NYS RISE
Resiliency Institute for Storms and Emergencies


# Research Work Unit 2.3
# Flooding Impacts on Wastewater Infrastructure

NYU Polytechnic School of Engineering | Cornell University


| | |
|---|---|
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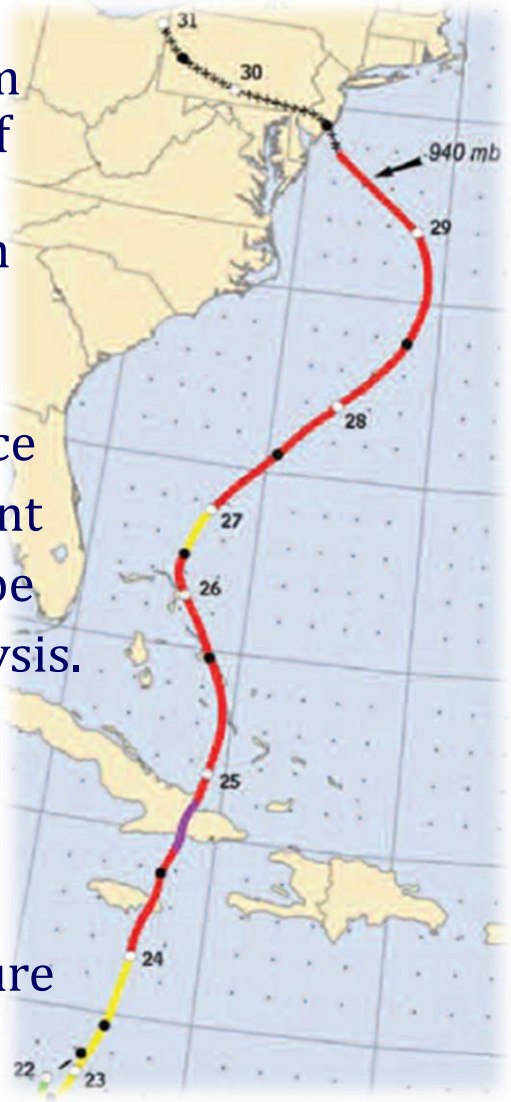
# Scope of Work

Inventory, mapping, and performance reviews of sewage treatment plants and pumping stations relative to storm surge levels, characteristics of plant damage, and loss of service at pump stations will be evaluated through a review of publicly available documents and information from government agencies and experts.

The most vulnerable treatment equipment and conveyance system components will be identified. Measures for plant protection and conveyance system improvements will be evaluated, and ranked on the basis of cost/benefit analysis. Temporal and spatial distributions of wastewater spills and dispersions in past storms.

Working with US-EPA, NYS-EFC, NYS-DOS, NYS-DEC and NYC-DEP to make recommendations on preventing future plant failures and mitigating environmental damages.

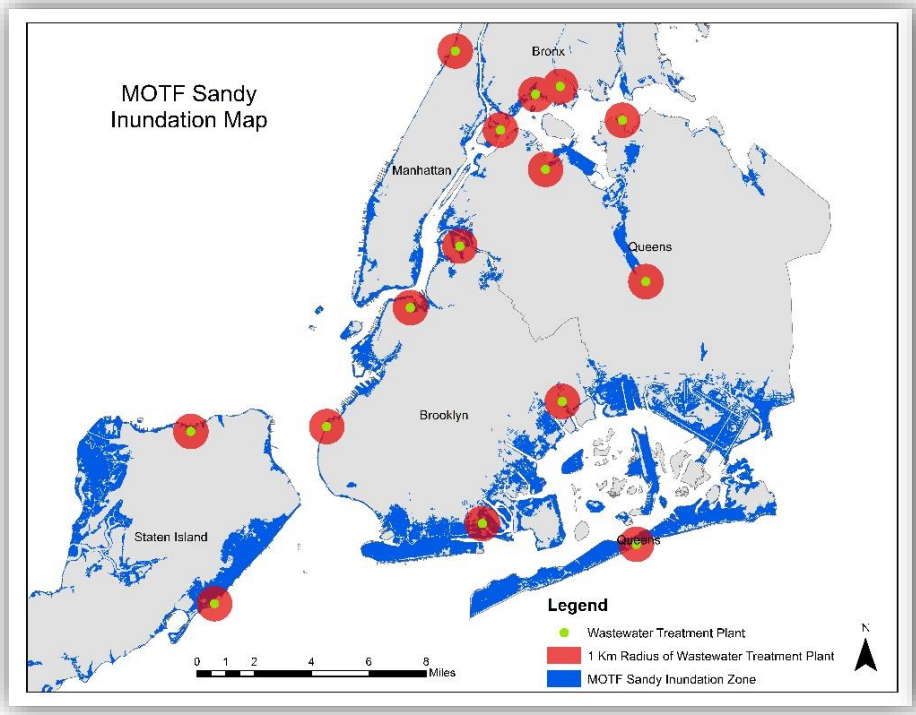


# A. FEMA MOTF

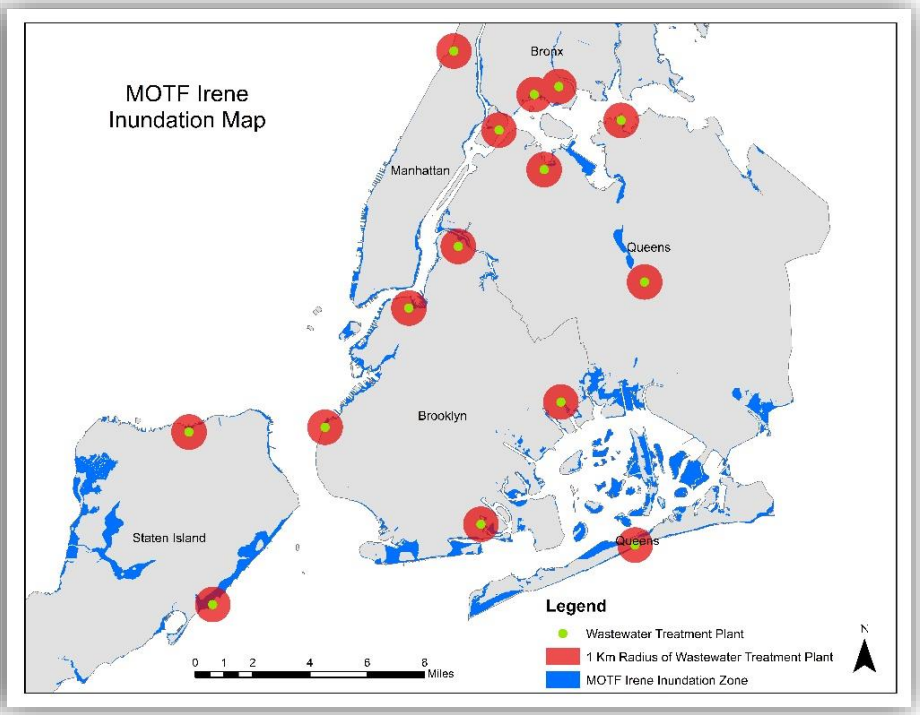
- FEMA MOTF (Federal Emergency Management Agency - Modelling Task Force), a group of modeling and risk analyst experts in support of disaster response operations that provides hazard, modeling and impact assessments information from a variety of information sources through coordination to develop:
  a) estimates of impacts before, during, and after events, and
  b) debris estimates
- Main purpose of FEMA MOTF is to develop raster data of disaster events which occur to do impact analysis
- For New York State (NYS) raster data is available for the following two Hurricane events:
  1. Hurricane Irene
  2. Hurricane Sandy

# FEMA MOTF OUTPUT NYC

**Hurricane Event**: Superstorm Sandy
**DEM:** 1-meter resolution




**Hurricane Event**: Tropical storm Irene
**DEM:** 3-meter resolution



# B. SLOSH

SLOSH: Sea, Lake, and Overland Surges from Hurricanes

- SLOSH is a computerized model developed by the National Weather Service (NWS) to estimate storm surge heights and winds resulting from hurricanes.
- Advantages: SLOSH is computationally efficient resulting in fast computer runs which makes it an ideal operational system.
- Disadvantages: Considers only flood caused by storm surge, does not account for normal river flow or rain induced flooding.
- SLOSH modeling approach to estimate surge could be deterministic (solving physics equations), stochastic (statistical approach), or composite (maximum envelopes of water).

# SLOSH Inundation Map

- **Data Sources:** Hurricanes could be historical, hypothetical or predicted
  - NY3 SLOSH MOM* from NOAA** National Hurricane Center
  - Digital Elevation Model (DEM) from NOAA's Ocean Service, Coastal Services Center

- **Steps to get inundation map:**

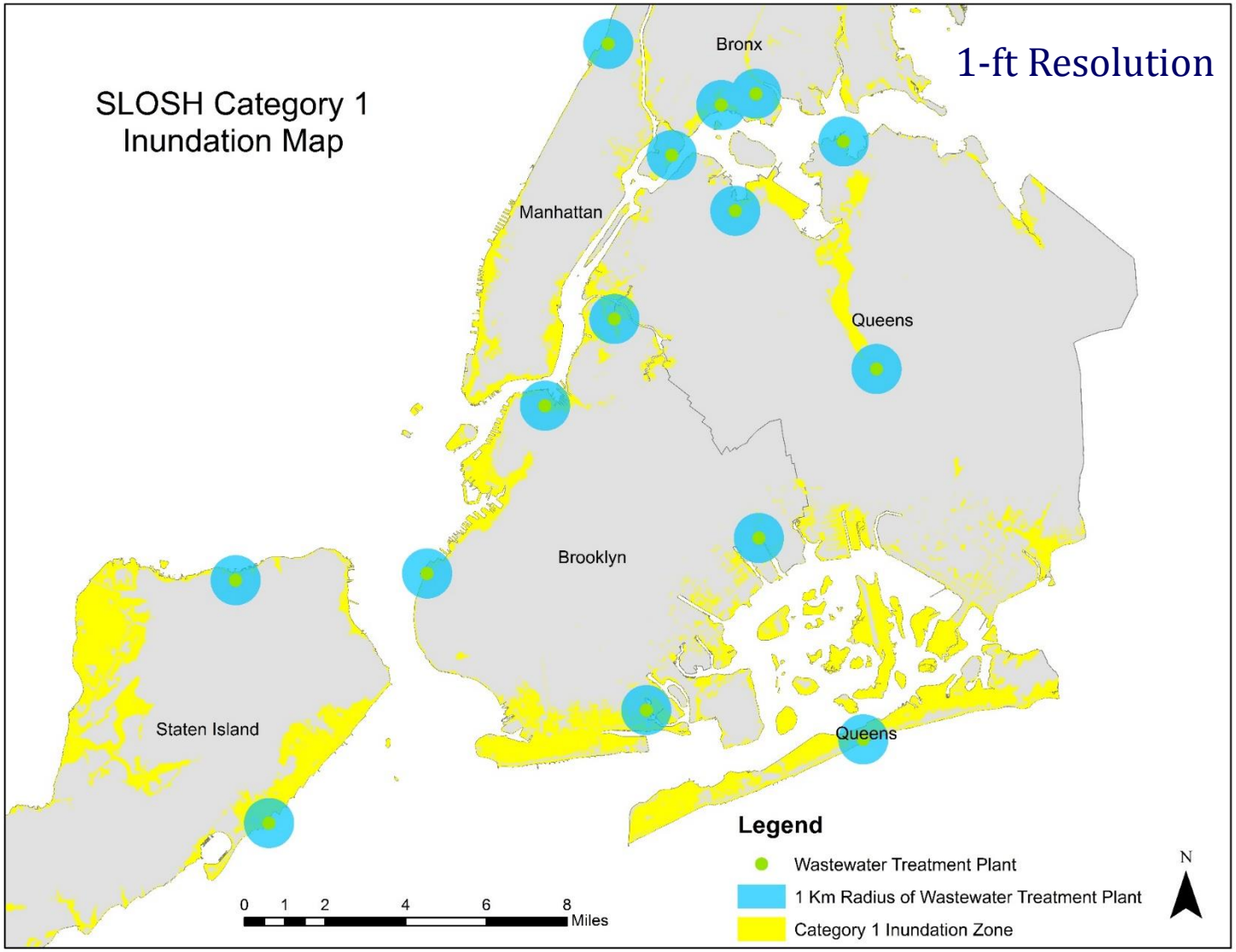
  1. Using Inverse Distance Weighted (IDW) interpolation to generate surface of surge heights from point estimates of surge heights.

