AECOM RECEIVING WATER MODEL WORK PLAN

(Task 5)

May 24, 2019

Revised July 18, 2019

5. Water Quality Modeling

Water quality models of the Alewife Brook / Upper Mystic River and Charles River will be developed, calibrated and applied as part of the MWRA's CSO Performance Assessment. These models will demonstrate compliance of the MWRA Combined Sewer Overflow (CSO) Long Term Control Plan (LTCP) with the requirements of the Clean Water Act, the Environmental Protection Agency's (EPA) CSO Policy, and MassDEP's water quality standards.

The specific objectives of the models are to:

- Assess whether remaining CSOs preclude attainment of bacterial water quality standards in the Typical Year and comply with the water quality based requirements of the Clean Water Act.

- Assess the performance of the completed LTCP controls relative to the CSO impact reduction and water quality improvement predictions that supported the Long Term Control Plan and its regulatory approvals.

These objectives address the needs of the Long Term Control Plan Performance Assessment. In addition, the models will be used to evaluate the potential for additional CSO control. Specific items to be included in the deliverables under this Task are:

- Summary of the water quality observations used for (a) upstream boundary conditions, (b) stormwater, and (c) CSO discharges.

- Explanations of how water quality observations were used to calibrate the models.

- For the three-month and one-year storms, and the Typical Year:

    - Plots of water quality results at different times during the simulations.

    - Tabulations of hours of water quality standards violations for bacteria, distinguishing bacteria loads from upstream, stormwater, and CSO sources.

- Sensitivity analyses on the values of the bacterial counts used for upstream, stormwater, and CSO sources.

- Reporting on the impact from remaining CSO discharges on bacteria concentrations over time and distance from the CSO discharge points in the Variance waterbodies.

There will be a separate report in which the calibration of the model is explained in detail.

5.1 Data Analysis *(note that the development of the Statistical "Receiving Water Quality Analysis Report" has been replaced with Receiving Water Models)*

As outlined in Section 5.2, receiving water models will be developed, using the indicated data sources, as well as results from MWRA's extensive water quality monitoring database, for the Alewife/Mystic and Charles Rivers. In addition, MWRA, together with Somerville and Cambridge, will collect Stormwater and CSO outfall data during 2019 and 2020 to use in the development of the updated Receiving Water Models. A monitoring plan describing this program is under development by MWRA, in consultation with DEP and EPA. Work on the Statistical Receiving Water Quality Analysis will not be continued.

5.2 Water Quality Model Development and Calibration

Table 1. Model Characteristics and Data Sources

	Alewife Brook / Upper Mystic	Charles River
Modeling Software	InfoWorks ICM	Delft3D
Model extent	Lower Mystic Lake to Amelia Earhart Dam, including the Alewife Brook	Watertown Dam to Charles River Dam
Bathymetry	FEMA measurements[1]	USGS Data
Upstream Boundary flow	*InfoWorks ICM Mystic River Basin Model* from City of Cambridge[2]	Waltham USGS Gauge
Upstream Boundary quality	MWRA monitoring for both the Lower Mystic Lake and Alewife Brook	Calibrated boundary conditions model[3]
CSO flows	MWRA collection system model	MWRA collection system model
CSO quality	• Planned MWRA monitoring[4] • Somerville Marginal CSO Facility NPDES effluent monitoring	• CSO Facilities influent monitoring • Cottage Farm CSO Facility NPDES effluent monitoring
Stormwater Flows	InfoWorks ICM Mystic River Basin Model from City of Cambridge	• BWSC Drain Model • USGS Charles River Stormwater Model
Stormwater Quality	• Planned MWRA monitoring • Planned community monitoring	• BWSC Drain Model • Planned community monitoring

[1] Bathymetry initially collected in 2002 (approx.) and later revised. Latest FIRM report is dated 2016.
[2] For both Lower Mystic Lake and Alewife Brook
[3] See below, Sec 5.2.2 and 5.2.3, for additional information
[4] *This sampling plan is to be developed by MWRA and is not part of this scope of work.*

5.2.1 Review of Monitoring Data

The water quality modeling will simulate *Enterococcus* and *E. coli* counts in the Alewife Brook / Upper Mystic River and the Charles River due to loadings from upstream, stormwater, and CSO sources.

