Alternative 3: Non-CSO Sources Capped at 50% of WQ Criterion

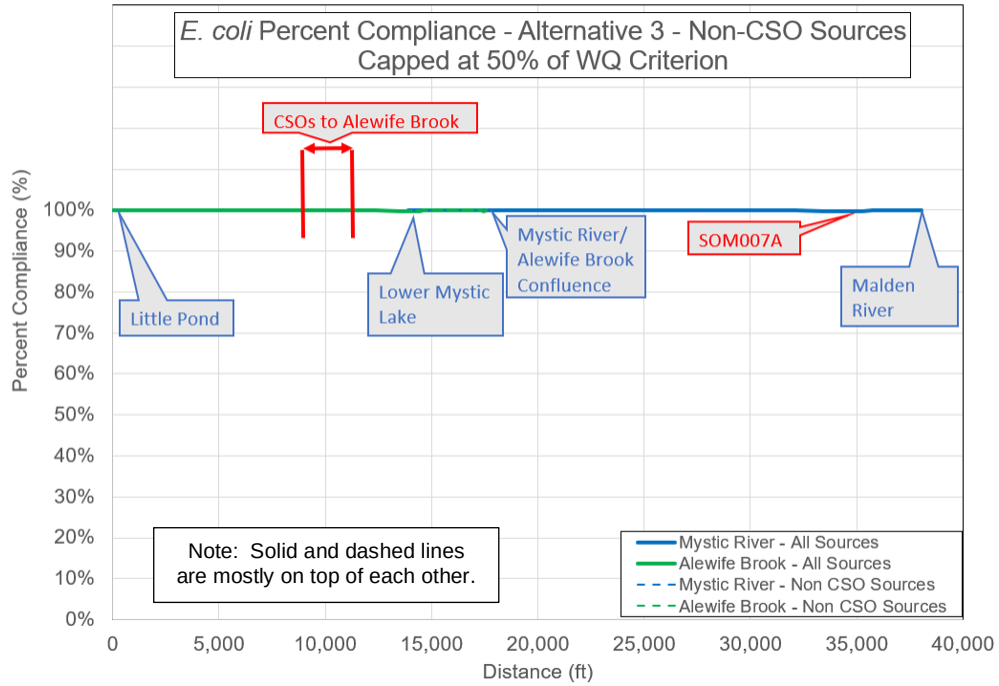

Figure 2-11. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Alewife Brook/Upper Mystic River – Alt 3: Non-CSO Sources Capped at 50% of WQ Criterion

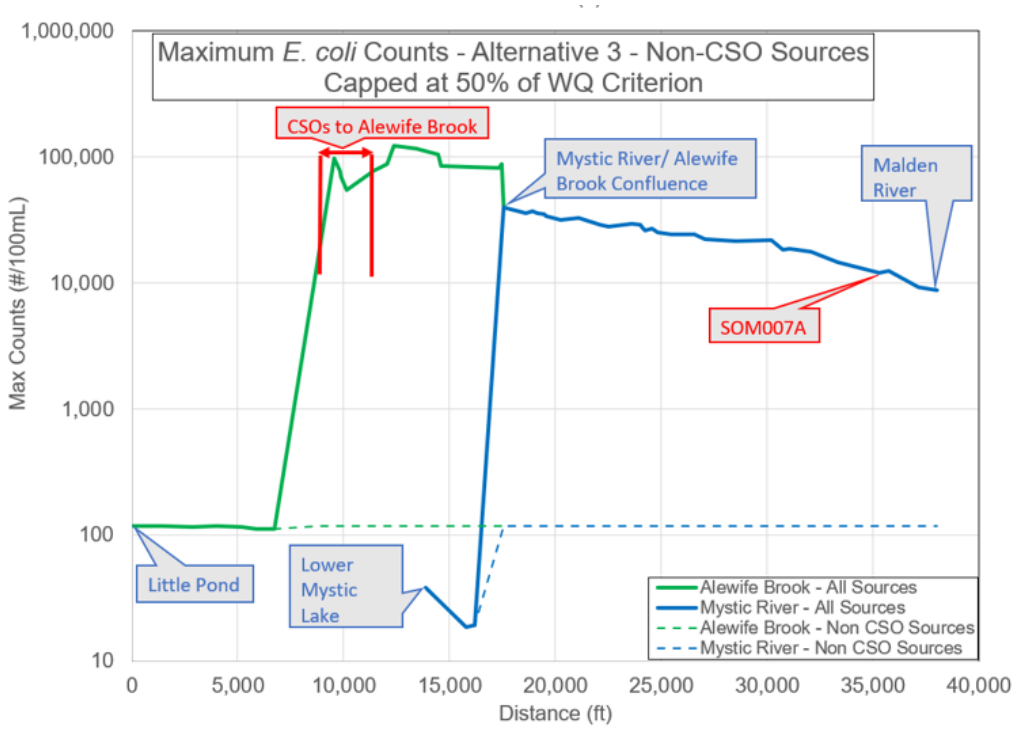

Figure 2-12 Maximum *E. coli* count during the Typical Year in the Alewife Brook / Upper Mystic River– Alternative 3: Non-CSO Sources Capped at 50% of WQ Criterion

Alternative 4. Q1-2021 Conditions but with all Outfalls Attaining the LTCP Goals for Activation Frequency and Volume

Description/Intent. As of the Q1-2021 collection system conditions, several CSO outfalls still exceeded the numerical LTCP goals in terms of activation frequency and/or volume. This alternative was intended to assess the improvement in attainment with water quality criteria that would be achieved if all outfalls were brought into attainment with the LTCP goals for CSO activation frequency and volume.

Model Simulation Approach. This alternative was modeled by removing CSO activations at outfalls where the Q1-2021 conditions activation frequency exceeded the number specified in the LTCP and, when needed, prorating the CSO flows down to meet the LTCP annual volume goal. Outfalls with fewer activations or lower volumes than the LTCP goals were left unchanged. Tables 2-6 and 2-7 summarize the adjustments made to the Q1-2021 activations and volumes to create the "LTCP Goals Attained" conditions, for the Charles River and Alewife Brook/Upper Mystic River, respectively.

All other sources were held at their original levels.

Results. The percent compliance for this alternative compared to the baseline case of Q1-2021 conditions is presented for the Charles River, Alewife Brook, and Upper Mystic River in Table 2-8. For the Charles River, the compliance statistics are identical to those of the baseline Q1-2021 conditions. For both the Alewife Brook and Upper Mystic River, the statistics are identical to those of the baseline conditions, except for the CSOs Only conditions where a slight improvement is noted.

