RPS asa

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CSO/Wet Weather Issues Specialty Conference
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Water Quality Modeling to Evaluate Multiple Combined Sewer Overflow Management Options for the Narragansett Bay Commission

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Presentation Overview

- NBC CSO History
- Current Status
- Present Modeling Study
  - Study Area
  - Modeling Overview
  - Model Verification
  - Modeling Scenarios: Simulations of Phase I, Phase II and Phase III alternatives

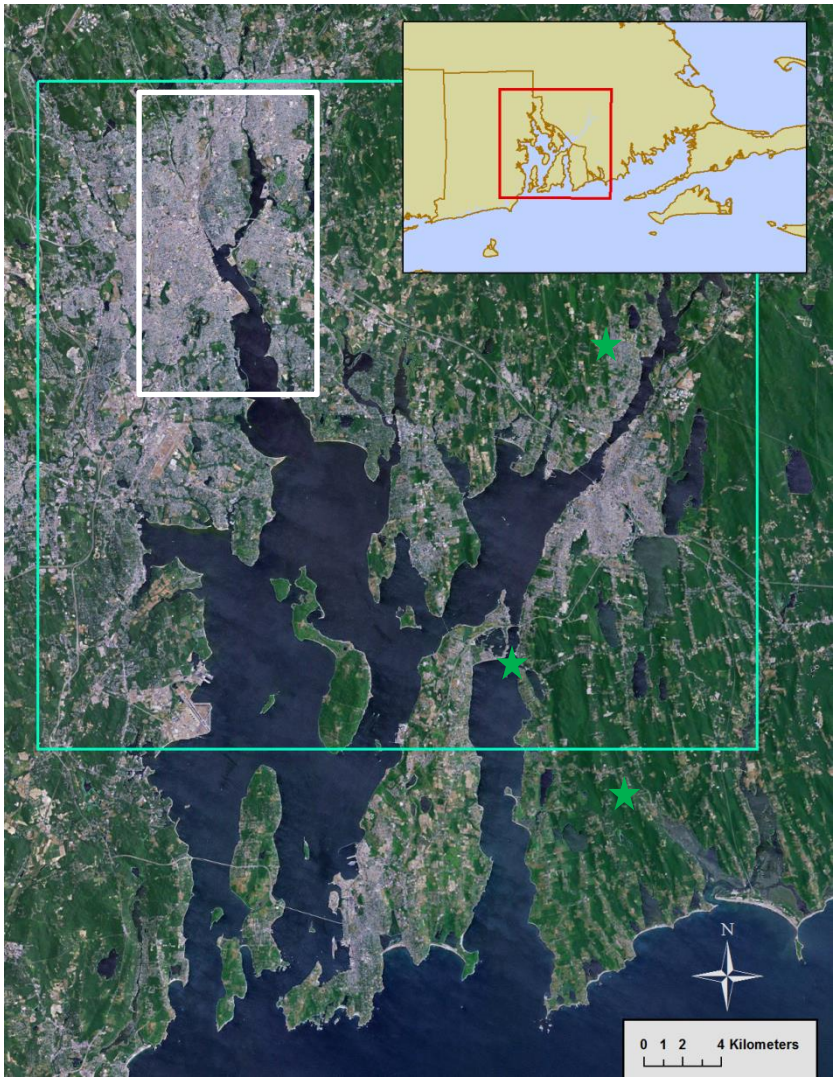
History

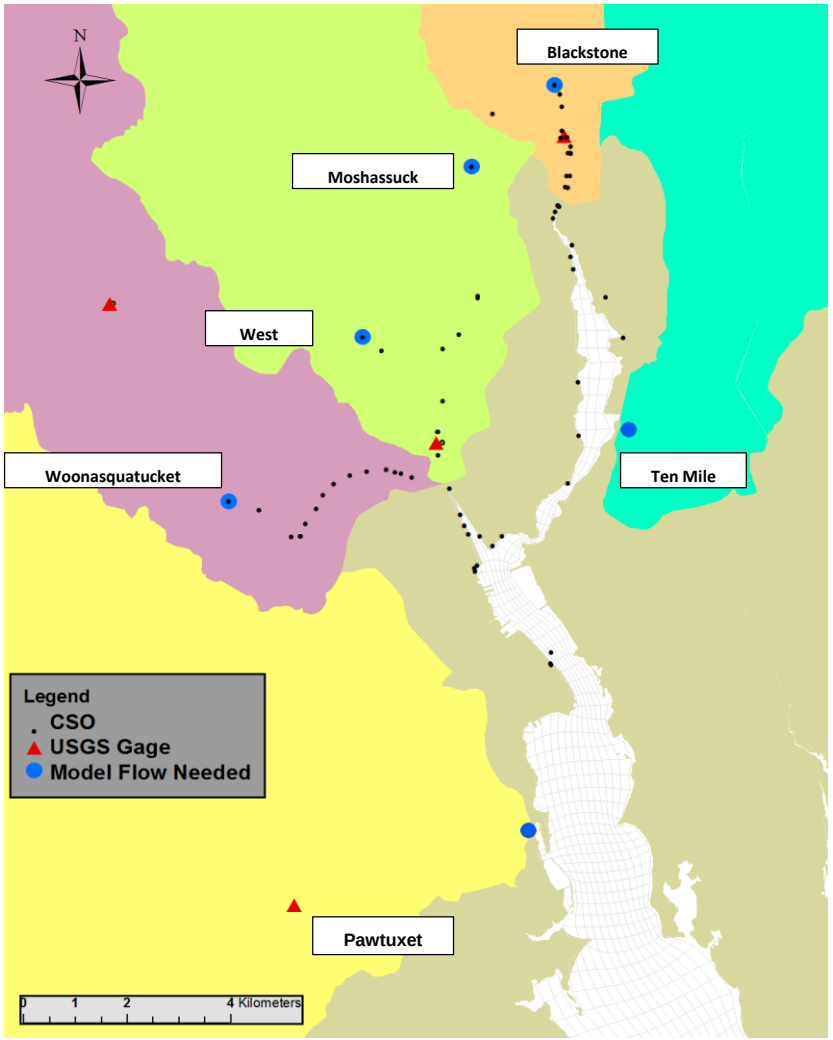
- March 1993 Narragansett Bay Commission (NBC) approved a CSO abatement program and entered into consent agreement with RIDEM
- April 1994 EPA adopted national CSO policy, allowing plans to be based on water quality improvements
- NBC presented preliminary design plans of high priority facilities to RIDEM January 1996 and potential alternatives in 1997
- 1998 RIDEM approved Conceptual Design Report Amendment, issued FONSI for Alternative 17:
  - 6 miles underground storage tunnels, 5 CSO interceptors, 1 wetland treatment area, sewer separation of 12 areas
- Three Phases
  - Phase I (2001-2008): Tunnel, tunnel pump station, seven drop shafts.
  - Phase II (2008 – 2015*): 2 Interceptors,2 sewer separation projects, 1 wetland treatment area.
  - Phase III(2013 – present): Originally planned as another deep rock tunnel; now under revaluation.

Current Status: Phase III Reevaluation

- Projected cost of initial design, reevaluation to determine affordability of plan
- NBC contracted MWH and Pare
  - Update costs
  - Conduct affordability analyses
  - Reevaluate technical solutions
- MWH subcontracted to RPS ASA to evaluate receiving water quality improvements for alternatives developed
  - Verify previously calibrated model performance to recent observations
  - Simulate design storms (3 Mo. and 12 Mo.)
    - Phase I
    - Phase II completion
    - Phase III alternatives

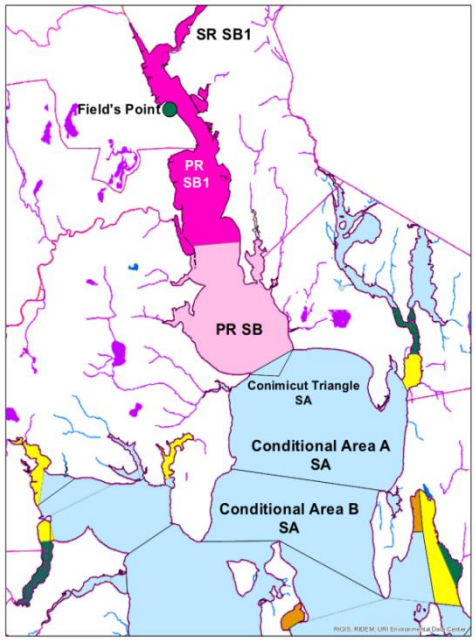
Study Area


N
0 1 2 4 Kilometers


N
Blackstone
Moshassuck
West
Woonasquatucket
Ten Mile
Pawtuxet
Legend
CSO
USGS Gage
Model Flow Needed
0 1 2 4 Kilometers

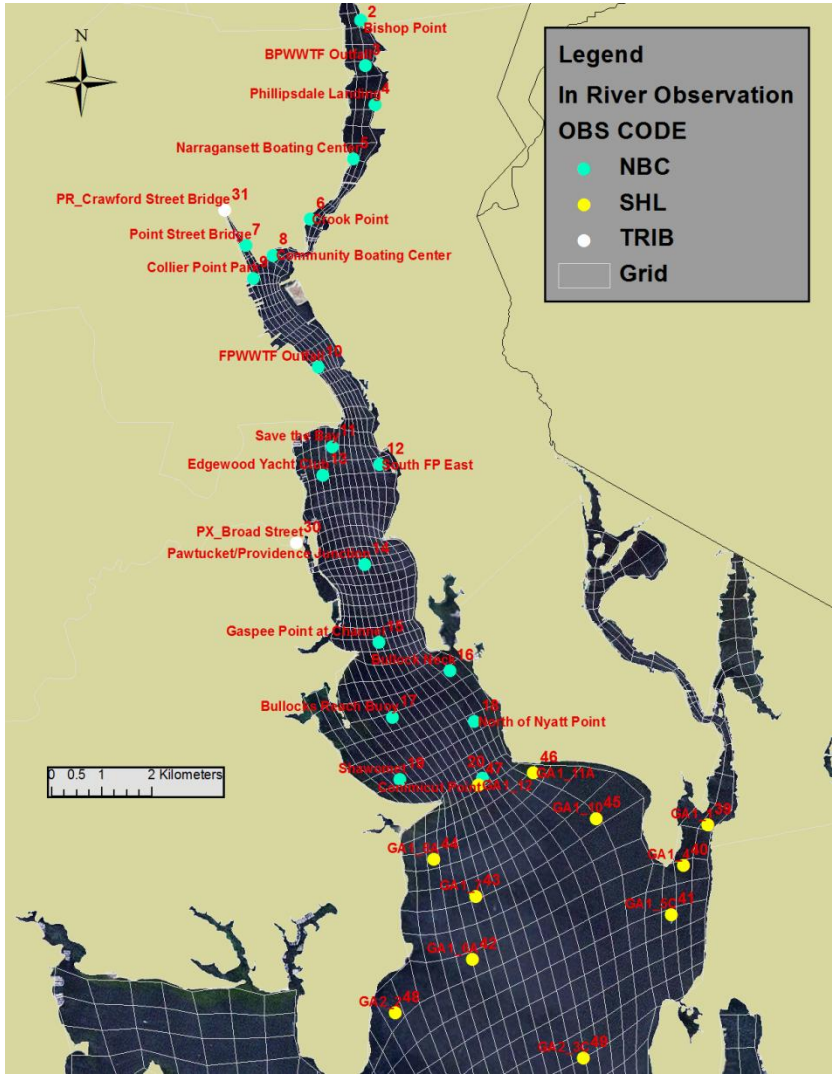
Modeling Overview

- Domain: Upper Narragansett Bay, Providence and Seekonk Rivers
- Model: WQMAP (BFHYDRO & BFMASS)
- Hydrodynamic modeling: rivers, tides, CSO flows
  - Temporally and spatially varying current fields
- Mass transport modeling: fecal coliform (FC) loads from tributaries, plants, sewers, CSO's
  - Spatially and temporally varying FC concentrations
- Model verification
  - Predictions compared to observations
  - Sensitivity to decay rate
  - Assessment of sources
- Model scenarios
  - Predictions compared to water quality standards
- WQ standards
  - Shellfishing: 14 MPN/100 mL & 49 MPN/100 mL
  - Contact Recreation: 50 MPN/100 mL & 400 MPN/100 mL



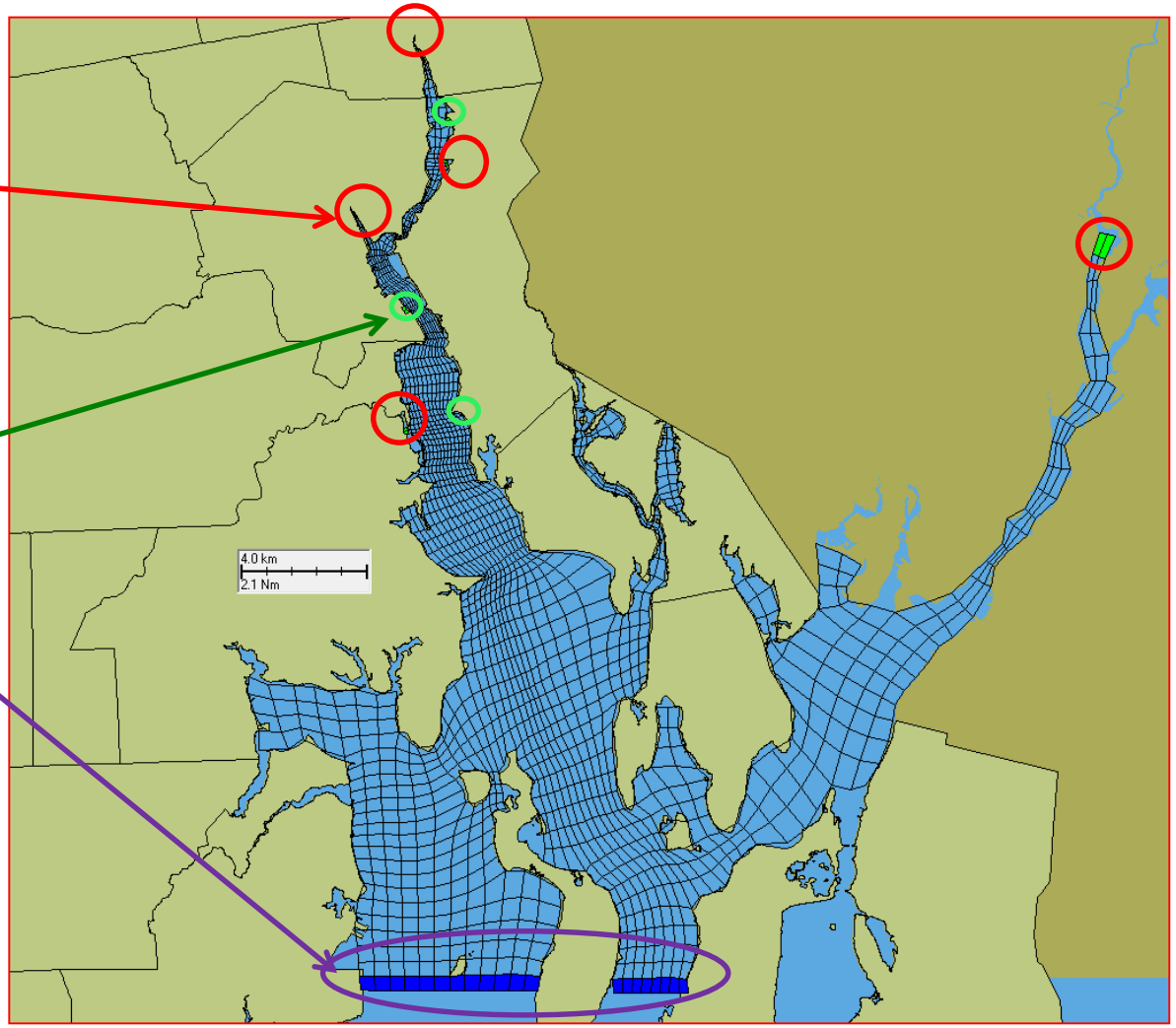
FC Observations

- Sampling Programs
  - Tributaries (NBC)
  - In Bay Stations (NBC)
  - Shellfish Areas (RIDEM)
- Sampling at surface
- NBC samples include one or two grabs
- Reported in MPN/100mL
- NBC sampled every two weeks
- Shellfish areas sampled frequently but not in sync with NBC
- Sampling period
  - March-August 2009
  - Captured four ~3 month storms
- Some sampling results used for developing loads, some for comparison to model predictions



