Memo

Date:	Wednesday, November 22, 2023
Project:	LIS-HWQMS Project
To:	DEP/EPA
From:	Andy Thuman, Rich Isleib (HDR)
Subject:	LIS ROMS Hydrodynamic Model Inputs and RCA Water Quality Model Load Development Approach

1. Introduction

This document describes the plan for acquiring or estimating model load inputs for the new Long Island Sound (LIS) hydrodynamic model (ROMS) and water quality model (RCA). As the available data are thoroughly analyzed and the model calibration continues, this plan may need to be updated if modifications are needed.

This document discusses the hydrodynamic model inputs used for the ROMS model calibration and the water quality loading methodology used in the previous System-Wide Eutrophication Model (SWEM) development along with the updated approach to be used for the RCA water quality model calibration. The water quality methodology differences are generally due to the differing availability of data at the time of SWEM load development and now. The new ROMS and RCA models will use recently collected data and will benefit from continued research in LIS since SWEM model development. The hydrodynamic model inputs and water quality model loading approach described for the new LIS models apply to the modeling time period from 2003 through 2022. Model testing with water year 1995 (WY95) data will use the original SWEM hydrodynamic model inputs and loads.

2. ROMS Hydrodynamic Model Inputs

a. Bottom Friction

Bottom stress is calculated in the model using a logarithmic velocity profile and a model bottom roughness length (ZoB) of 0.002 meters throughout the model grid with adjustments to 0.05 meters in the East and Harlem Rivers, and 0.05 meters on the eastern end of LIS where sand and gravel bottom types are present. The bottom roughness length adjustment on the eastern end of LIS was based on ROMS modeling by others (Whitney and Codiga, 2011; Jia and Whitney, 2019). Figure 1 shows the spatial extent of the area with the higher bottom friction coefficient in the East and Harlem Rivers used to reflect the narrow reaches of these water bodies as part of the model water elevation and salinity calibration. The bottom friction coefficient may be further reviewed and adjusted as the model calibration proceeds.

b. Boundary Conditions

To supply ROMS with the required offshore model boundary condition inputs, output from an ADCIRC (Advanced Circulation Model) model (version ec2001_V2e) was used to supply both water elevations and velocities by mapping the ADCIRC output onto the ROMS model grid (https://adcirc.org/products/adcirc-tidal-databases/). ADCIRC databases are available and provide tidal constituents and current