  2. Using Surface of surge heights to subtract DEM will get the flood depth.

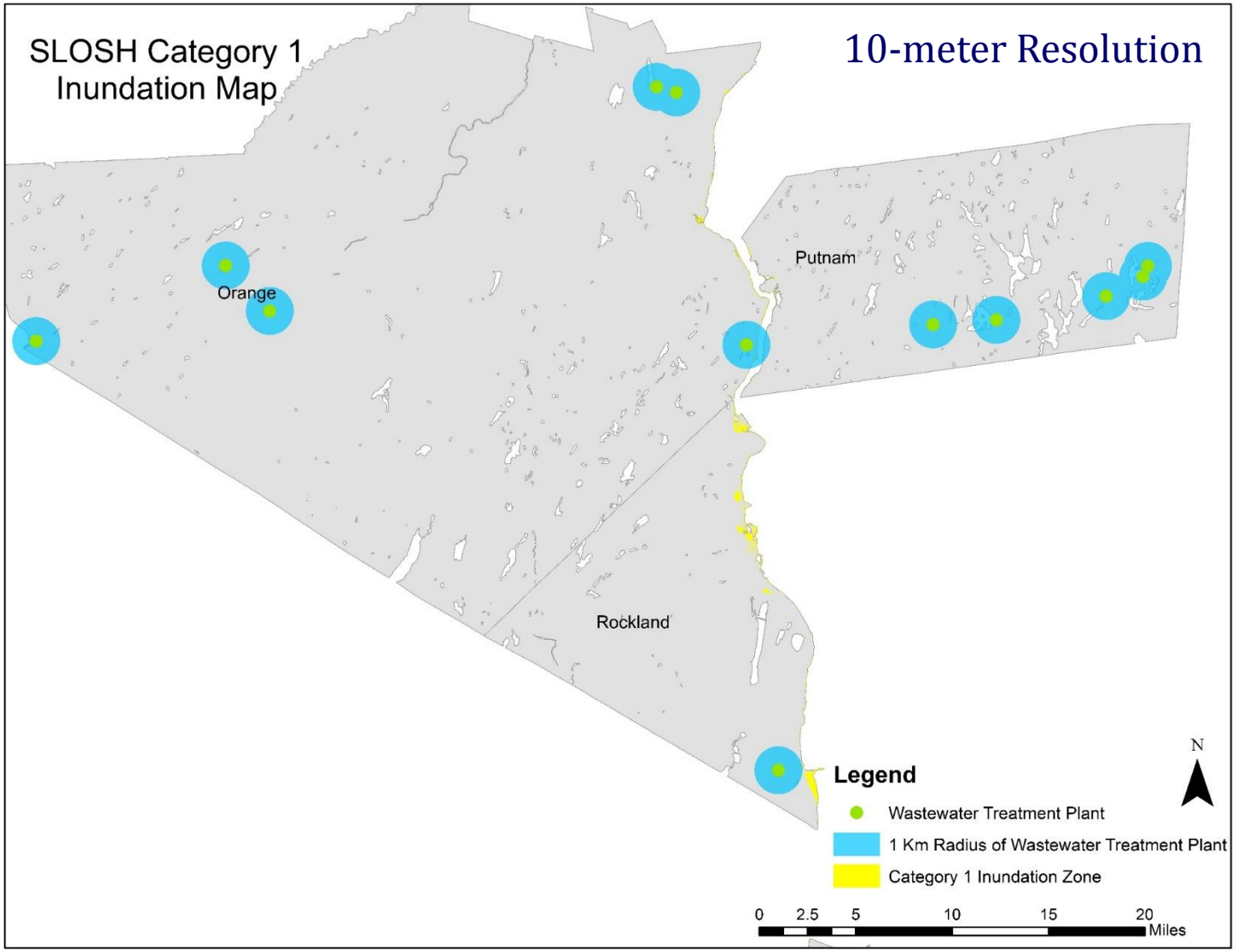
*MOM: Maximum of the Maximum

**NOAA: National Oceanic and Atmospheric Administration

# SLOSH Inundation Map of NYC (various categories)

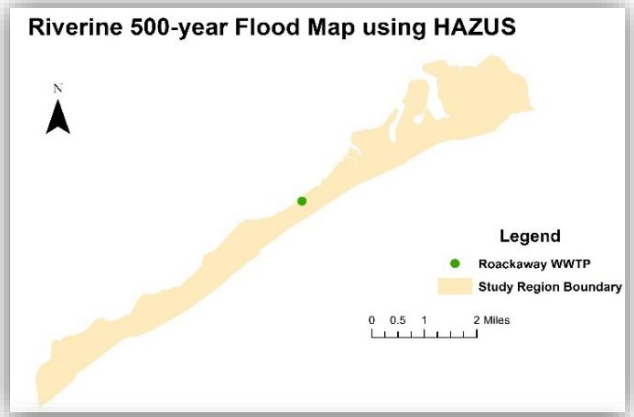


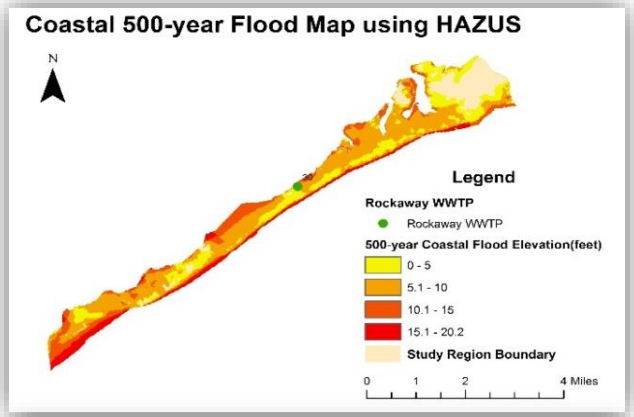
# SLOSH Inundation Map of Rockland and Putnam Counties (various categories)

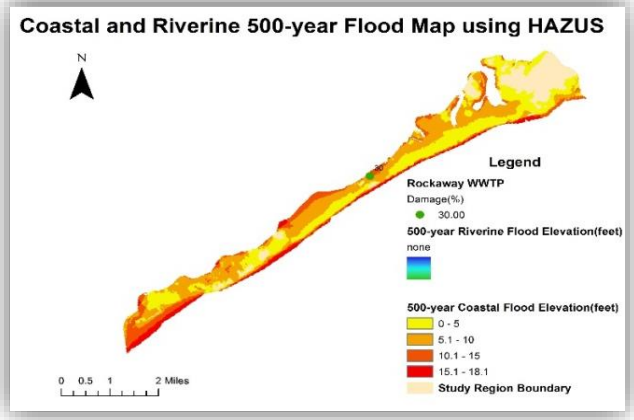


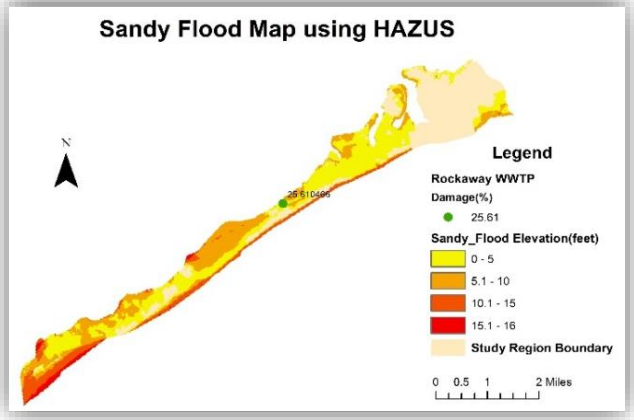
# C. HazUS-MH

- HazUS (Hazards US – Multi-Hazards) is a software developed by FEMA for estimating potential direct/indirect losses from floods, winds and earthquakes
- Uses Geographic Information Systems (GIS) technology to graphically depict economic losses, structural damages, etc. for various scenarios
- Hazard Type: Coastal, Riverine, Coastal & Riverine, or Coastal Surge & Hurricane



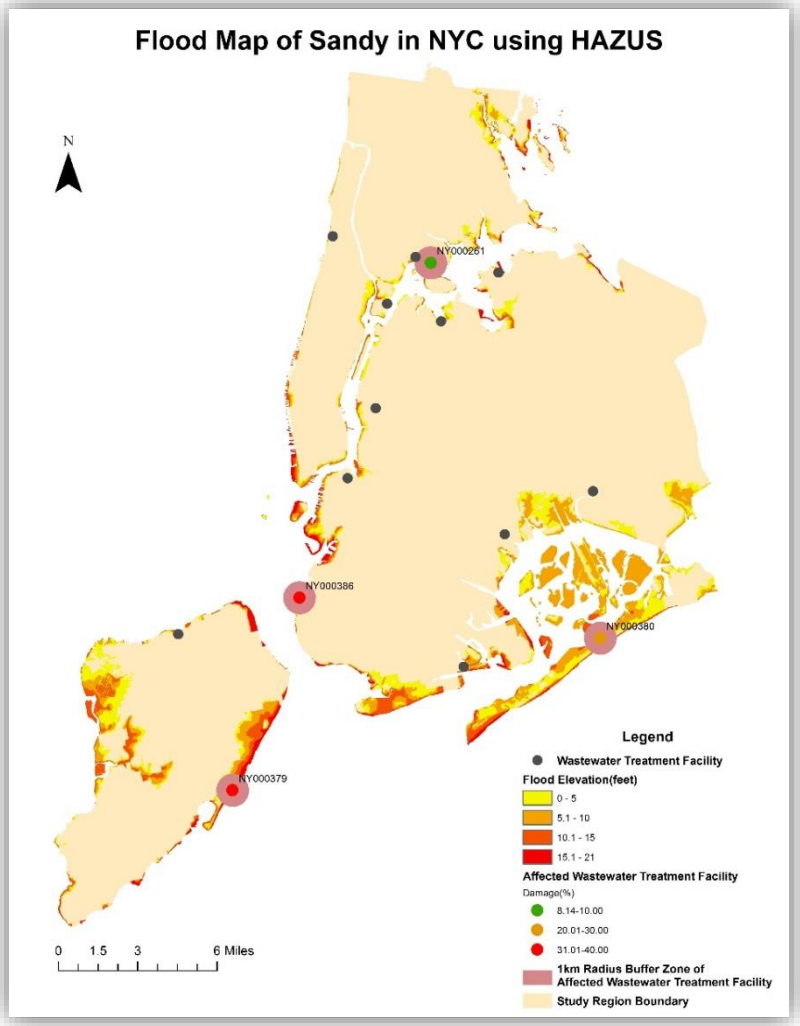



# Comparison of NYCDEP and HazUS-MH

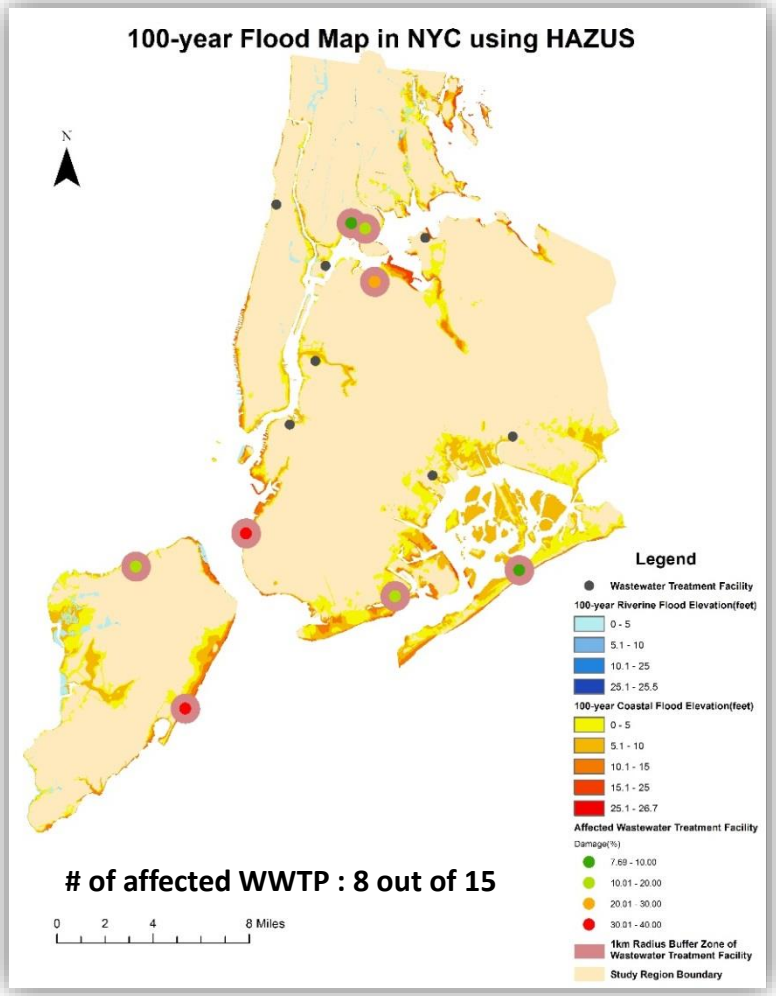
| NYC Wastewater Treatment Plant (WWTP) | Flood Elevation (feet, NAVD88) | | | | |
|---|---|---|---|---|---|
| | 100-year | | Sandy | | |
| | DEP (+30 inches) | HAZUS | DEP | | HAZUS |
| 26th Ward | 13.5 | N F | Major | 12.6 | N F |
| Hunts Point | 17.5 | 2.52 | Minor | 10.2 | 2.42 |
| Jamaica | 13.5 | N F | Minor | N F | N F |
| Oakwood Beach | 16.5 | 13.25 | Major | 13.1 | 18.15 |
| Rockaway | 14.5 | 4.57 | Major | 11.4 | 13.20 |
| Bowery Bay | 15.5 | 5.36 | Minor | 11.6 | N F |
| Coney Island | 15.5 | 3.36 | Major | 10.1 | N F |
| Newtown Creek | 13.5 | N F | Minor | 10.0 | N F |
| Owls Head | 14.5 | 9.97 | Major | 13.5 | 15.89 |
| Port Richmond | 14.5 | 5.01 | Major | 12.1 | N F |
| Wards Island | M: 17.5<br>Bx: 14.5 | N F | Minor | 10.7 | N F |
| Red Hook | 14.5 | N F | Minor | 11.7 | N F |
| North River | 12.5 | N F | Major | 9.7 | N F |
| Tallman Island | 15.5 | N F | Minor | 10.1 | N F |