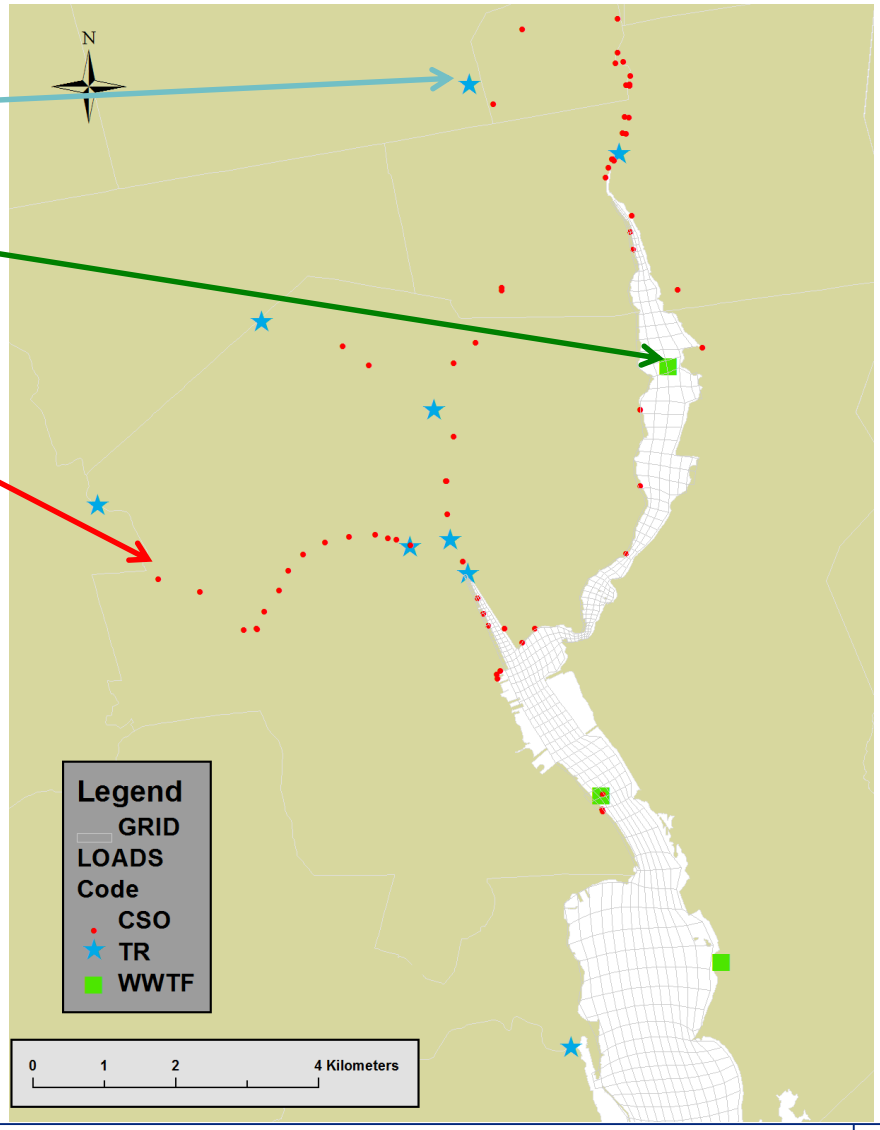
Hydrodynamic Model Forcing

- Hydrodynamic Forcing
  - River flow
    - Blackstone
    - Providence
    - Ten Mile
    - Pawtuxet
    - Taunton
  - Continuous flow at gauges
  - Flow scaled
  - Plant flow
    - Bucklin Point
    - Fields Point
    - East Providence*
  - Tidal Constituents (Quonset)
- CSO flow included in tributary forcing

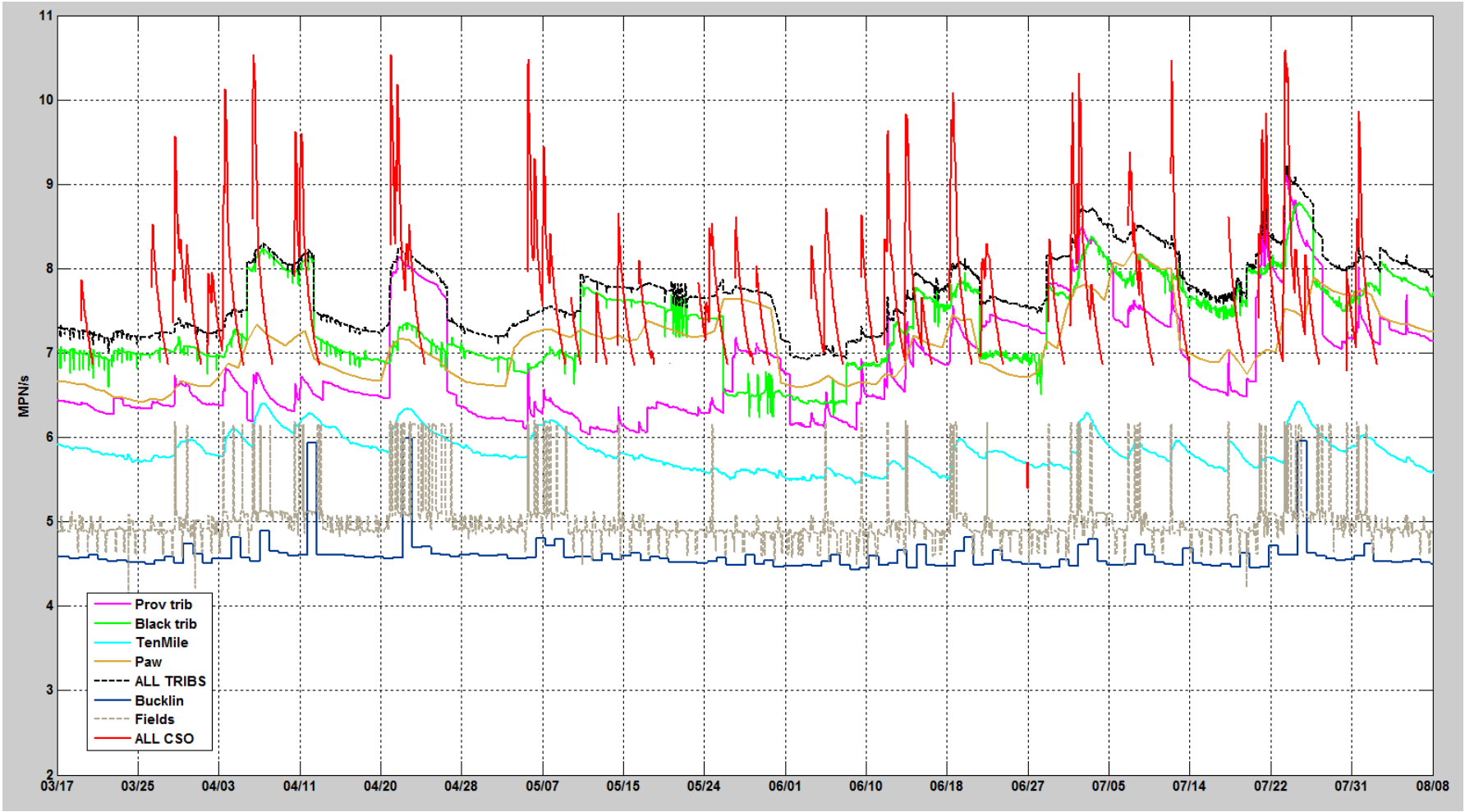


Mass Transport Model Forcing

- Mass Transport Forcing
  - Tributary Loads
  - Plant Loads
  - CSO Loads
- Loads
  - Continuous flow
  - Sporadic concentrations available
  - Concentration held constant between sampling data times
  - Flow weighted
- Out-grid CSO loads combined and added to tributary loads in the grid
- In-grid CSO loads modeled explicitly
- Tidal flow enters domain with zero fecal coliform concentration



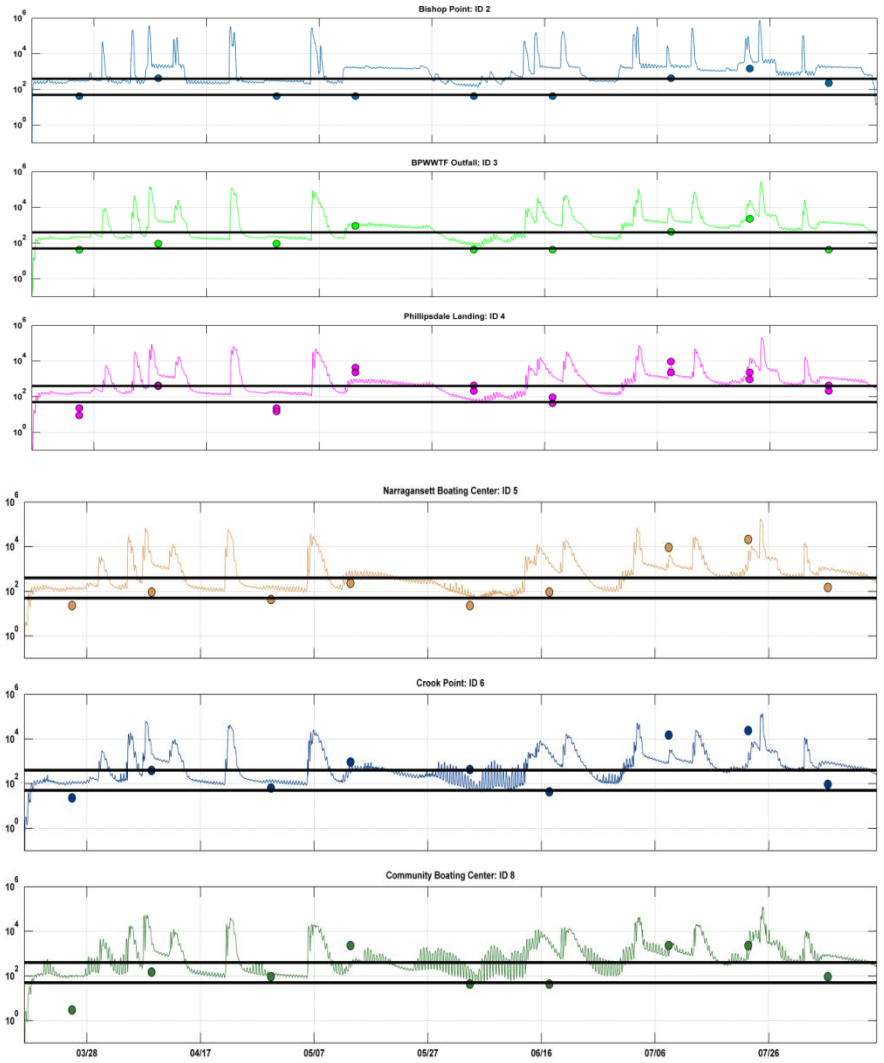
Loading Rates (log10)

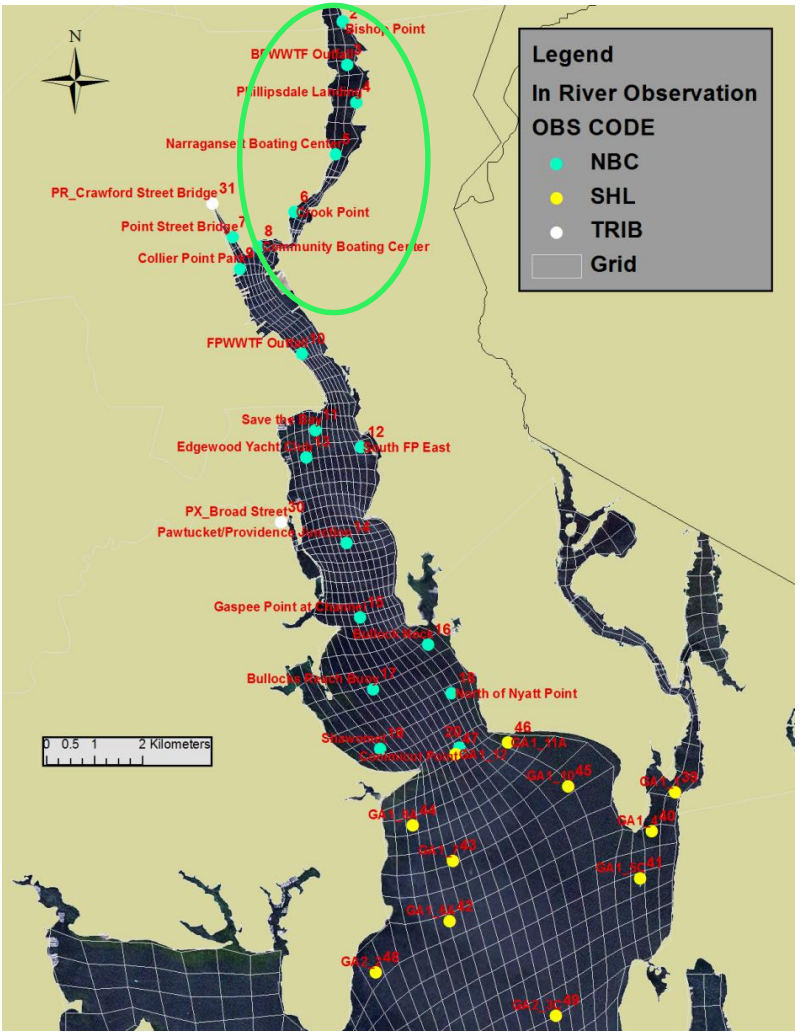


Model Predictions vs Observations

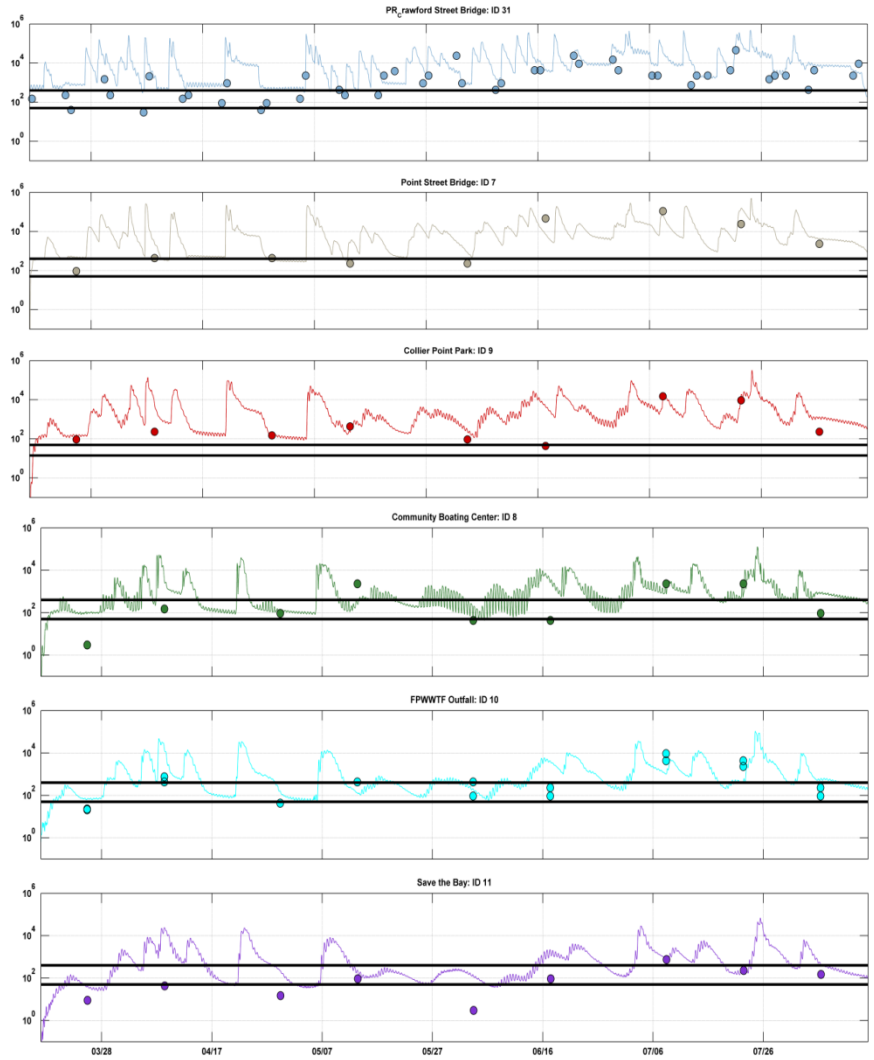
- Model time series at each in-river station shown with markers overlaid representing observations
- Y-axis is log10(MPN/100 mL)
- Model output is at a 15 minutes time step