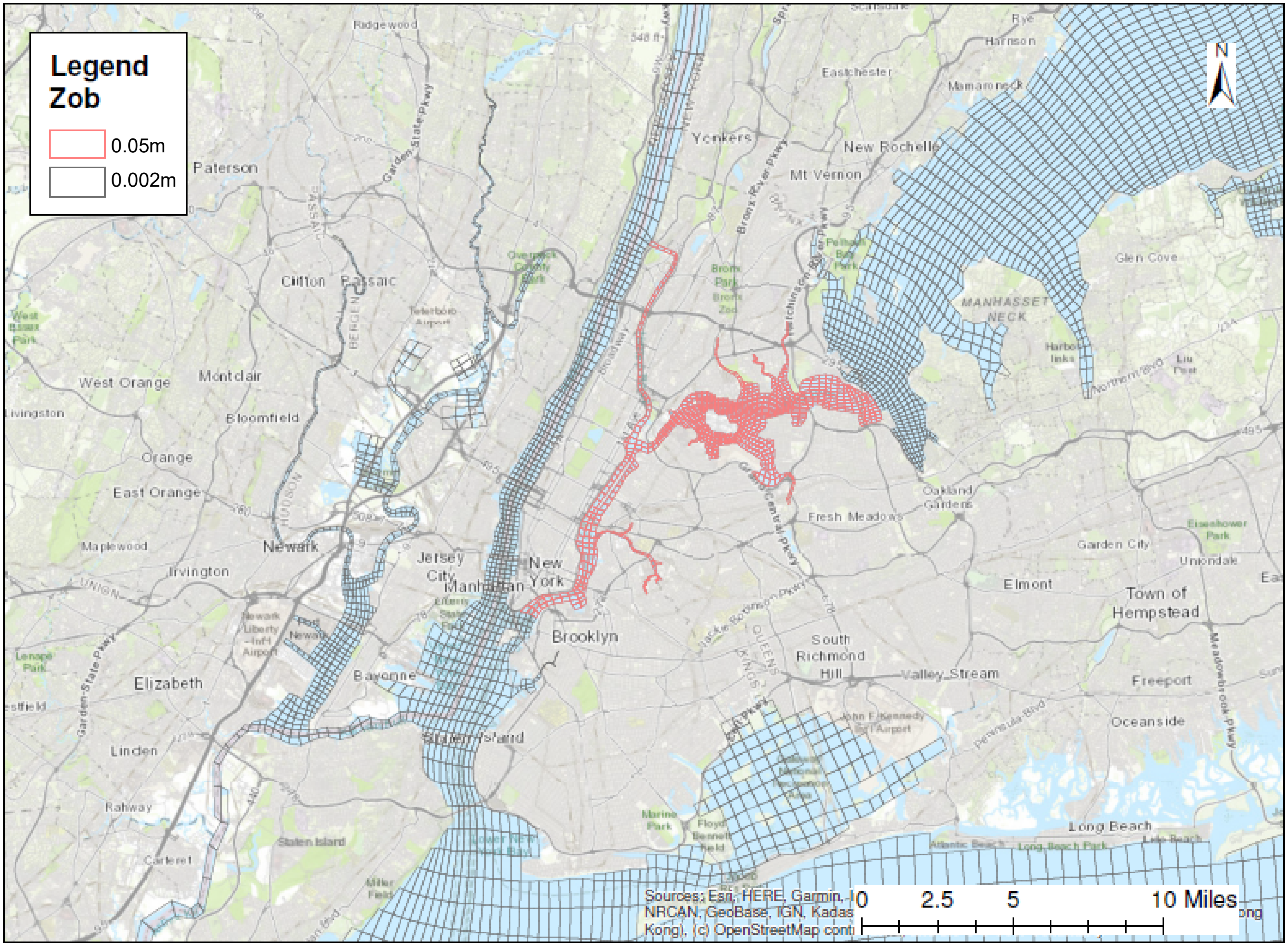


Figure 1. Model Bottom Roughness Length

velocities for a desired location and is another circulation model that has been applied to different portions of the globe.

ADCIRC only supplies the tidal harmonic portion of the water elevations (i.e., astronomical component). Meteorological forcings such as wind speed/direction and atmospheric pressure also affect tidal water elevations. To account for the meteorological forcings effect on the water elevations at the offshore boundary condition locations, a 35-hour low-pass filter was applied to the NOAA water elevation data at Atlantic City, NJ (NOAA station ID 8534720) and added to the ADCIRC tidal harmonic based water elevations.

Temperature and salinity model inputs are assigned to the boundary conditions locations using model output from the Northeast Coastal Ocean Forecast System (NECOFS), which is a Finite-Volume Community Ocean Model (FVCOM) of the northeast US coastal region developed by the Marine Ecosystem Dynamics Modeling Laboratory (MEDM-Lab) at the School for Marine Science and Technology, University of Massachusetts-Dartmouth. Model output from NECOFS archived files were extracted to provide ROMS model temperature and salinity inputs at the model boundary condition input locations on a daily basis. Figure 2 presents the location of example surface and bottom model boundary condition inputs presented in Figure 3. Figure 3 presents the original World Ocean Atlas (WOA) temperature and salinity boundary condition inputs originally used and the new NECOFS boundary condition inputs currently in use for comparison.

ROMS includes several options for specifying boundary condition inputs (Boundary Conditions - WikiROMS (myroms.org)). Table 1 presents the chosen options for the ROMS calendar year (CY) 2005-2006 model inputs. The western and northern boundaries are closed because they border land, New Jersey to the west and Connecticut and Rhode Island to the north.