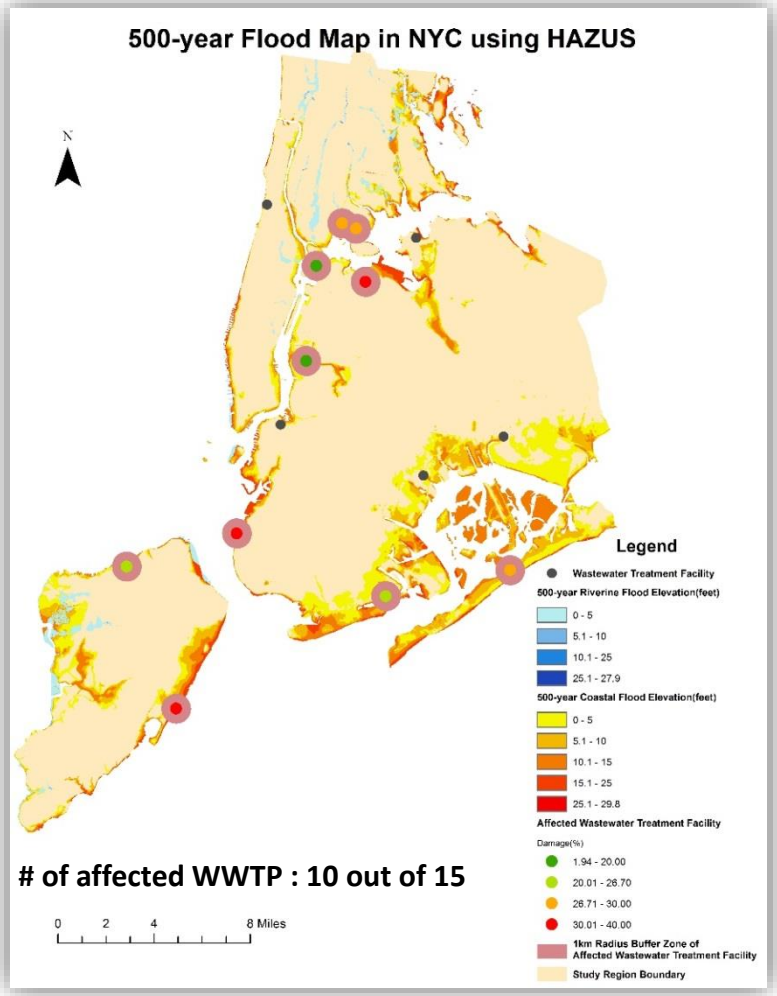
N F: not flooded



# Case Study : NYC

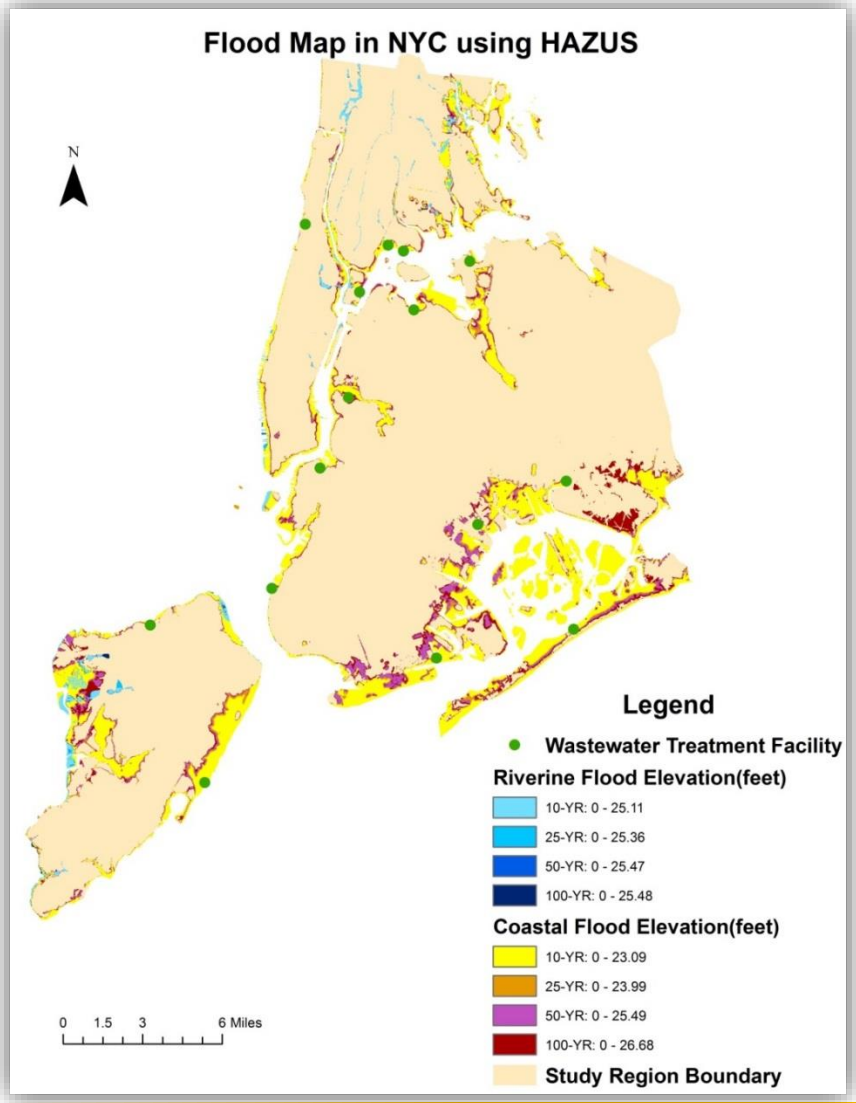
DEM: 1 arc second resolution (~30 meters)
Develop Network: 0.5 mi$^2$ of drainage area
Hazard Type: Riverine and Coastal



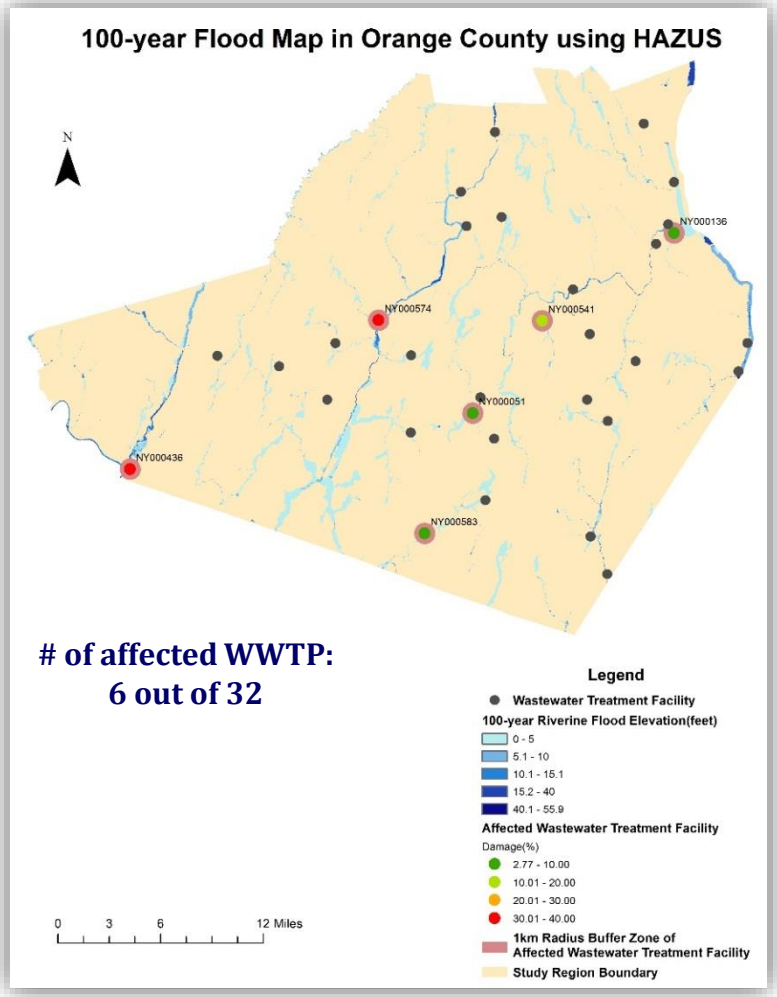
# NYC Damage Analysis based on a 100-year event

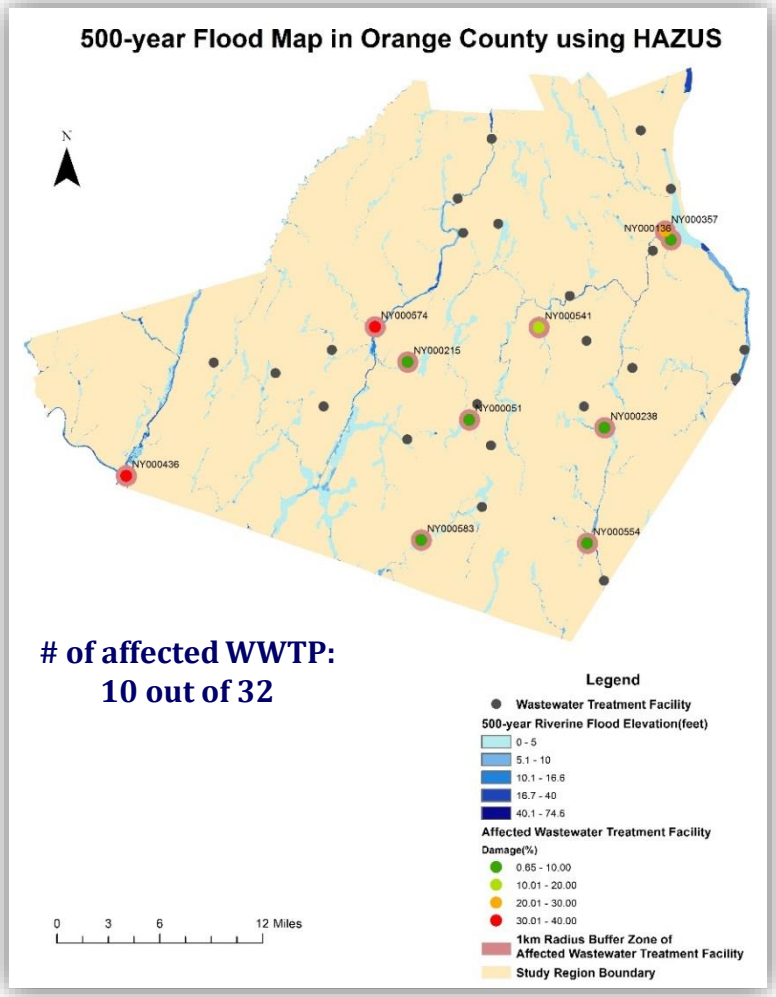
| Facility Name | Damage % | Flood Elevation (ft) | Economic Loss ($) |
|---|---|---|---|
| Hunts Point | 10.16 | 2.52 | 7,981,096 |
| Oakwood Beach | 40.00 | 13.25 | 31,435,200 |
| Rockaway | 7.69 | 4.57 | 6,045,222 |
| Bowery Bay | 26.80 | 5.36 | 21,066,258 |
| Coney Island | 15.42 | 3.36 | 12,115,576 |
| Owls Head | 39.76 | 9.97 | 31,245,402 |
| Port Richmond | 11.75 | 5.01 | 9,236,918 |
| NY Organic Fertilizer Co. | 9.46 | 2.73 | 7,436,224 |



# Case Study: Orange County

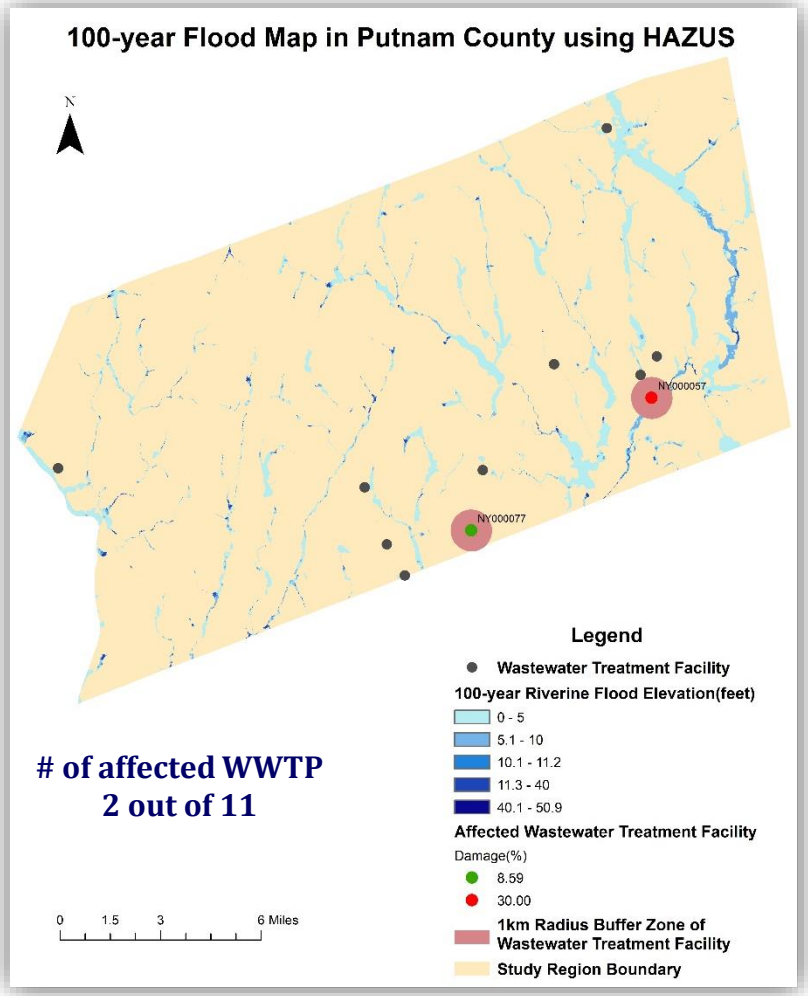
DEM: 1 arc second resolution (~30 meters)
Develop Network: 2 $mi^2$ of drainage area
Hazard Type: Riverine only