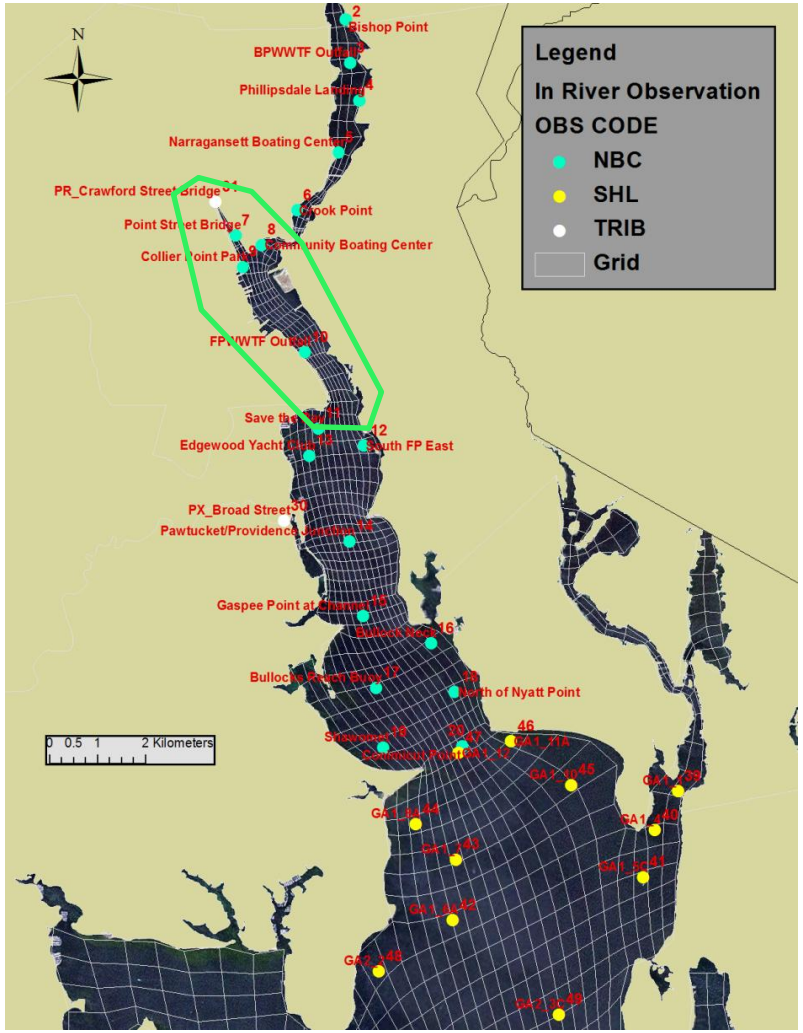
Model Predictions vs Observations – Seekonk River



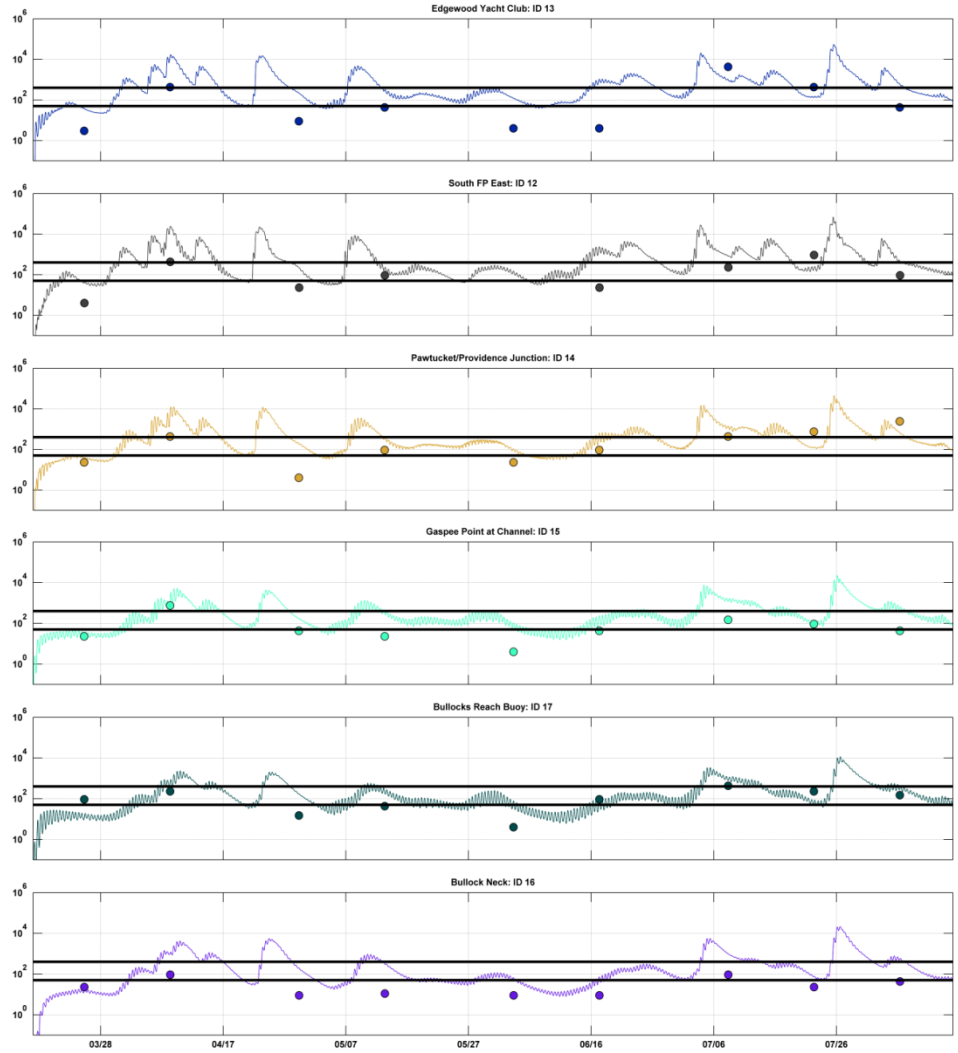


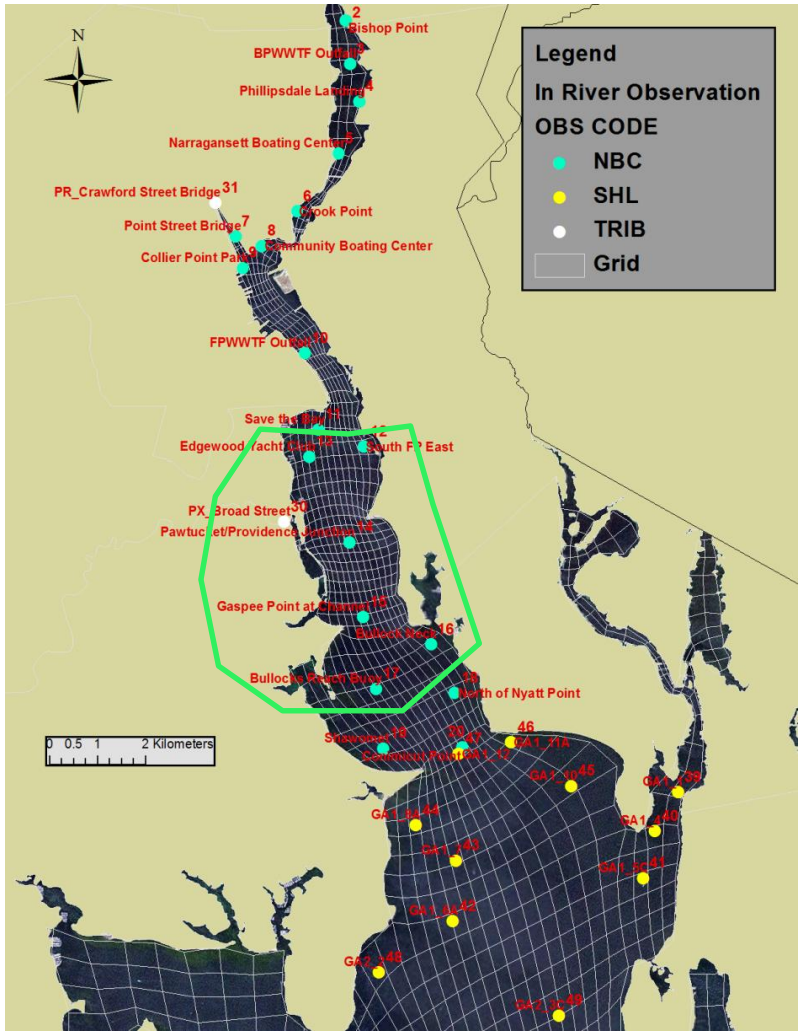
Model Predictions vs Observations – Providence Harbor



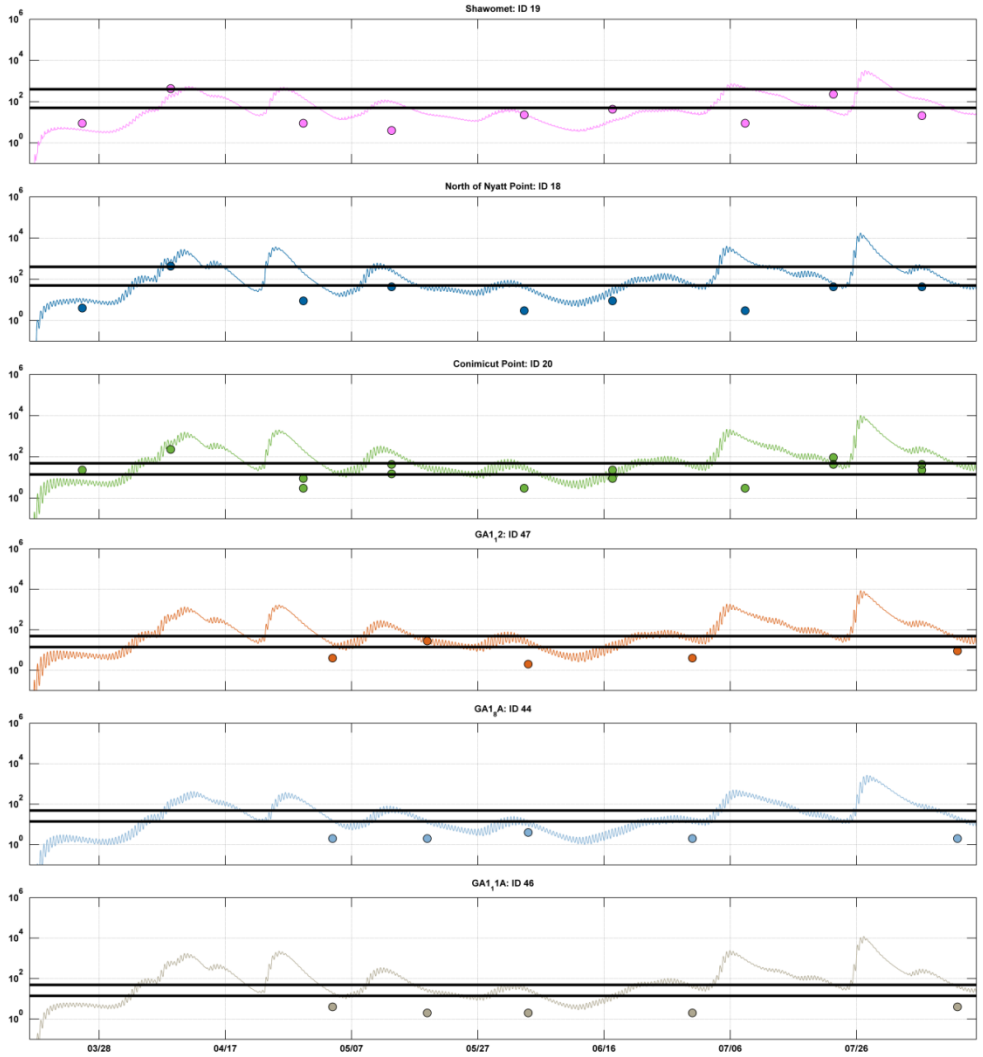


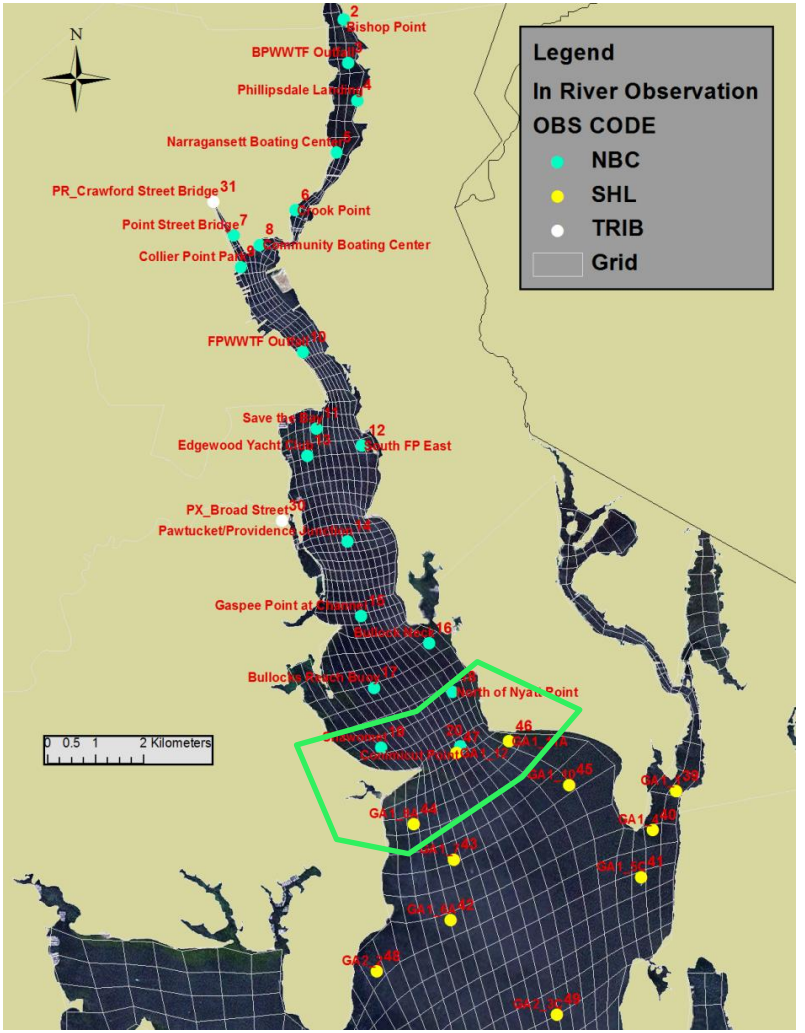
Model Predictions vs Observations – Upper Bay