Contour plots of compliance and maximum *E. coli* counts for the Charles River for this alternative are presented in Figures 2-13 and 2-14. Corresponding linear plots for the Alewife Brook/Upper Mystic River are presented in Figures 2-15 and 2-16.

Feasibility. The relatively marginal improvement in attainment with the water quality criteria demonstrated by the " LTCP Goals Attained" alternative compared to Q1-2021 Conditions will need to be considered when evaluating the costs and potential implementation challenges of alternatives needed to meet the numerical LTCP goals for the outfalls assessed.

Table 2-6. Charles River CSO Activations during Typical Year when LTCP Goals Attained Conditions

Date	Rainfall		CSO Volume (MG)[1]						
	Peak 15-Min Intensity (in/hr)	Depth (in)	CAM005	CAM007	MWR018	MWR019	MWR020	MWR201 (Cottage Farm)	MWR023[2]
Q1-2021 (Activations/Volume)			7 / 0.66 MG	2 / 0.45 MG	2 / 1.14 MG	2 / 0.51 MG	2 / 0.57 MG	2 / 8.95 MG	1 / 0.14 MG
LTCP Goal (Activations/Volume)			3 / 0.84 MG	1 / 0.03 MG	0 / 0 MG	0 / 0 MG	0 / 0 MG	2 / 6.3 MG	2 / 0.13 MG
Notes			Removed 4 smallest activations	Removed smallest activation	Removed 2 activations	Removed 2 activations	Removed 2 activations	Reduced volume by ratio	Reduced volume at RE046-381
1/4/1992	0.48	1.15							
1/14/1992	0.52	0.49							
1/23/1992	0.4	1.38							
2/15/1992	0.2	0.87							
2/25/1992	0.24	0.84							
3/7/1992 (3-mo Storm)	0.22	1.89							
3/11/1992	0.48	0.97							
3/19/1992	0.08	0.42							
3/26/1992	0.16	0.67							
3/28/1992	0.08	0.42							
4/11/1992	0.4	0.52							
4/16/1992	0.28	1.02							
4/24/1992	0.24	0.88							
5/2/1992	1.32	1.14	~~0.06~~						
6/1/1992	0.48	2.24							
6/6/1992	1	1.34	~~0.01~~						
6/20/1992	0.56	0.45							
6/24/1992	0.24	0.56							
7/6/1992	0.36	0.38							
7/15/1992	0.32	0.5							
7/23/1992	0.28	0.42							
7/31/1992	0.68	0.59							
8/11/1992	1.24	0.87	0.12						
8/18/1992	0.8	2.91	~~0.06~~						
9/3/1992	0.68	1.19							
9/9/1992	1.72	0.57	0.09	0.03					
9/11/1992	0.36	0.38							
9/22/1992 (1-yr Storm)	0.65	2.8	~~0.06~~		~~0.71~~	~~0.28~~	~~0.04~~	5.06	
9/26/1992	0.36	0.74							
10/10/1992	0.72	2.04							
10/23/1992	1.08	1.18	0.26	~~0.19~~	~~0.43~~	~~0.23~~	~~0.52~~	1.21	0.13
10/24/1992	0.16	0.38							
11/3/1992	0.2	0.94							
11/5/1992	0.16	0.31							
11/21/1992	0.36	1.93							
11/23/1992	0.36	1.93							
11/26/1992	0.24	0.51							
12/3/1992	0.2	0.82							
12/12/1992	0.24	3.89							
12/17/1992	0.2	0.58							
12/29/1992	0.16	0.37							
12/30/1992	0.12	0.44							
Total CSO Volume in Typical Year			**0.46**	**0.03**	**0.00**	**0.00**	**0.00**	**6.27**	**0.13**

Notes:

(1) CAM017 and MWR010 do not activate during the Typical Year. CAM009 and CAM011 were closed by the City of Cambridge in 2007 on an interim basis. The City of Cambridge maintains CAM009 and CAM011 in a closed condition while it continues to evaluate hydraulic conditions in the local sewer system before making a decision to close them permanently.

(2) For the receiving water quality modeling, all CSO discharge from BOS046 regulators was represented as discharging out of MWR023.

Table 2-7. Alewife/Mystic CSO Activations during Typical Year when LTCP Goals Attained Conditions

Date	Rainfall		CSO Volume (MG)[1]					
	Peak 15-Min Intensity (in/hr)	Depth (in)	CAM001	MWR003	CAM401A	CAM401B	SOM001A	SOM007A/ MWR205A
Q1-2021 (Activations/Volume)			1 / 0.02 MG	3 / 0.60 MG	5 / 0.66 MG	4 / 0.50 MG	8 / 4.47 MG	5 / 4.50 MG
LTCP Goal (Activations/Volume)			5 / 0.19 MG	5 / 0.98 MG	5 / 1.61 MG	7 / 2.15 MG	3 / 1.67 MG	3 / 3.48 MG
Notes			Currently Meeting LTCP	Currently Meeting LTCP	Currently Meeting LTCP	Currently Meeting LTCP	Removed 5 smallest activations reduced rest	Removed 2 smallest activations reduced rest
1/4/1992	0.48	1.15						
1/14/1992	0.52	0.49						
1/23/1992	0.4	1.38						
2/15/1992	0.2	0.87						
2/25/1992	0.24	0.84						
3/7/1992 (3-mo Storm)	0.22	1.89						~~0.04~~
3/11/1992	0.48	0.97						
3/19/1992	0.08	0.42						
3/26/1992	0.16	0.67						
3/28/1992	0.08	0.42						
4/11/1992	0.4	0.52						
4/16/1992	0.28	1.02						
4/24/1992	0.24	0.88						
5/2/1992	1.32	1.14			0.02	0.01	~~0.37~~	2.77
6/1/1992	0.48	2.24						
6/6/1992	1	1.34			0.02		~~0.08~~	
6/20/1992	0.56	0.45						
6/24/1992	0.24	0.56						
7/6/1992	0.36	0.38						
7/15/1992	0.32	0.5						
7/23/1992	0.28	0.42						
7/31/1992	0.68	0.59						
8/11/1992	1.24	0.87					~~0.61~~	
8/18/1992	0.8	2.91		0.05	0.18	0.07	0.32	
9/3/1992	0.68	1.19					~~0.07~~	
9/9/1992	1.72	0.57					~~0.24~~	
9/11/1992	0.36	0.38						
9/22/1992 (1-yr Storm)	0.65	2.8		0.26	0.20	0.26	0.44	
9/26/1992	0.36	0.74						
10/10/1992	0.72	2.04						
10/23/1992	1.08	1.18	0.02	0.30	0.23	0.16	0.90	0.39
10/24/1992	0.16	0.38						
11/3/1992	0.2	0.94						
11/5/1992	0.16	0.31						
11/21/1992	0.36	1.93						
11/23/1992	0.36	1.93						
11/26/1992	0.24	0.51						
12/3/1992	0.2	0.82						0.32
12/12/1992	0.24	3.89						~~0.14~~
12/17/1992	0.2	0.58						
12/29/1992	0.16	0.37						
12/30/1992	0.12	0.44						
Total CSO Volume in Typical Year			**0.02**	**0.61**	**0.66**	**0.50**	**1.67**	**3.48**

Notes:

(1) CAM002 does not activate during the Typical Year.