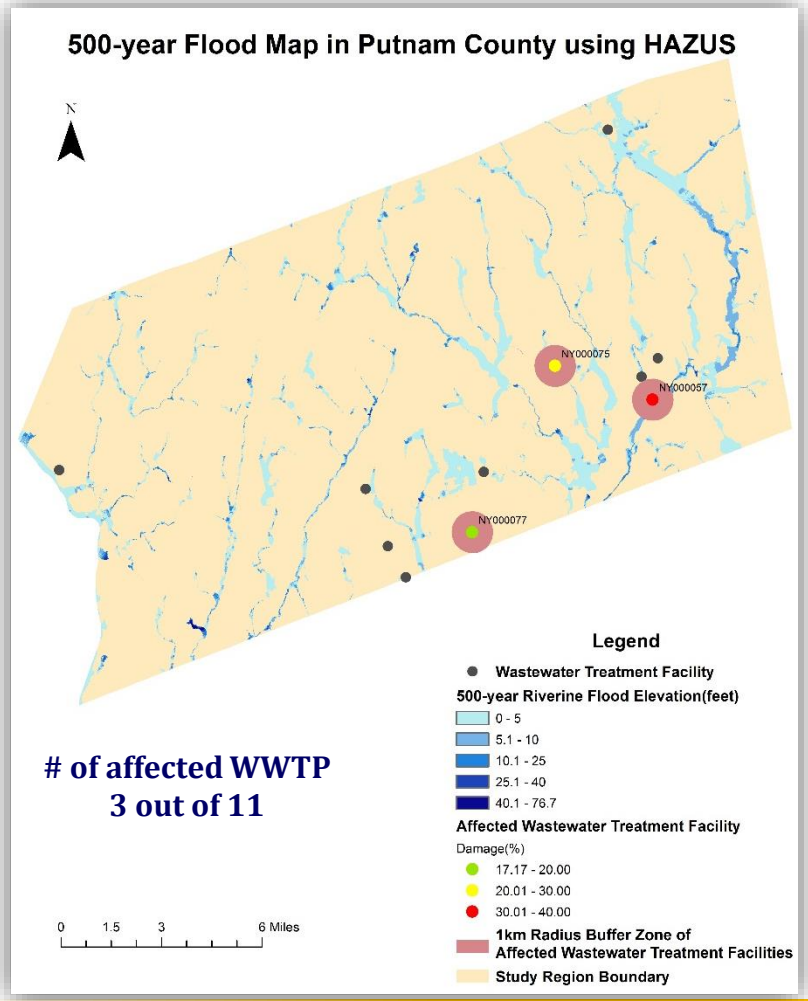


# Case Study: Putnam County

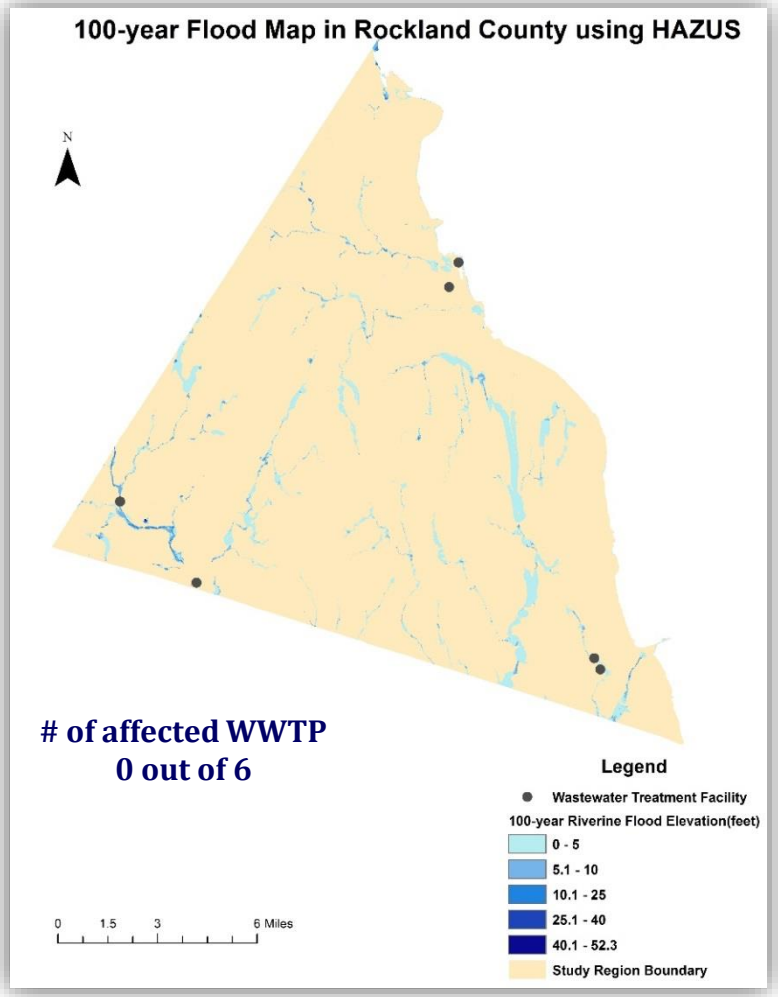
DEM: 1 arc second resolution (~30 meters)
Develop Network: 0.5 $mi^2$ of drainage area
Hazard Type: Riverine only

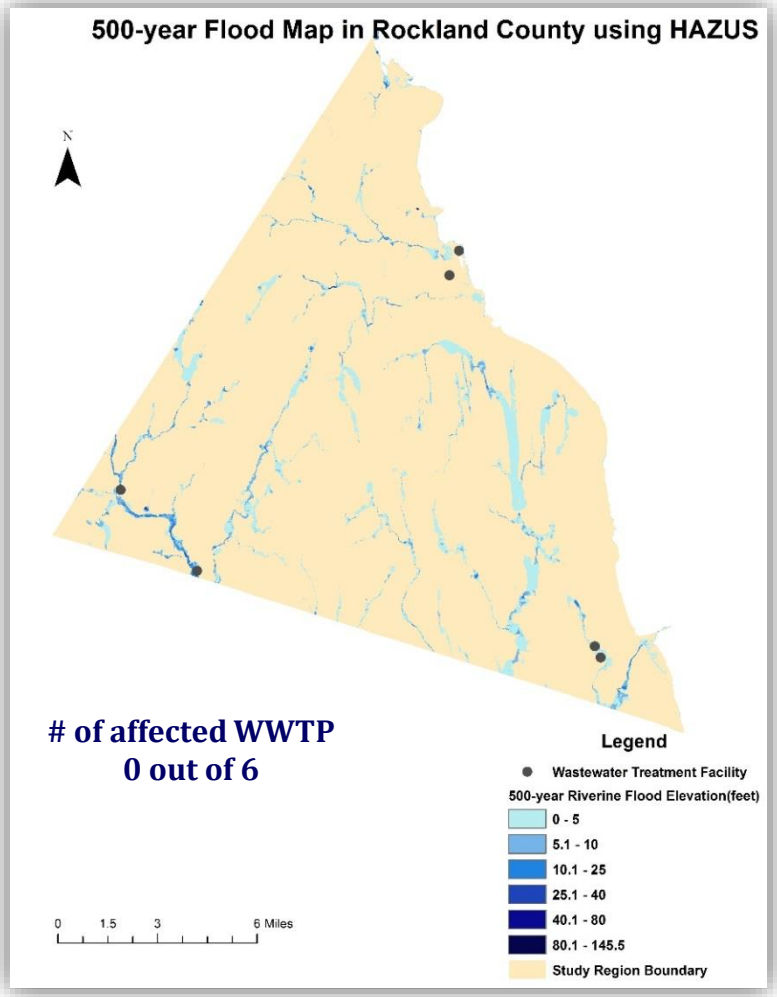


# Case Study: Rockland County

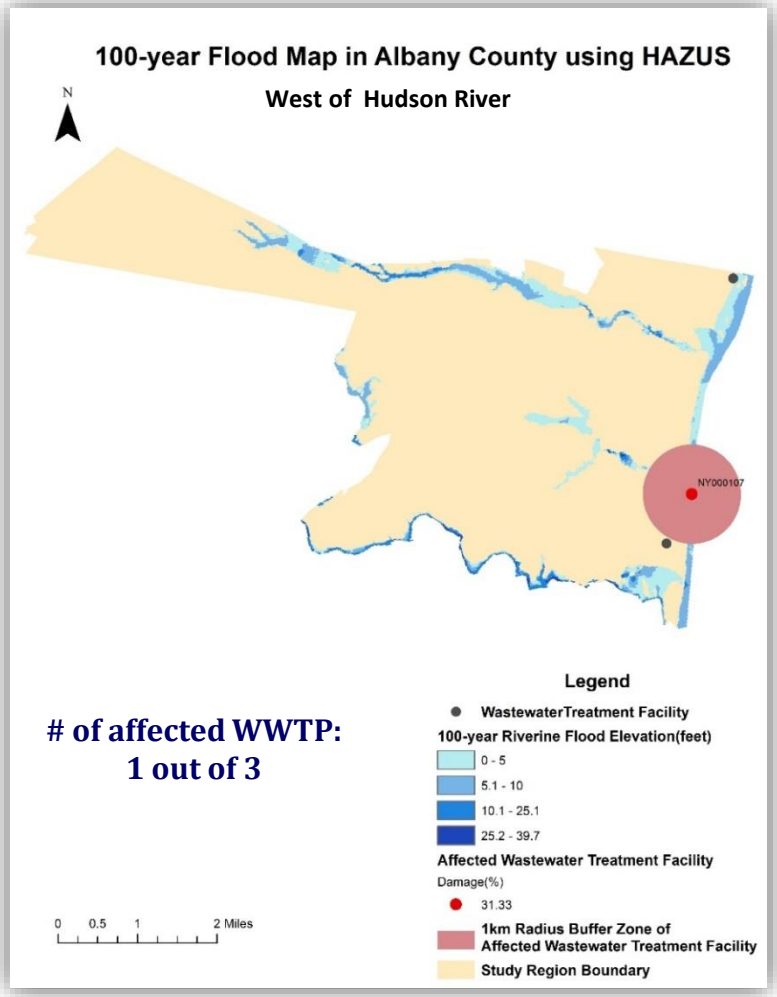
DEM: 1 arc second resolution (~30 meters)
Develop Network: 0.5 $mi^2$ of drainage area
Hazard Type: Riverine only

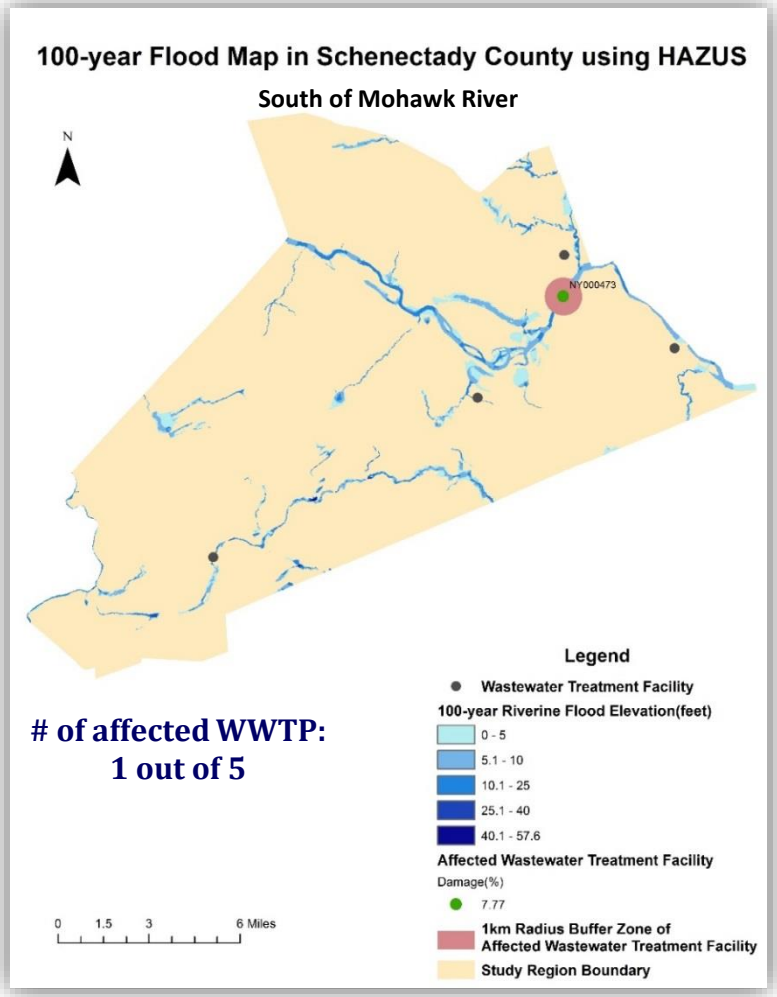


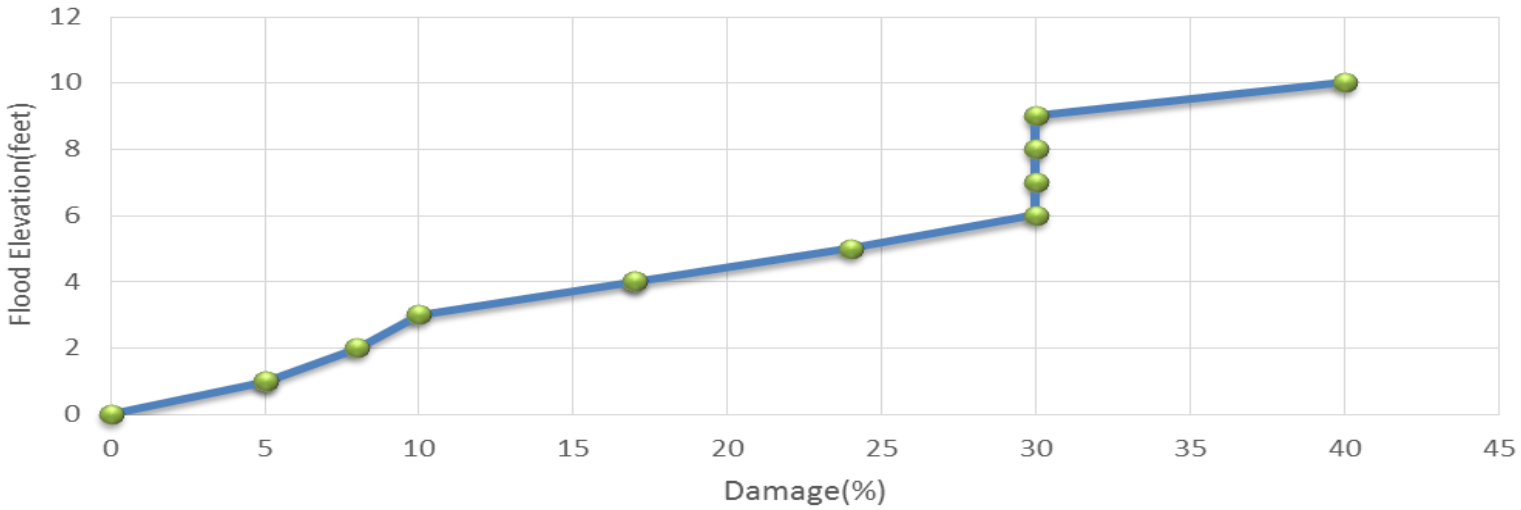
# Case Study: Albany and Schenectady Counties

DEM: 1 arc second resolution (~30 meters)
Develop Network: 2 $mi^2$ of drainage area
Hazard Type: Riverine only



# Results




| County | Name | Damage(%) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 10-year | 25-year | 50-year | 100-year | Sandy | 500-year |
| NYC | Owls Head WPCP | 30 | 30 | 30 | 39.76 | 40 | 40 |
| | Bowery Bay WPCP | 8.34 | 9.91 | 18.87 | 26.81 | No flooded | 37.63 |
| Orange | PORT JERVIS STP | 27.21 | 30 | 38.76 | 40 | - | 40 |
| | TAPPAN HOMES SD | 8.85 | 9.56 | 10.03 | 11.87 | - | 18.99 |
| Putnam | BREWSTER WWTP | 28.41 | 30 | 30 | 30 | - | 40 |
| | CARMEL SD#7 - COUNTRY MANOR | 6.77 | 7.64 | 8.18 | 8.59 | - | 17.17 |

0-10%

10.01-20%

20.01-30%

30.01-40%

# Research Results To Date

- Literature review has been completed
- Inventory and mapping has been completed
- Performance review of Wastewater Treatment Plants (WWTPs) and Pumping Stations (PSs) is in progress
- Gathering of technical information and data from all associated NYS and NYC agencies has been initiated
- WWTPs performance and vulnerability evaluation is in progress
- Over 80% of WWTPs plants review has been completed

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# WWTP/PS-Specific Data Gathering

| | | |
|---|---|---|
| Facility: | | ❑ WWTP/WPCP<br>❑ PS<br>❑ |
| Leading agency: | | Coordinates |
| Address: | | ____° ____' ____" N |
| City State Zip code | | ____° ____' ____" E |

| Wastewater Treatment or Water Pollution Control Plant (WWTP/WPCP) | Pumping Station (PS) |
|---|---|

o

| Description and physical characteristics | | | |
|---|---|---|---|
| WWTP/WPCP type: | ❑ Activated sludge<br>❑ _____<br>❑ _____ | PS type: | ❑ Combined<br>❑ Stormwater<br>❑ Municipal |
| Dewatering facilities: | ❑ Yes - ❑ No | Pump type: | ❑ Submersible - ❑ _____ |
| Local grade: | feet | Local grade: | feet |
| Elevation of the lowest electrical control: | feet | Elevation of the lowest electrical control: | feet |
| Elevation of the lowest mechanical device: | feet | Elevation of the lowest mechanical device: | feet |

| Hydraulic characteristics | | | |
|---|---|---|---|
| Design dry weather flow: | MGD | Operating capacity: | MGD |
| Maximum wet weather flow: | MGD | Maximum allowable capacity: | MGD |
| Discharge waterbody: | | Connected to other stations: | ❑ Yes - ❑ No |
| Critical flood elevation: | feet | Critical flood elevation: | feet |
| Hurricane Sandy: | feet | Hurricane Sandy: | feet |
| Contributing area: | acres | Affected area: | acres |

| Historical information | |
|---|---|
| Hurricane Sandy flood elevation: | feet |
| Hurricane Sandy flood damage: | ❑ Catastrophic - ❑ Major - ❑ Significant/Noticeable - ❑ Minor/Limited - ❑ None |
| Historic flooding: | ❑ Yes - ❑ No, if yes, describe: |
| Historic loss of power: | ❑ Yes - ❑ No, if yes, describe: |
| Affected by Hurricane Sandy: | ❑ Yes - ❑ No, if yes, describe: |
| Beach affected: | ❑ Yes - ❑ No, if yes, describe: |

# Deliverables

- A final report will be produced that summarizes the most important causes of damage and component vulnerability during a storm in the wastewater treatment systems in the study region. Analysis of the design, operation and capacity characteristics of the existing wastewater infrastructure system will be performed based on historical data, drawings and characteristics of the wastewater infrastructure. The limitations, deficiencies, potentials and dynamics of each component of the system will be determined and analyzed.