Table 1 above summarizes the overall characteristics of the models and data sources for model development. Further details are provided in the text below. MWRA will coordinate with Boston, Cambridge, and Somerville to assess available datasets, and, if necessary, develop plans to collect more up-to-date data. The data sources and how they will be used in the modeling will be presented to MWRA for input and concurrence in a Review of Monitoring Data meeting and Technical Memorandum.

DELIVERABLES: Provide a draft and final technical memorandum providing a review of monitoring data.

5.2.2 Alewife Brook / Upper Mystic River Model Development

Modeling Software

For the Alewife Brook / Upper Mystic River, the model will be one-dimensional, using the InfoWorks ICM software. The one-dimensional approach was chosen as the waterbodies are not wide and are of relatively constant depth. The model will be based on the *InfoWorks ICM Mystic River Basin Model* developed by the City of Cambridge from the 2016 Federal Emergency Management Agency (FEMA) flood mapping model, which used the Army Corps of Engineers Hydrologic Engineering Center's River Analysis System (HEC-RAS) and Hydrologic Modeling System (HEC-HMS) software for flow and hydrology respectively. Should the Cambridge model not be available, AECOM will develop an InfoWorks ICM model of the rivers and stormwater from the FEMA models.

Bathymetry

Cross section profiles measured as part of the FEMA flood mapping studies will be used. These data will be supplemented by more recent data, if available.

Upstream Boundary Conditions

Flow boundary conditions at the Lower Mystic Lake Dam will be developed using the *InfoWorks ICM Mystic River Basin Model* from the City of Cambridge for the periods of interest. This model will also be used to specify the upstream boundary flow condition for Alewife Brook, although this flow is very small, as the brook is entirely contained in the model area.

For water quality, the model will start downstream of the Lower Mystic Lake Dam. For influent water quality the approach that was previously used involved constant dry weather and wet weather bacterial fecal coliform concentrations that were specified based on MWRA monitoring observations. These will be adapted to *Enterococcus* and *E.coli* observations based on more

recent monitoring and the specification of those indicator bacteria in the latest state water quality standards.

CSO Flows

CSO volumes and durations will be specified based on MWRA's collection system model (2019) calibrated at approximately 170 flow monitoring locations including 66 CSO locations

CSO Quality

For CSO discharge quality, MWRA will perform CSO monitoring in summer 2019 at selected untreated CSOs discharging into the Alewife Brook / Upper Mystic River. For the treated discharges from the freshwater outfall of the Somerville Marginal CSO Facility (MWR205A), NPDES permit required effluent monitoring results will be used.

Stormwater Discharge Flows

Stormwater discharge flows will come from the *InfoWorks ICM Mystic River Basin Model.* This model covers the entire Mystic River watershed and was updated in 2015. Discharges from the City of Cambridge will be obtained from the Cambridge stormwater collection system model.

Stormwater Quality

The main data source will be stormwater quality monitoring conducted by MWRA in conjunction with Cambridge and Somerville, starting in summer 2019. Available stormwater quality observations from other recent sources, such as community monitoring, will be examined for suitability.

5.2.3 Charles River Model Development

Modeling Software

Delft3D will be used for the Charles River to capture lateral variations of bacterial counts, in particular in the Lower Basin, which is quite wide. While Delft3D is a three-dimensional model, it will be run in two-dimensional mode as the previous (2002) Charles River model was also a two-dimensional model.

The salt wedge that is present in the Charles River Lower Basin will be taken into account in the modeling. The salt wedge modeling approach will be presented to MWRA for discussion and concurrence. Sensitivity of the results to the salt wedge method will be examined and quantified.

