RECEIVING WATER QUALITY MODEL CALIBRATION FOR MWRA CSO PROGRAM

Dominique Brocard (AECOM), Rachael Hager (AECOM), Salma Taha (AECOM), Betsy Reilley (MWRA)

Outline

- Purpose
- Models and Approaches
- Charles River Model
  - Model Coverage and Discretization
  - Flow inputs
  - Boundary Condition
  - Model calibration
- Alewife Brook/Upper Mystic River Model
  - Model Coverage and Discretization
  - Flow inputs
  - Boundary Condition
  - Model calibration

AECOM

Purpose

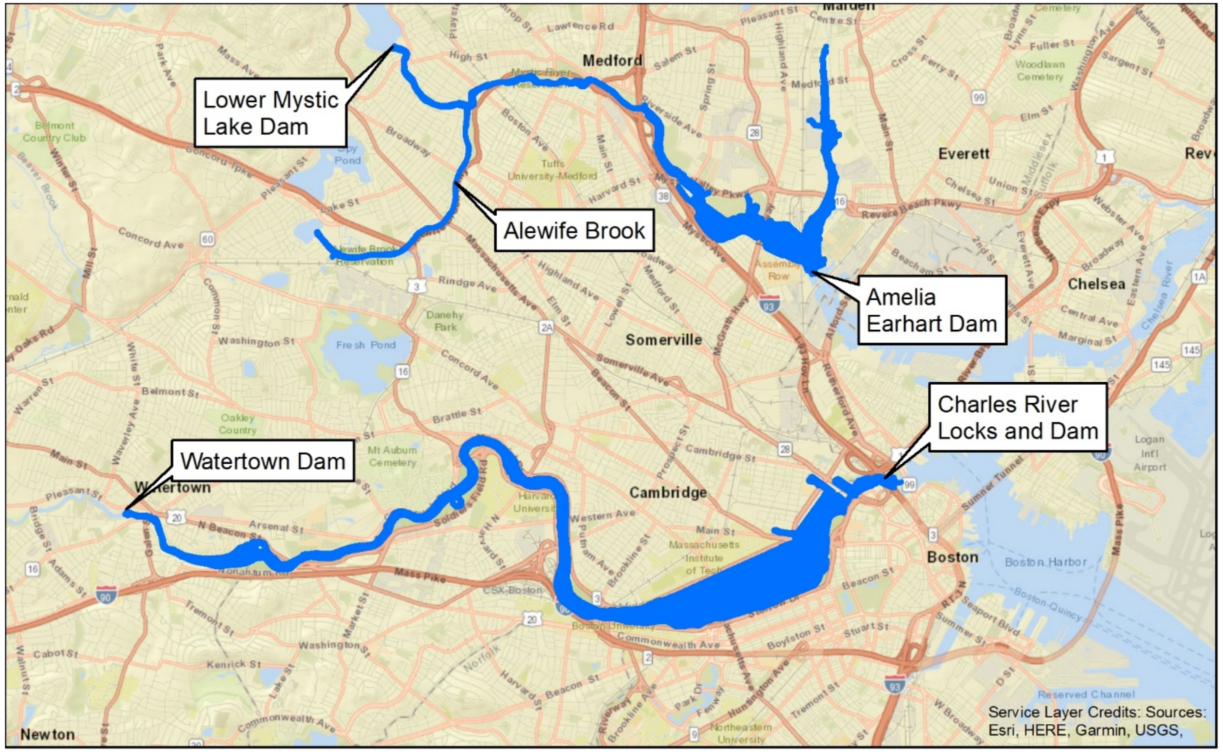
- To confirm the receiving water quality benefits of the MWRA CSO program predicted by the CSO Long Term Control Plan (LTCP)
- Concentrate on receiving waters with Massachusetts Water Quality Standards Variances
  - Charles River
  - Alewife Brook / Upper Mystic River
- Concentrate on Bacteria
  - *E. coli*
  - *Enteroccus*
- This presentation is limited to the calibration of the water quality models that are being used to assess current conditions and evaluate alternatives

AECOM

Models and Approaches

Models

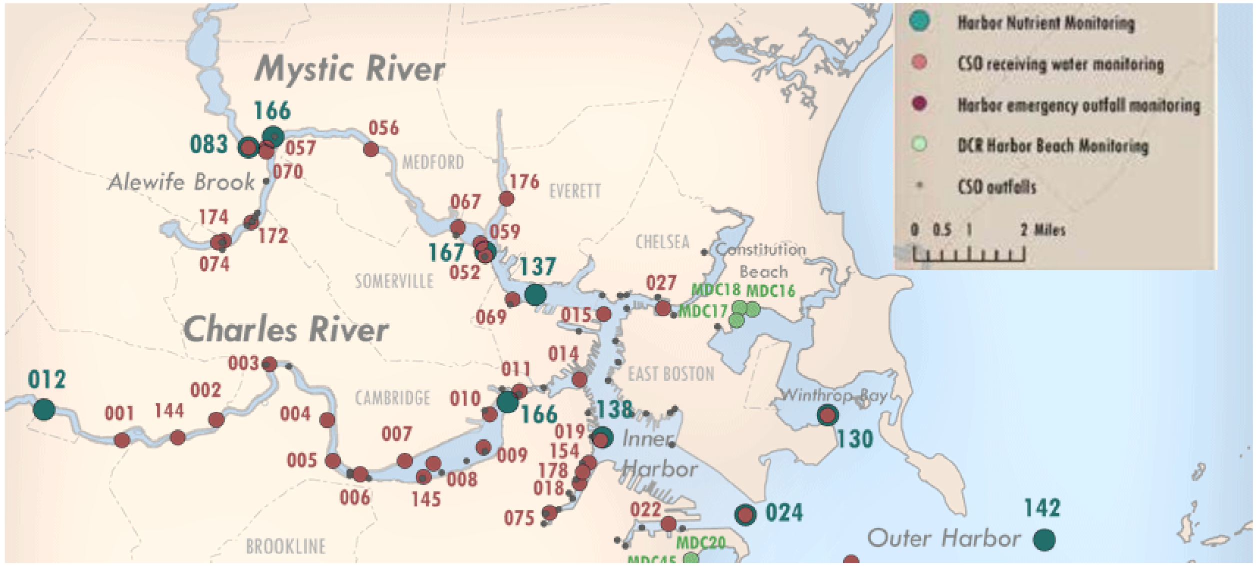
- Two Models receiving water models:
  - Charles River
  - Alewife Brook/Mystic River
- MWRA CSO model
- Stormwater models



AECOM

Calibration Approach

- Calibration Parameters
  - Die-off rates
  - Stormwater counts
- Calibration Data
  - MWRA stream monitoring
  - 2017, 2018 and 2019
  - 17 station in Charles
  - 16 stations in Alewife Brook / Upper Mystic River
- Calibration Approach
  - Vary calibration parameters within justifiable ranges to achieve the best match with the calibration data
  - Document sensitivity



Calibration Approach

- Weight of Evidence Approach
  - Peak bacterial counts
  - Shape of bacterial count variations with time
- Quantitative Assessments
  - Average counts
  - Wilmot Index of Agreement
    - P = predicted
    - O = observed

$$IA = 1 - \frac{\sum_{i=1}^{n} \left| P_i - O_i \right|^2}{\sum_{i=1}^{n} \left(\left| P_i - \overline{O} \right| + \left| O_i - \overline{O} \right| \right)^2}$$

Water Quality Standards

- To put measured/modeled bacterial counts in perspective
- Current Standards

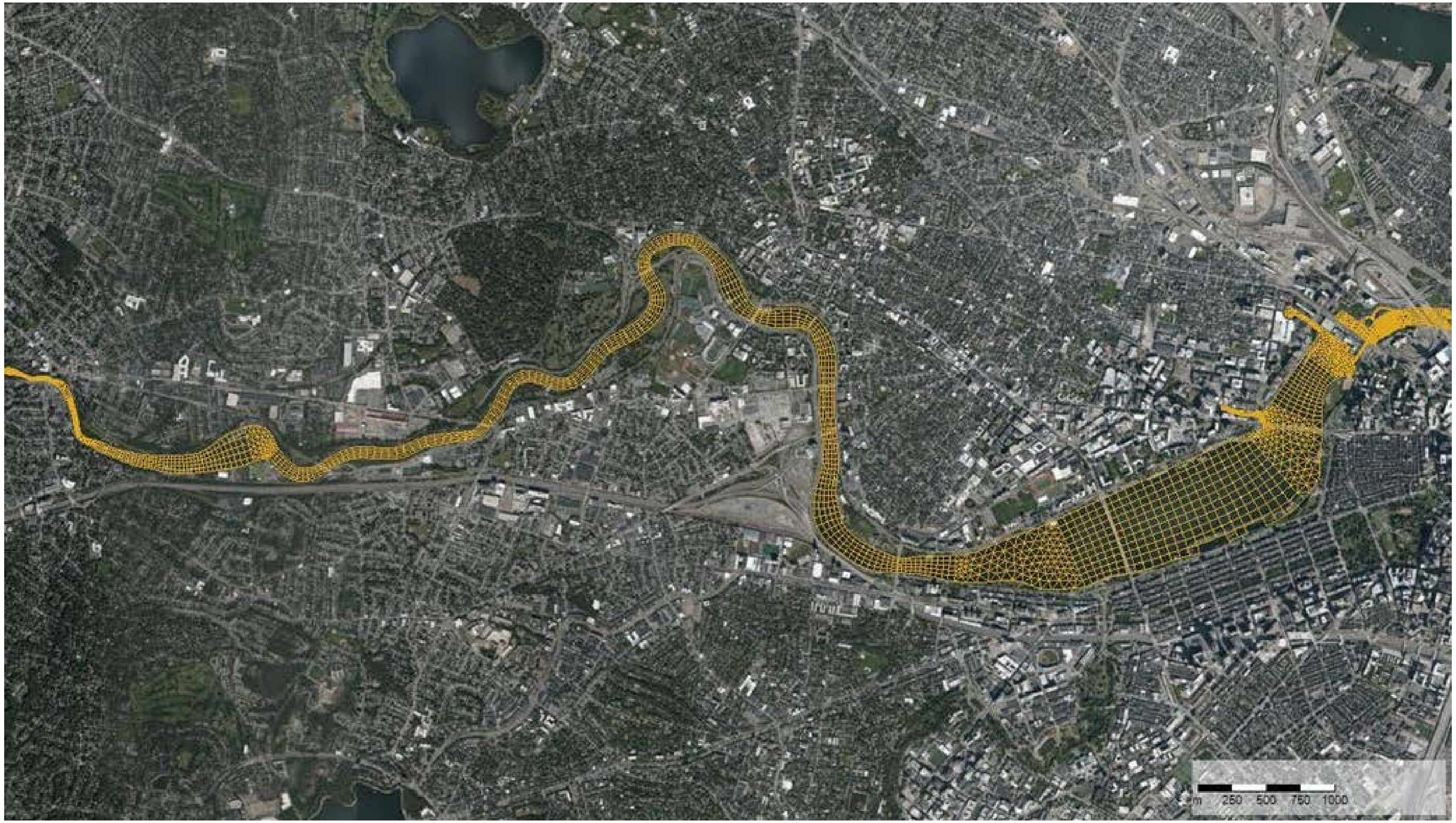
Parameter	**Class B Criteria for Non-Bathing Beach Waters[1]**	
	Existing Class B Criteria	
	6-month Geometric Mean (colonies/100 mL)	Single Sample Maximum (colonies/100 mL)
E. coli	126	235
Enterococcus	33	61