Table 2-8.Compliance Statistics for LTCP Goals Attained Conditions, Compared to Q1-2021 Baseline Conditions

Alternative	Percent Annual Compliance with *E. coli* Single Sample Maximum Criterion (235#/100mL)					
	All Sources	Non-CSO Sources Only	Stormwater Only	Dry Weather Sources Only	Boundaries Only	CSOs Only
Charles River						
1 - Q1-2021 Conditions	48%	48%	64%	100%	59%	99.9%
4 - "LTCP Goals Attained" Conditions	48%	48%	64%	100%	59%	99.9%
Alewife Brook						
1 - Q1-2021 Conditions	45%	45%	48%	100%	100%	99.6%
4 - "LTCP Goals Attained" Conditions	45%	45%	48%	100%	100%	99.8%
Upper Mystic River						
1 - Q1-2021 Conditions	54%	55%	56%	100%	91%	97.9%
4 - " LTCP Goals Attained" Conditions	54%	55%	56%	100%	91%	99.0%

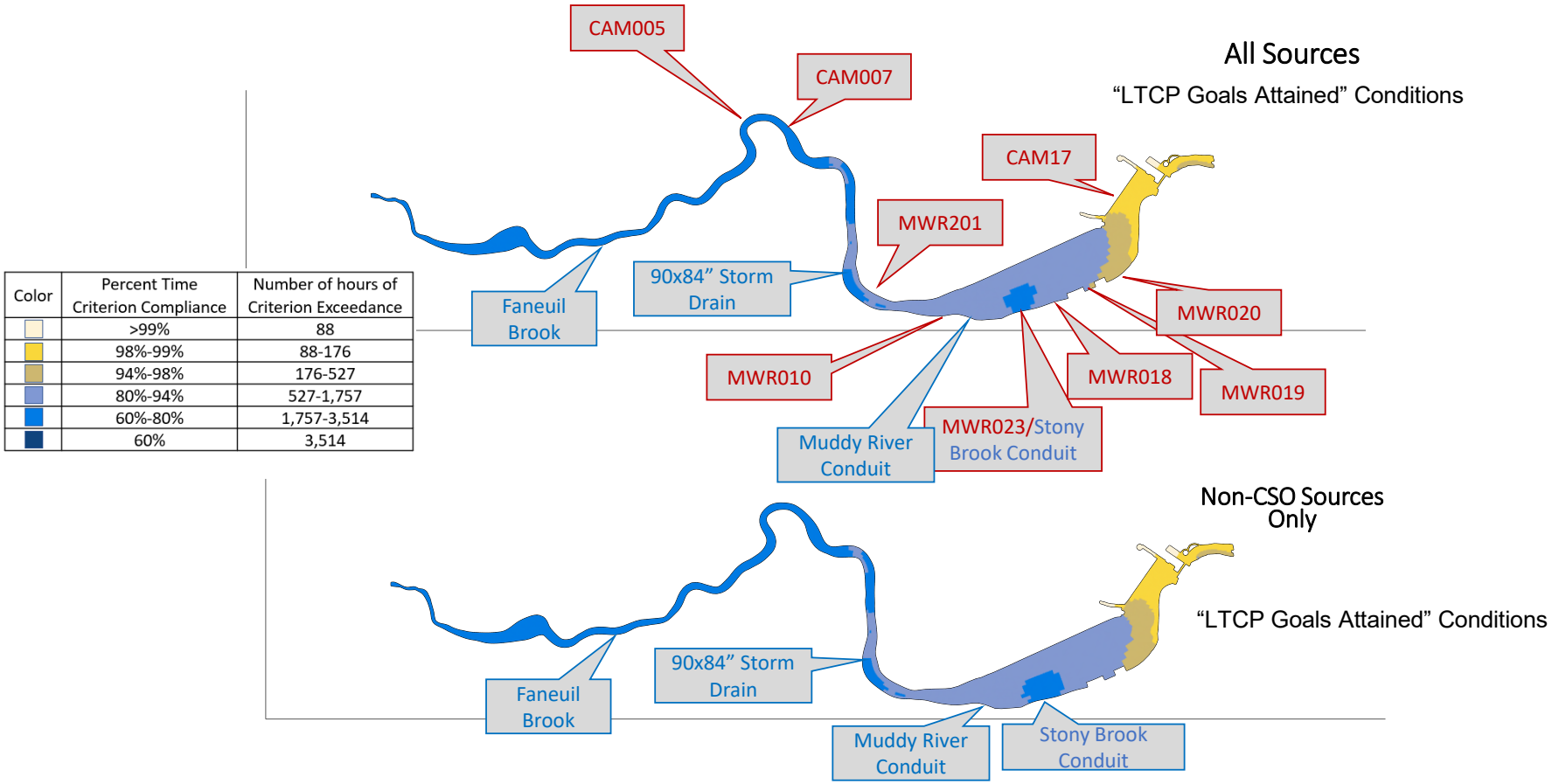

Figure 2-13. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Charles River – Alternative 4: "LTCP Goals Attained" Conditions