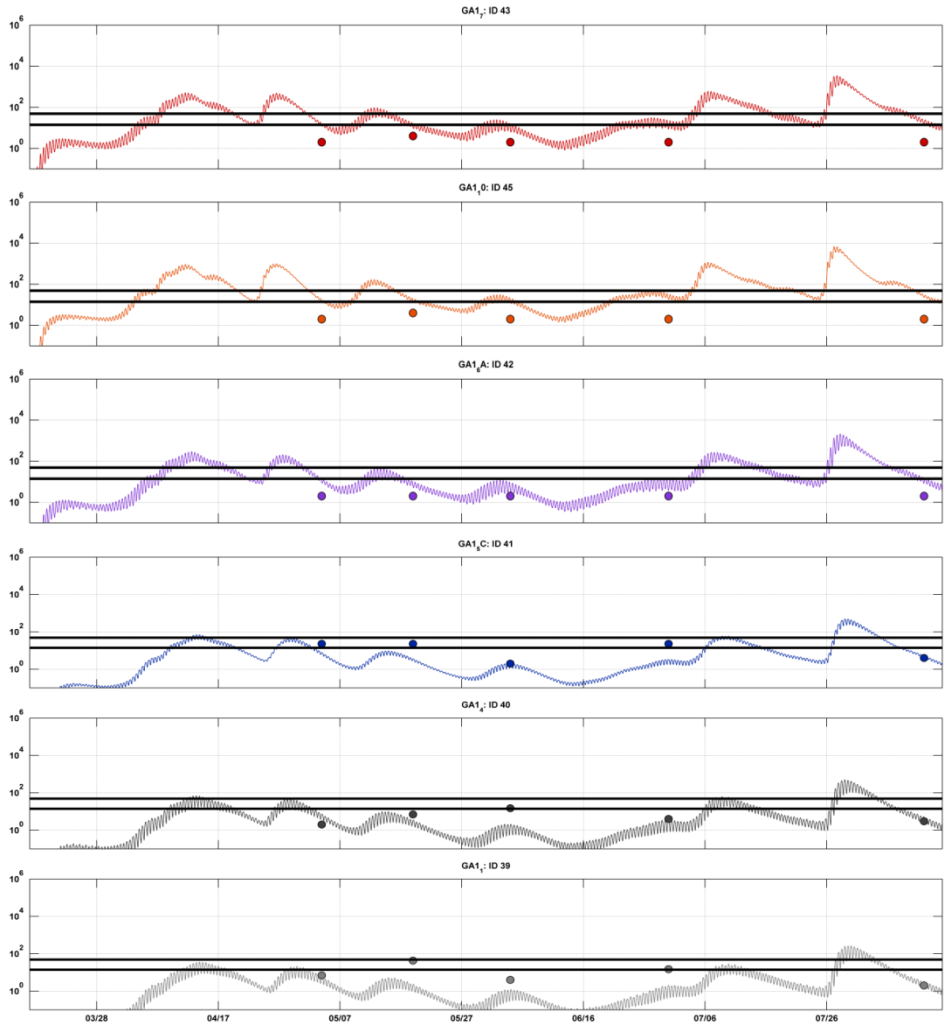


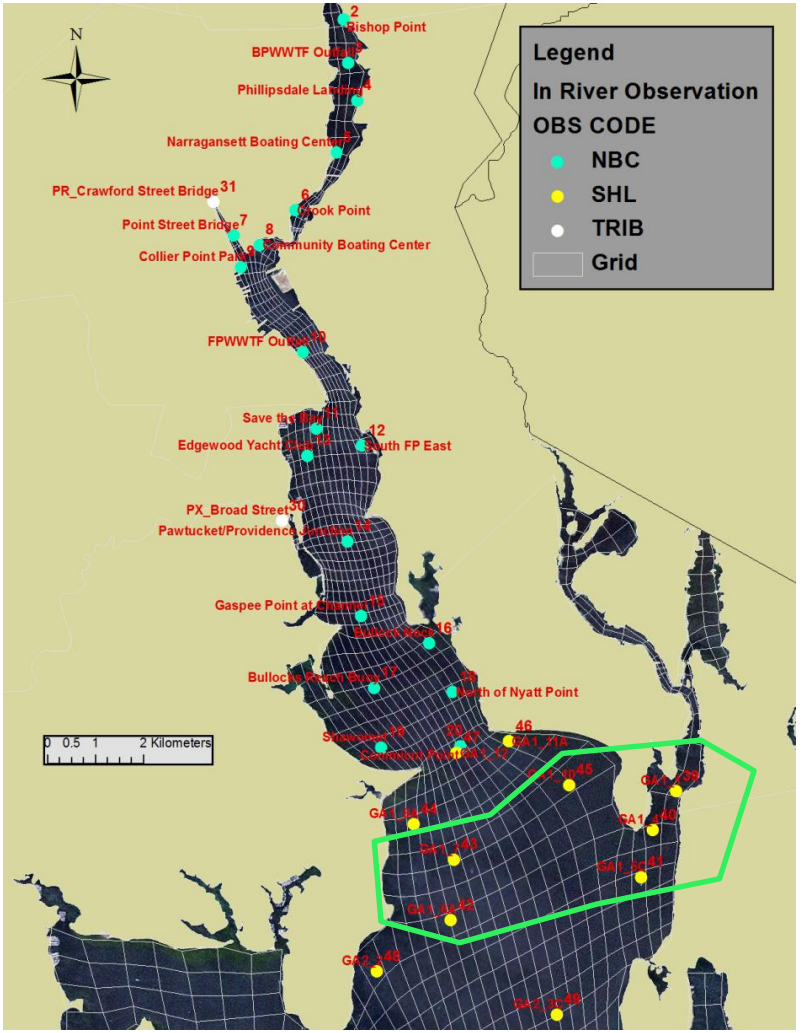
Model Predictions vs Observations – Upper Bay and Conditional Area A & B



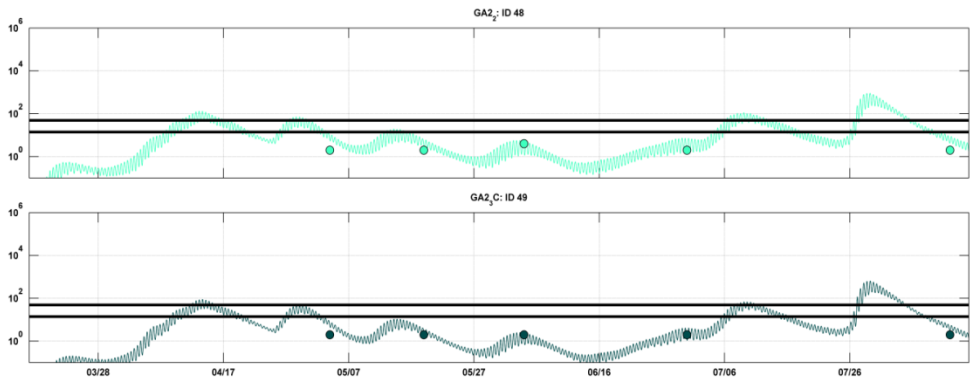


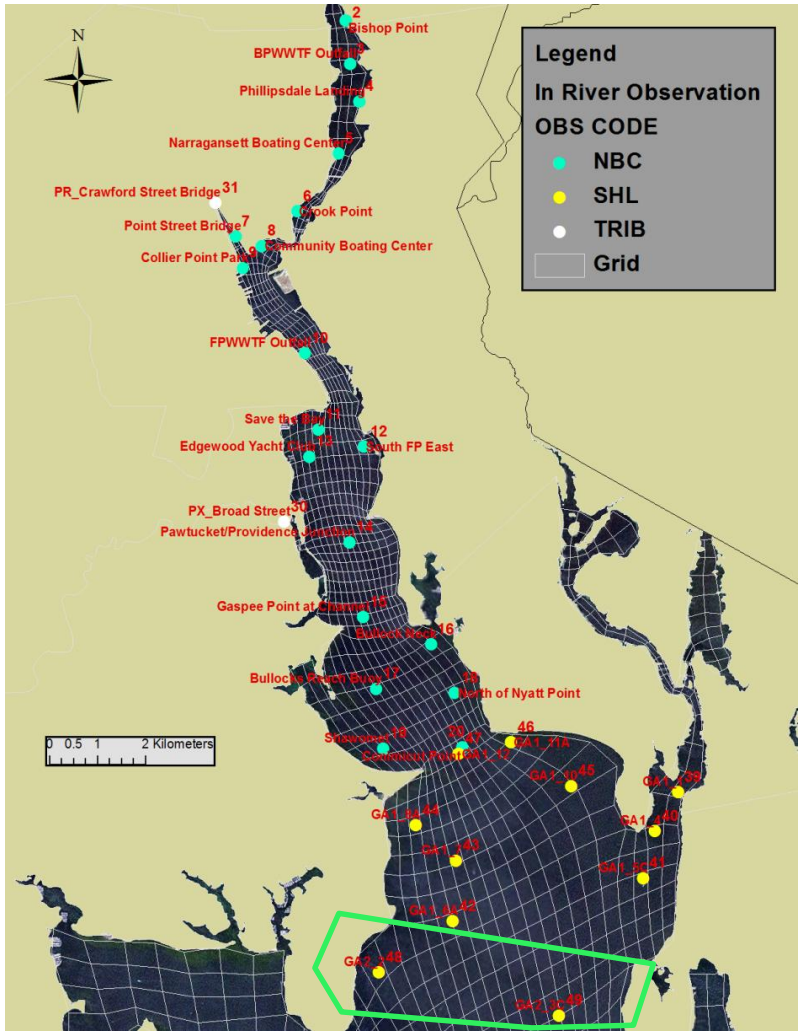
Model Predictions vs Observations – Upper Bay and Conditional Area A & B





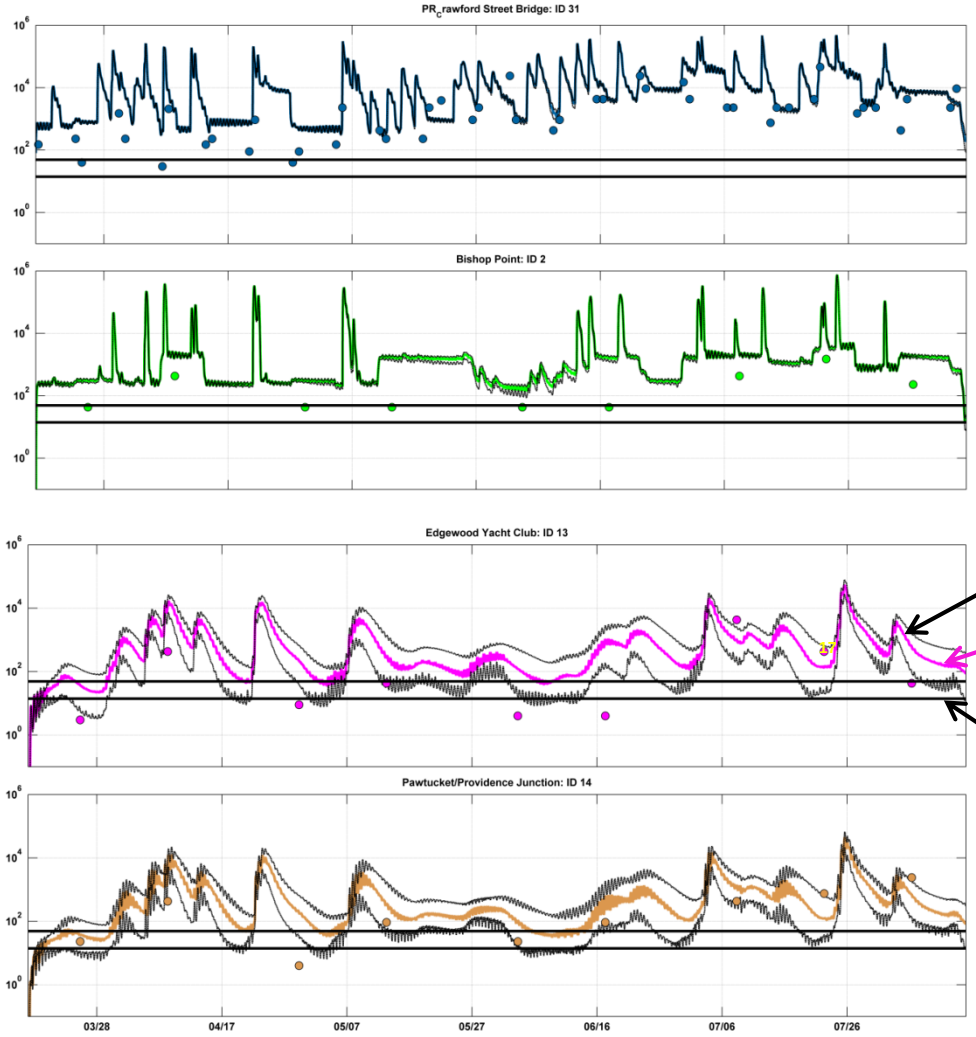
Model Predictions vs Observations – Upper Bay and Conditional Area B