- New Standards are forthcoming

Charles River Model

Model Coverage and Discretization

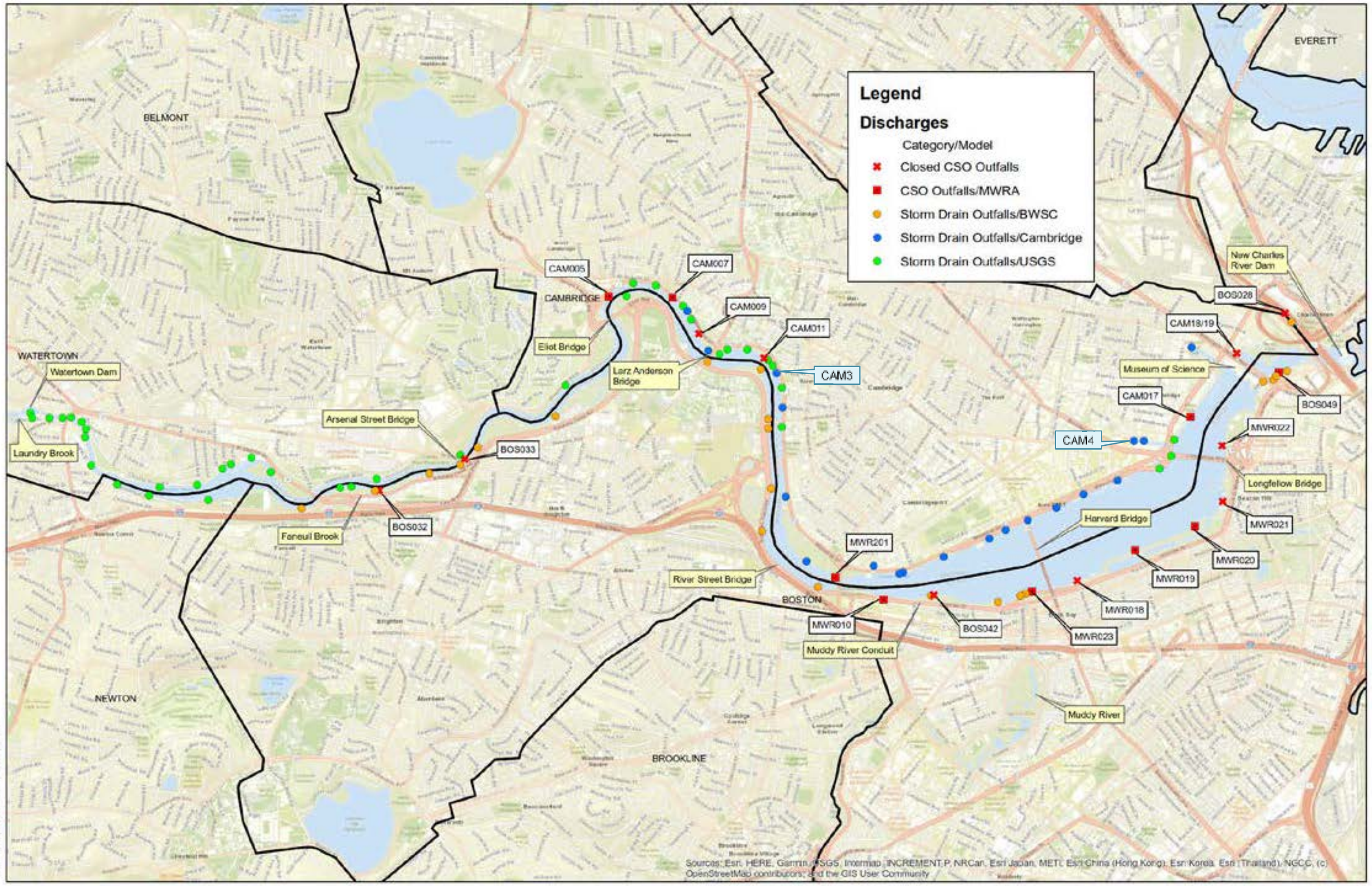
- From Watertown Dam to New Charles River Dam
- Delft-3D in two-dimensional mode. 4,400 grid cells



AECOM

Flow Inputs

- Stormwater from Cambridge, BWSC and USGS models
- CSOs from MWRA Collection System Model



AECOM

CSO Quality

– Cottage Farm and Prison Point inflow monitoring to characterize untreated CSOs

		Cottage Farm(1)	Prison Point(2)
	Number of Measurements	31	16
	Number of Storms	7	6
E. coli (#/100 mL)	Arithmetic Average	1,306,000	175,000
Enterococcus (#/100 mL)	Arithmetic Average	206,000	52,000

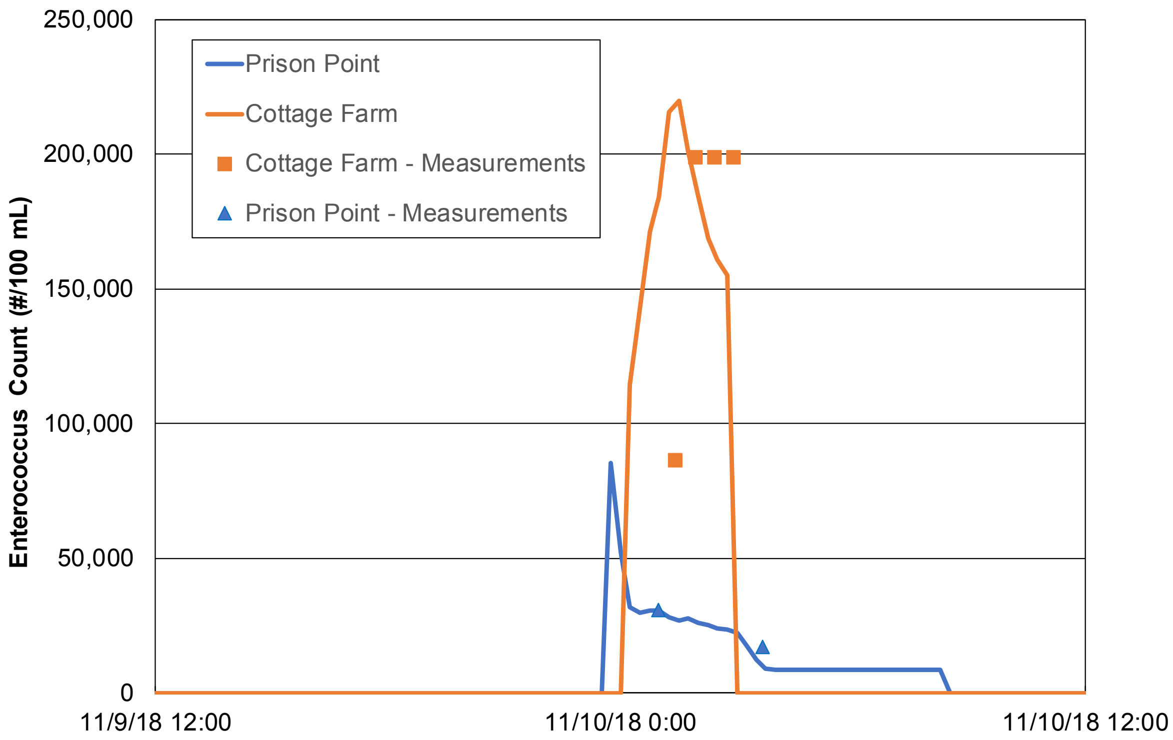
(1) Data collected between October 2017 and August 2019
(2) Data collected between January 2018 and December 2019

Very different bacterial counts at Cottage Farm and Prison Point

CSO Quality

– Sanitary fraction from Collection System Model
– Bacterial counts in sanitary and stormwater fractions

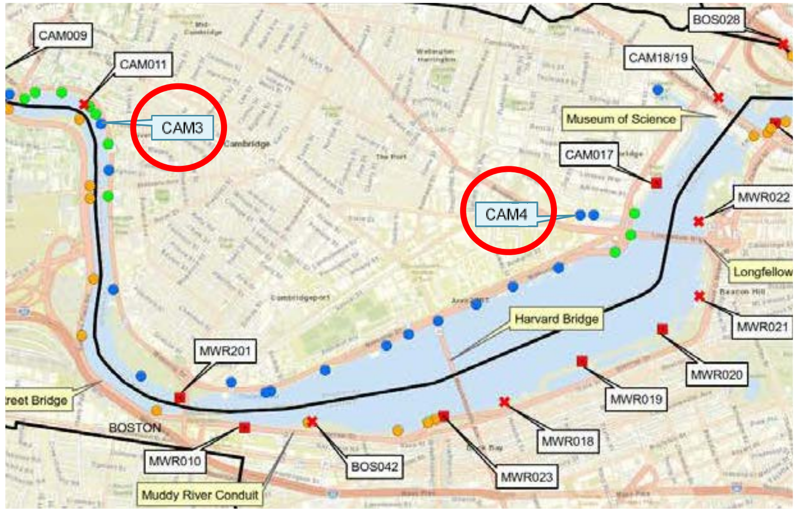
	Sanitary	Stormwater
Enterococcus	1,000,000	5,600
E.coli	6,300,000	17,000



AECOM

Stormwater Quality

– 2019 Monitoring



Date	10/7/2019	10/27/2019	11/18/2019	11/24/2019	12/13/2019	Averages	
Depth (in) (1)	0.16	1.43	0.24	1.51	1.41		
Duration (hr)	2.5	10.5	6	17	17.25		
Peak Int. (in/hr)(2)	0.16	0.56	0.12	0.6	0.24		
Prior Dry Days	2	3	5	1	2.2		
E. coli							
CAM3	42,000	3,017		4,367	15,650	16,258	16,667
CAM4	542	2,308		11,288	54,167	17,076	
Enterococcus							
CAM3	6,017	2,465		5,350	9,650	5,870	3,674
CAM4	1,273	1,153		1,603	1,877	1,477	