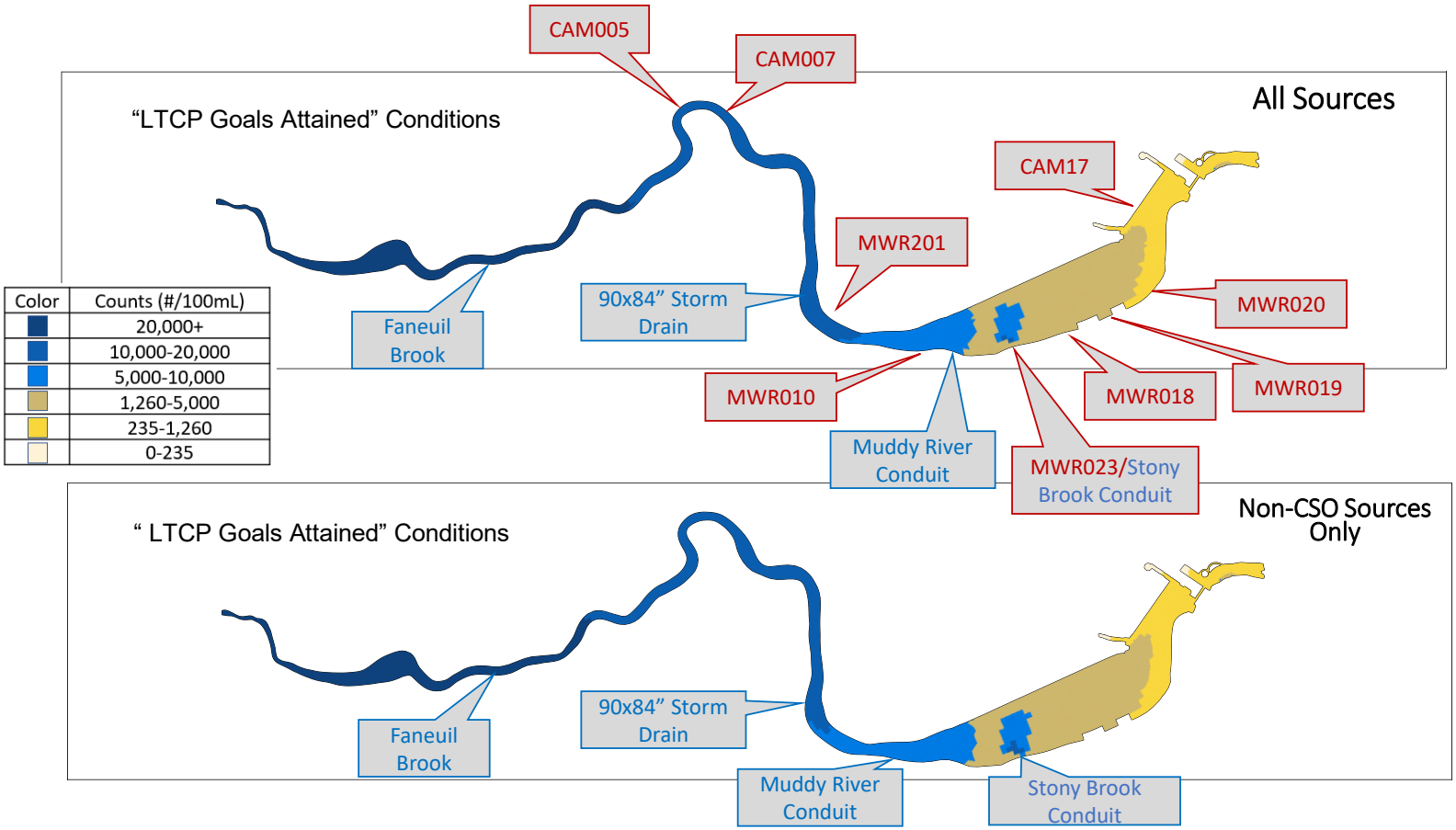

Figure 2-14. Maximum *E. Coli* Count during Typical Year in the Charles River - Alternative 4: " LTCP Goals Attained" Conditions

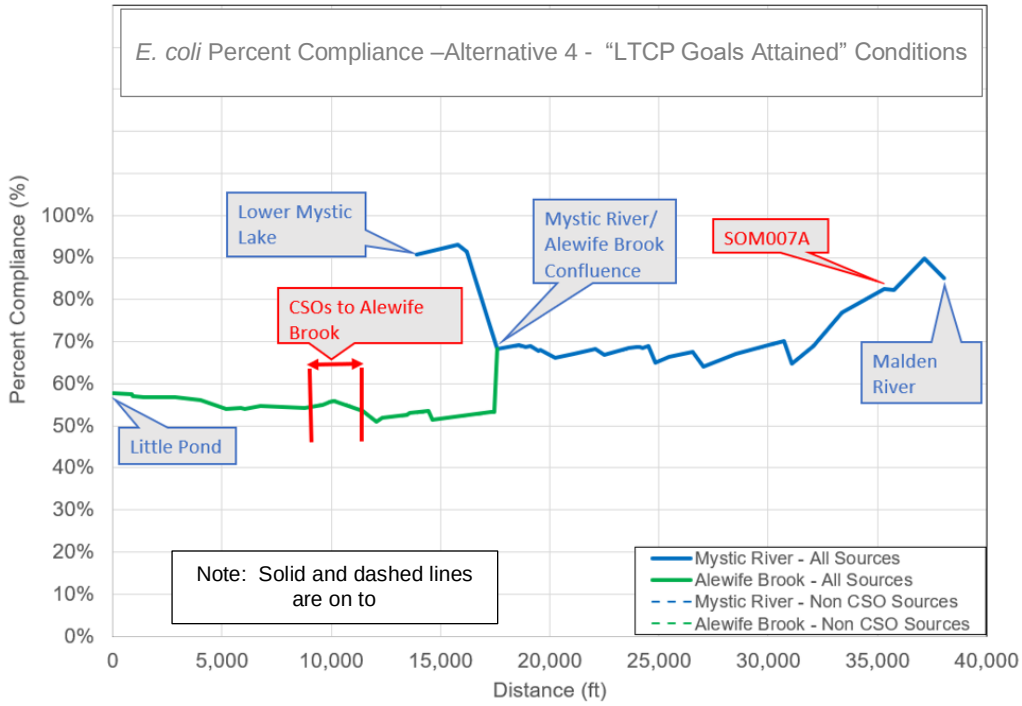

Figure 2-15. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Alewife Brook / Upper Mystic River – Alternative 4: "LTCP Goals Attained" Conditions