Bathymetry

The bathymetry used for the previous modeling of the Charles River will be used, with modifications as needed. The previous modeling bathymetry was created from contours provided by USGS as well as measured depth at various points along the river.

Upstream Boundary Conditions

Data from the Waltham USGS gauge will be used for flow. For water quality, a separate model (based on a buildup/washoff formulation) previously developed by AECOM to predict the fecal coliform concentrations during storms will be used. This model was used for the Charles River water quality modeling conducted for the variance and also for the 4-month long modeling conducted by AECOM for the USEPA to assess the benefits of stormwater best management practices. The model will be adjusted to provide counts of *Enterococcus* and *E. coli*. The model will be calibrated *to* recent MWRA monitoring at station 012 (Watertown Dam) and 001.

CSO Flows

CSO volumes and durations for the nine CSOs discharging to the Charles River will be specified based on MWRA's 2019 calibrated collection system model, which incorporates data from approximately 170 flow monitoring locations including 66 CSO regulator locations.

CSO Quality

Bacteria counts from the influent of the Cottage Farm and Prison Point CSO facilities will act as a proxy for untreated CSO discharge quality. For treated CSO discharges from Cottage Farm, the model will use bacteria counts from the NPDES sampling program at the facility.

Stormwater Discharge Flows

Stormwater flows will be specified based on stormwater collection systems models, which include the *BWSC Drain Model* and the SWMM-based *USGS Charles River Stormwater Model*. The *BWSC Drain Model* simulates stormwater flows in the City of Boston. BWSC has authorized use of their model for this project. The BWSC Drain Model uses the PCSWMM software.

The *USGS Charles River Stormwater Model* includes four separate models for i) Laundry Brook, ii) Faneuil Brook, iii) Muddy River/Stony Brook, and iv) ungauged areas. Extensive efforts were devoted to develop runoff parameters depending on land use and other factors, as well as using twenty storms for model calibration. These models were made available to AECOM (then Metcalf and Eddy) for previous Charles River water quality modeling. The Laundry Brook model as well as the Ungauged areas model will be used for this renewed modeling. For Faneuil Brook and Muddy River/Stony Brook, the BWSC *Drain Model* will be used.

In conjunction, these models cover all the stormwater discharges to the Charles River.

Stormwater Discharge Quality

For Boston, the BWSC Drain Model will be used. This model simulates stormwater water quality and accounts for ongoing stormwater quality improvement programs which include green infrastructure (GI) construction and the illicit connections (IC) removal. BWSC is also beginning

a wet weather storm drain sampling program in late 2019. Data from that program will be used in the model if available in time.

For Cambridge, MWRA will coordinate with Cambridge to sample storm drains to characterize stormwater quality on that side of the river.

5.2.4 Model Calibration of Alewife Brook/Mystic River and Charles River Water Quality Models

Following development, the models will be calibrated for *Enterococcus* and *E.coli* counts based primarily on existing, in-stream MWRA monitoring data. Data collected by the watershed associations will also be considered. It is expected that MWRA will assist in locating these other data. Both dry weather and wet weather calibrations will be conducted by comparison of model predictions with the MWRA in-stream monitoring data, as well as other data (see below). The parameters to be adjusted will be:

- the CSO bacterial counts
- the stormwater bacterial counts
- the decay rates for *Enterococcus* and *E. coli*
- diffusion and dispersion coefficients
- dry weather loadings
- naturally occurring background conditions

Initial values will be developed based on available data or literature values and adjusted as warranted within typical parameter ranges to match measurements. AECOM will discuss any adjustments in the calibration in a workshop with MWRA and document those changes in a Technical Memorandum.

Calibration will be quantitatively assessed using Wilmott "Index of Agreement" and well as the Root-Mean-Square Deviation. A weight-of-evidence methodology will also be used for a more global assessment. The elements that will be considered in the weight-of-evidence approach include i) the in-stream monitoring data, ii) the inherent variability of environmental measurements (reflected in the scatter of the monitoring data), iii) the reasonableness of the resulting calibration parameters, iv) unusual conditions, e.g. prolonged wet or dry period (which could affect wastewater strength).