Sensitivity to Decay Rate

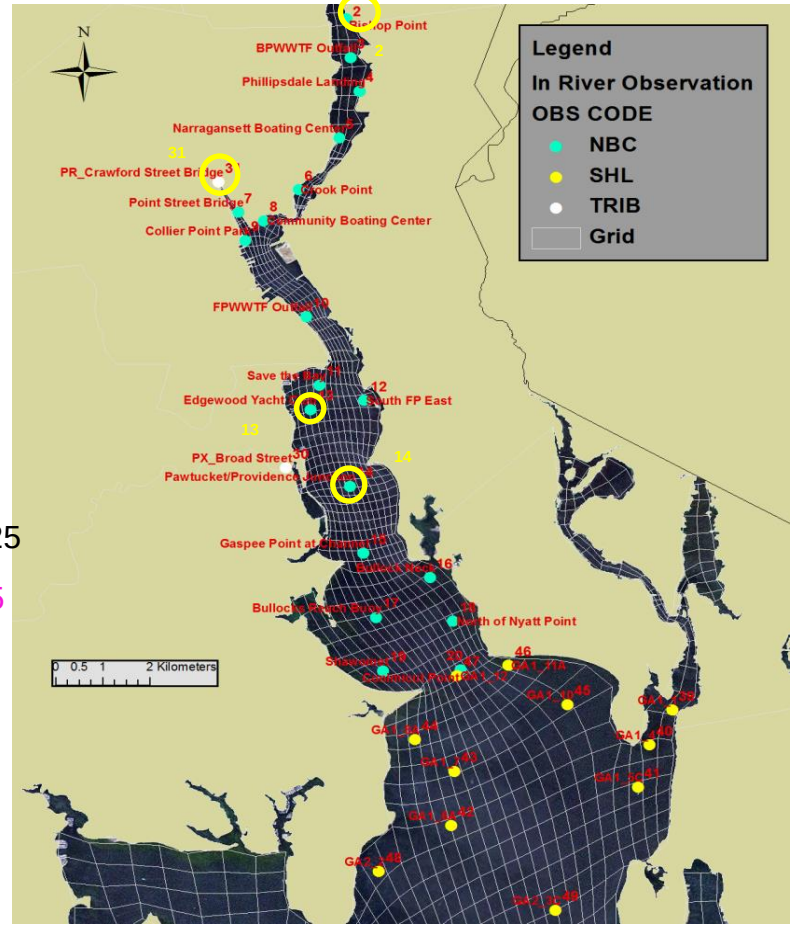
Base - 0.5/day High -1/day Low -0.25/day



0.25

0.5

1.0



Sensitivity to Decay Rate

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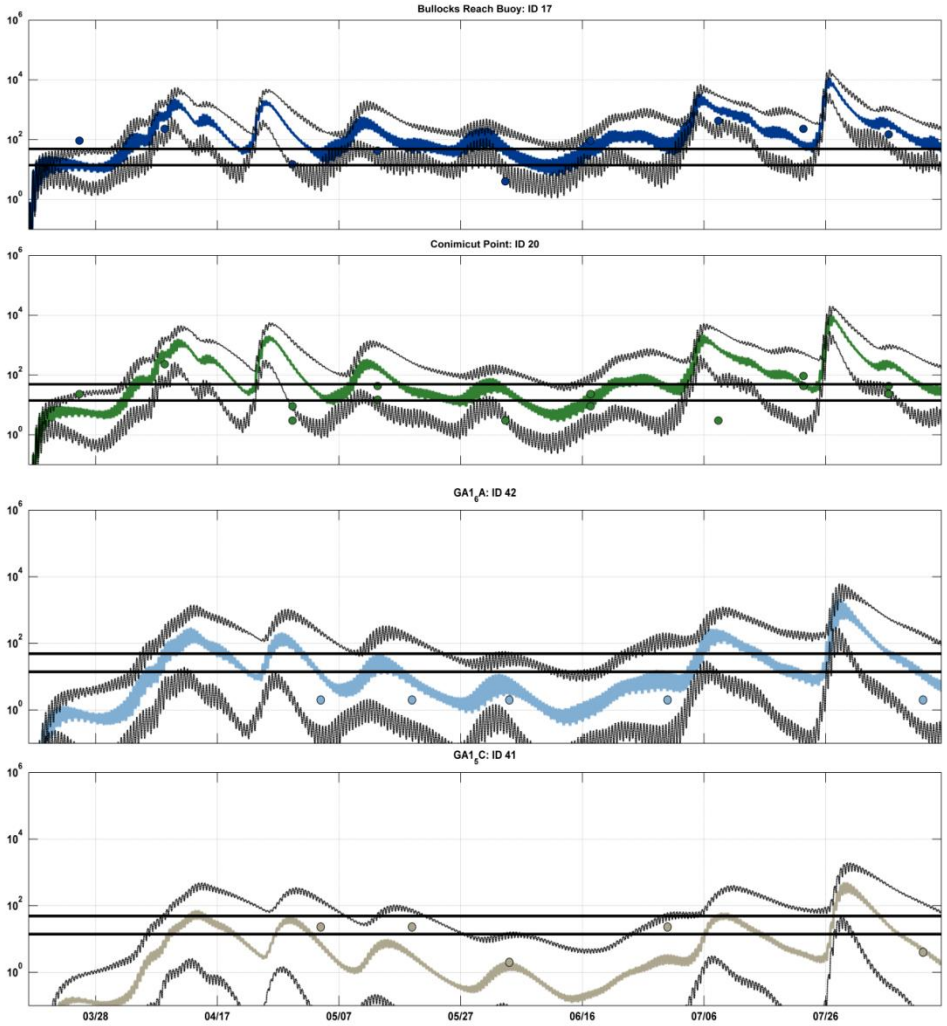
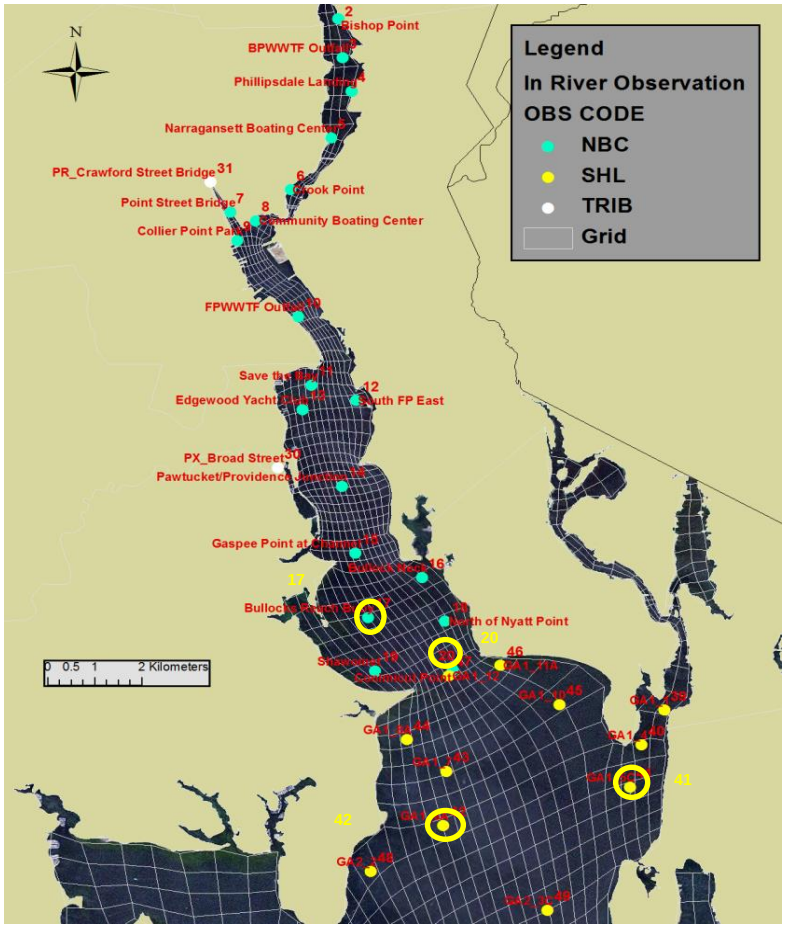
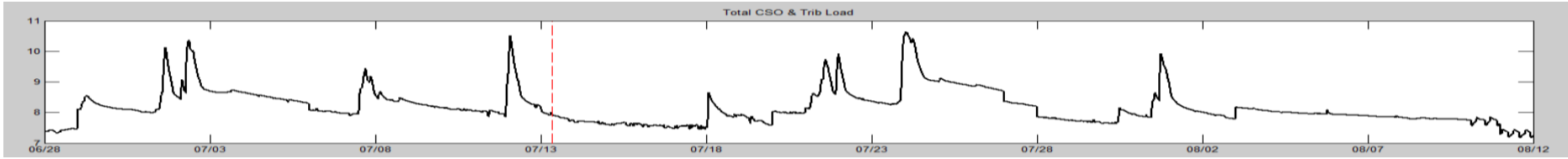
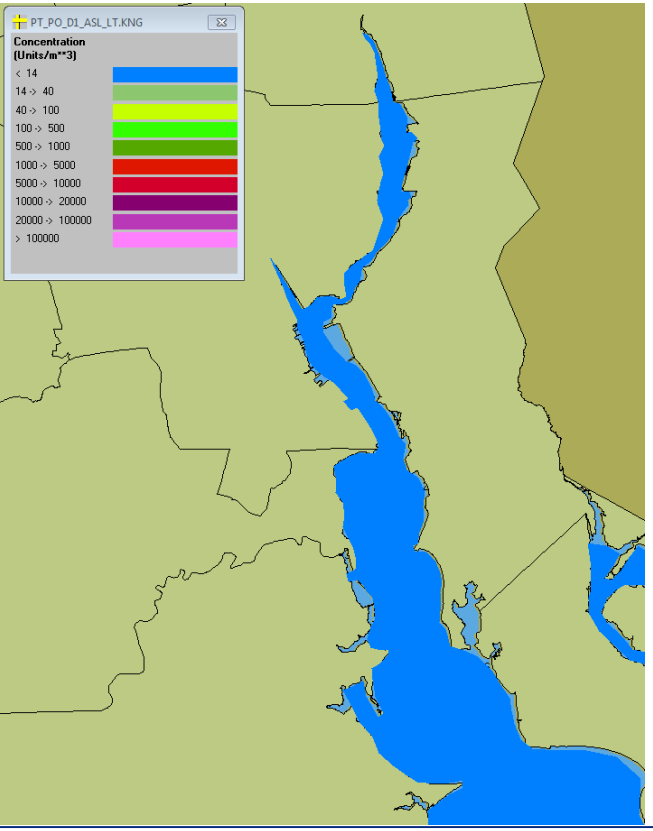


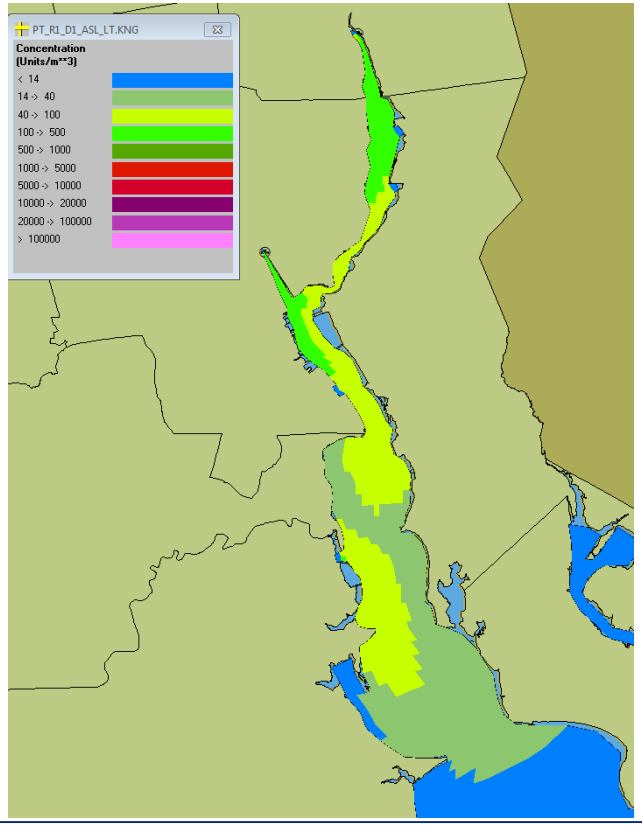


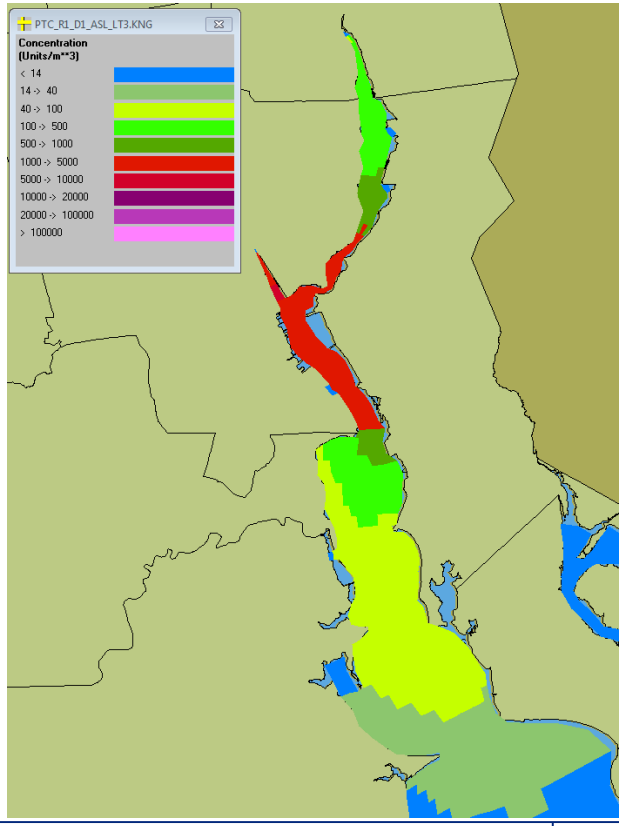
Results

- Plants only (left), Plants plus tributaries (center), All loads (right)









Results

- CSO loading is dominant, though intermittent
- Tributary loading rate is 2-3 orders of magnitude smaller than CSOs
- Tributary cumulative load is 1-2 orders of magnitude smaller than CSOs
- Tributary loading has high uncertainty, concentrations under sampled in both time and space
- Plant loading rate is 5-6 orders of magnitude smaller than CSOs
- Model able to predict trends in space and time
- Decay rate of 0.5/day provides best match to observations

Alternatives Modeling Overview

- Overall study focuses on re-evaluation of planned Phase III CSO controls in relation to operational Phase I controls and in-progress Phase II controls. Re-evaluation for Phase III included five possible control configurations.
- Model study objective was to evaluate fecal coliform loading and resulting in-water FC concentrations from each configuration for two representative weather events
  - 3 month return period storm
  - 12 month return period storm
- MWH developed flows and loads needed as input for modeling
- RPS ASA modeled in-water concentrations for each load / storm scenario

Alternatives Modeling Approach

- Hydrodynamics
  - River flows provided by MWH, tidal constituents from NOAA
  - Modeling output consisted of time varying current fields for 3-month and 12-month storm scenarios
- Mass Transport (FC)
  - Simulations included loads from tributaries, WWTFs, separated sewers, and CSOs
  - Tributary loading profile provided by MWH
  - Flow and concentrations for WWTFs and CSOs provided by MWH
- Post Processing Products
  - Time histories of model predicted FC concentrations
  - Plan views of FC concentrations at defined time intervals
  - Closure areas

Scenarios Modeled

- Phases I and II plus five Phase III alternatives simulated for both 3-month and 12-month design storms for a total of fourteen scenarios

Phase / Alternative	3-mo Design Storm	12-mo Design Storm
I	CSO control in the Field's Point Service Area with the primary control being construction of a storage tunnel to capture the CSO flows during a storm and then pumped to the FP WWTF for treatment. Construction was completed in 2008. MWH simulated system flows for that phase.	MWH simulated system flows for that phase.
II	The second phase focused on two interceptors along the Woonasquatucket and Moshassuck Rivers and is scheduled for completion in 2015. MWH simulated system flows for that phase.	MWH simulated system flows for that phase.
III-1	**Removal of all Phase III CSOs.** Eliminated the flows from all Phase III CSOs.	Modified the flows from all CSOs by subtracting the 3-mo flows from the Phase II 12-mo flows.
III-2	**Only CSO 220 removed.** Eliminated the flow from CSO 220 with all other CSO flows unchanged from Phase II.	Modified the flow from CSO 220 by subtracting the 3-mo flow from the Phase II 12-mo flows with all other CSO flows unchanged from Phase II.
III-3	**CSO 205 to 218 removed (tunnel application)** Eliminated the flows from CSO 205 through 218 with all other CSO flows unchanged from Phase II.	Modified the flows from CSO 205 through 218 by subtracting the 3-mo flow from the Phase II 12-mo flows with all other CSO flows unchanged from Phase II.
III-4	**CSO 218 routed through the WWTP** Rerouted the flow from CSO 218 through the BP WWTF for treatment with all other CSO flows unchanged from Phase II.	Rerouted the flow from CSO 218 through the BP WWTF for treatment with all other CSO flows unchanged from Phase II.
III-5	**Storage/Treatment** CSOs 205 to 218 rerouted via an interceptor to tank storage and discharged with various levels of treatment.	CSOs rerouted via an interceptor to tank storage and discharged with various levels of treatment.