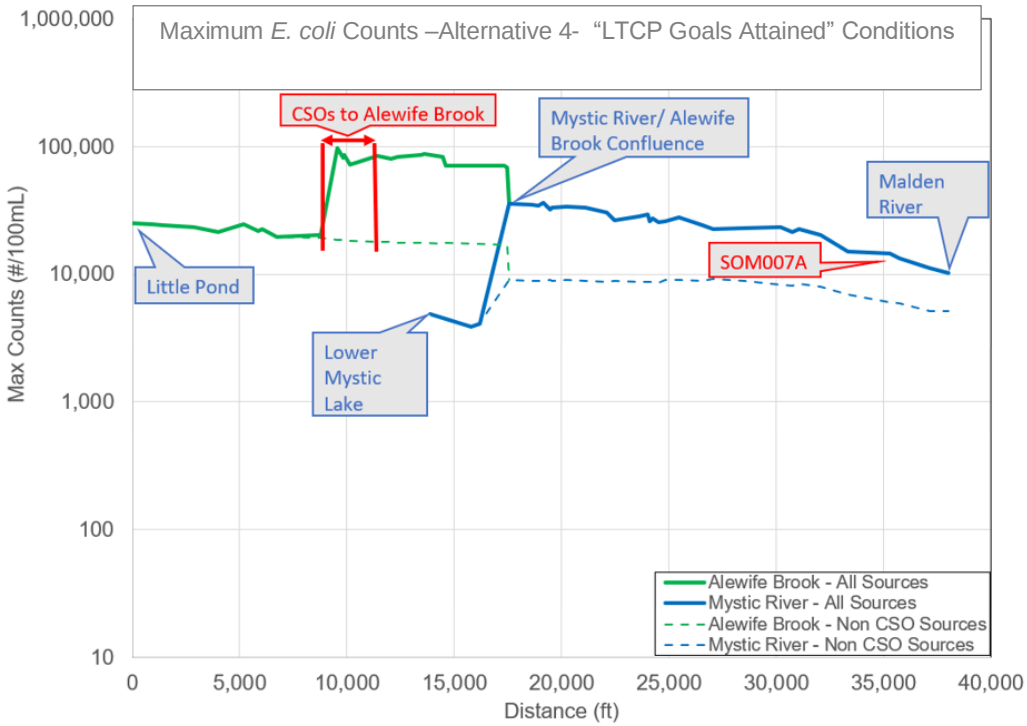

Figure 2-16. Maximum *E. coli* count during the Typical Year in the Alewife Brook / Upper Mystic River– Alternative 4: "LTCP Goals Attained" Conditions

Alternative 5. BMPs to Control First Inch of Rain in Stormwater Areas

Description/Intent. Alternatives 2 and 3 examined the benefits of reducing Non-CSO loads (mostly stormwater) by capping the *E. coli* counts from these sources at the single sample maximum criterion and to half that value. For these alternatives, the stormwater flows were unchanged. One of the stormwater Best Management Practices (BMPs) targeted for use in meeting Total Maximum Daily Load (TMDL) goals for stormwater involves infiltrating stormwater runoff, with a typical target being to infiltrate the runoff from the first inch of rain. This approach would decrease the runoff flows but increase the dry weather flows resulting from groundwater infiltration. Bacteria counts in the remaining stormwater were assumed to be the same as the base case. Alternative 5 was aimed at assessing the potential benefits of applying this BMP over the entire separate stormwater area tributary to the Charles River and Alewife Book/Upper Mystic River included in the model.

Model Simulation Approach. An accurate simulation of the infiltration BMP would require extensive modification to the hydrological models used to estimate stormwater runoff and dry weather discharges to the streams. To provide a general indication of the benefits of this approach, separate stormwater runoff from storms of less than 1 inch was removed, but runoff from larger storms as well as dry weather discharges were unchanged – so the effects of increased dry weather flows from higher groundwater infiltration were not modeled. This approach somewhat underestimates the benefit of the BMP, as runoff from larger storms would in reality be reduced by some fraction. In addition, there could be a disproportionate reduction of bacteria by capturing any “first flush”, although the stormwater data collected to support the water quality model development did not show consistent evidence of a “first flush”. This approach would, however, represent the benefits achieved during the more common smaller storms. As a sensitivity analysis, this approach was considered to be acceptable.

The number of storms in the Typical Year applied to the separate stormwater areas was reduced from 42 to 15 and the total rainfall depth from 43.9 inches to 28.0 inches. Thus, the number of storms was reduced by 60%, but the total rainfall depth was only reduced by 36%. This difference reflects the fact that the storms that were removed were smaller storms.

Results. The percent compliance for this alternative compared to the baseline case of Q1-2021 Conditions is presented for the Charles River, Alewife Brook, and Upper Mystic River in Table 2-9.

For the Charles River the percent compliance for All Sources (50%) is not much different than for the baseline condition (48%). This is because the boundary sources were unchanged assuming, in effect, that the BMPs were applied only downstream of the Watertown Dam. For Stormwater Only conditions, the percent compliance increased from 64% to 71%.

For Alewife Brook and Upper Mystic River, the percent compliance increased substantially for All Sources, Non-CSO Sources Only, and Stormwater Only. The CSOs Only statistics were unchanged, as expected.

These results suggest that the smaller rain events have a relatively larger impact on compliance in the Alewife Brook/Upper Mystic River than in the Charles River.

Feasibility. As for Alternatives 2 and 3, this alternative is a hypothetical condition which is not likely to be achievable over the entire tributary area, but it nevertheless provides an indication of the potential benefits.

Table 2-9. Compliance Statistics for BMPs to Control First Inch of Rain in Stormwater Areas, Compared to Q1-2021 Baseline Conditions

Alternative	Percent Annual Compliance with *E. coli* Single Sample Maximum Criterion (235#/100mL)					
	All Sources	Non-CSO Sources Only	Stormwater Only	Dry Weather Sources Only	Boundaries Only	CSOs Only
Charles River						
1 - Q1-2021 Conditions	48%	48%	64%	100%	59%	99.9%
5 - BMPs to Control First Inch of Rain in Stormwater Areas	50%	50%	71%	100%	59%	99.9%
Alewife Brook						
1 - Q1-2021 Conditions	45%	45%	48%	100%	100%	99.6%
5 - BMPs to Control First Inch of Rain in Stormwater Areas	82%	82%	82%	100%	100%	99.6%
Upper Mystic River						
1 - Q1-2021 Conditions	54%	55%	56%	100%	91%	97.9%
5 - BMPs to Control First Inch of Rain in Stormwater Areas	76%	80%	80%	100%	91%	97.9%