- Recommendations for protection of each system component and improved service (in terms of improvement of the efficiency and capacity of each component) will be developed and ranked on the basis of cost/benefit assessment. Studies of wastewater treatment infrastructure systems in NYC, Long Island (both Nassau and Suffolk Counties), Westchester County, Orange County, Rockland County, and Putnam County will be conducted, the lessons from which can be implemented in the flood prone locations of other counties of New York State, as needed.

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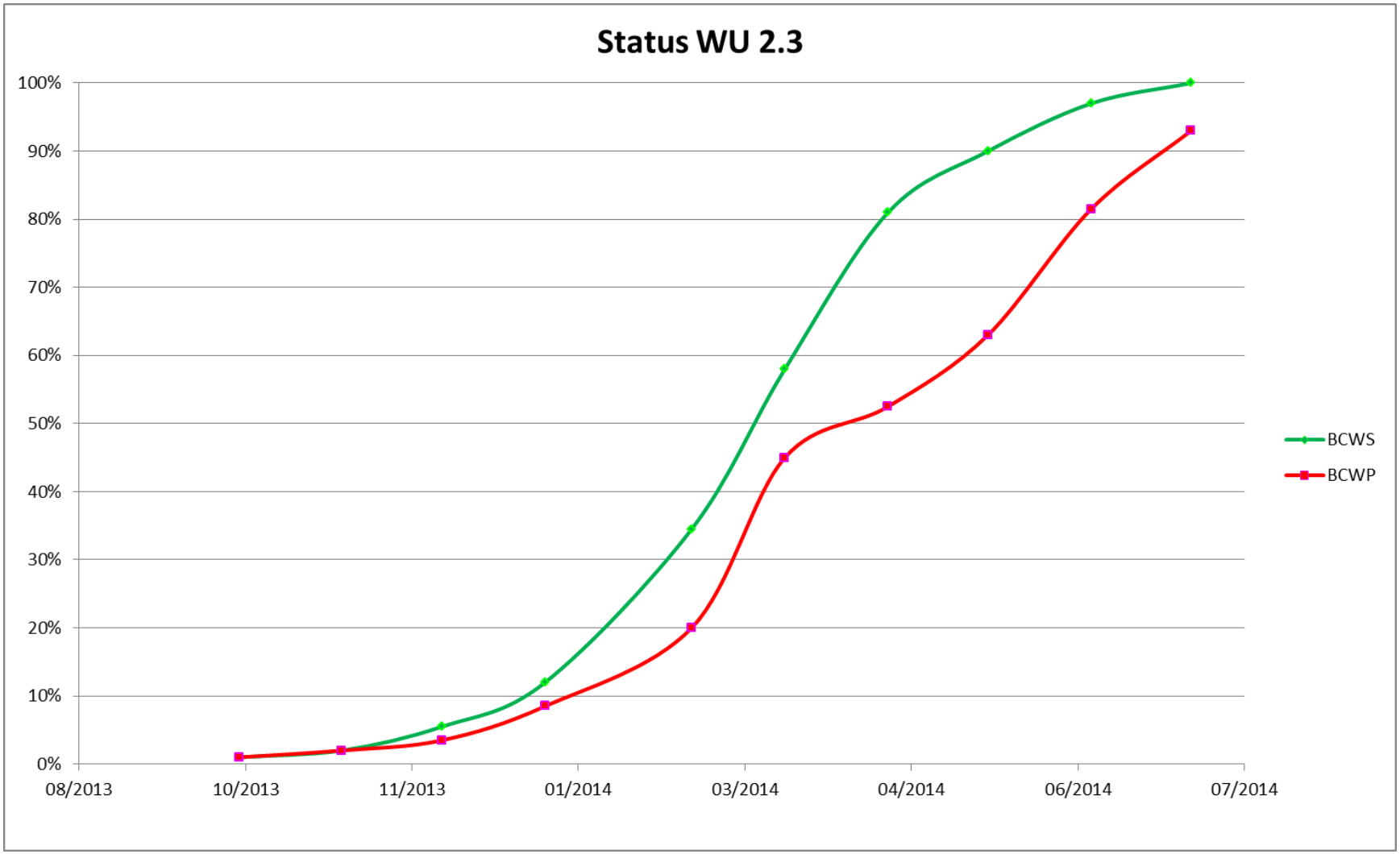
# Actual/Projected Assessment of Base Plan

| ABP | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WU 2.3 Assessment of Base Plans** | | **2013** | | | **2014** | | | | | | | |
| **Tasks** | **Budget** | **10/2013** | **11/2013** | **12/2013** | **01/2014** | **02/2014** | **03/2014** | **04/2014** | **05/2014** | **06/2014** | **07/2014** | **08/2014** |
| Work unit technical management | $4,774.61 | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | |
| Literature review | $4,774.61 | 10% | 10% | 20% | 40% | 20% | | | | | | |
| Inventory, mapping, and performance review of WWTPs | $19,098.45 | | | 10% | 20% | 30% | 40% | | | | | |
| Working with NYS EFC, DOS, DEC and NYC DEP | $14,323.84 | | | | | 20% | 50% | 30% | | | | |
| Select sample Counties | $4,774.61 | | | | | 50% | 50% | | | | | |
| WWTP performance and vulnerability evaluation | $23,873.07 | | | | | 20% | 20% | 20% | 20% | 20% | | |
| Draft report preparation & submission | $14,323.84 | | | | | 30% | | 70% | | | | |
| Recommendations and ranking on the basis of cost/benefit analysis | $4,774.61 | | | | | | | 50% | 50% | | | |
| Final report | $4,774.61 | | | | | | | | 20% | 30% | 50% | |
| **TOTAL** | **$95,492.26** | | | | | | | | | | | |
| **Projected** | **Earned Value** | $954.92 | $954.92 | $3,342.23 | $6,207.00 | $21,485.76 | $22,440.68 | $21,963.22 | $8,594.30 | $6,684.46 | $2,864.77 | |
| | **%** | 1% | 1% | 4% | 7% | 23% | 24% | 23% | 9% | 7% | 3% | |
| | **BCWS** | 1% | 2% | 6% | 12% | 35% | 58% | 81% | 90% | 97% | 100% | |
| | **BCWP** | 1% | 2% | 4% | 9% | 20% | 45% | 53% | 63% | 82% | 93% | |
| | **%** | 1% | 1% | 2% | 5% | 12% | 25% | 8% | 11% | 19% | 12% | 0% |
| **Actual** | **Earned Value** | $954.92 | $954.92 | $1,432.38 | $4,774.61 | $10,981.61 | $23,873.07 | $7,161.92 | $10,026.69 | $17,666.07 | $10,981.61 | |
| **Tasks** | **Budget** | **Oct** | **Nov** | **Dec** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** |
| Work unit technical management | $4,774.61 | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | 10% | |
| Literature review | $4,774.61 | 10% | 10% | 20% | 40% | 10% | 10% | | | | | |
| Inventory, mapping, and performance review of WWTPs | $19,098.45 | | | | | 20% | 30% | | 30% | 10% | 10% | |
| Working with NYS EFC, DOS, DEC and NYC DEP | $14,323.84 | | | | | 10% | 50% | 20% | | | 10% | |
| Select sample Counties | $4,774.61 | | | | | 20% | 30% | 20% | 20% | | 10% | |
| WWTP performance and vulnerability evaluation | $23,873.07 | | | | 10% | 10% | 30% | | | 30% | 10% | |
| Draft report preparation & submission | $14,323.84 | | | | | 10% | 10% | 20% | 20% | 30% | | |
| Recommendations and ranking on the basis of cost/benefit analysis | $4,774.61 | | | | | | | | | 40% | 45% | |
| Final report | $4,774.61 | | | | | | | | | 40% | 45% | |
| **TOTAL** | **$95,492.26** | | | | | | | | | | | |

# Actual/Projected Status of WU 2.3



# References (selected)


- NYC Wastewater Resiliency Plan (Climate Risks Assessment and Adaptation Study), NYC Environmental Protection, October 2013
- HazUS-MH Flood Technical Manual", Department of Homeland Security - Federal Emergency Management Agency Mitigation Division, Washington, D.C
- HAZUS-MH MR4 User Manual", Department of Homeland Security - Federal Emergency Management Agency Mitigation Division, Washington, D.C
- "HazUS-MH Coastal Flood Model FEMA Region IV Standard Operating Procedure", Coastal Flood Hazard and Loss Analysis SOP, August 2012
- "FEMA Modeling Task Force (MOTF) Sandy Impact Analysis." [http://www.arcgis.com/home/item.html]

# NYS RISE Work Unit 2.3: Flooding Impacts on Wastewater Infrastructure

R. Lawrence Swanson, Robert Wilson, Bruce Brownawell, Kaitlin Willig, Park Ng, Tesia Moore

# Objectives

- Examine causes of damage and component vulnerability in wastewater treatment systems in select areas of Long Island, including the analysis of the design, operation and capacity characteristics of the existing wastewater infrastructure system and the limitations, deficiencies, potentials and dynamics of each component of the system.
- Assess performance of specific facilities during Superstorm Sandy including increases in loadings of chemical contaminants.

# Deliverables

- Report on damage and component vulnerability in wastewater treatment systems in the study region caused by Superstorm Sandy and other storms.

- Computer code for hydrodynamic modeling of dilution patterns from the outfall in Reynolds Channel and relief discharge in East Rockaway Channel associated with the flooding at the Bay Park Publicly Owned Treatment Works (POTW), including a map and an interpretation of distribution of sewage tracers in sediments.

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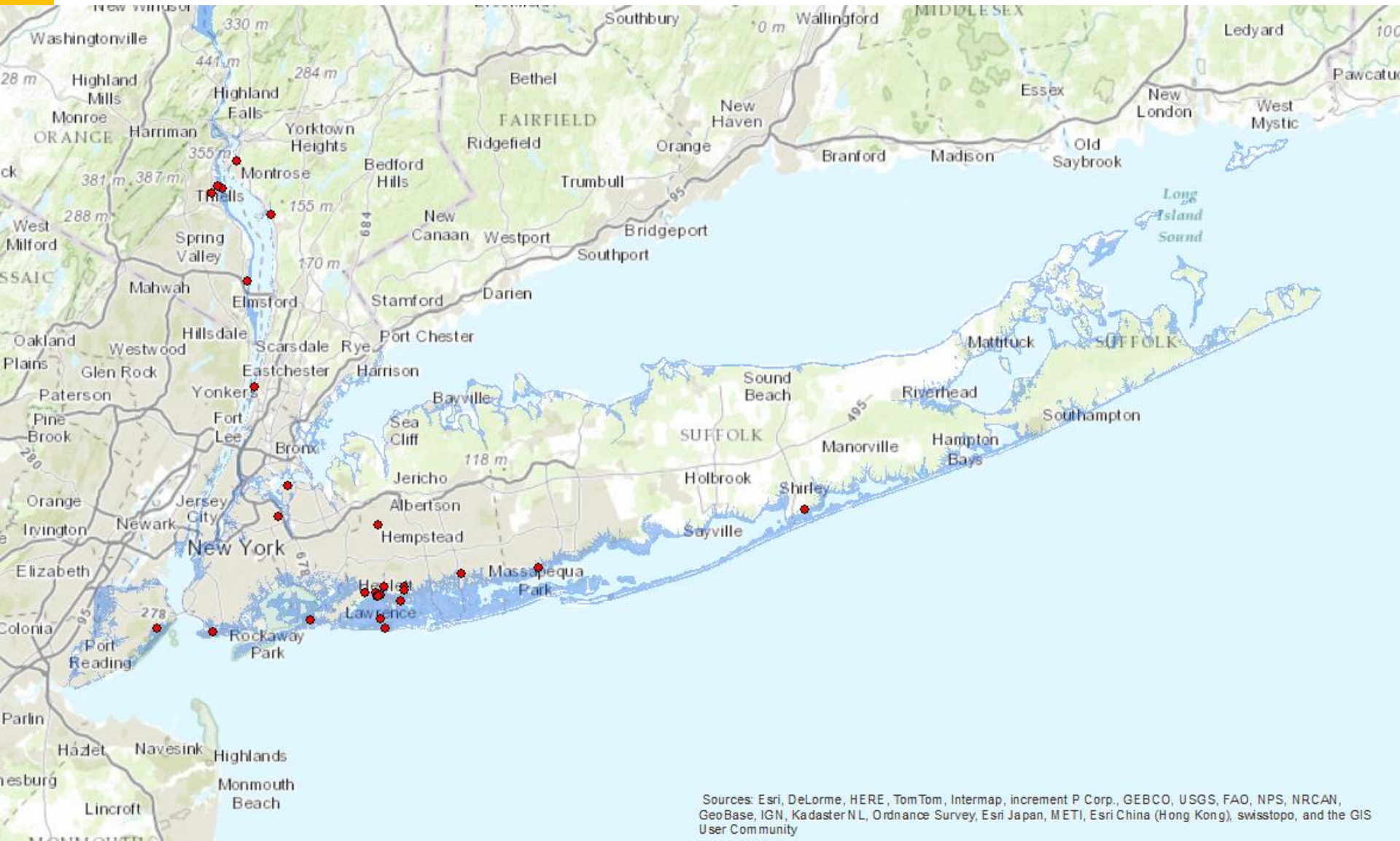
# NYDEC Reports of Raw Sewage Spills - 14 out of 32 Located in Western Bays Watershed