Scenario Loads

- Total FC load is calculated as sum from CSOs, WWTFs, separated sewers, and tributaries over model simulation period (19.25 days)
- All loads input at actual source locations

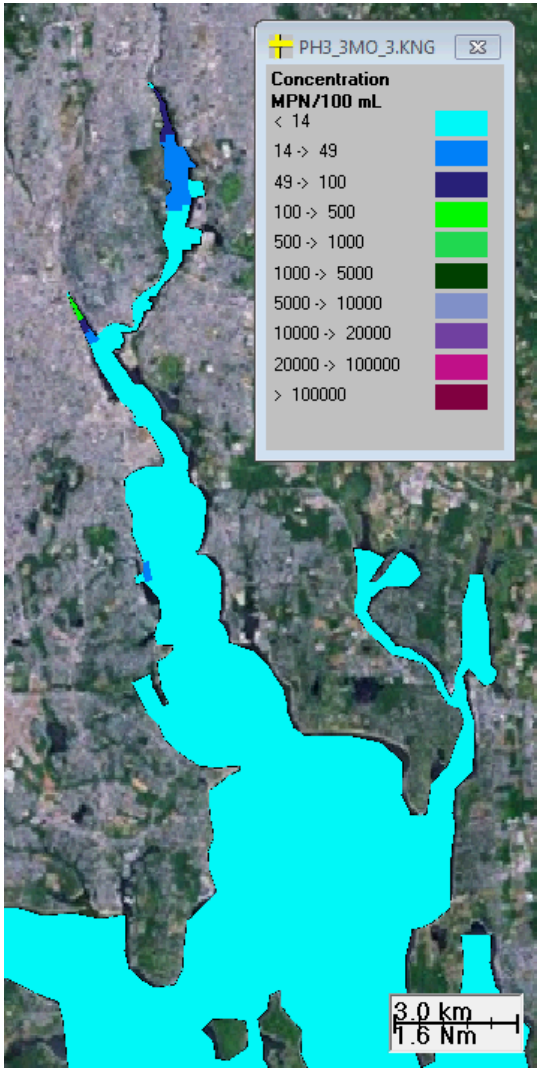
Phase – Alternative 3 Month	Total (FC)	CSOs (% of Total)	Rank by Highest Total
I	8.52E+14	86.5	1
II	6.75E+14	82.9	2
III-1	1.15E+14	0.0	7
III-2	6.32E+14	81.8	3
III-3	2.90E+14	60.3	6
III-4	5.92E+14	80.6	4
III-5	3.46E+14	66.7	5
12 Month			
I	1.75E+15	87.5	1
II	1.62E+15	86.4	2
III-1	1.06E+15	79.2	7
III-2	1.57E+15	86.0	3
III-3	1.23E+15	82.2	5
III-4	1.54E+15	85.8	4
III-5	1.14E+15	80.7	6

Scenarios Modeling Output

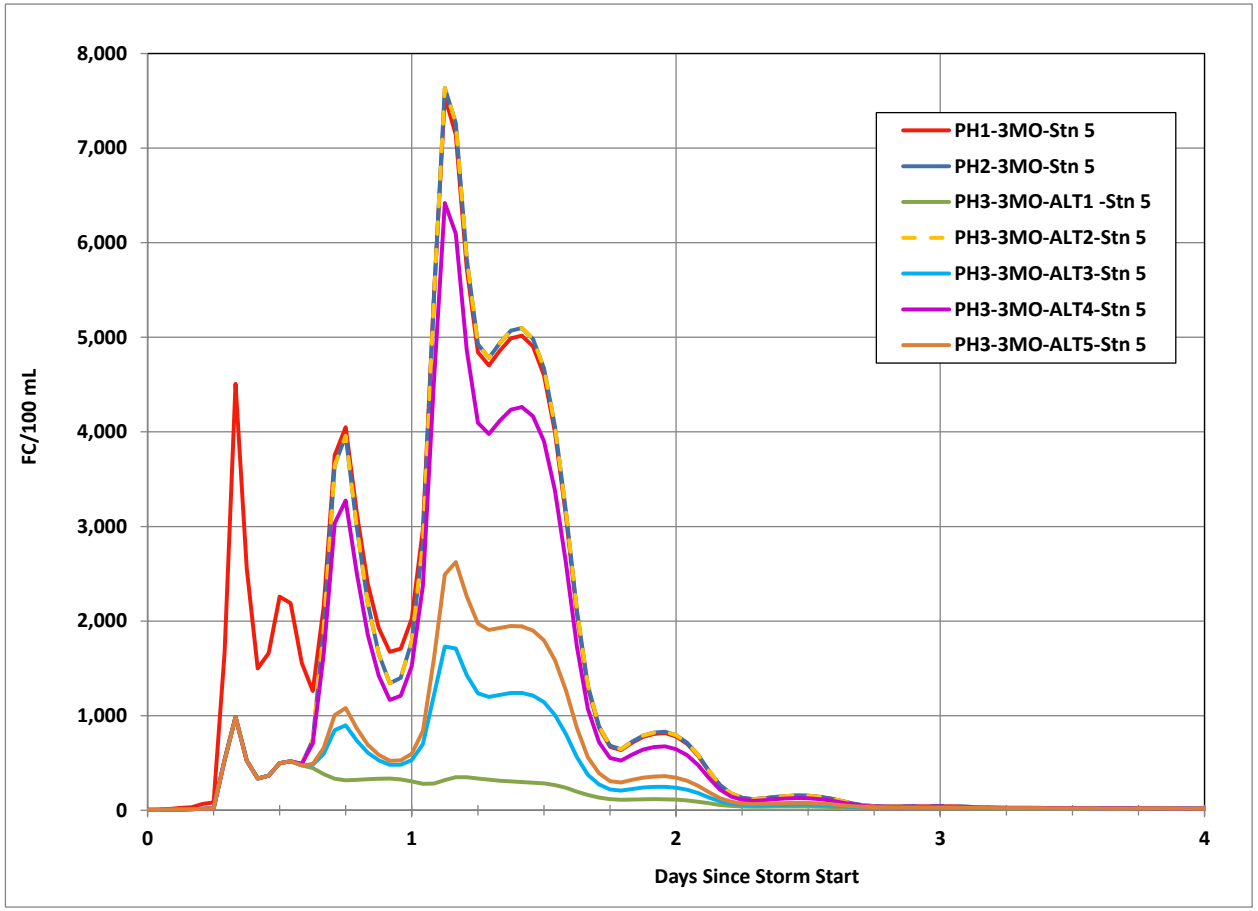
- Plan view animations
- Time series at four NBC monitoring station locations distributed N-S from Seekonk River to Upper Bay
  - Station 5 Narragansett Boating Center
  - Station 9 Collier Point Park
  - Station 13 Edgewood Yacht Club
  - Station 20 Conimicut Point
- Plan views scenario comparisons at Days 1.5, 2, 3, 5, 7, 9, 11 (start of storm at Day 1.0)
- Closure area tables for three conditional closure areas and three SB water quality areas
  - Conditional Areas A, B and Triangle
  - Water Quality Classification Areas: Providence River-SB, Providence River-SB1, Seekonk River-SB1

Model Results – Plan View Animations

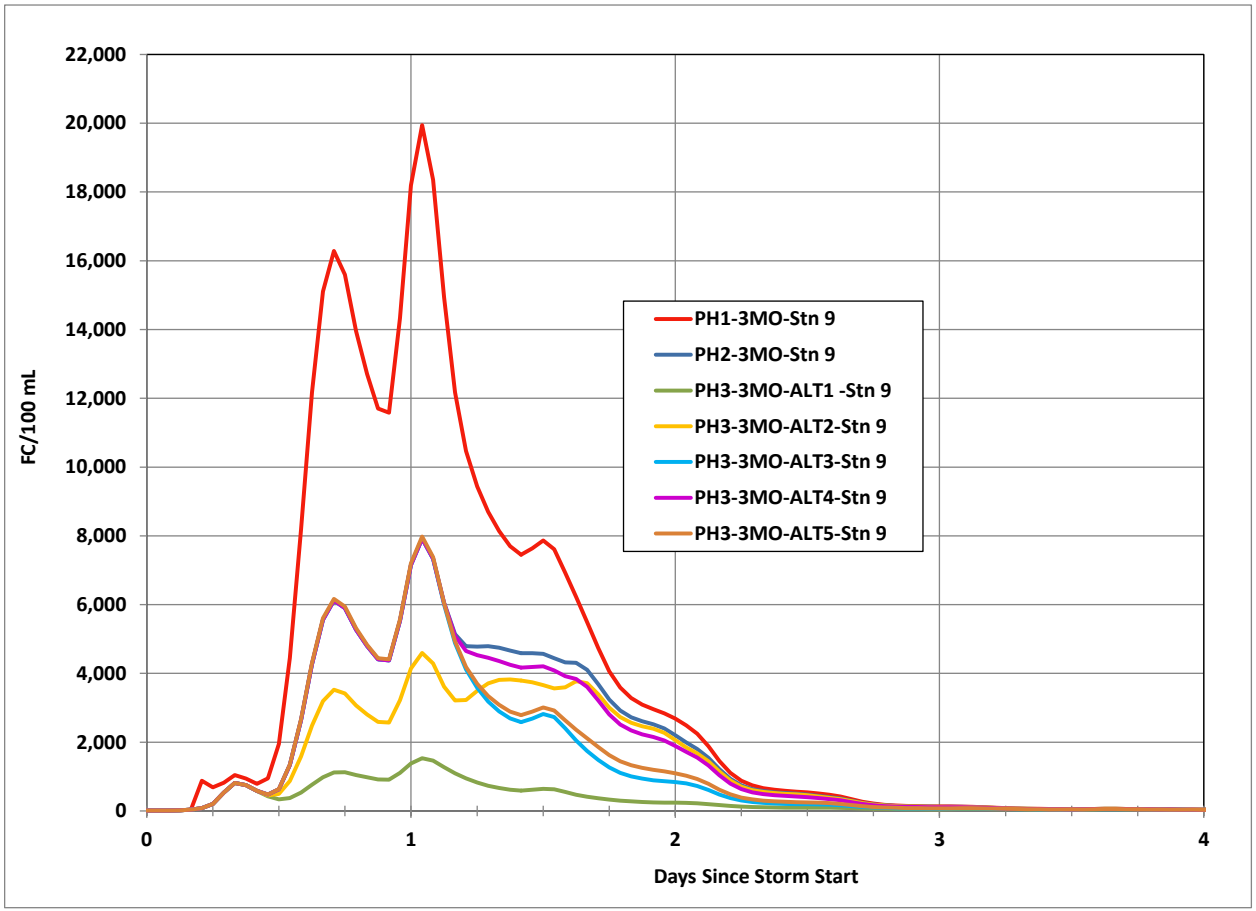
- Example: animation for Phase III Alternative 3 (preferred by NBC)
- Color legend defines FC concentration levels
- Starts with dry weather loading
- Wet weather loads last from 11 to 280 hrs based on system model and/or data
- Tidal signal clearly seen in plume movement



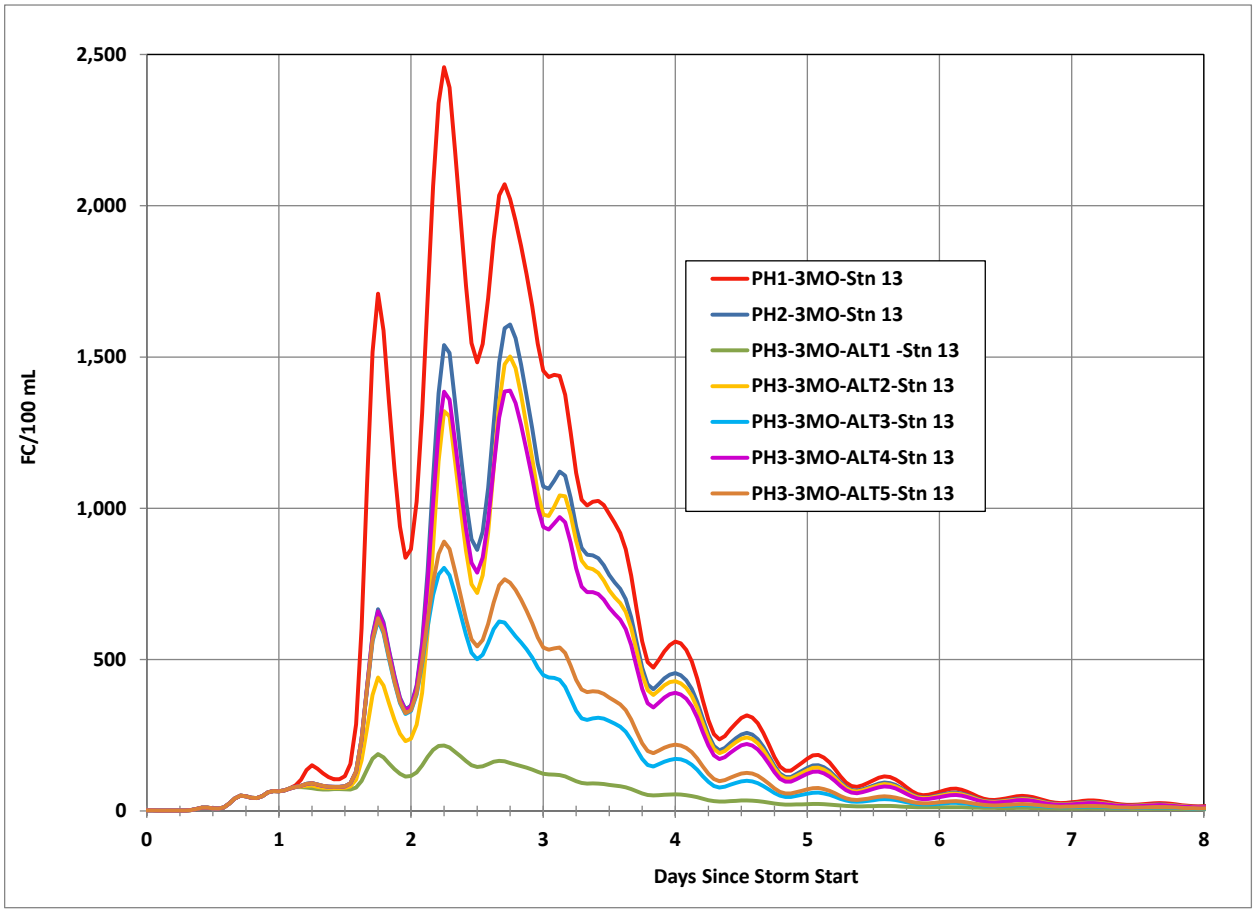
Model Results – Time Series
Station 5 – Narragansett Boating Center