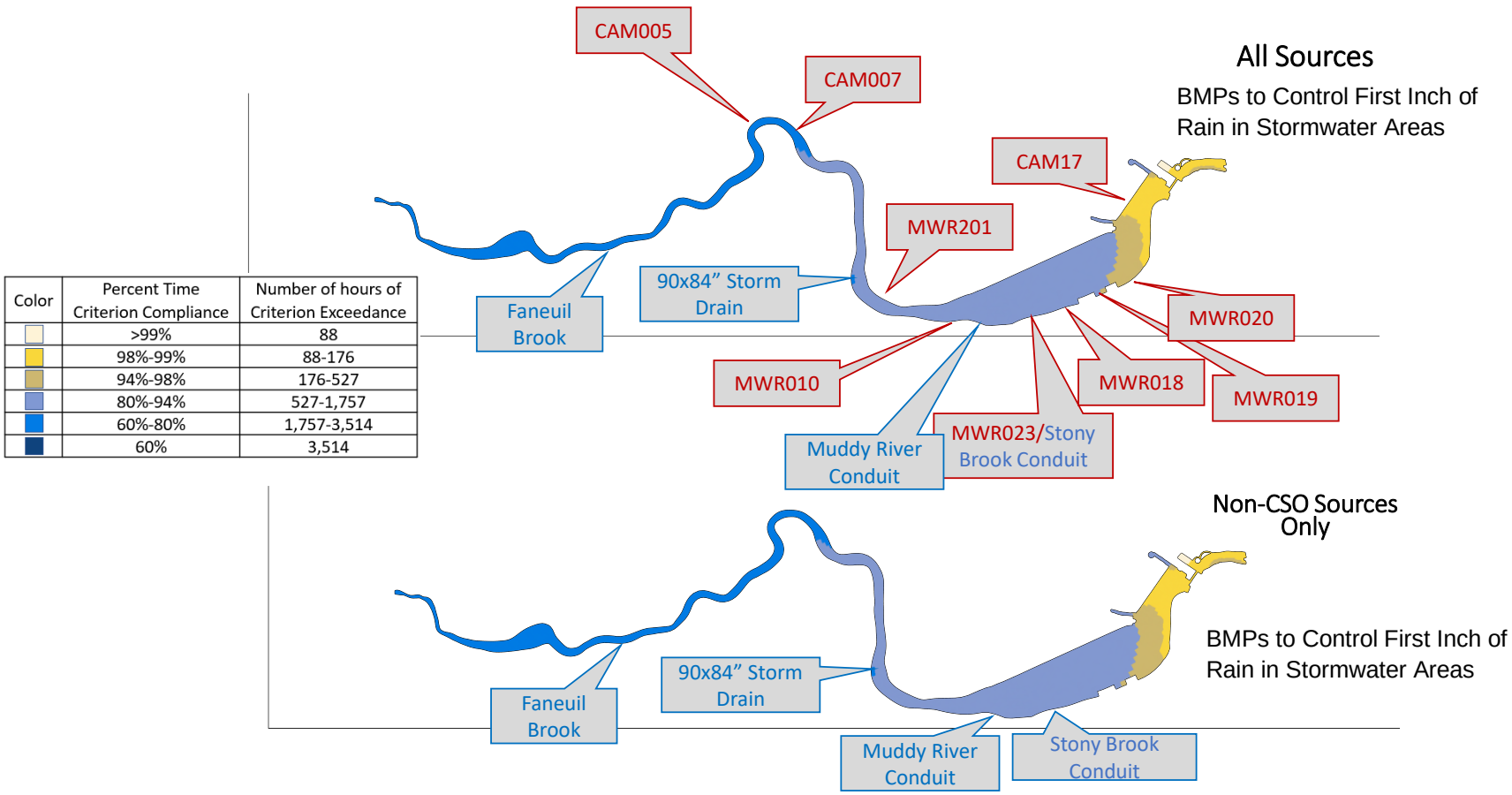

Figure 2-17. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Charles River – Alternative 5: BMPs to Control First Inch of Rain in Stormwater Areas