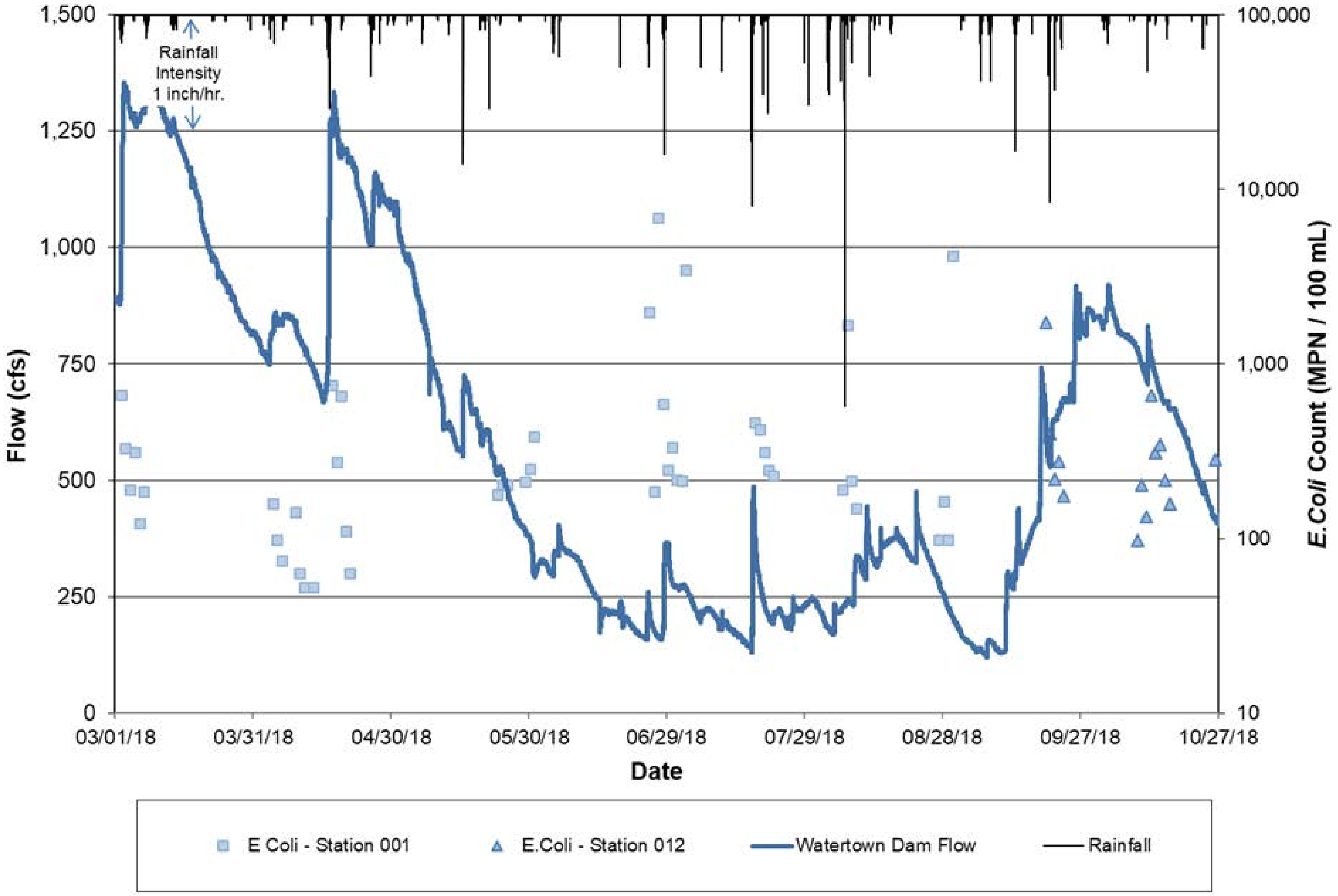
(1) Somerville Marginal Data

(2) 15-min peak intensity

AECOM

Upstream Boundary Condition

– Flow from upstream brings large quantities of *Enterococcus* and *E. coli*



AECOM

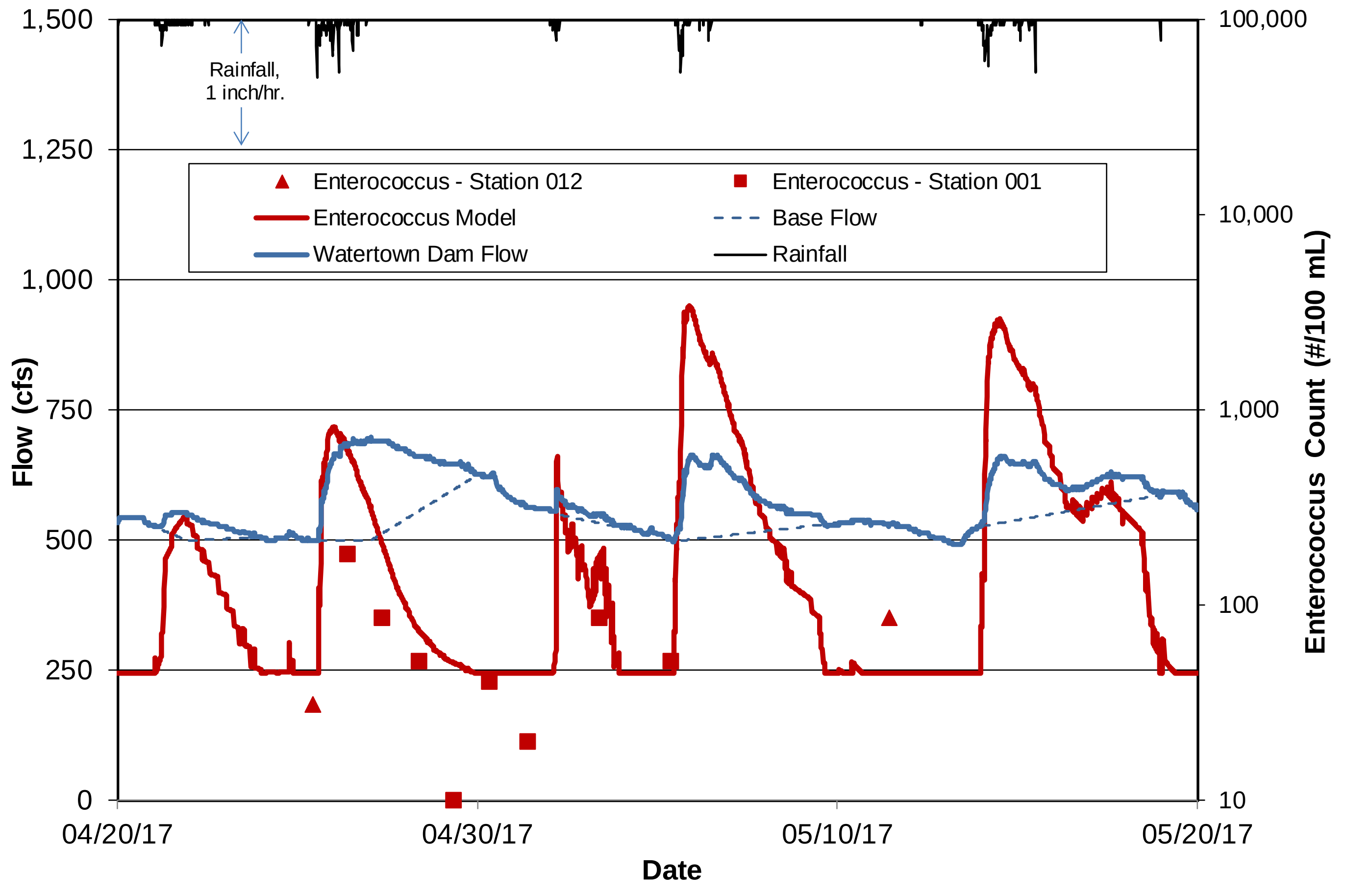
Upstream Boundary Condition

– Buildup/washoff model based on USGS flows at Waltham Gauge

	Build-up Rate		Washoff Coeffi-cient	Washoff Exponent	Die-off Rate	Base Flow Count	Ave Meas.	Ave Model	IA
	a (#/mi^2/day)	Winter/ Fall Ratio	α	β	K (day^{-1})	C_B #/100ml			
Entero 2017	1.7 x 10^{11}	0.2 / 0.5	8 x 10^{-4}	1.4	0.5	45	405	408	0.92
Entero 2018	1.7 x 10^{11}	0.2 / 0.5	8 x 10^{-4}	1.4	0.5	45	432	423	0.91
E. coli 2017	3.5 x 10^{11}	0.2 / 0.5	8 x 10^{-4}	1.4	0.5	134	997	1,094	0.87
E. coli 2018	3.5 x 10^{11}	0.2 / 0.5	8 x 10^{-4}	1.4	0.5	134	975	879	0.93