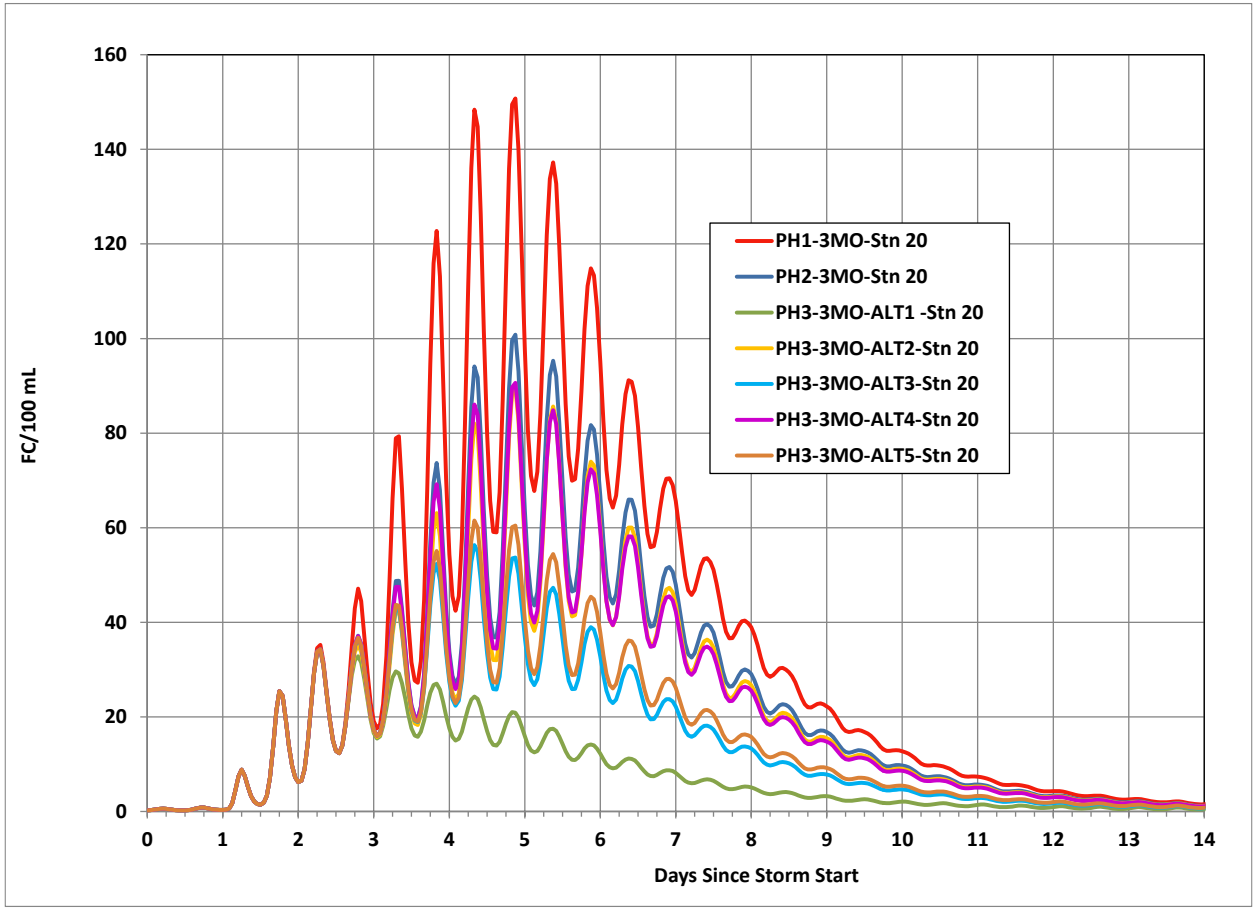
Model Results – Time Series Station 9 – Collier Point Park



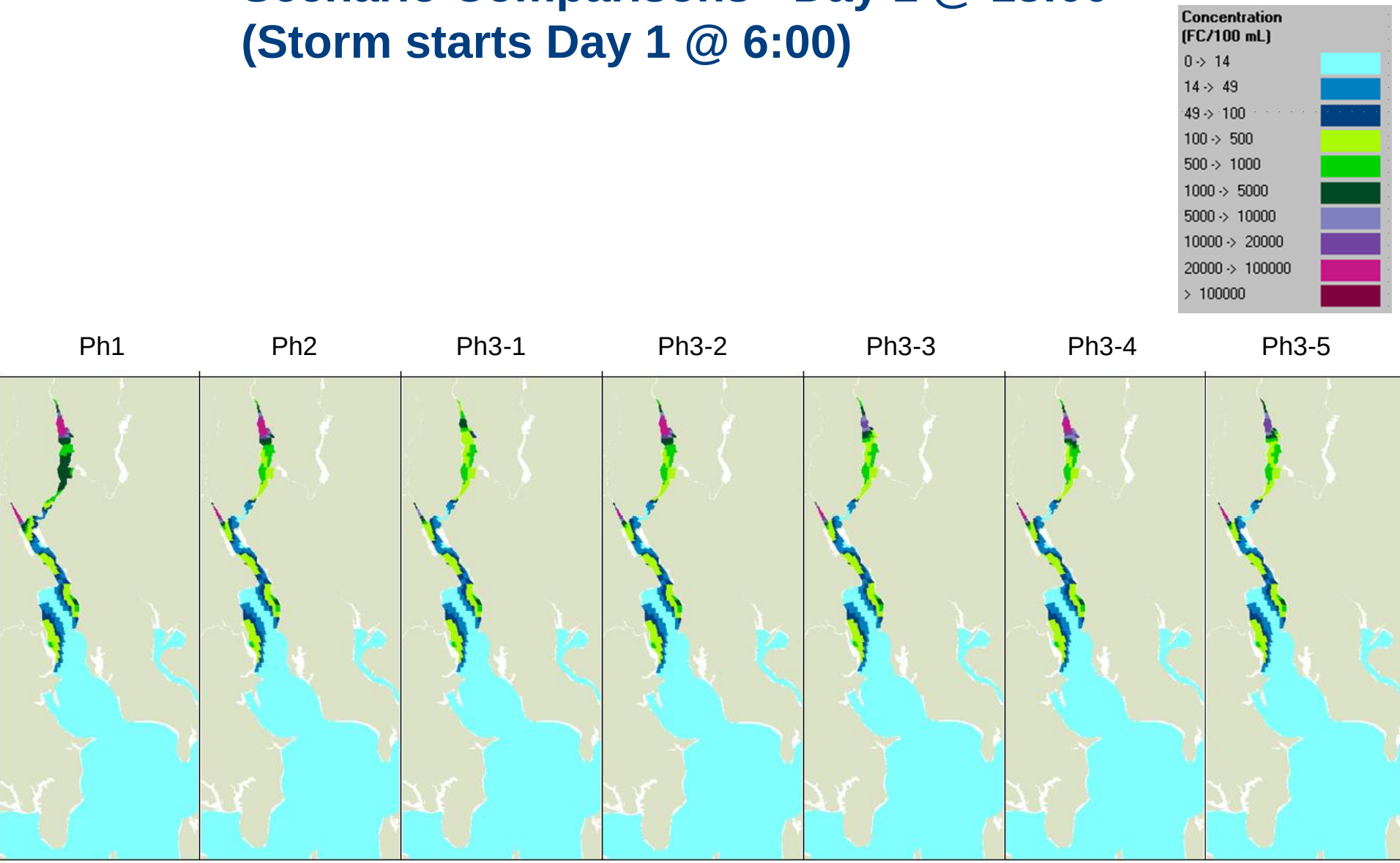
Model Results – Time Series
Station 13 – Edgewater Yacht Club



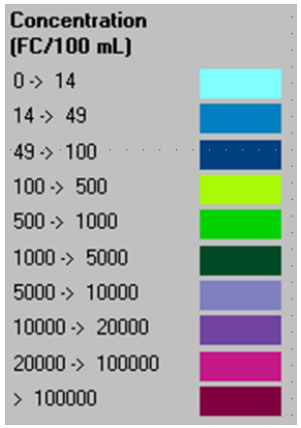
Model Results – Time Series Station 20 – Conimicut Point



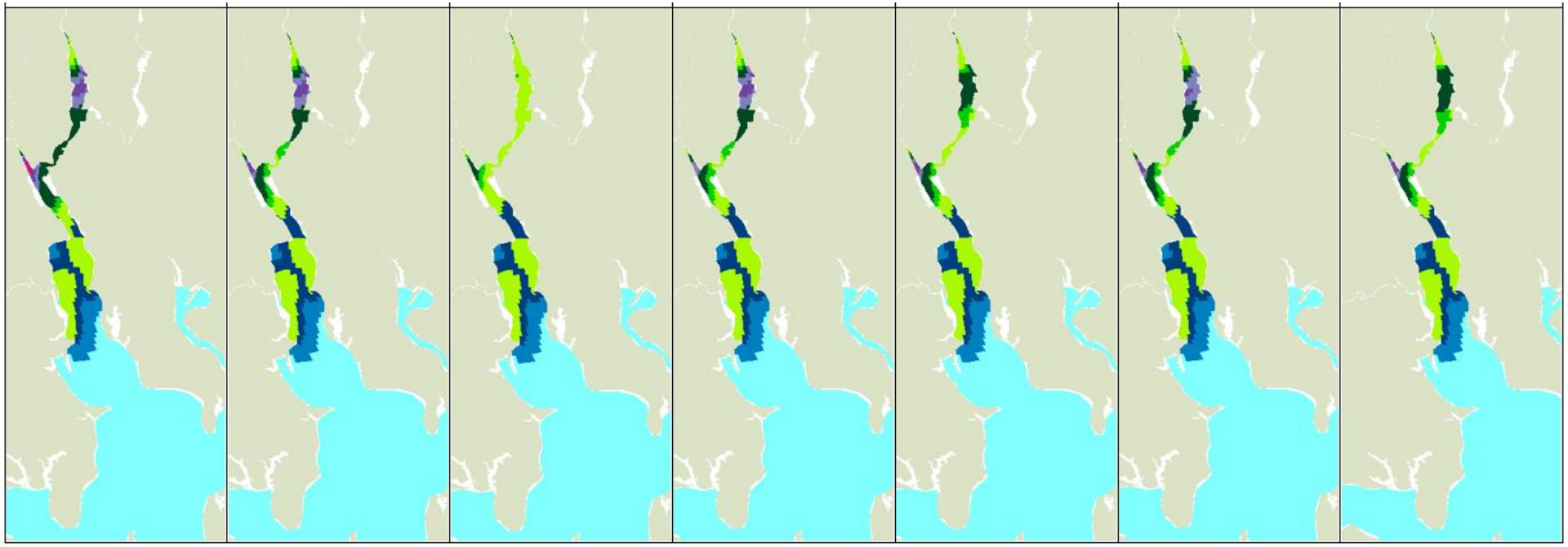
Scenario Comparisons - Day 1 @ 18:00 (Storm starts Day 1 @ 6:00)



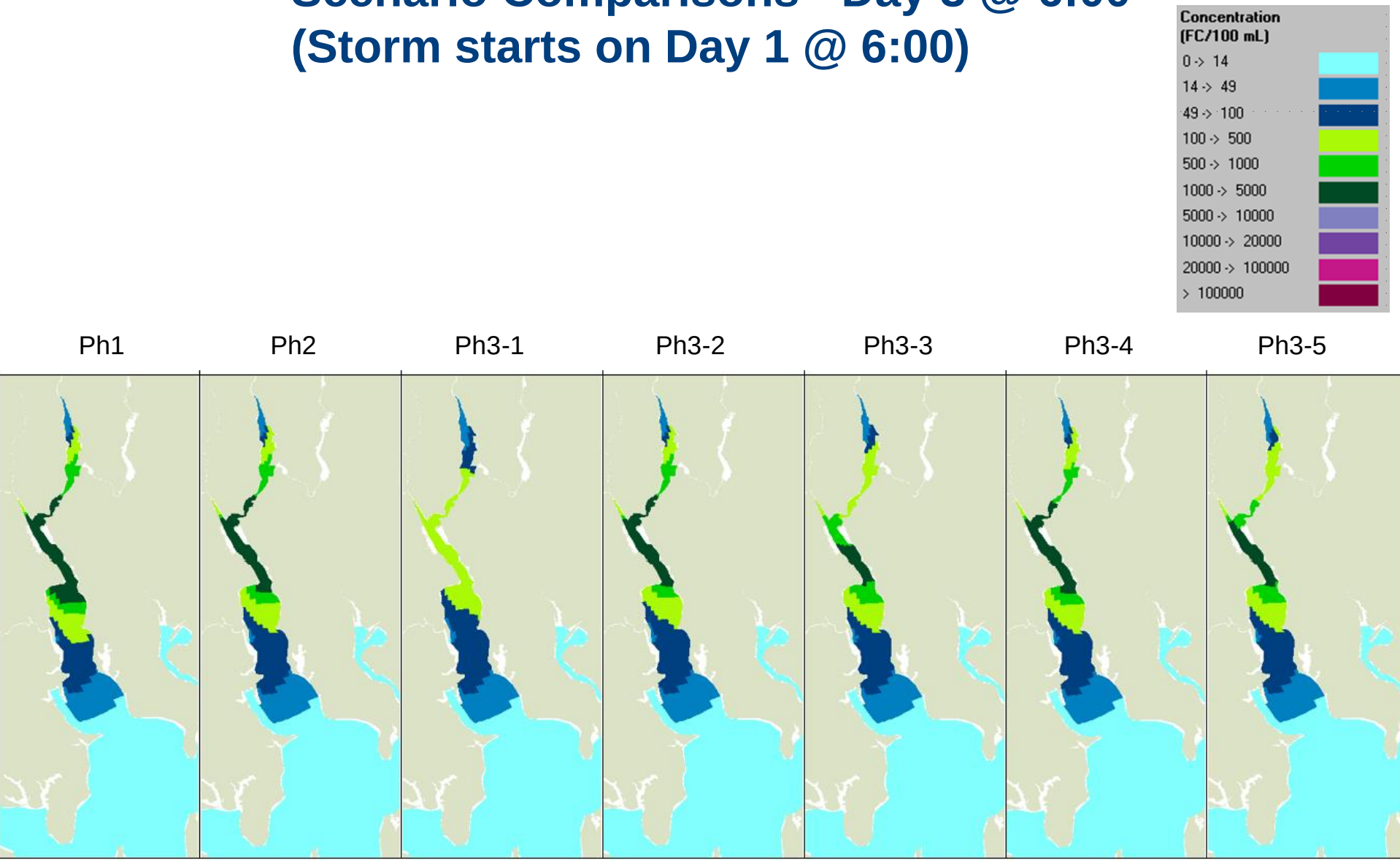
Scenario Comparisons - Day 2 @ 6:00 (Storm starts on Day 1 @ 6:00)