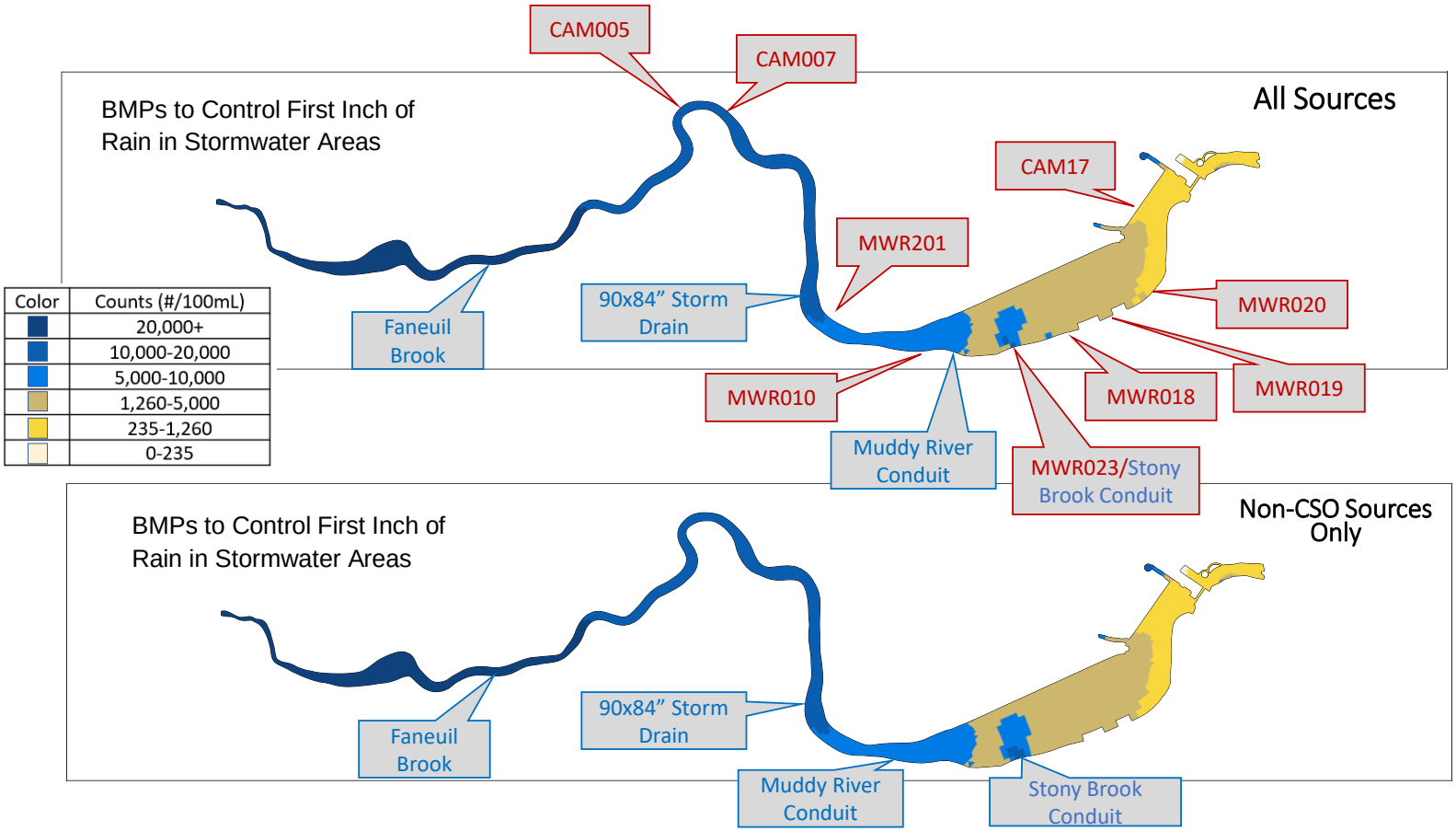

Figure 2-18. Maximum *E. Coli* Count during Typical Year in the Charles River – Alternative 5: BMPs to Control First Inch of Rain in Stormwater Areas

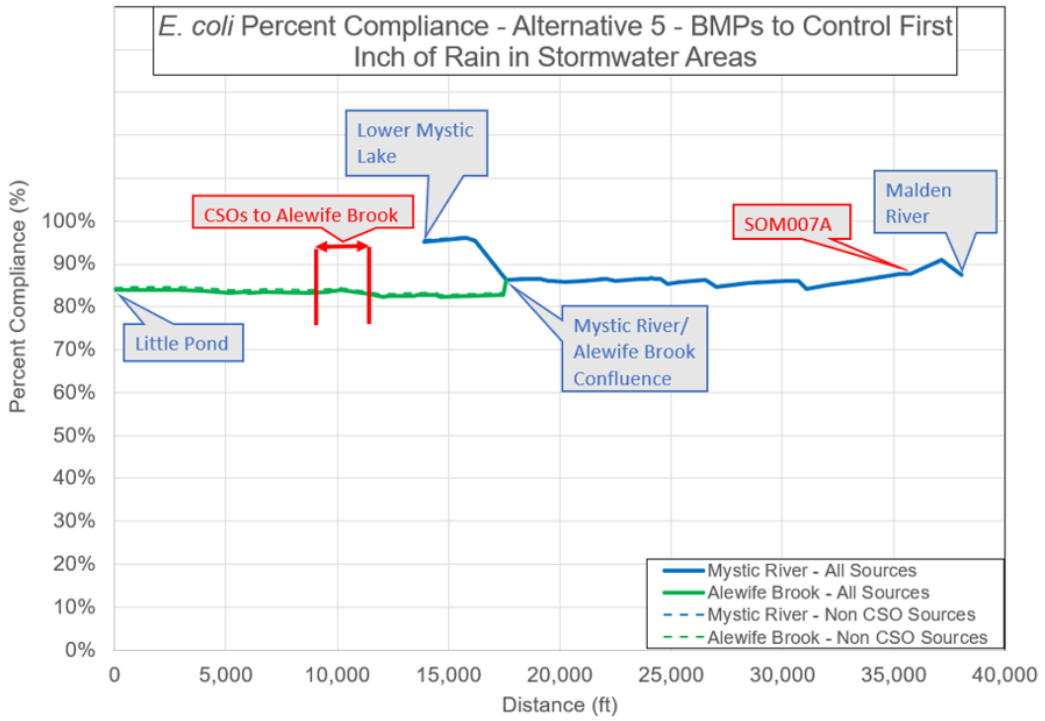

Figure 2-19. Percent Compliance with the *E. coli* Single-Sample Max. Criterion for the Typical Year in the Alewife Brook / Upper Mystic River – Alternative 5: BMPs to Control First Inch of Rain in Stormwater Areas

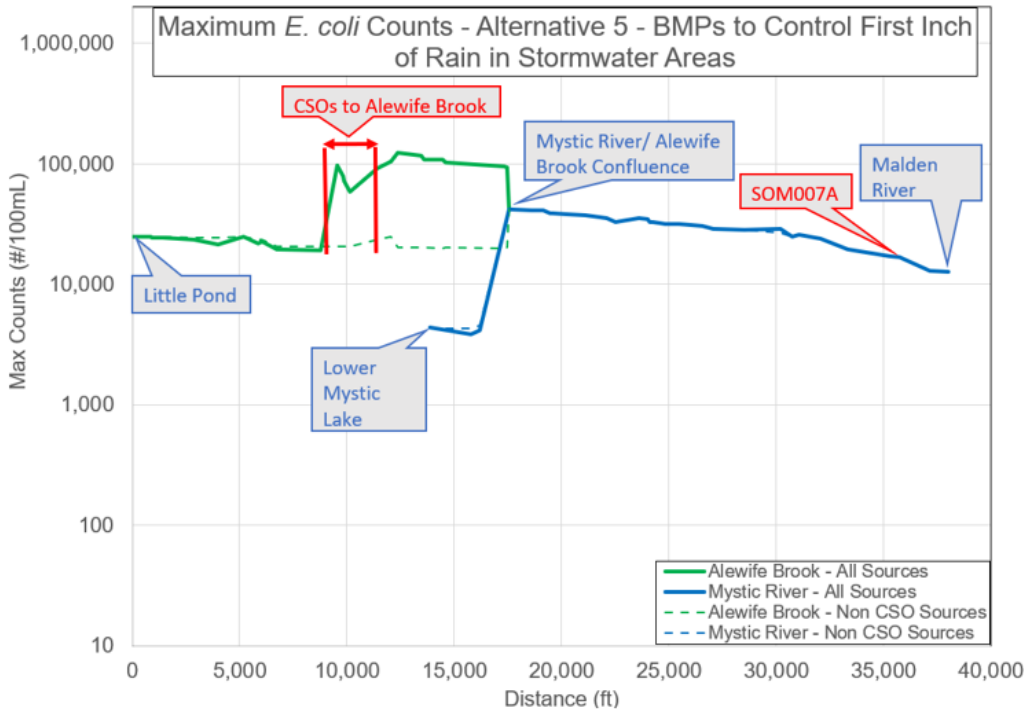

Figure 2-20. Maximum *E. coli* count during the Typical Year in the Alewife Brook / Upper Mystic River– Alternative 5: BMPs to Control First Inch of Rain in Stormwater Areas

3. Other Alternatives

The “Other Alternatives” below are alternatives that have been suggested by stakeholders but were either already addressed in previous reports, did not require additional model runs, or were not amenable to simulation with the models as they currently exist.