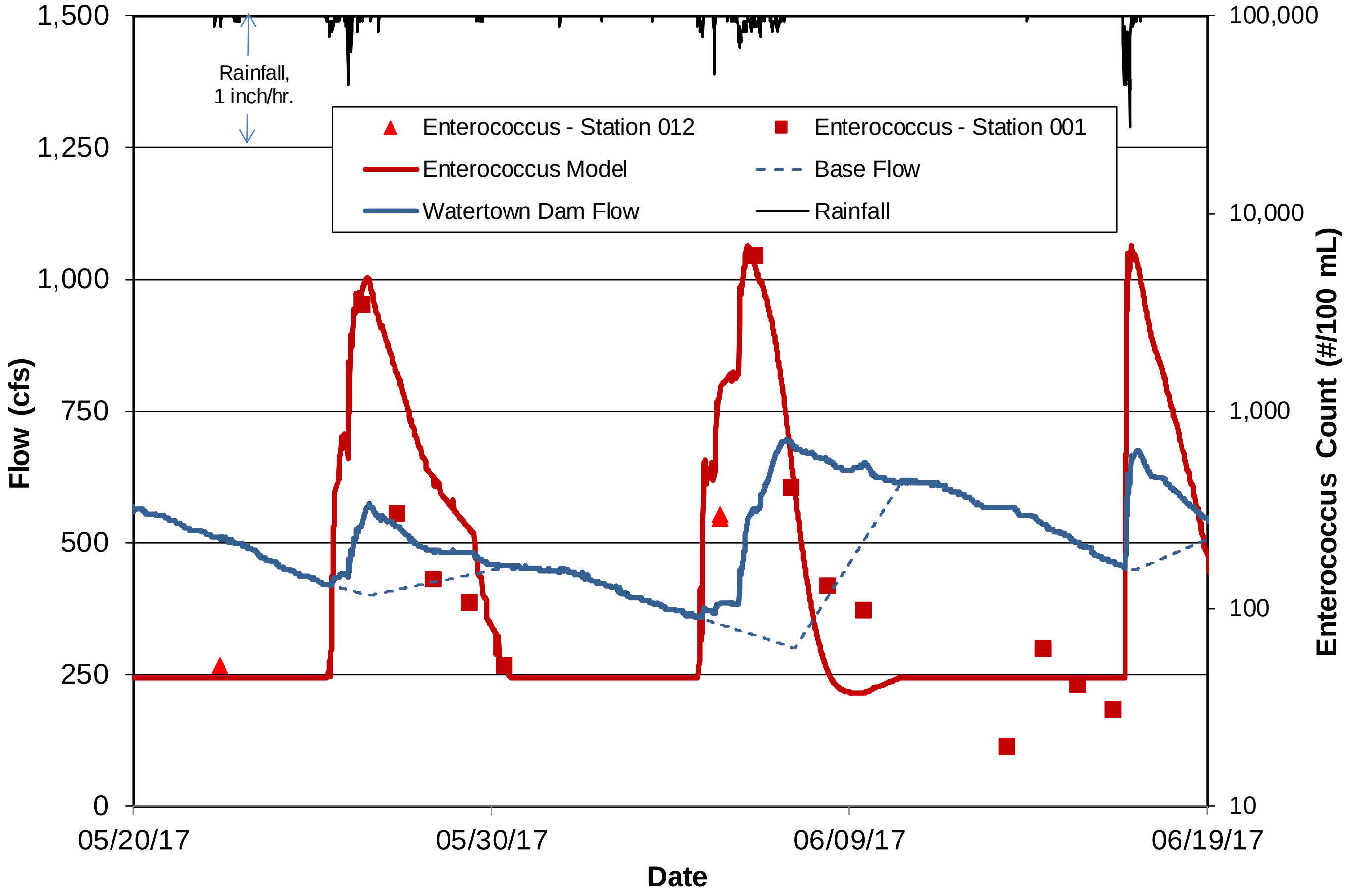
AECOM

Upstream Boundary Condition



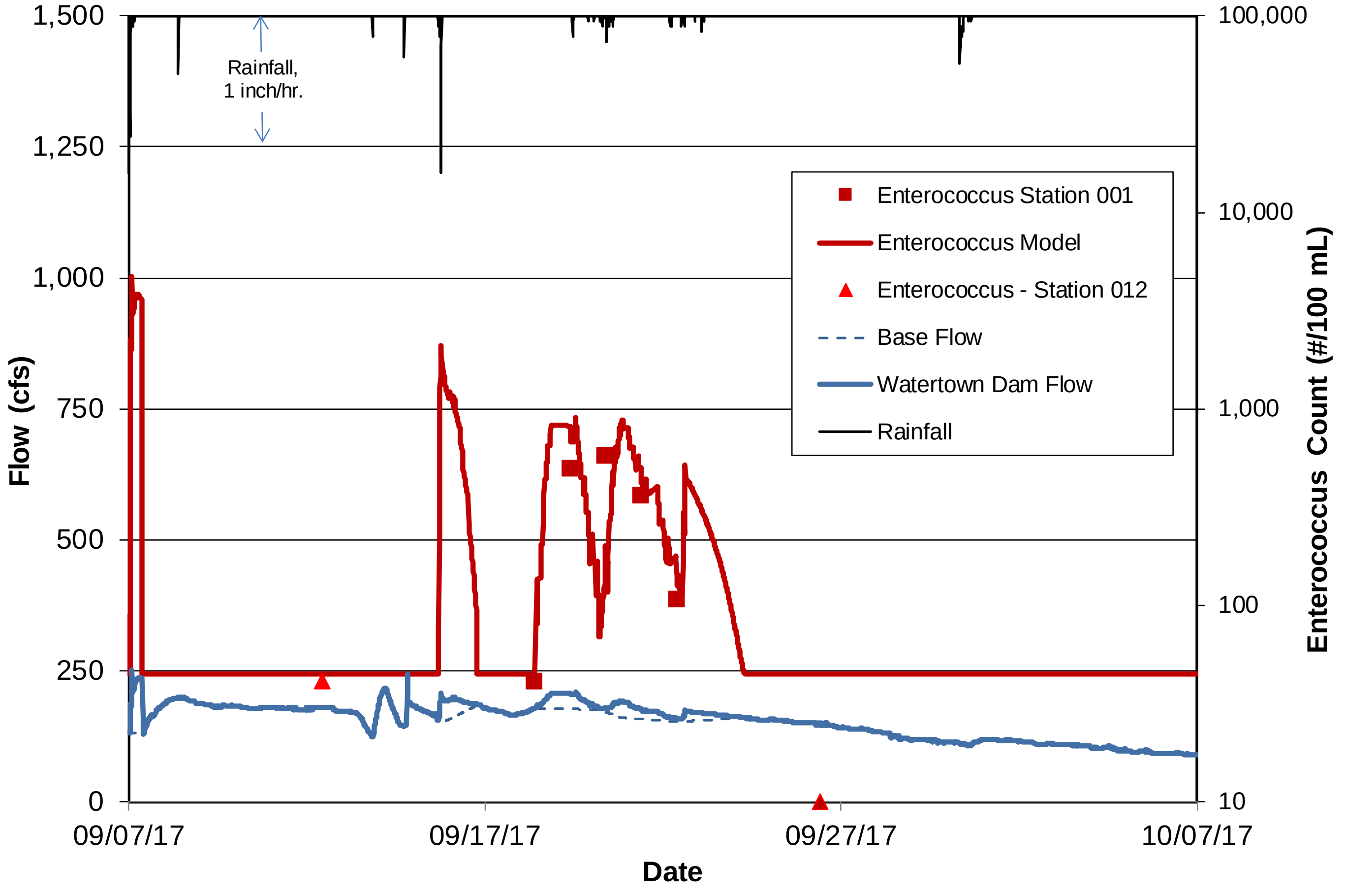
AECOM

Upstream Boundary Condition



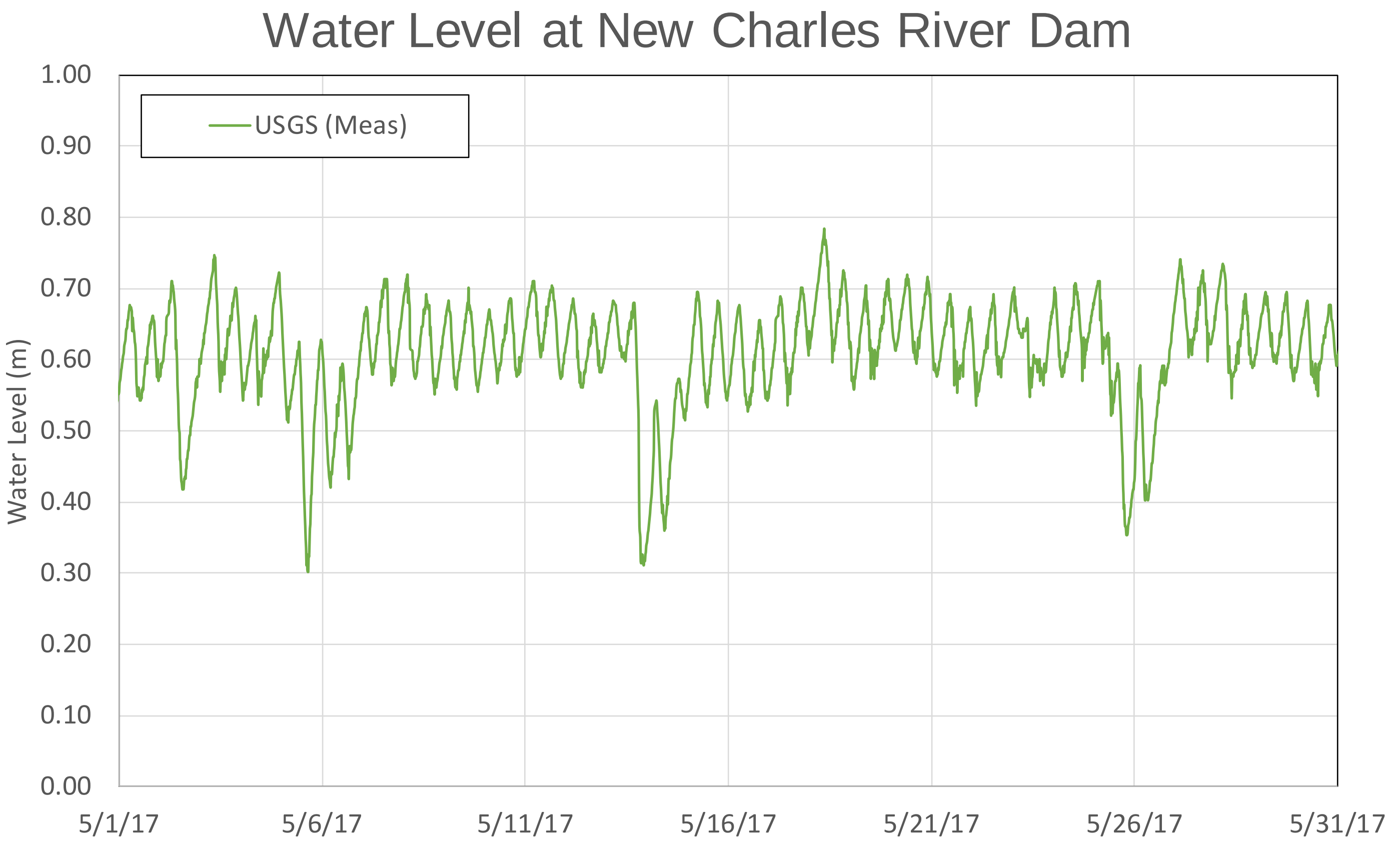
AECOM

Upstream Boundary Condition

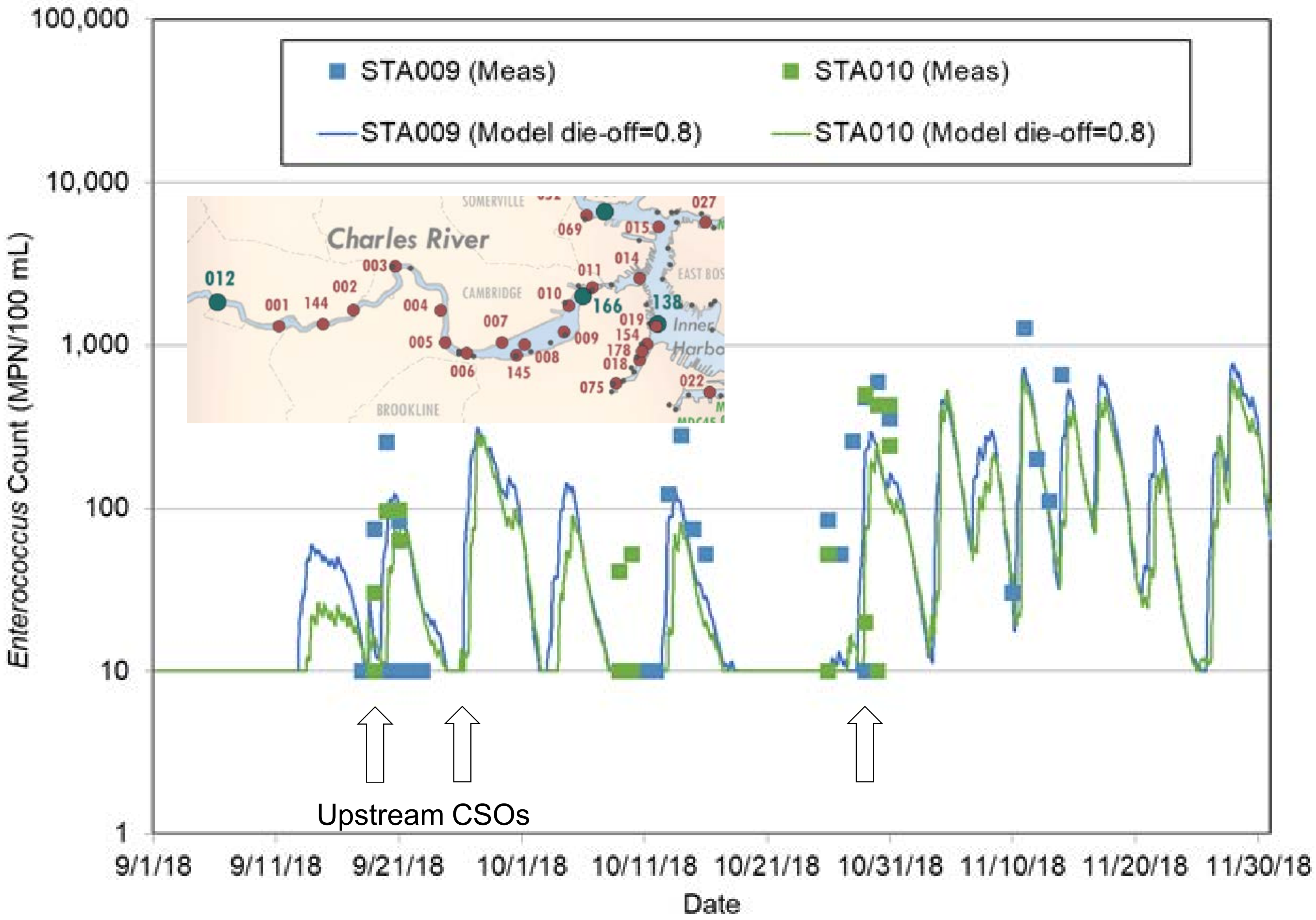


Downstream Boundary Condition

- Water level is kept approximately constant
- Small variations due to discharges at low tide and pumping before storms
- In model: USGS water levels specified as boundary condition