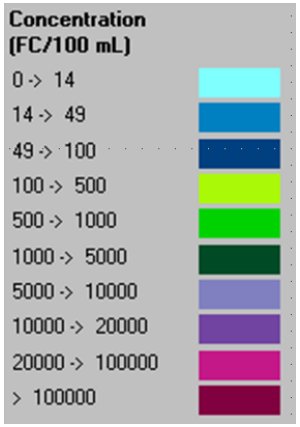
Ph1 Ph2 Ph3-1 Ph3-2 Ph3-3 Ph3-4 Ph3-5



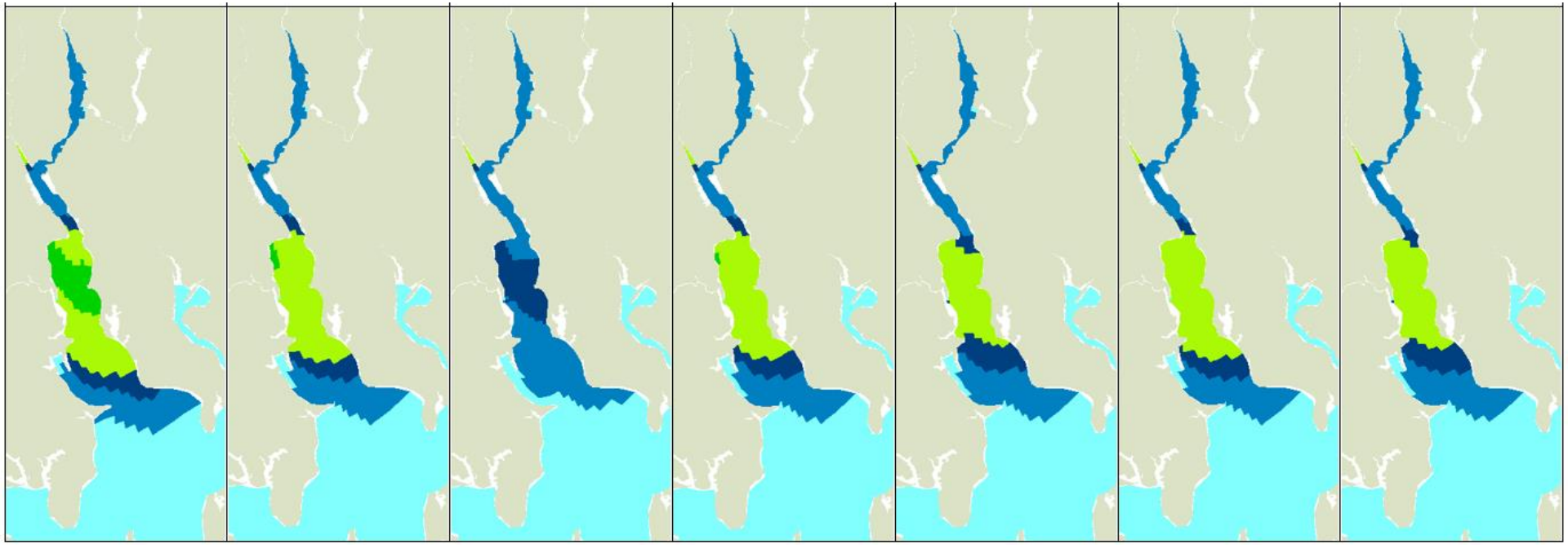
Scenario Comparisons - Day 3 @ 6:00 (Storm starts on Day 1 @ 6:00)



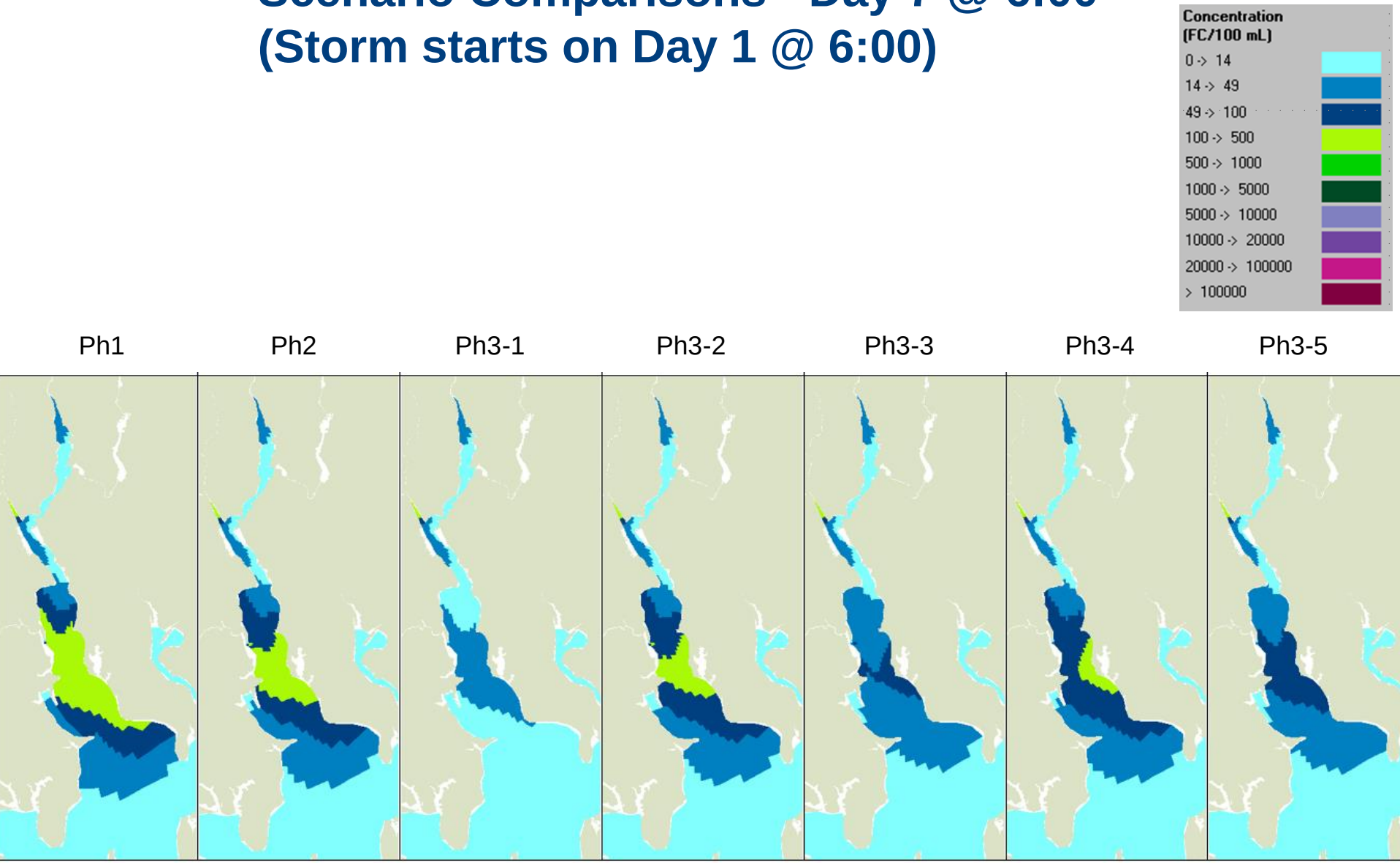
Scenario Comparisons - Day 5 @ 6:00 (Storm starts on Day 1 @ 6:00)



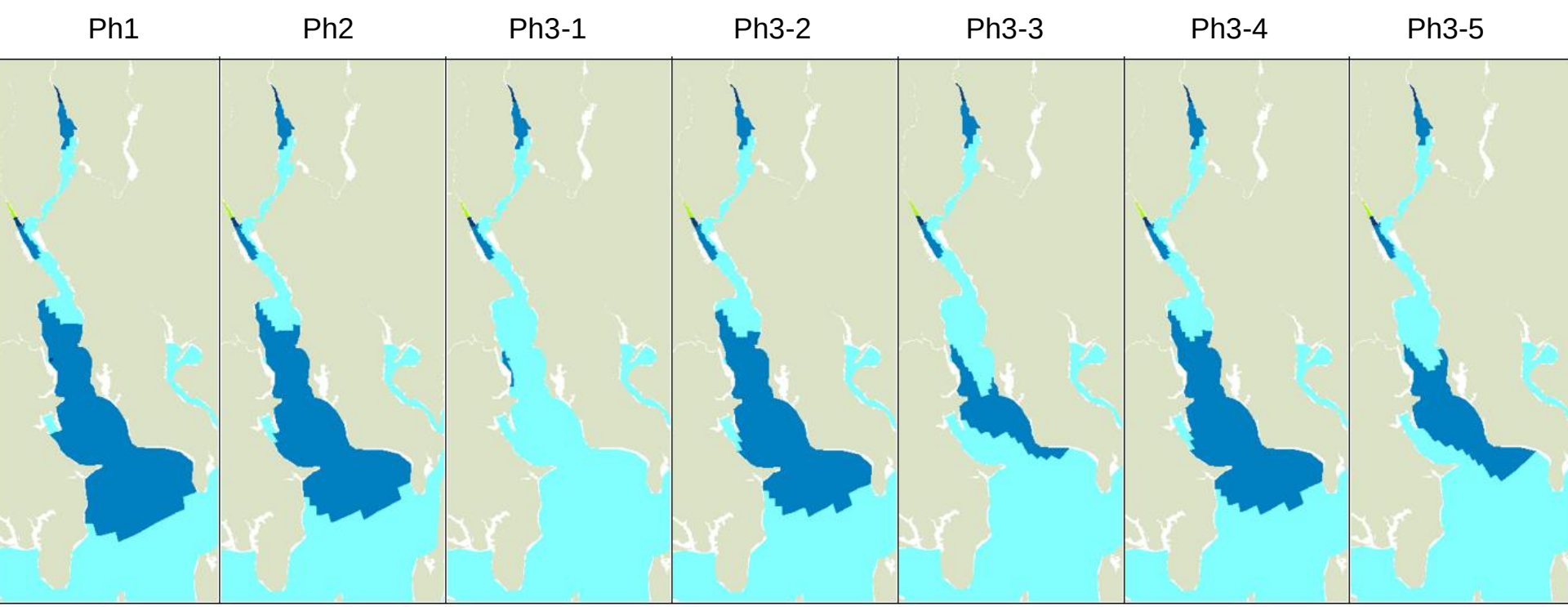
Ph1 Ph2 Ph3-1 Ph3-2 Ph3-3 Ph3-4 Ph3-5



Scenario Comparisons - Day 7 @ 6:00 (Storm starts on Day 1 @ 6:00)



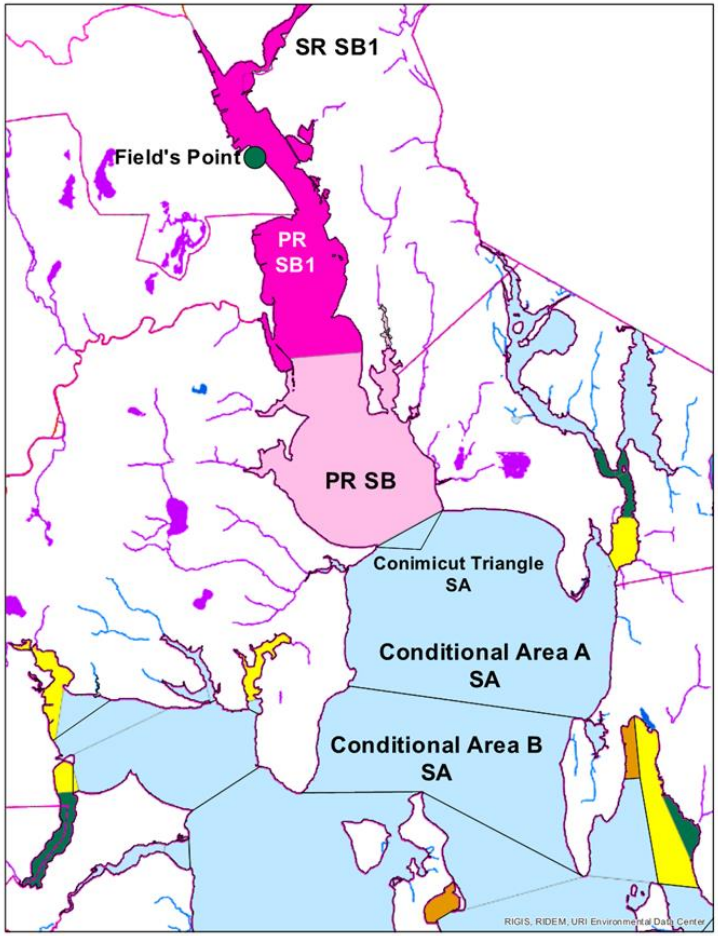
Scenario Comparisons - Day 9 @ 6:00 (Storm starts on Day 1 @ 6:00)



Conditional Closure Areas

Criterion	CLASS SA, SA {b}	CLASS SB, SB1, SB{a}, SB {a}
Fecal Coliform Bacteria (MPN/100mL)	**Shellfishing Criteria**: Not to exceed a geometric mean MPN value of 14 and not more than 10% of the samples shall exceed an MPN value of 49 for a three-tube decimal dilution.	
	Primary Contact Recreational/Swimming Criteria-Not to exceed a geometric mean value of 50 MPN/100mL and not more than 10% of the total samples taken shall exceed 400 MPN/100mL, applied only, when adequate enterococci data are not available.	

Area	Geomean Limit	Upper 10% Limit	Area Size (ac)
Conditional Area B	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	3,711
Conditional Area A	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	5,836
Conimicut Triangle Conditional Area	Shellfish at 14 FC/100mL	Shellfish at 49 FC/100mL	119
Providence River SB	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	3,000
Providence River SB1	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	2,355
Seekonk River SB1	Contact Recreation at 50 FC/100mL	Contact Recreation at 400 FC/100mL	708



Scenario Comparisons – Conditional Closure Area Tables

Acre-Day is defined as the product of the area exceeding a given FC concentration times the duration of that exceedance. Tables shown for areas from south to north.

Conditional Area B	14 FC/100mL	49 FC/100mL
Phase	AcreDay	AcreDay
I	266	0
II	1	0
III-1	0	0
III-2	0	0
III-3	0	0
III-4	0	0
III-5	0	0

Conditional Area A	14 FC/100mL	49 FC/100mL
Phase	AcreDay	AcreDay
I	15,300	2,800
II	10,900	1,110
III-1	1,960	0
III-2	9,710	784
III-3	5,860	69
III-4	9,890	833
III-5	6,620	148

Conimicut Triangle	14 FC/100mL	49 FC/100mL
Phase	AcreDay	AcreDay
I	2,040	840
II	1,860	423
III-1	744	0
III-2	1,810	323
III-3	1,440	61
III-4	1,790	335
III-5	1,530	100

Providence River-SB	50 FC/100mL	400 FC/100mL
Phase	AcreDay	AcreDay
I	11,300	530
II	9,040	113
III-1	1,880	1
III-2	8,350	65
III-3	5,590	1
III-4	8,420	65
III-5	6,220	1

Providence River-SB1	50 FC/100mL	400 FC/100mL
Phase	AcreDay	AcreDay
I	10,200	4,200
II	9,820	3,320
III-1	6,300	221
III-2	9,690	3,000
III-3	8,170	1,750
III-4	9,530	3,010
III-5	8,590	2,050

Seekonk River-SB1	50 FC/100mL	400 FC/100mL
Phase	AcreDay	AcreDay
I	1,420	646
II	1,400	619
III-1	1,180	162
III-2	1,400	619
III-3	1,260	450
III-4	1,360	594
III-5	1,300	497

RPS asa

Conclusions

- Previously developed and calibrated model was successfully used in this project with newly collected data
- CSO loading rate is intermittent but during storms is 2-3 orders of magnitude greater than tributary loading rate and 5-6 orders of magnitude greater than WWTFs
- Level of impacts to areas below Providence Harbor are generally a function of total load but not in Harbor and the Seekonk River due to distribution of source loads
- Post processed model results can be effectively used as part of the reevaluation analysis