Alternative O1. Simulate conditions when the design capacities of Cottage Farm and Somerville Marginal are exceeded

Description/Intent. A stakeholder comment was that flows to the CSO facilities can occasionally exceed the facilities’ design flows and, when this occurs, the effluent bacterial counts may be higher than the values used in the models. The results from MWRA’s CSO facilities effluent monitoring shows occasionally high bacterial counts, although these are not necessarily related to high wastewater flows.

Discussion. Flows into the Cottage Farm facility are limited by the capacity of the influent pumps, which is matched to the design capacity of the disinfection system. Under certain unique conditions, the actual pumping capacity can exceed the design capacity, but this condition would not be expected for the storms that occur during the Typical Year. Flow through the Somerville Marginal facility is by gravity, and the peak flow in the Typical Year did not exceed the design capacity. Because the basis for the performance assessment is the Typical Year, as well as the 3-month and 1-year storms, which are part of the Typical Year, model runs with larger flows and higher effluent counts at the facilities were not conducted.

Alternative O2. Simulate CSO elimination by sewer separation.

Description/Intent. A stakeholder noted that one means of eliminating CSOs is sewer separation, which is different than the “Non-CSO Sources Only” case that has been simulated. To simulate CSO elimination by sewer separation, the CSO flows and loads would be zero and stormwater flows and loads would increase. In the “Non-CSO Sources Only” simulation the CSO flows are unchanged but their bacterial counts are set at zero, while the non-CSO source loads are not changed.

Discussion. The stormwater flow increases resulting from sewer separation would require considerable stormwater model modifications, which could not be implemented in this project. Therefore, sewer separation was not simulated. Because the additional stormwater flows would contain elevated bacterial counts and would discharge to the streams for every wet weather event, compliance with the water quality criteria would likely be reduced compared to the “All Sources” simulation.

Alternative O3. Simulate varying stormwater bacterial counts.

Description/Intent. A stakeholder stated that in many cases higher bacterial counts are observed during the early part of storms, a period commonly designated as “first flush”. It was thought that simulating these variations could provide a better estimate of stormwater impacts.

Discussion. In general, “first flush” effects are primarily observed for small catchments. Larger catchments involve different travel times to the catchment outlets so that the first flush from farther locations is mixed with post-first flush from nearer locations, and distinctive first flush effects at the outfall are not apparent. The stormwater quality monitoring conducted by MWRA in 2019 involved collecting four to five samples during the storms, and distinctive first flush effects were not observed. The December 2020 *Task 5.2 Receiving Water Quality Model Development and Calibration Report* (AECOM 2020) addressed the question of whether to use constant average values for *E. coli* and *Enterococcus* counts for all stormwater inputs, or if a basis could be established for varying the stormwater counts based on factors such as rainfall or tributary area parameters. As documented in that report, no clear basis for varying the stormwater counts could be established from the available data, which included small as well as large catchments. The decision was therefore made to use constant average values for *E. coli* and *Enterococcus* counts in stormwater. Using average counts yielded very good calibration of the model during storms that did not have CSOs, and it is not clear that simulating variable stormwater counts during storms would lead to significantly different results than using average counts. Based on these considerations, simulating variable bacterial counts in stormwater was not implemented.

Alternative O4. Evaluate partial sewer separation

Description/Intent. A stakeholder suggested evaluating partial sewer separation scenarios, where a limited-capacity connection to the combined sewer system would allow the “first flush” of separated stormwater to be captured, while the majority of the remaining stormwater would be discharged at a separate stormwater outfall.

Discussion. The Q1-2021 conditions model includes the partial sewer separation project completed in Cambridgeport. This project includes two small-diameter connections between the separate stormwater system and MWRA’s interceptor system to capture the initial stormwater flows.

Between the “LTCP Goals Attained” alternative presented as Alternative 4 above and the Non-CSO Sources Only results for the Q1-2021 conditions presented above as part of Alternative 1, the relatively limited potential benefits of further CSO reduction on attainment of the *E. coli* water quality criterion could be inferred. If sewer separation were to be considered as an option for further reducing CSO activations and/or volumes at specific outfalls, the potential benefit of configuring the sewer separation as a “partial” separation project with a remaining low-flow connection to the sewer system similar to the Cambridgeport project would need to be further evaluated. It is noted that the stormwater sampling data collected as part of this program did not show a consistent “first flush” effect with regard to bacteria counts in the stormwater.

Alternative O5. Simulate CSO variability

Description/Intent. A stakeholder noted that because CSO bacterial counts are variable, MWRA should conduct a statistical analysis of CSO variability and conduct simulations with multiple counts (e.g. median, 25%, 75%) rather than use a single value.

Discussion. As described in the December 2020 *Task 5.2 Receiving Water Quality Model Development and Calibration Report* (AECOM 2020), the modeling uses variable CSO bacterial counts based on the sanitary fraction in the CSO as calculated by the collection system model. This approach replicated the variation in measured bacterial counts at sampled locations, and yields significant variability in the CSO bacterial counts between outfalls and during activations. In addition, sensitivity analyses were conducted where CSO counts were multiplied by a factor of two as described in the August 2021 *Task 5.3 Water Quality Assessment Report* (AECOM 2021). This increase of *E. coli* count was aimed at addressing possible variability in CSO concentrations due to factors not accounted for in the Typical Year model run such as the timing of the storm relative to the wastewater flow diurnal cycle or the season of the discharge. The increase resulted in a small (1% or less) decrease of the percent compliance due to CSOs only. Decreases in CSO concentrations would similarly result in small improvements in the percent compliance.

The modeling approach used and the sensitivity analyses conducted address the intent of the stakeholder comment.

4. References

AECOM. 2020. *CSO Post Construction Monitoring and Performance Assessment: Task 5.2 Receiving Water Quality Model Development and Calibration Report.* Prepared for MWRA. Boston: Massachusetts Water Resources Authority. Report 2020-15. 180 p.

AECOM. 2021. *CSO Post Construction Monitoring and Performance Assessment: Task 5.3 Water Quality Assessment Report.* Prepared for MWRA. Boston: Massachusetts Water Resources Authority. Report 2021-019. 68 p.