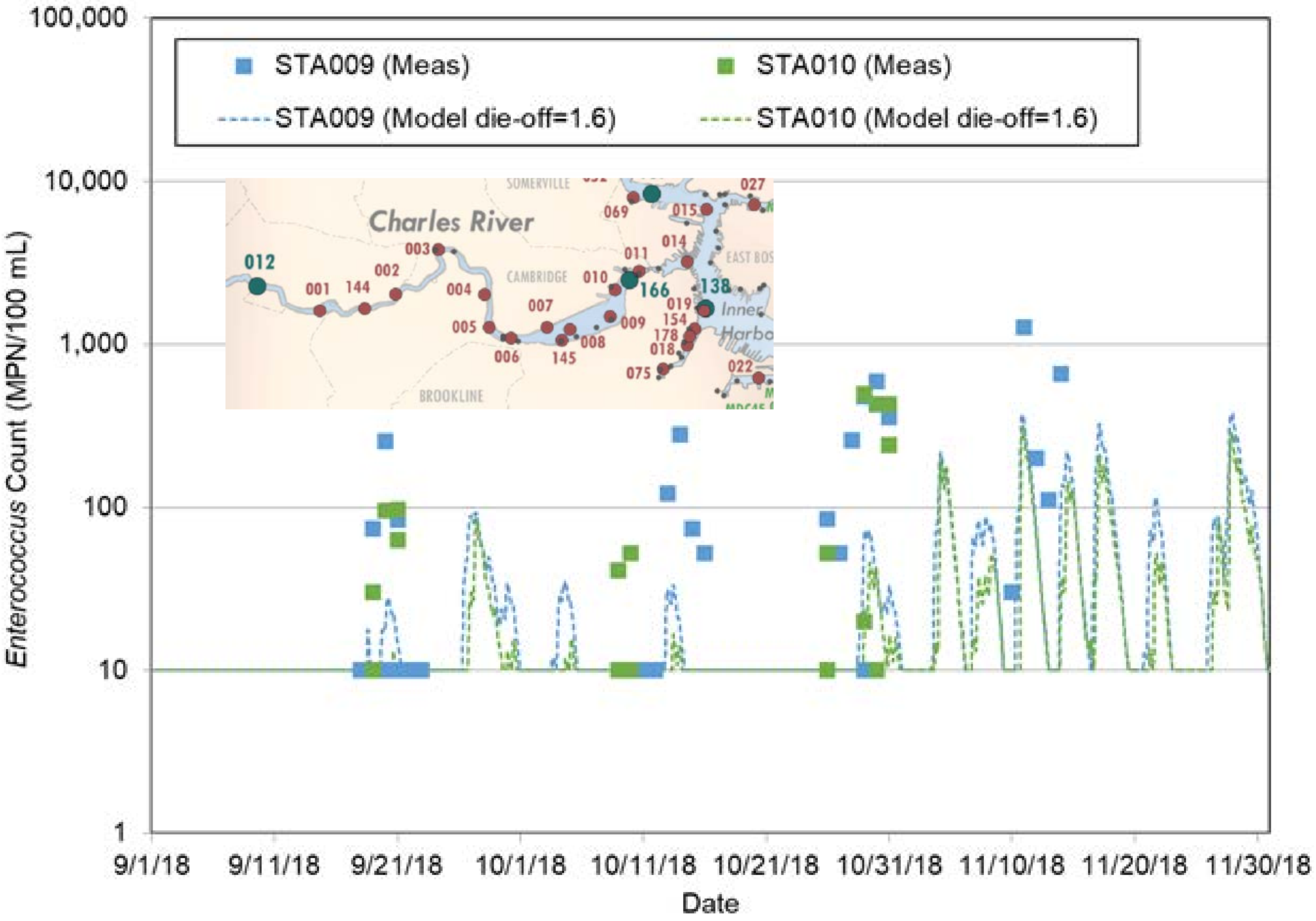


Water Quality Calibration

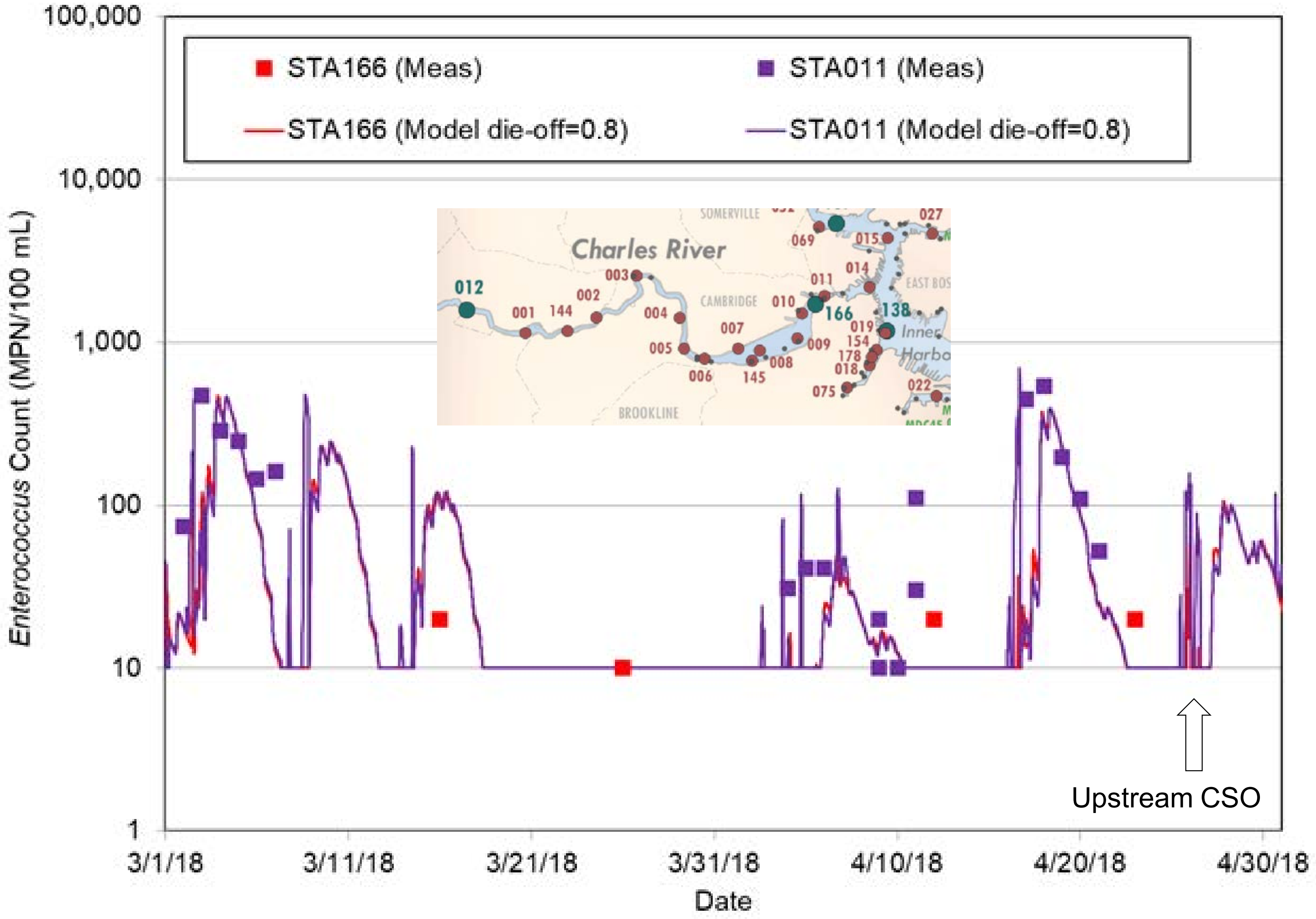


AECOM

Water Quality Calibration

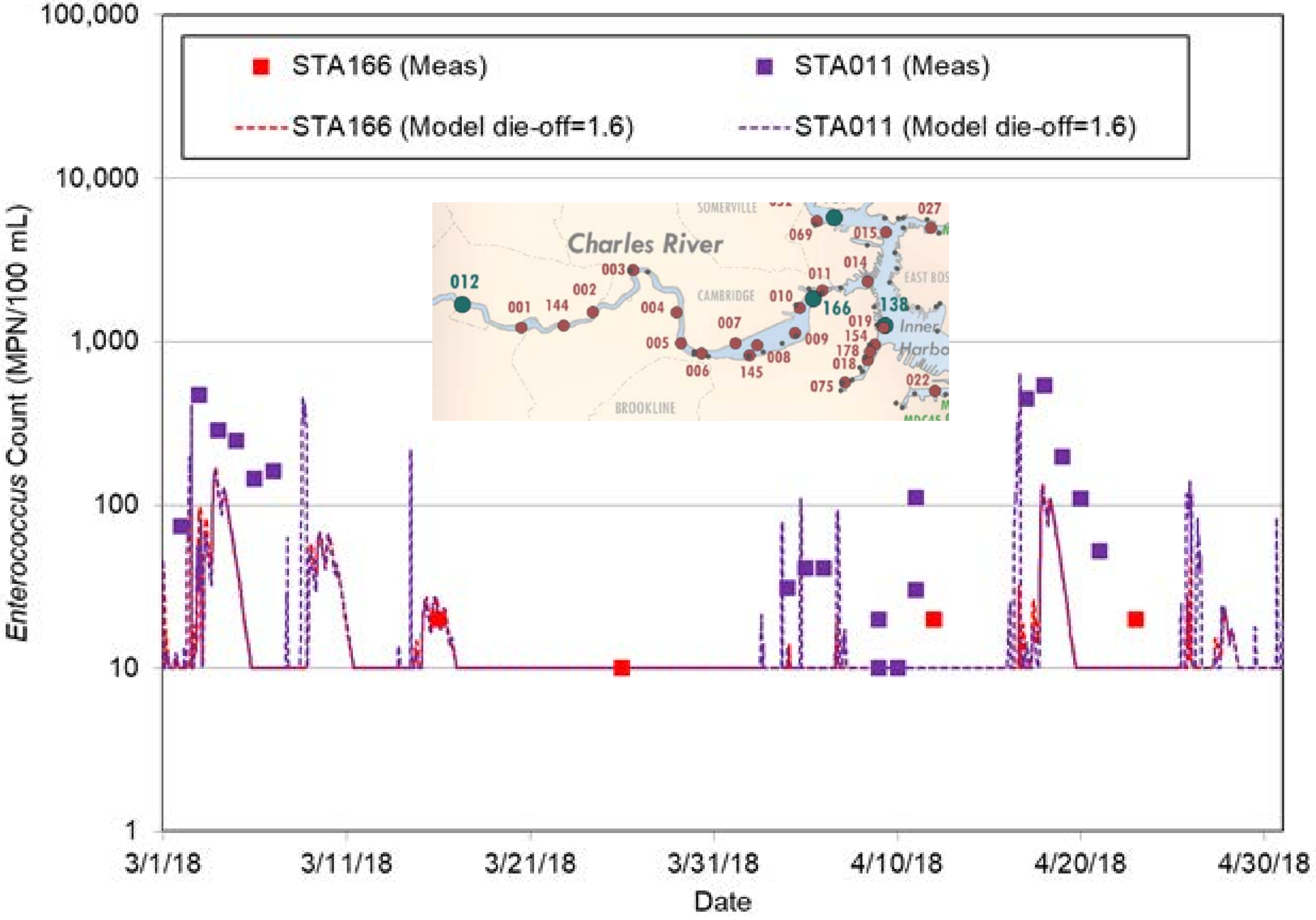


Water Quality Calibration



AECOM

Water Quality Calibration

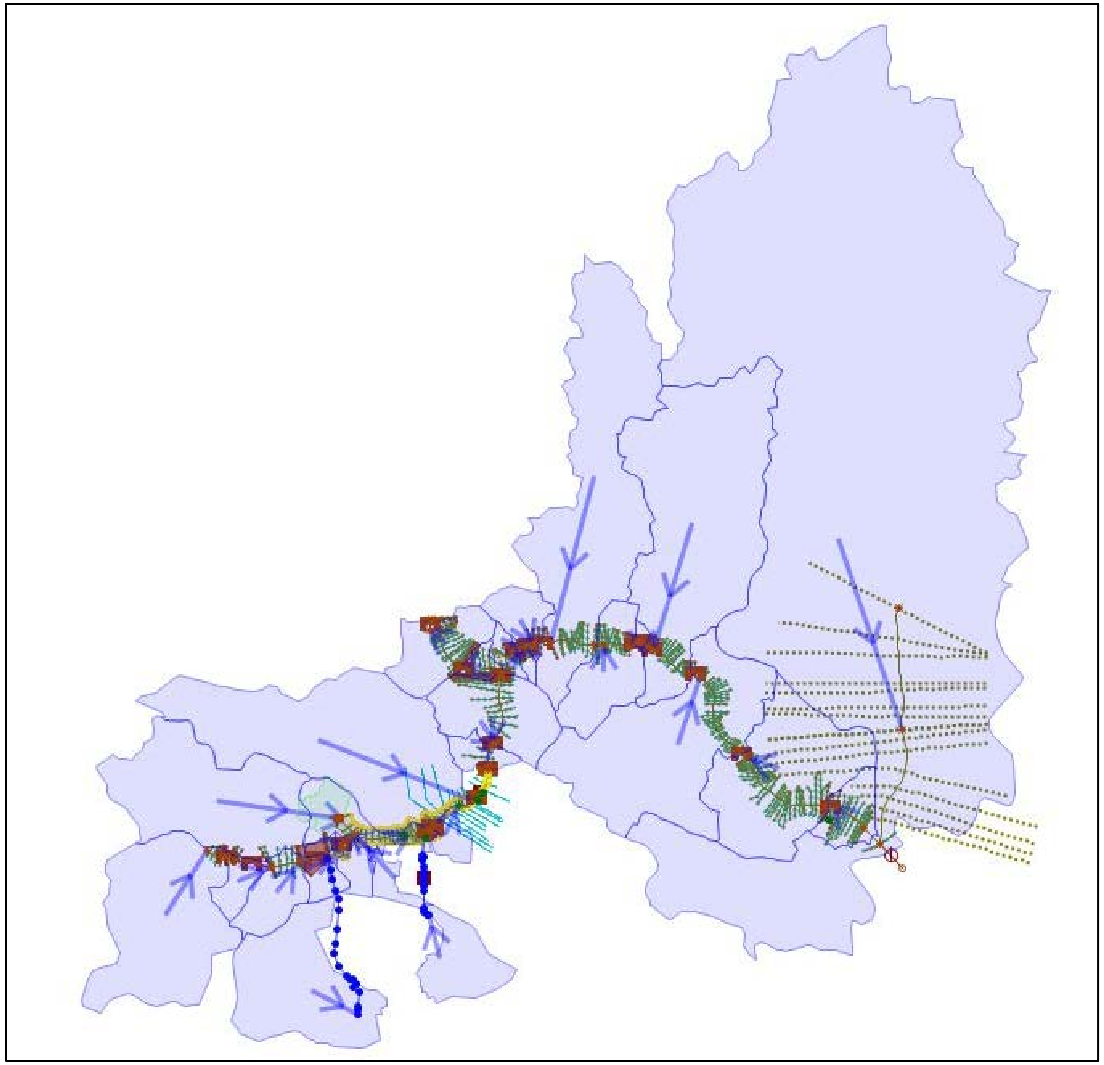


AECOM

Alewife Brook / Upper Mystic River Model

Model Coverage and Discretization

- From Amelia Earhart Dam to Lower Mystic Lake
- InfoWorks ICM
  - Based on FEMA Model
  - The FEMA model covers the entire watershed.
  - 278 cross-section

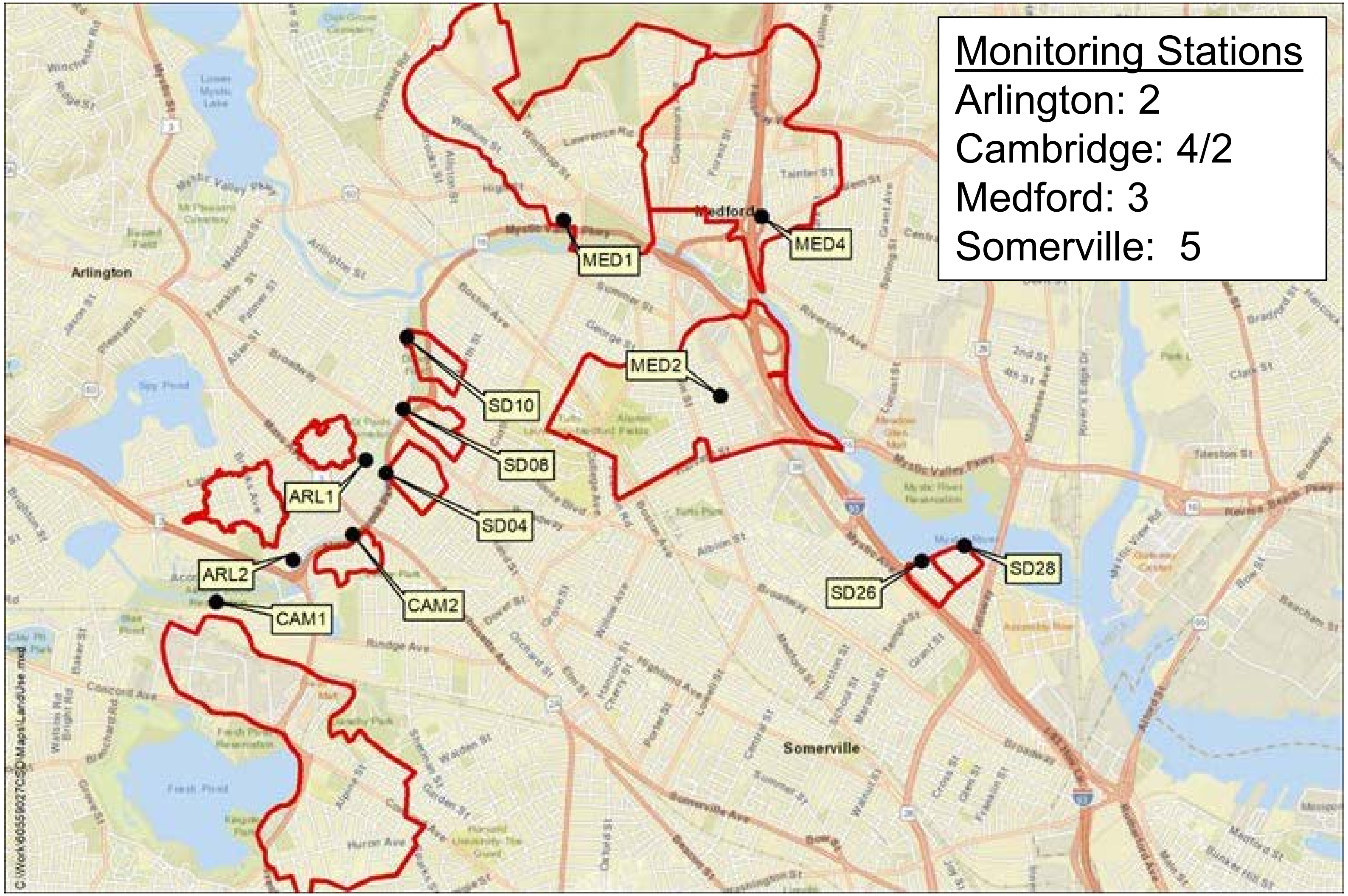


CSO Quality

- Same approach as for the Charles River: CSO counts calculated from based on sanitary fractions derived by the collection system model.