5.2.5 Model Development and Calibration Technical Memorandum

DELIVERABLES: Provide a draft and final technical memorandum summarizing the model developmennt and calibration of the Alewife Brook/Upper Mystic and Charles River water quality models.

5.3 Water Quality Assessment

Following calibration, the model will be applied for the 3-month and 1-year design storms as well as the Typical Year for current conditions; i.e., with the CSO program completed. If possible, a 1-year long continuous simulation with Typical Year rainfall will also be run.

Simulations will be conducted with loadings from CSOs, stormwater and upstream boundaries for *Enterococcus* and *E. coli*. The simulations will be conducted with different tracers for each individual source and constituents so that individual runs will provide results for different conditions. Because the transport equation is linear, results with loadings from different sources are additive. Thus, the water quality effects of CSOs, stormwater, and boundary conditions can be separated. Varied bacterial loading levels will be implemented to capture the range in potential impacts.

Results will be presented in plots of bacterial counts as a function of distance (for Alewife Brook) and contour plots of bacterial counts (for the Charles River) for various times as well as tables of criteria exceedance durations for the different sources and conditions.

DELIVERABLES: Provide a draft and final Water Quality Asessment report summarizing the baseline and LTCP asessments.

5.4 Alternatives Simulations

Up to fifteen (15) additional simulations will be conducted to evaluate different bacterial loading reductions. It is anticipated that the conditions for the different simulations will be developed jointly by MWRA and AECOM. Simulations will conducted for the 3-month and 1-year storms and the Typical Year.

The following simulations will be included in the 15 simulations conducted:

- Assumption that bacterial concentrations from other sources are i) zero, ii) 50% of the water quality standard and iii) 100% of the water quality standard.

- A statistical analysis of CSO data will be conducted to estimate variability and modeling will be conducted with multiple CSO concentrations based on distribution of data (e.g., median, 25th percentile, 75th percentile) and using real sample results from multiple CSO facilities and outfalls.

- The modeling may include additional management scenarios

DELIVERABLES: Provide a draft and final Alternatives Simulation Report summarizing the results of this analysis.

Deliverables

- Draft Review of Monitoring Data Technical Memorandum
- Final Review of Monitoring Data Technical Memorandum
- Draft Model Development and Calibration Technical Memorandum
- Final Model Development and Calibration Technical Memorandum
- Draft Water Quality Assessment Report

- Final Water Quality Assessment Report
- Draft Alternatives Simulations Report
- Final Alternatives Simulations Report

Schedule

The schedule presented below is based on the following assumptions:

  - Notice to Proceed on May 1, 2019
  - Community model files and sampling data are provided by June 15, 2019.
  - MWRA Water Quality Sampling Data provided to AECOM by June 2020

The schedule is as follows

- Kick-off meeting May 15, 2019
- Review of Monitoring Data Technical Memorandum
  - Meeting August 1, 2019
  - Draft August 15, 2019
  - Final October 1, 2019
- Model Development and Calibration Technical Memorandum
  - Meeting June 1, 2020
  - Draft 1 July 1, 2020 (MWRA Review draft)
  - Draft 2 August 1, 2020 (DEP and EPA Review draft)
  - Final October 1, 2020
- Water Quality Assessment Report
  - Meeting December 1, 2020
  - Draft 1 February 1, 2021 (MWRA Review draft)
  - Draft 2 April 1, 2021 (DEP and EPA Review draft)
  - Final September 30, 2021
- Alternatives Simulations Report
  - Meeting September 1, 2021
  - Draft 1 October 1, 2021 (MWRA Review draft)
  - Draft 2 November 1, 2021 (DEP and EPA Review draft)
  - Final December 1, 2021