Sources: Esri, DeLorme, HERE, TomTom, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, and the GIS User Community

# Wastewater Treatment Facilities Whose Addresses Lie Within Sandy (blue) and Slosh Model Category 3 (orange) Inundation Zones – Nassau County more Susceptible


| | # Facilities | Sandy | Category 3 |
|---|---|---|---|
| Region-wide | 161 | 27 | 54 |
| Nassau | 22 | 8 | 17 |
| Suffolk | 56 | 2 | 5 |
| Westchester | 10 | 1 | 4 |

# Treatment Plants Contacted- Nassau

| County | Facility | Treatment Level | Flow Design (MGD) | Ave. Flow (MGD, 2010) | Pop. Served | Interviewed | Visited | Damaged During Sandy | Looking to Upgrade |
|---|---|---|---|---|---|---|---|---|---|
| Nassau | Bay Park | Secondary | 70.0 | 49.9 | 532,400 | X | X | X | X |
| Nassau | Glen Cove | Tertiary | 5.5 | 3.0 | 28,000 | | | | |
| Nassau | Cedar Creek | Secondary | 72.0 | 58.6 | 569,000 | X | | | |
| Nassau | Long Beach | Secondary | 7.5 | 5.0 | 37,000 | X | | X | |
| Nassau | Lawrence | Secondary | 1.5 | 1.3 | 5,500 | X | | X | X |
| Nassau | Greater Atlantic Beach | Secondary | 1.5 | 0.6 | 2,000 | X | | X | X* |
| Nassau | Great Neck | Secondary | 3.8 | 2.5 | >15,000 | | | | |
| Nassau | Great Neck Village | Secondary | 1.5 | 0.9 | 9,000 | | | | |
| Nassau | Port Washington | Secondary | 4.0 | 2.8 | 35,000 | | | | |
| Nassau | Belgrave | Secondary | 2.0 | 1.5 | 14,000 | | | | |
| Nassau | Oyster Bay | Tertiary | 1.8 | 1.3 | 8,500 | X | | X | X** |

*May be linked as a pump station to Bay Park STP based on current proposals for upgrades

** Dependent on funding availability

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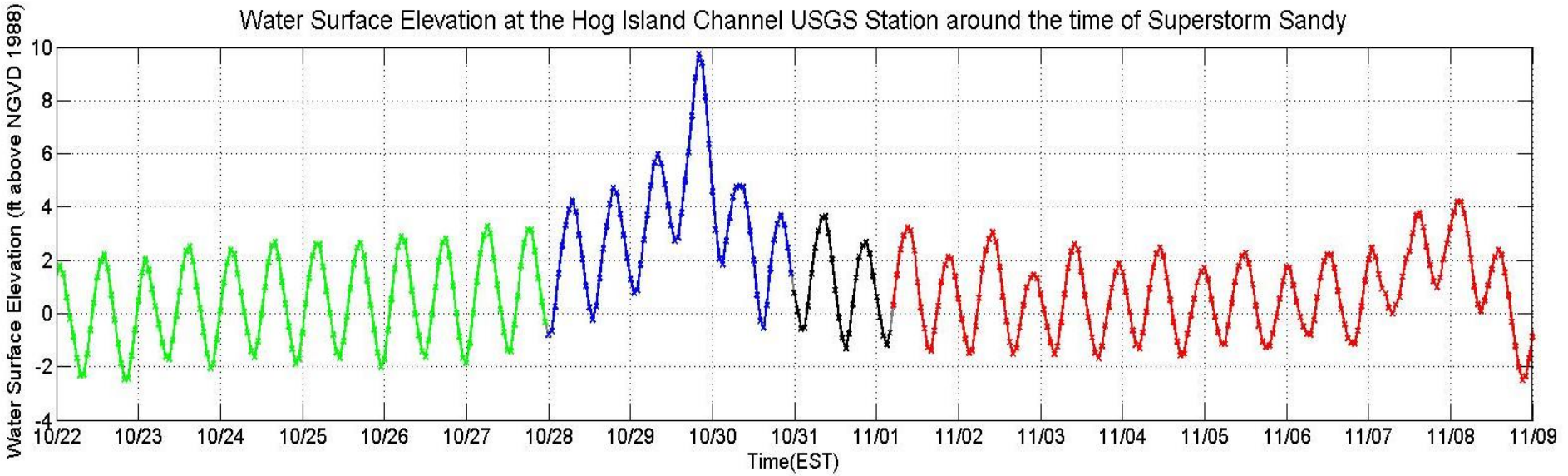


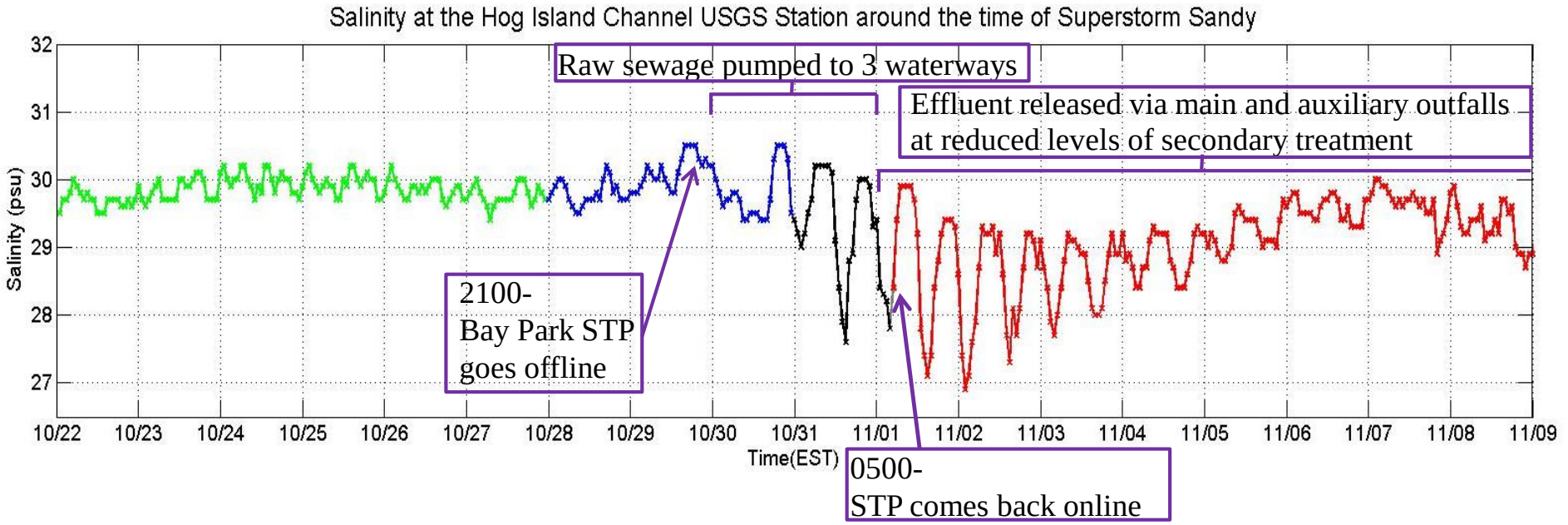


November 24, 2012 - Effluent no longer released via the auxiliary outfall in times of high tide and high volume flow.
December 13, 2012 - SPDES permit compliance achieved.

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# From the Bay Park STP:

## Normal and Post Sandy Estimated Sewage flows past Hog Island Site and their impact on Salinity

| | Normal Discharge MG/tidal day | Normal Flow up Hog Island Channel MG/tidal day | Post Sandy Discharge MG/tidal day | Post Sandy Flow in Hog Island Channel MG/tidal day |
|---|---|---|---|---|
| **The Block** | 51.7 | 21 | 70 | 56 |
| **Auxiliary Outfall** | - | - | 33 | 27 |
| **Total** | 51.7 | 21 | 103 | 83* |

* Observed decline in salinity = 1.2
Estimated from dilution by increased sewage flow = 1.5

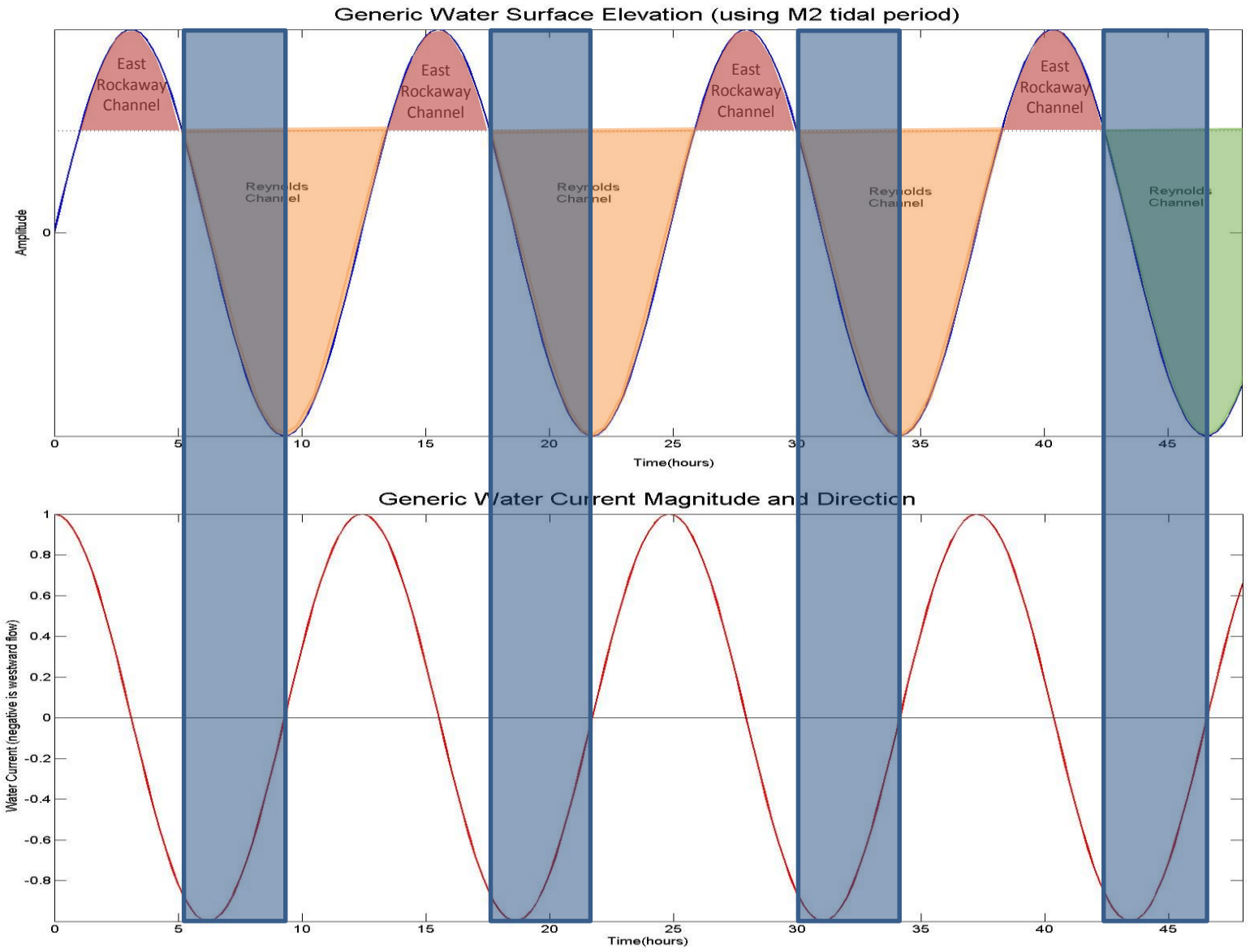
# CBOD

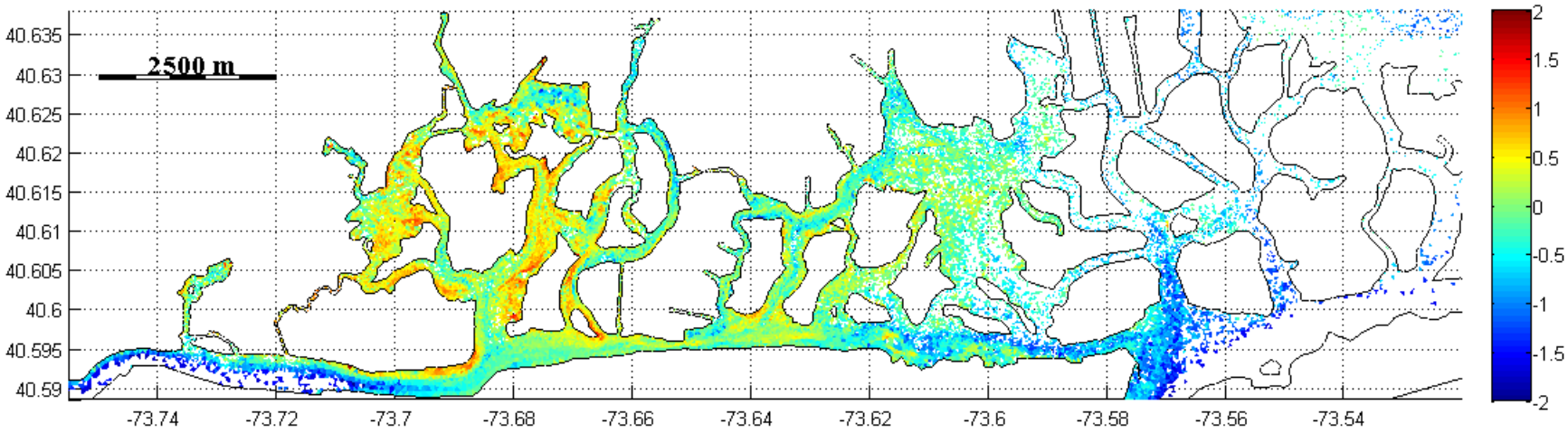
| | Average Influent $CBOD_5$ mg/L | Average Effluent $CBOD_5$ mg/L | Average Effluent $CBOD_5$ Load ton/d | Weighted Average Effluent $CBOD_5$ ton/d | Weighted Average Effluent Nov 1-6 $CBOD_5$ ton/d |
|---|---|---|---|---|---|
| Oct | 225 | 9 | 1.8 | | |
| Nov | 213 | 98 | 29.7 | 28.7 | 27.4 |

Bay Park STP. Influent and effluent $CBOD_5$ concentration and average effluent loads to West Bay during October and November 2012.