FACILITY	LOCATION	SAMPLE TIME LOCAL	E. COLI #/100ML	ENTEROCOCCUS #/100ML
CAMB-CSO	401A	8/29/19 0:20	54,800	36,500
CAMB-CSO	401A	8/29/19 0:40	86,600	61,300
CAMB-CSO	401A	8/29/19 1:20	86,600	54,800
CAMB-CSO	401A	10/17/19 0:31	130,000	54,800
CAMB-CSO	401A	10/17/19 0:46	36,500	22,500
CAMB-CSO	401A	10/17/19 1:01	21,900	17,900
CAMB-CSO	401A	10/17/19 1:16	13,100	30,800
CAMB-CSO	401A	10/17/19 1:31	17,200	16,100
SOM-CSO	001A	8/29/19 0:52	72,700	38,700
SOM-CSO	001A	8/29/19 1:09	81,600	22,500
SOM-CSO	001A	10/17/19 2:18	61,300	13,700
SOM-CSO	001A	10/17/19 3:06	43,500	13,300

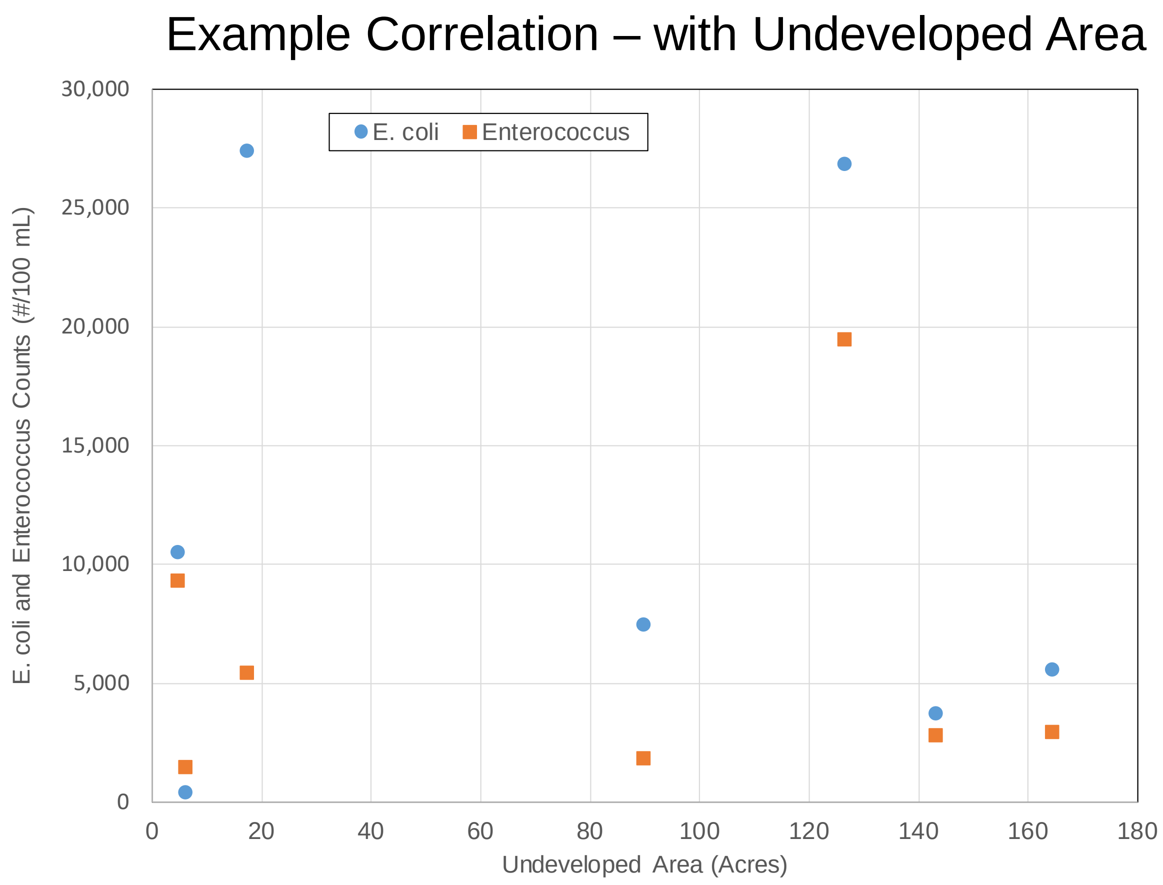
Stormwater Quality: 2019 Monitoring



AECOM

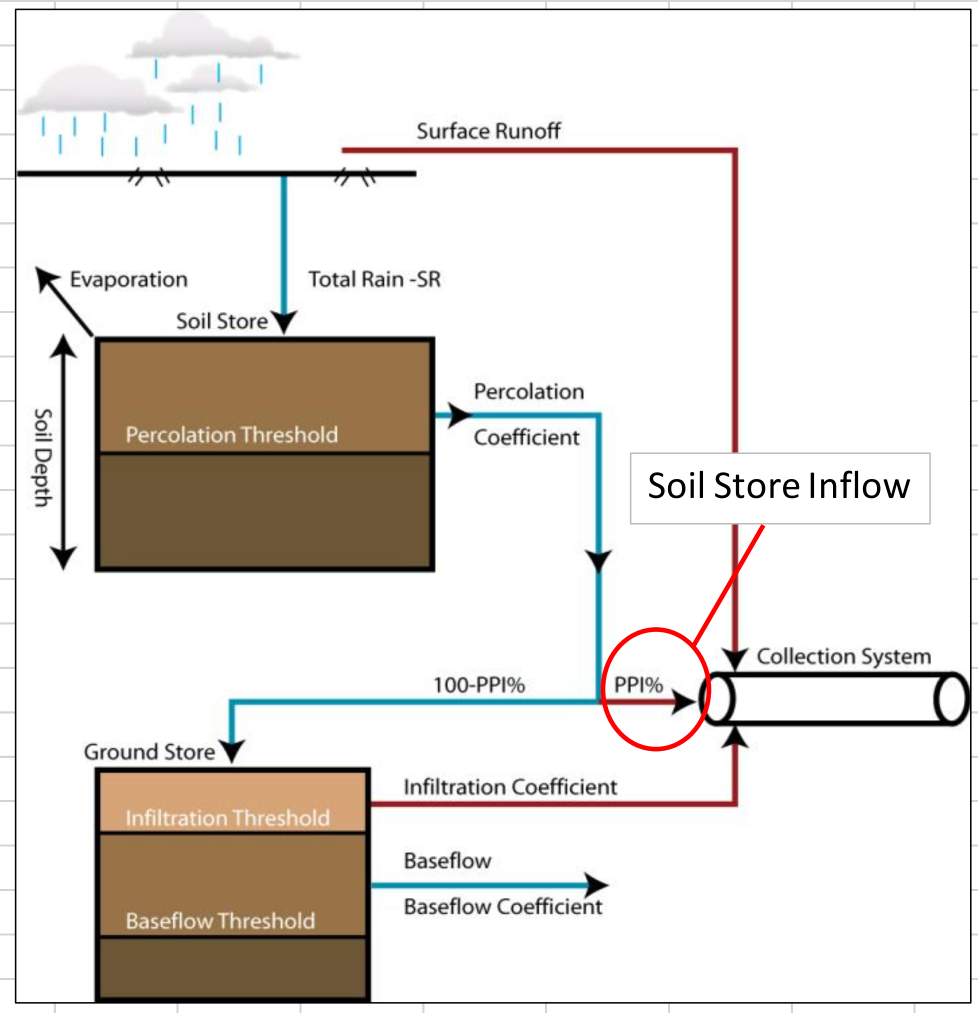
Stormwater Quality

- No correlation found with sub-catchment parameters
  - Sub-catchment area
  - Percent undeveloped
  - Undeveloped area
  - Percent residential
  - Residential area
  - Storm depth
  - Prior dry days
- Average counts selected
  - *E. coli*: 12,800 / 100 mL
  - *Enterococcus*: 5,600 / 100 mL



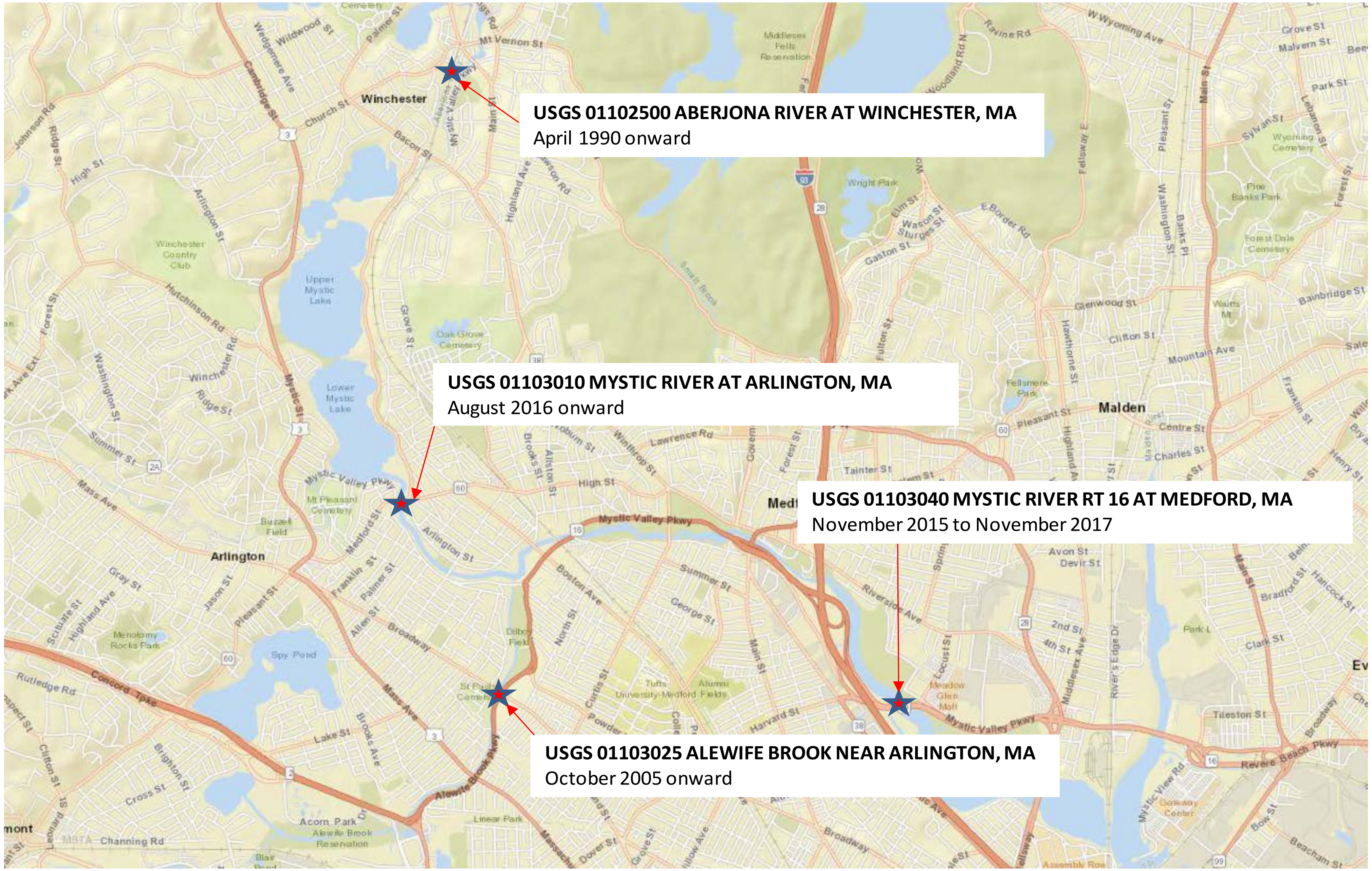
Hydrology Calibration

- Original FEMA model geared towards extreme events
- For continuous simulations, the hydrology was changed to the SWMM formulation with groundwater routines
- Parameters to be specified
  - Percent impervious
  - Catchment width
  - Percent routed from impervious to pervious
  - Evaporation (monthly)
  - Evaporation depth
  - Percolation coefficient
  - Percolation threshold

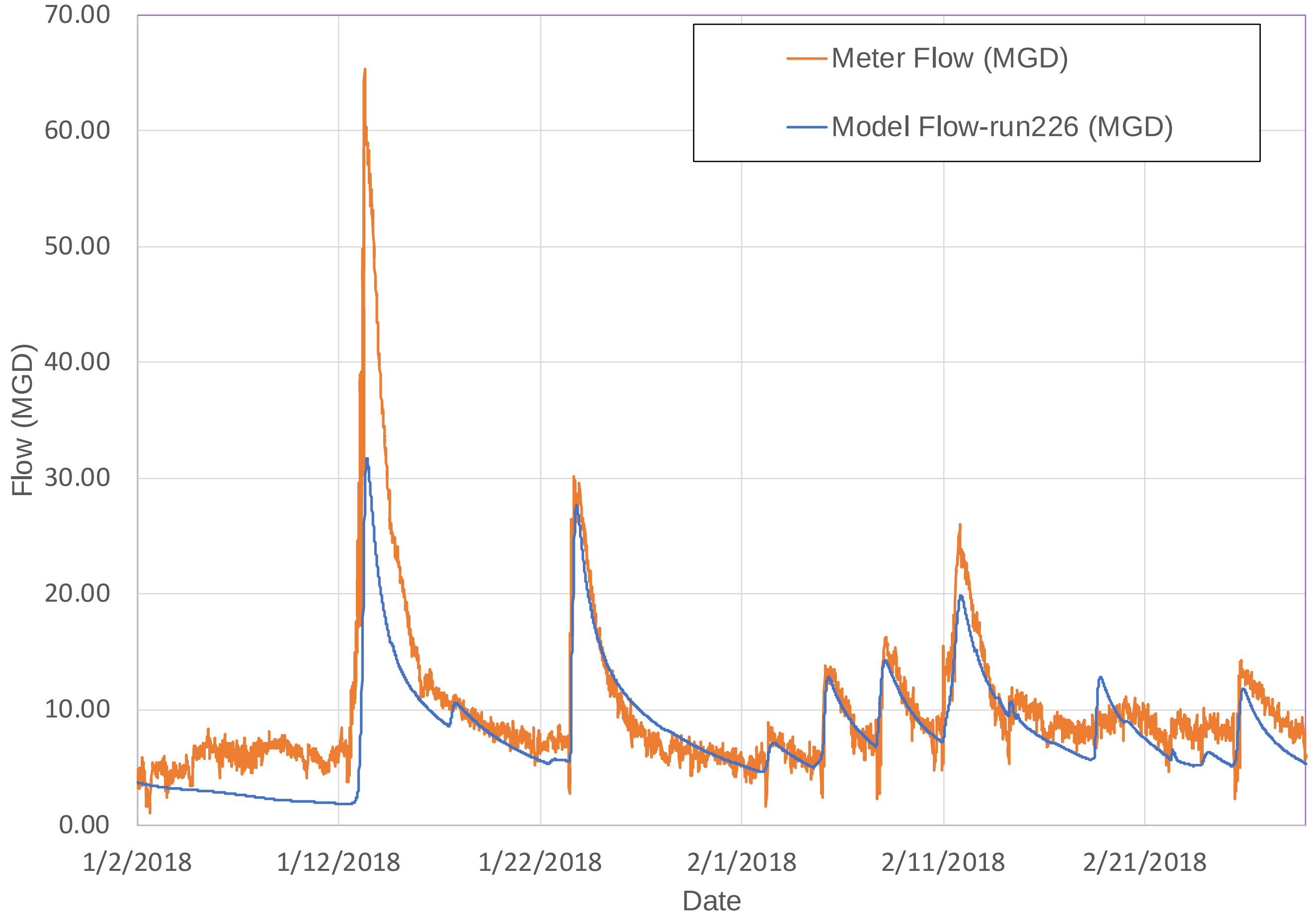


AECOM

Hydrology Calibration – USGS Flow Gauges



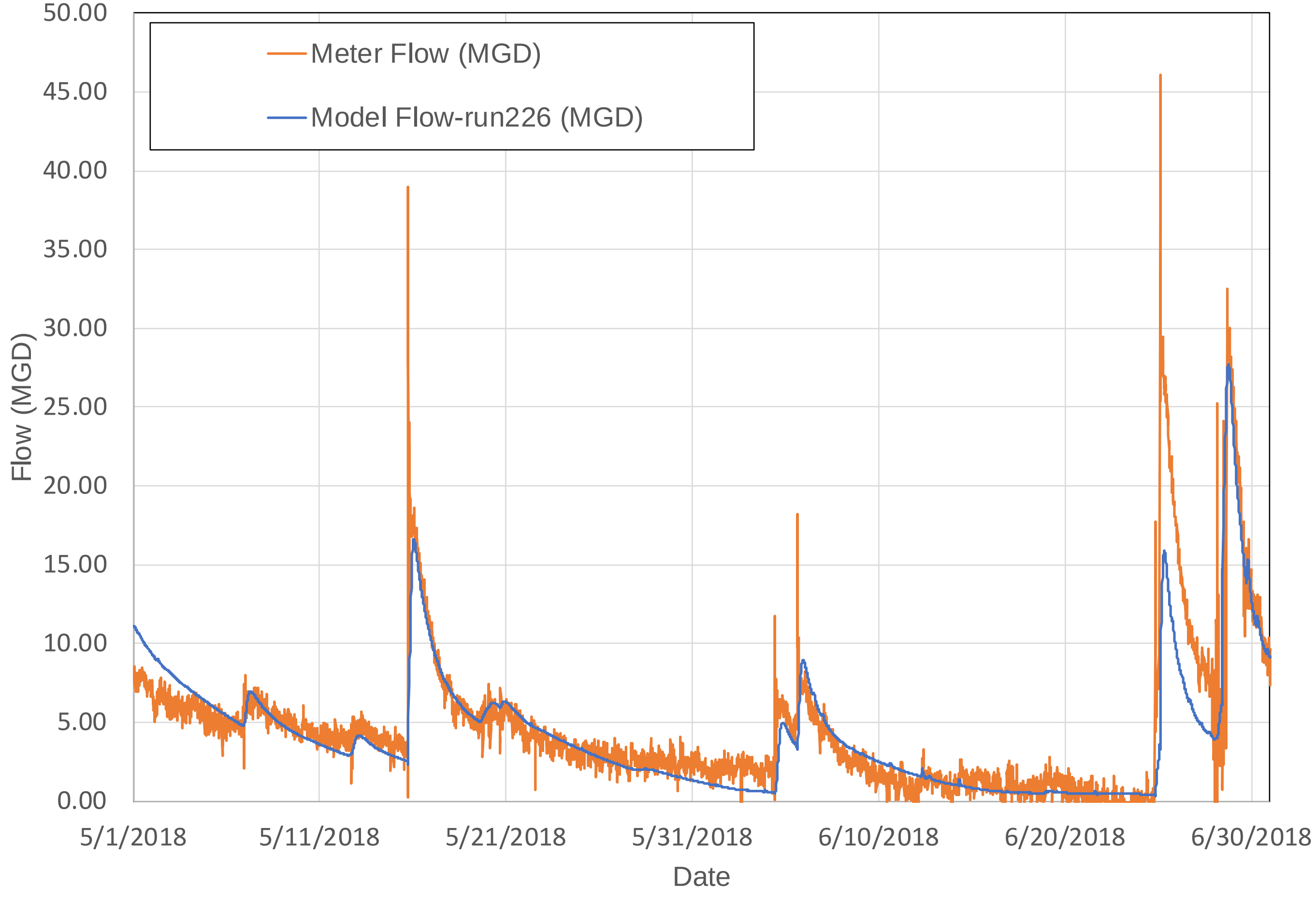
Hydrology Calibration – Alewife Brook Gauge



January-February

AECOM

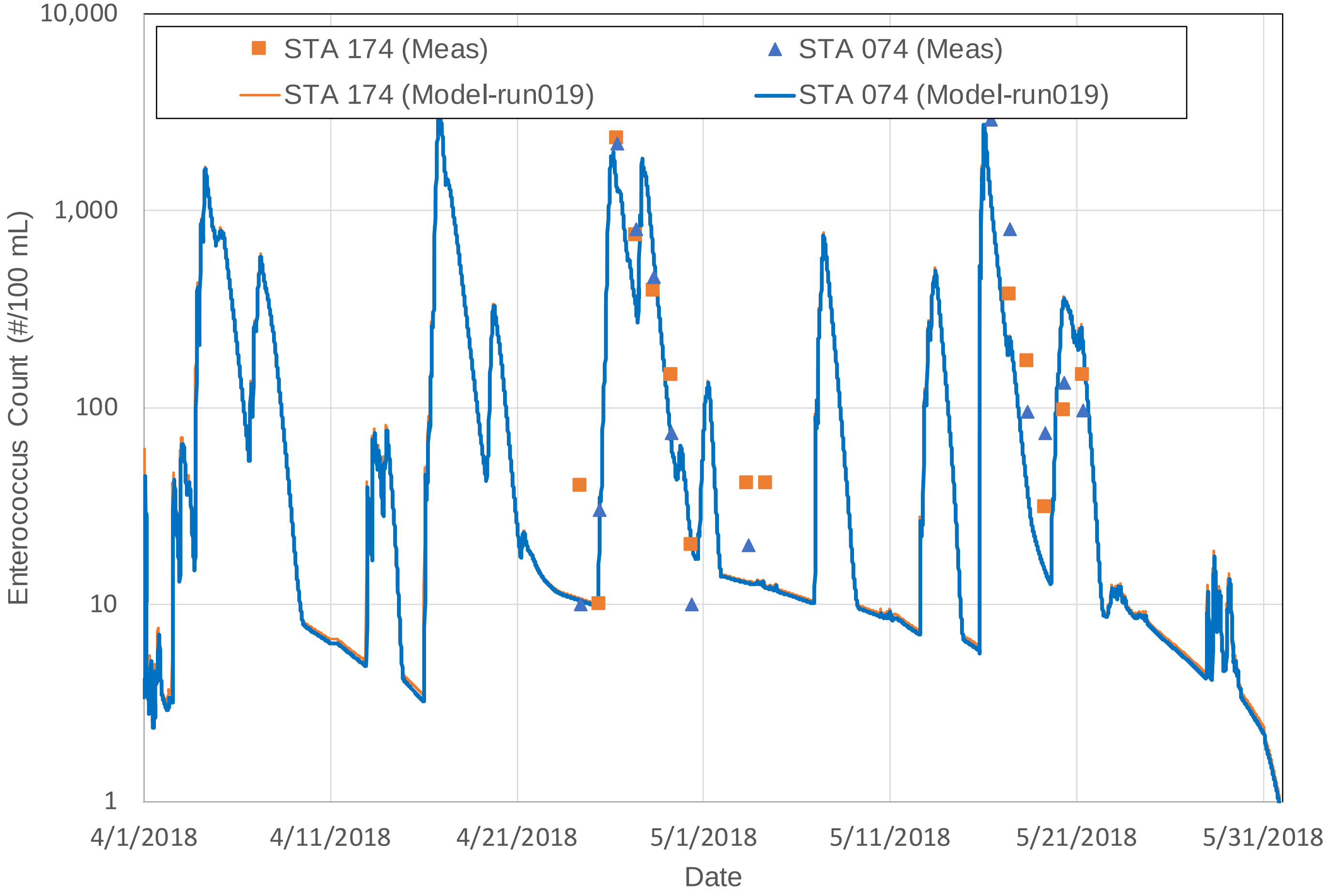
Hydrology Calibration – Alewife Brook Gauge