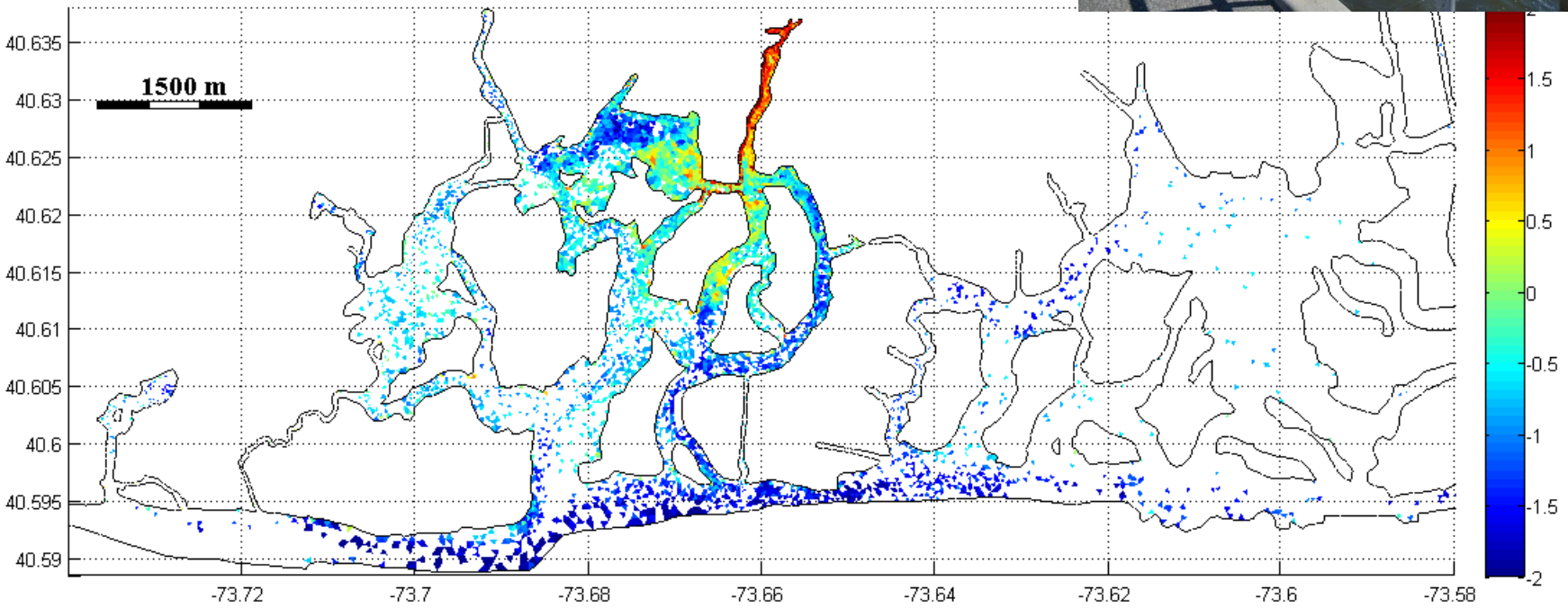
# Dissolved oxygen concentrations, saturation concentrations, and percent saturation at select times pre- and post-Sandy at the USGS Water Quality Station in Hog Island Channel.

| Date/Time EDT | T °C | S | DO Obs mg/L | % Sat | DO Sat mg/L |
|---|---|---|---|---|---|
| 1300 10/24 | 15.6 | 29.8 | 6.8 | 81.93 | 8.30 |
| 1300 10/25 | 15.5 | 30.0 | 6.5 | 78.22 | 8.31 |
| 1300 10/26 | 15.9 | 29.8 | 7.2 | 87.27 | 8.25 |
| 1300 10/27 | 15.9 | 29.7 | 7.0 | 84.85 | 8.25 |
| 0100 10/29 | 15.3 | 29.8 | 7.4 | 88.62 | 8.34 |
| 2112 10/29 | 14.8 | 30.3 | 7.6 | 90.37 | 8.41 |
| 0100 11/1 | 13.5 | 29.4 | 6.5 | 74.88 | 8.68 |
| 2224 high tide 11/1 | 12.9 | 29.4 | 6.9 | 78.50 | 8.79 |
| 0354 low tide 11/2 | 12.3 | 27.5 | 4.6 | 51.05 | 9.01 |
| 1300 11/6 | 11.2 | 29.7 | 6.5 | 71.43 | 9.10 |


Generic Water Surface Elevation (using M2 tidal period)
East Rockaway Channel
Reynolds Channel
Amplitude
0
Time(hours)
Generic Water Current Magnitude and Direction
Water Current (negative is westward flow)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
5
10
15
20
25
30
35
40
45
Time(hours)

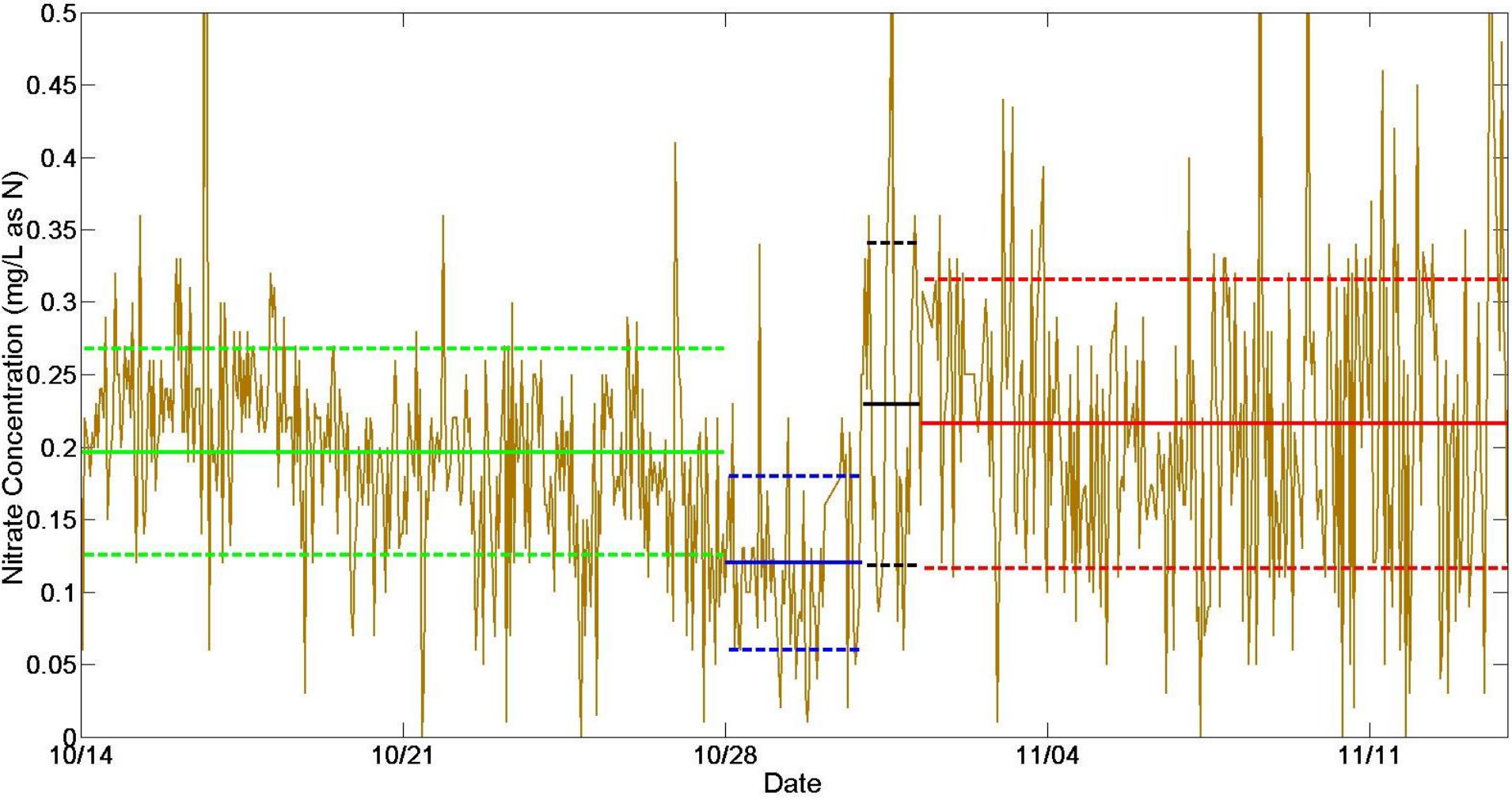



Dilution pattern at **240 hours** after initiation of a release at the site of the Bay Park outfall in Reynolds channel. Dilution defined as particle concentration in an element divided by concentration in the source element; presented as **log to the base 10 of the percent dilution**. Results are from Lagrangian particle tracking simulations; the release was maintained during that part of the tidal cycle when water level in Reynolds Channel **was below MTL**.




Dilution pattern at **240 hours** after initiation of a release at the site of the Bay Park outfall in Reynolds channel. Dilution defined as particle concentration in an element divided by concentration in the source element; presented as **log to the base 10 of the percent dilution**. Results are from Lagrangian particle tracking simulations; the release was maintained during that part of the tidal cycle when water level in Reynolds Channel **was below MTL**.

# Nitrate Concentrations Surrounding Superstorm Sandy

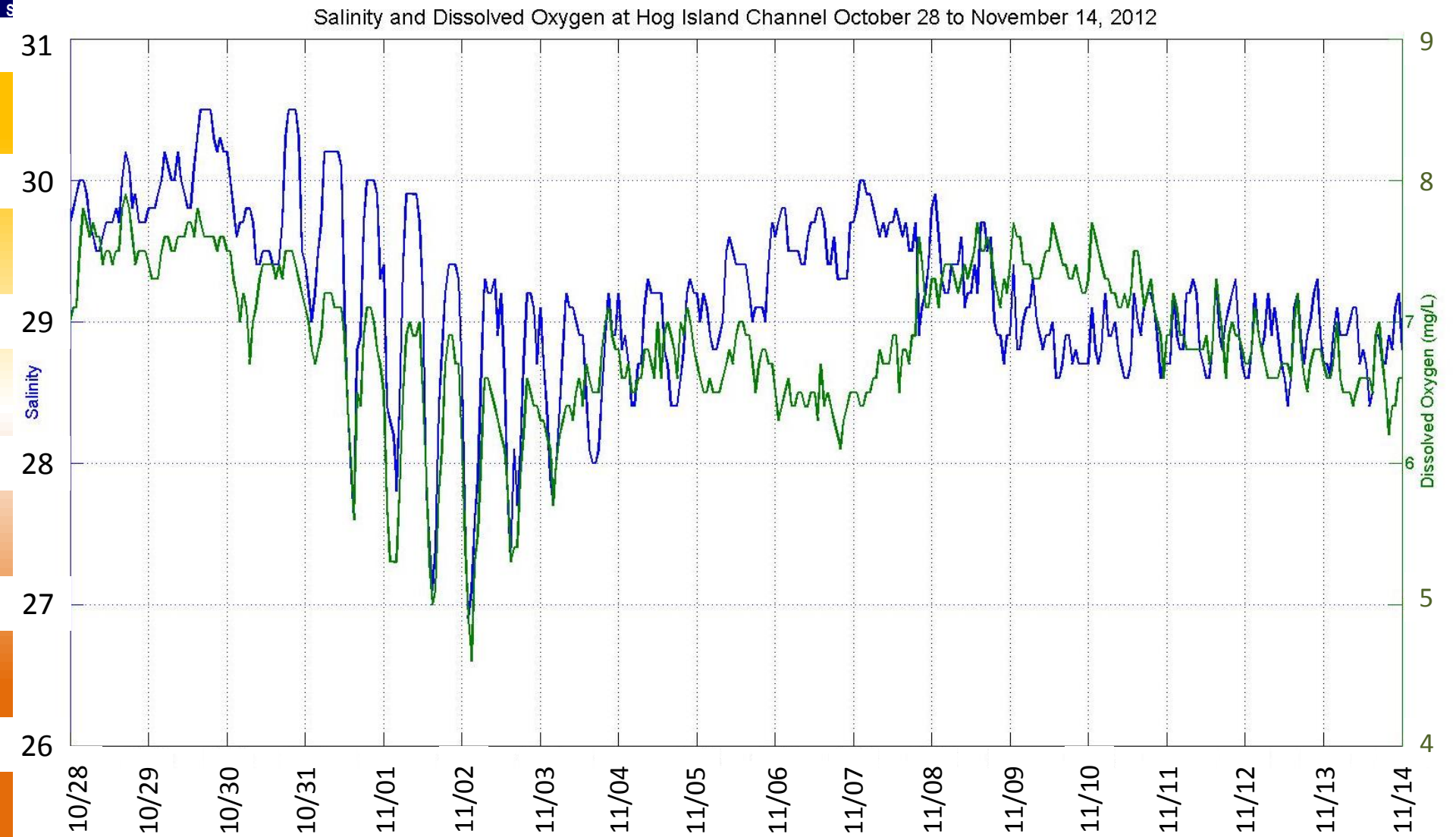



Mean = 0.197 mg/L
std. dev. = 0.071 mg/L

Mean = 0.120 mg/L
std. dev. = 0.060 mg/L

Mean = 0.230 mg/L
std. dev. = 0.111 mg/L

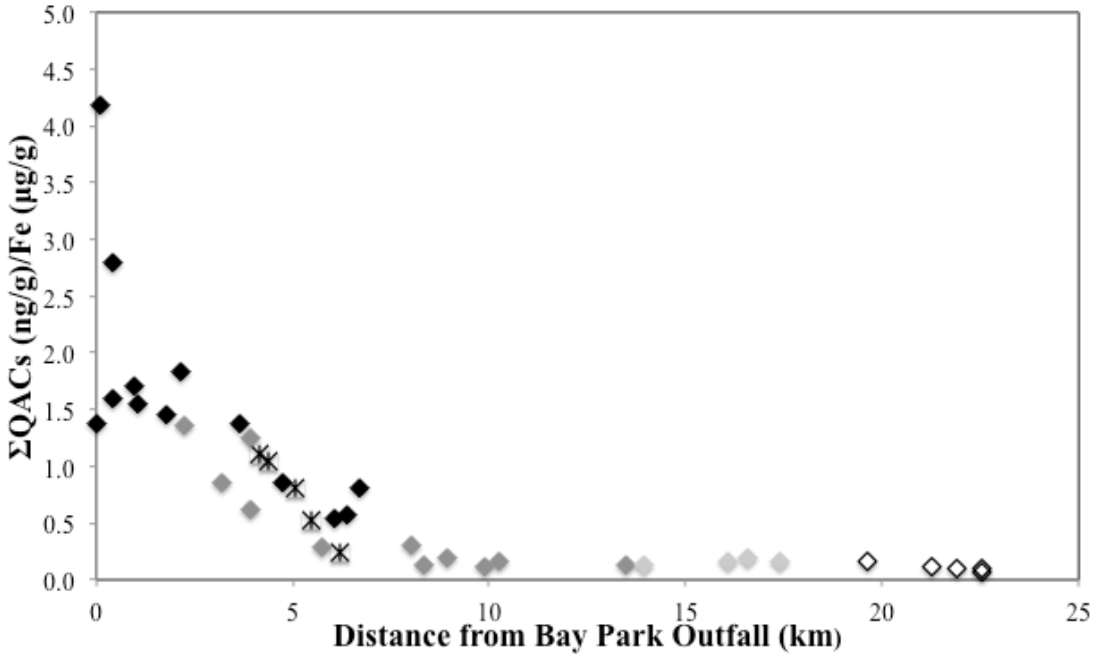
Mean = 0.216 mg/L
std. dev. = 0.100 mg/L


Salinity and Dissolved Oxygen at Hog Island Channel October 28 to November 14, 2012
Salinity
Dissolved Oxygen (mg/L)
31
30
29
28
27
26
9
8
7
6
5
4
10/28
10/29
10/30
10/31
11/01
11/02
11/03
11/04
11/05
11/06
11/07
11/08
11/09
11/10
11/11
11/12
11/13
11/14

# Impacts of Sandy on the Distributions and Inputs of Sewage Derived Contaminants in Hempstead Bay Sediments

**Pre-Sandy** (2011/2012) analysis of quaternary ammonium compound sewage tracers and other contaminants in sediments of Hempstead Bay (60 sites and 4 dated sediment cores)

- Levels of QACs nearly as high as most sewage-contaminated areas of Jamaica Bay
- Decreases of QACs from the Bay Park Outfall, especially when comparing similar sediment types.



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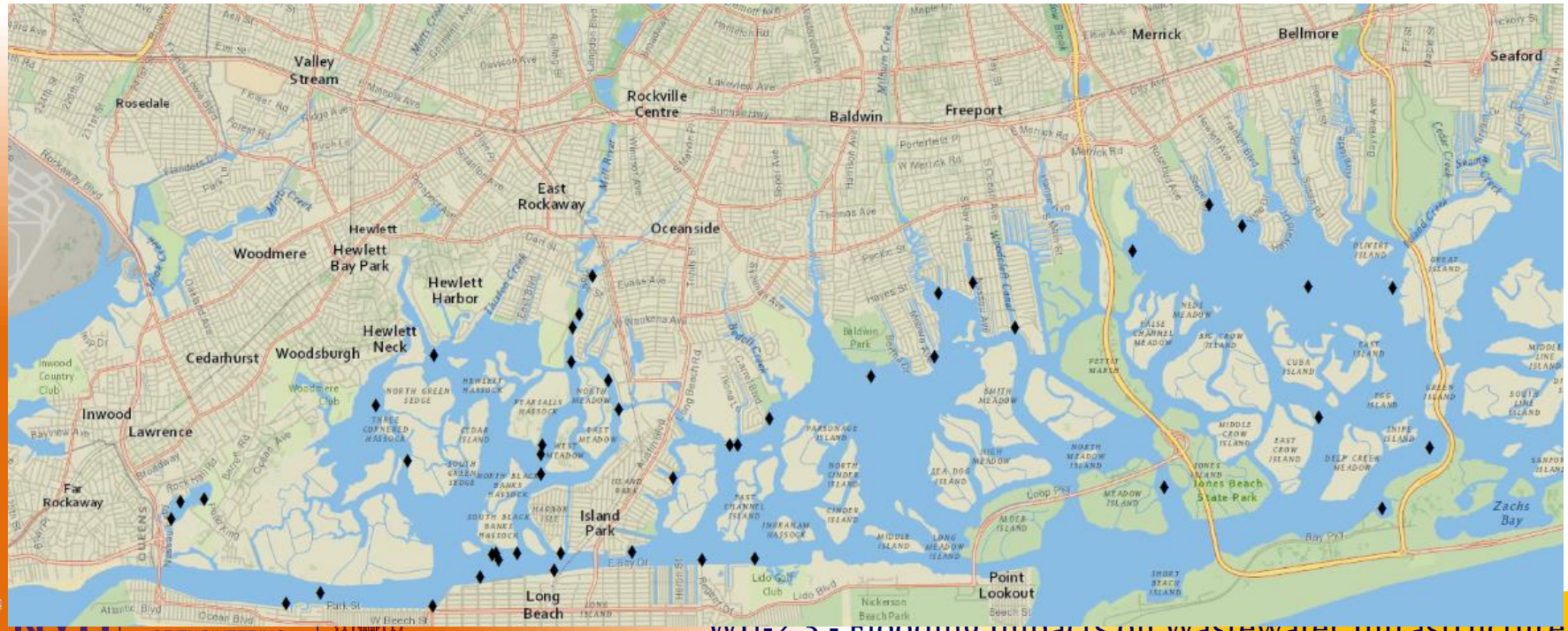
**Post-Sandy** sampling indicated:

- All types of sediments were eroded during Sandy
- A new layer of fine grain sediment was deposited in most formerly muddy areas
- Grain size and organic matter changed at sites nearer to Reynolds Channel



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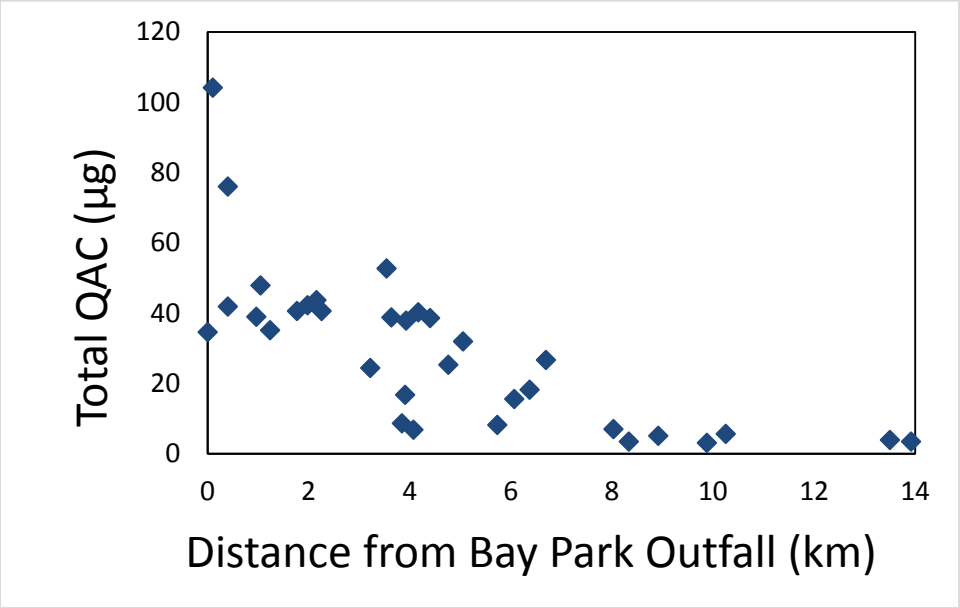
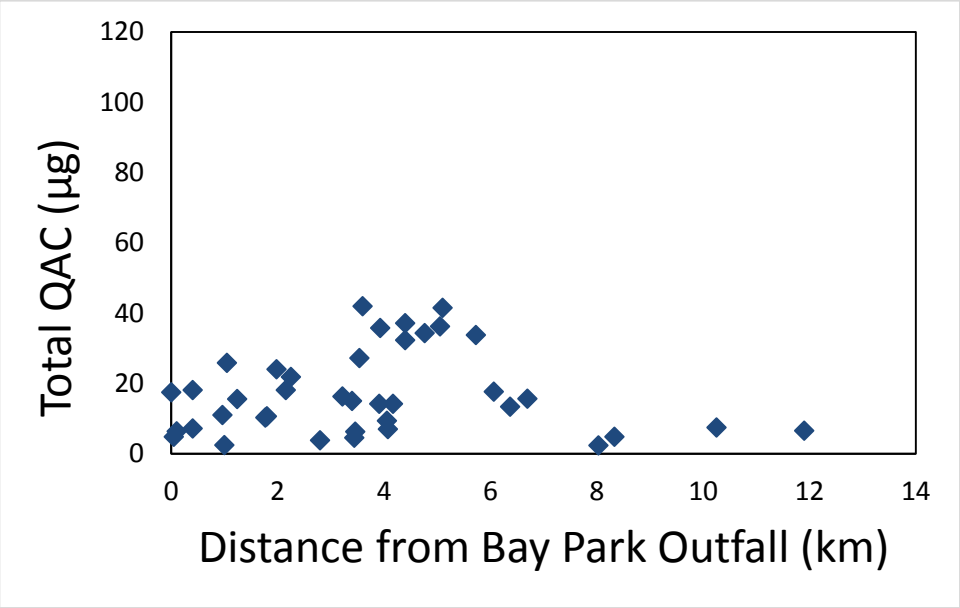
**ΣQAC are reduced in concentration in areas near the outfall (dilution with a source of cleaner fine grain sediment) but are much more similar in areas away from Reynolds Channel– without prior data, the Post-Sandy distributions might suggest a source from East Rockaway Channel inputs of sewage while Bay Park Plant was not pumping all sewage to Reynold's Channel – however, we conclude this is not the primary explanation for observed patterns**

**Pre-Sandy (2011/12)** → **Post-Sandy (2013)**



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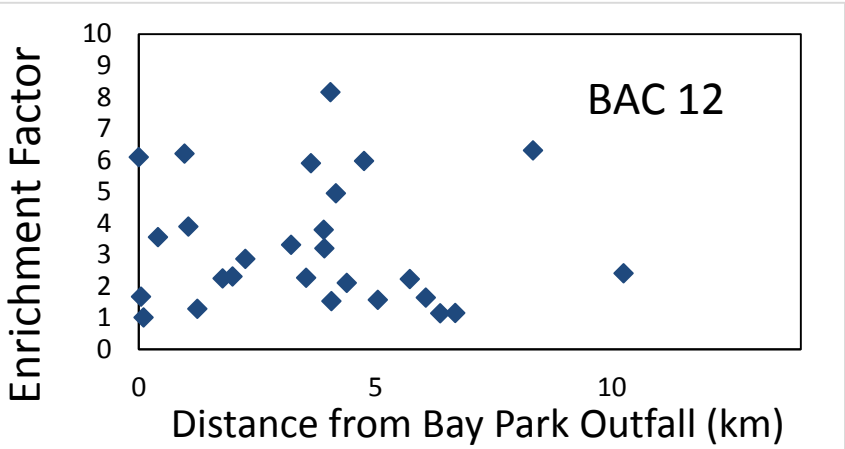
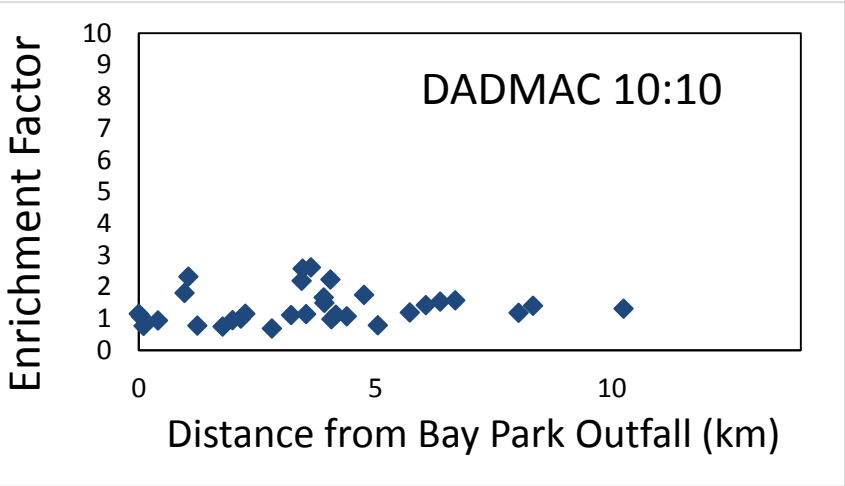
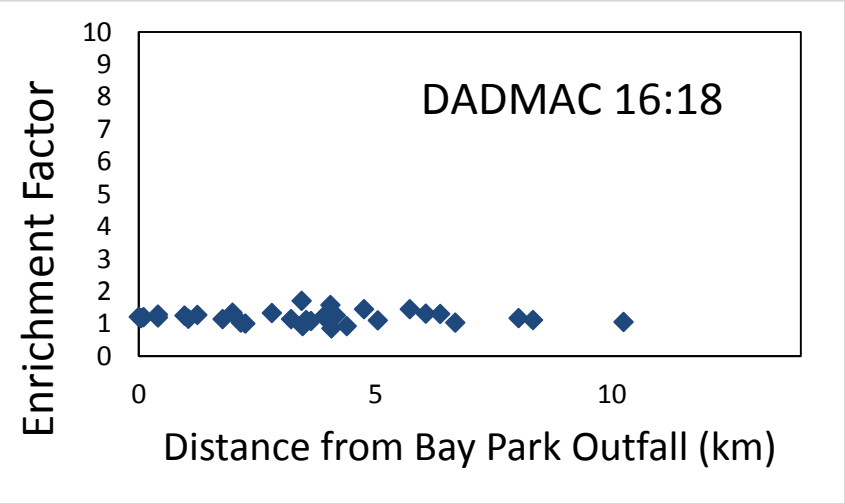
QAC specific variations in degree of average enrichment (Post/Pre levels at same Stations) match expectations for **increased inputs during period of less effective sewage treatment** (e.g., same order near CSOs (Li and Brownawell, 2010)

Also observed for pharmaceuticals in Jamaica Bay (Benotti and Brownawell, 2007) - less treated sewage will lead to greatest enrichment of wastewater contaminants normally well removed by treatment (e.g., consider pathogens without disinfections)

**Increasing Removal by Secondary Treatment**



# Bay Park STP Impacts in West Bay following Sandy

- Short Term- Water Column
  - Decreased salinity
  - Increased BOD
  - Decreased DO
  - Increased Nitrate
  - Decreased pH
- Long Term- Water Column and Sediments
  - Redistributed sewage contaminated sediments
  - Contributed to impaired status

# Bay Park STP Remediation

- Constructing an 18ft berm around the facility
- Elevating electrical supply
- Installing check valves and slide gates on two stormwater outfalls
- Eliminating need for auxiliary outfall
- Implementing seasonal dissolved nitrogen removal*

* Part of the debate over the ocean outfall