May-June

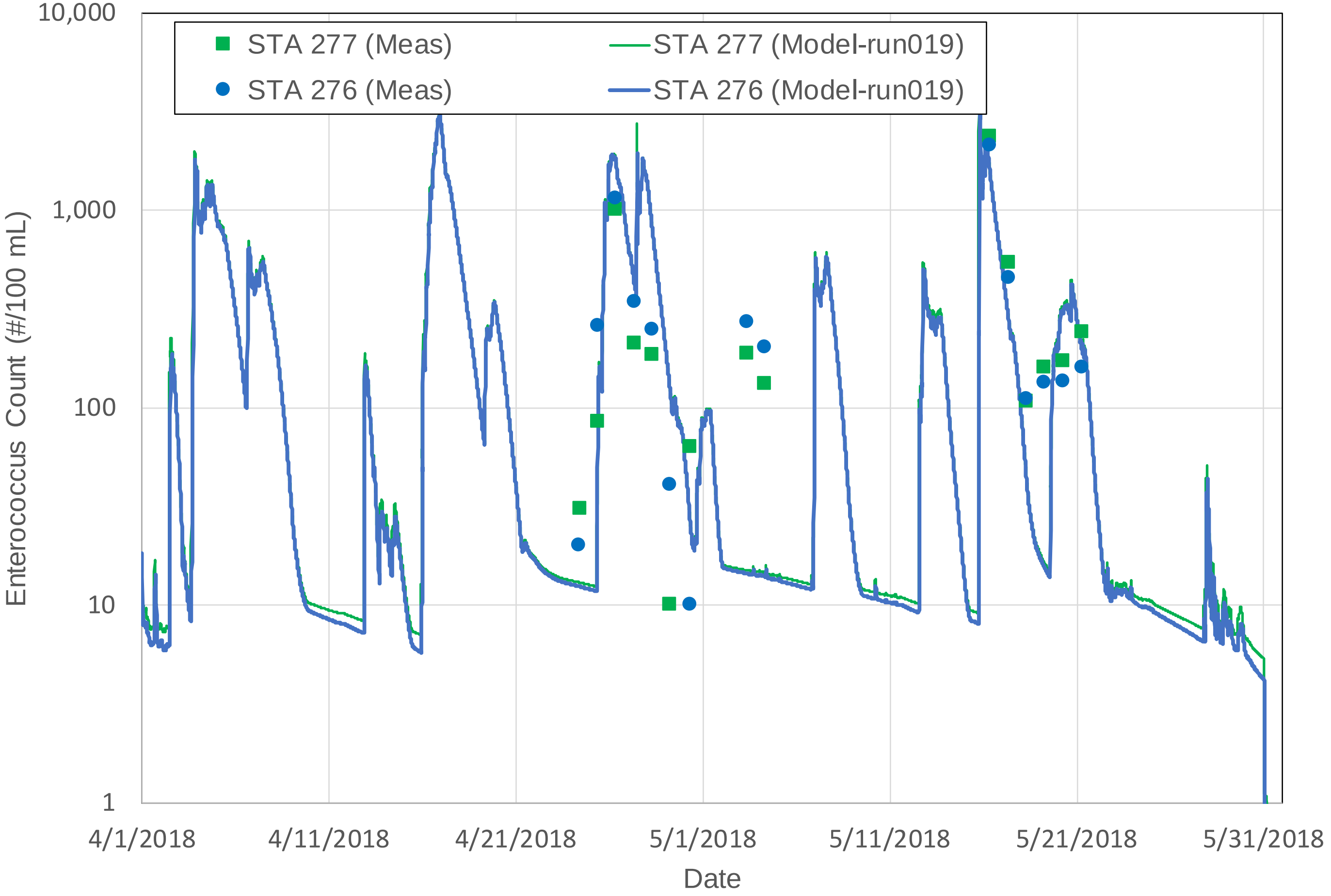
AECOM

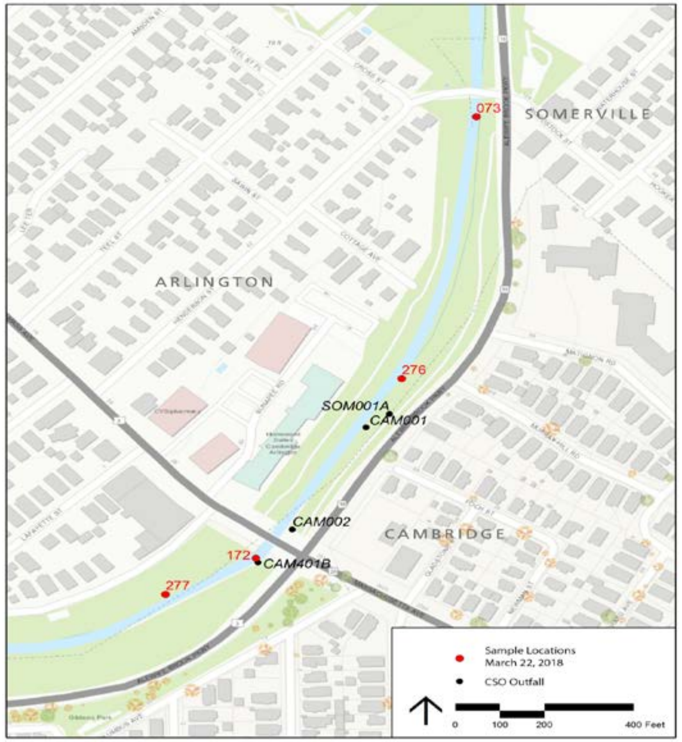
Water Quality Calibration



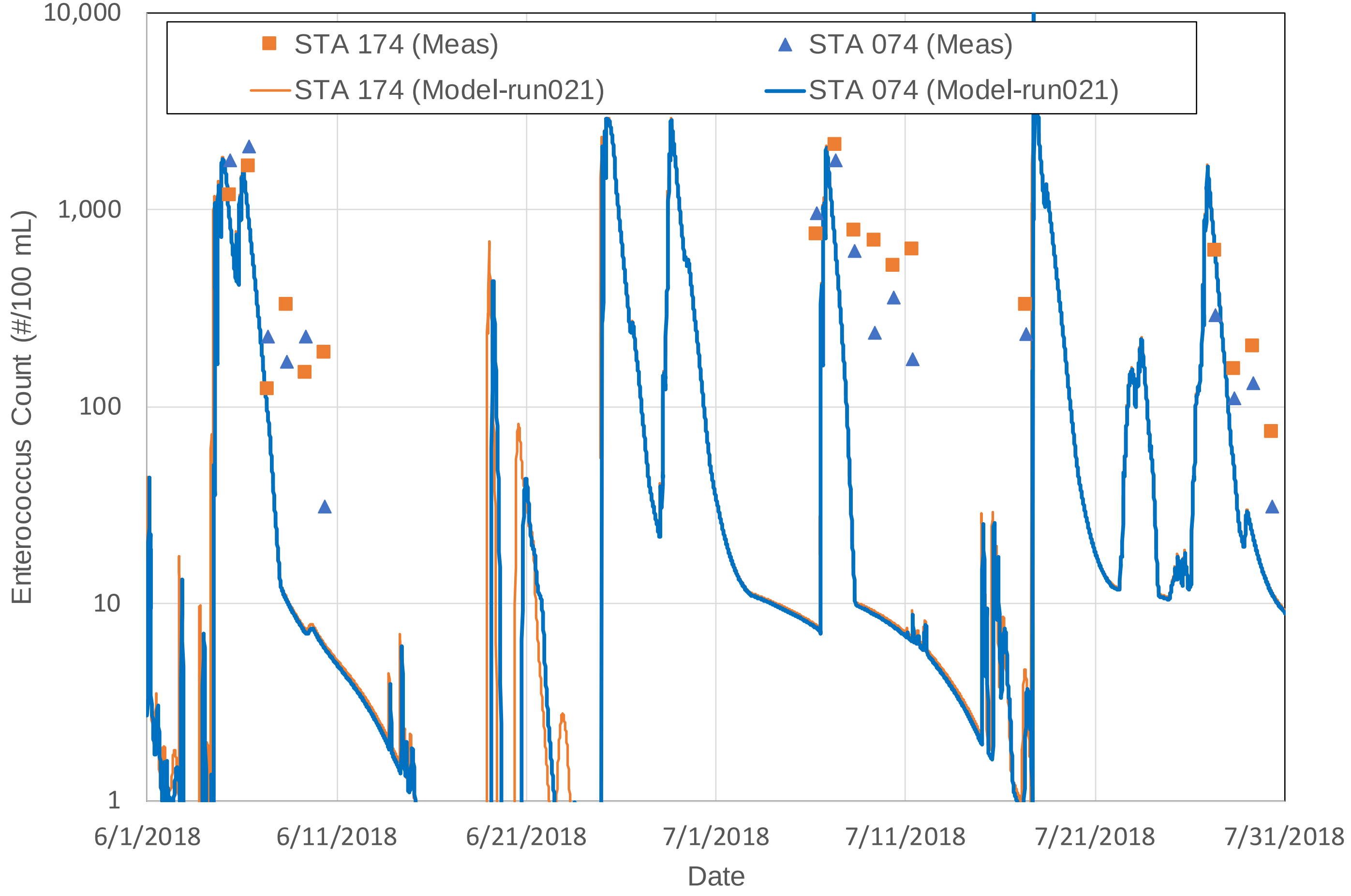
AECOM

Water Quality Calibration

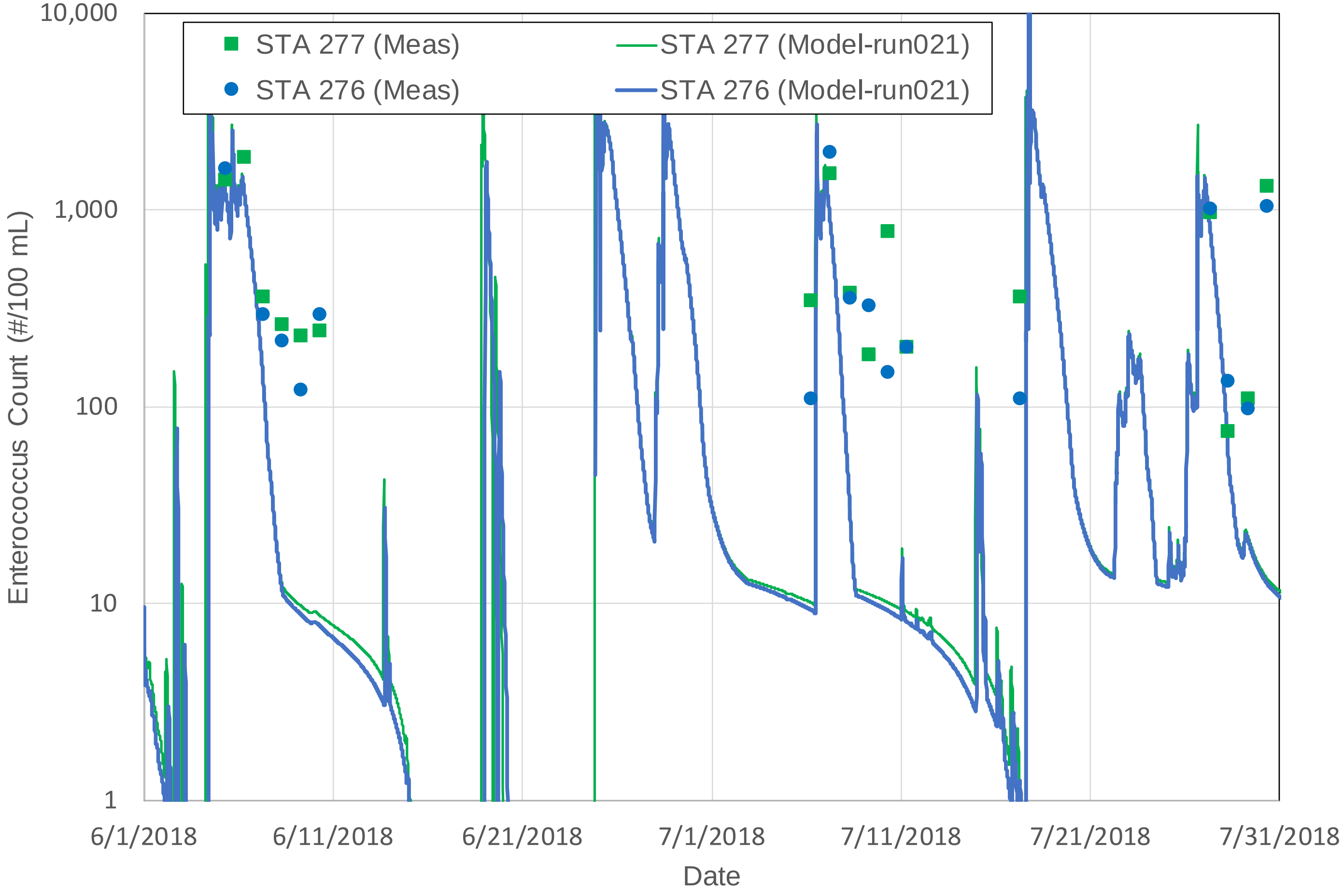


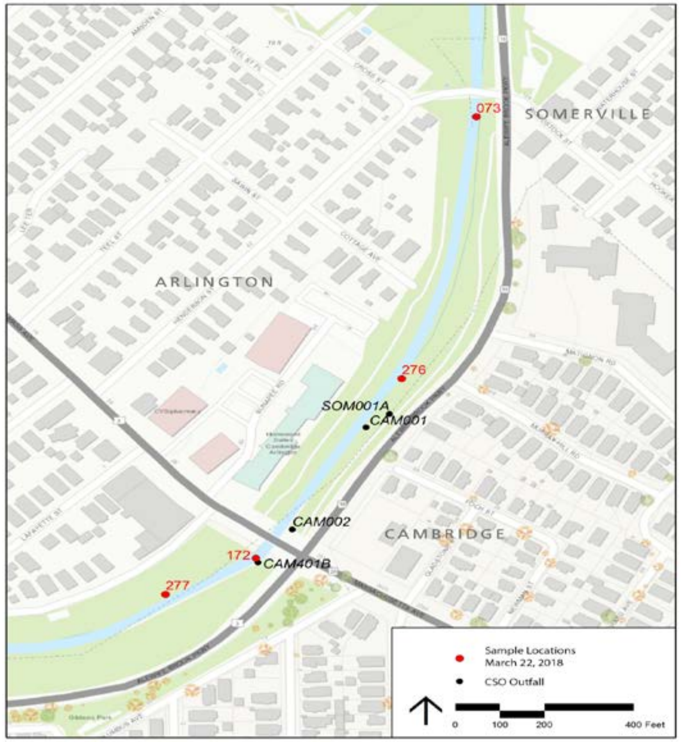


Water Quality Calibration



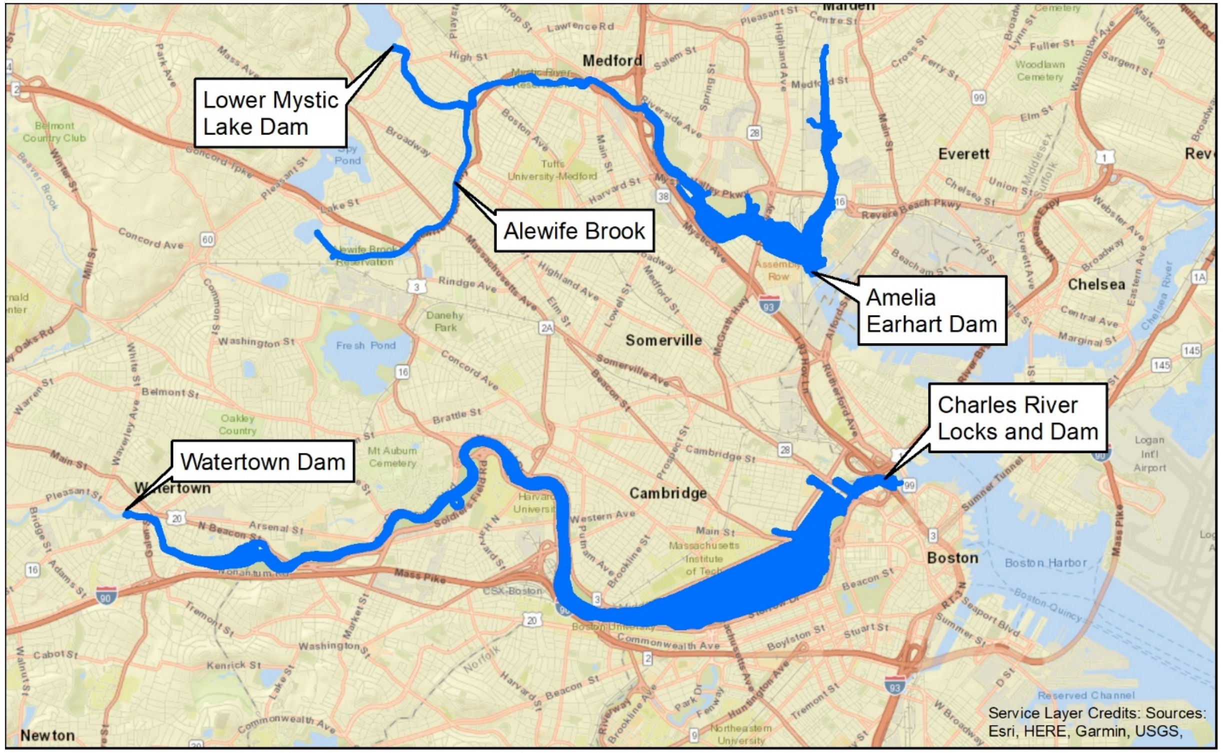
Water Quality Calibration





Summary

- CSO and stormwater quality measurements have been reviewed and analyzed
- Satisfactory calibration for both models
- The models are being used to:
  - Assess current conditions
  - Assess alternatives
    - Further CSO reductions
    - Stormwater BMPs



AECOM

Thank You