Table 1. Offshore Boundary Condition Options

Boundary Condition	West	South	East	North
Free-surface	Closed	Chapman	Chapman	Closed
2D U-momentum	Closed	Flather	Flather	Closed
2D V-momentum	Closed	Flather	Flather	Closed
3D U-momentum	Closed	Radiation	Radiation	Closed
3D V-momentum	Closed	Radiation	Radiation	Closed
Mixing TKE	Closed	Radiation	Radiation	Closed
Temperature	Closed	Radiation-Nudging	Radiation-Nudging	Closed
Salinity	Closed	Radiation-Nudging	Radiation-Nudging	Closed

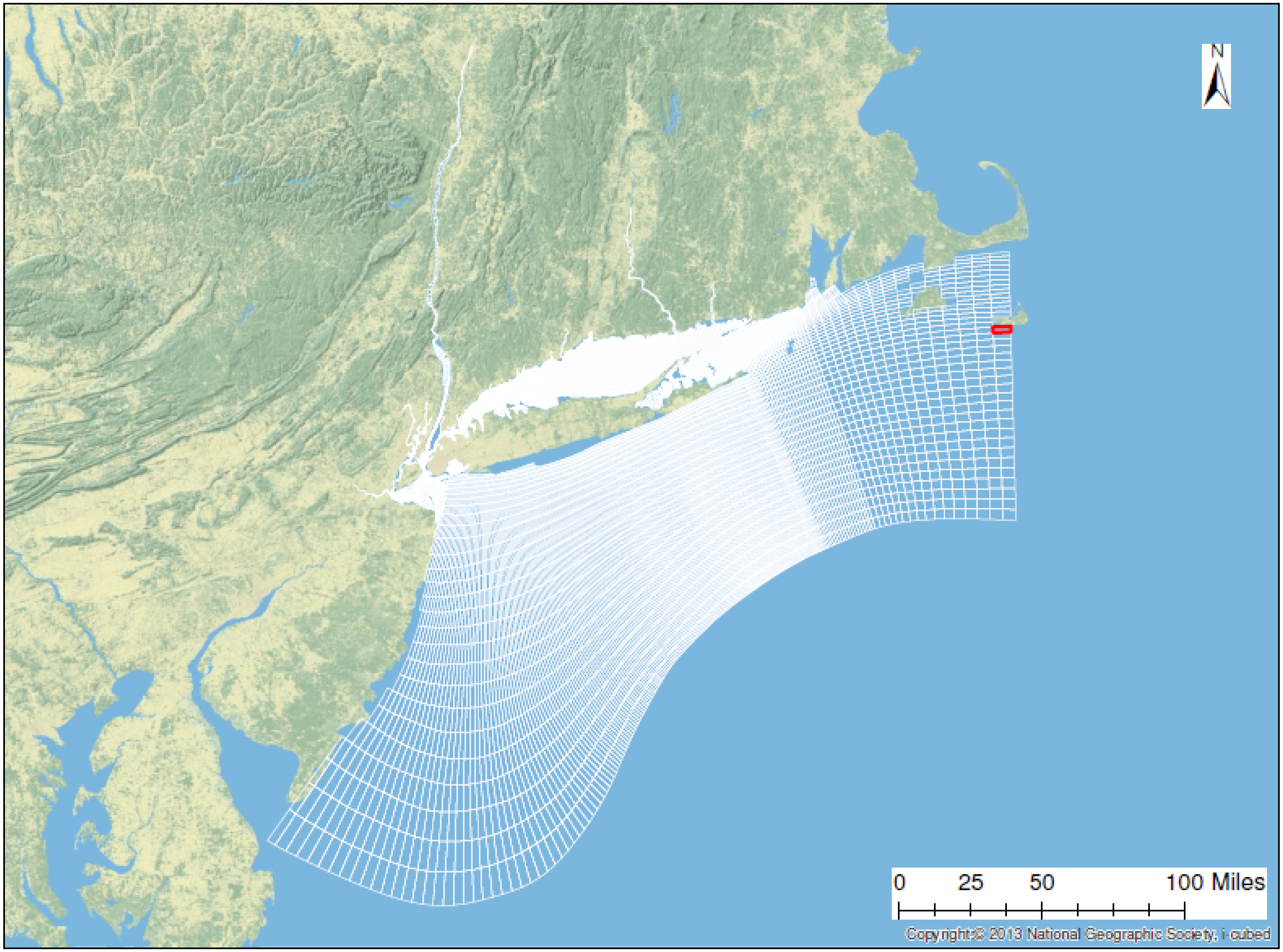


Figure 2. Location of Example Boundary Condition Model Segment

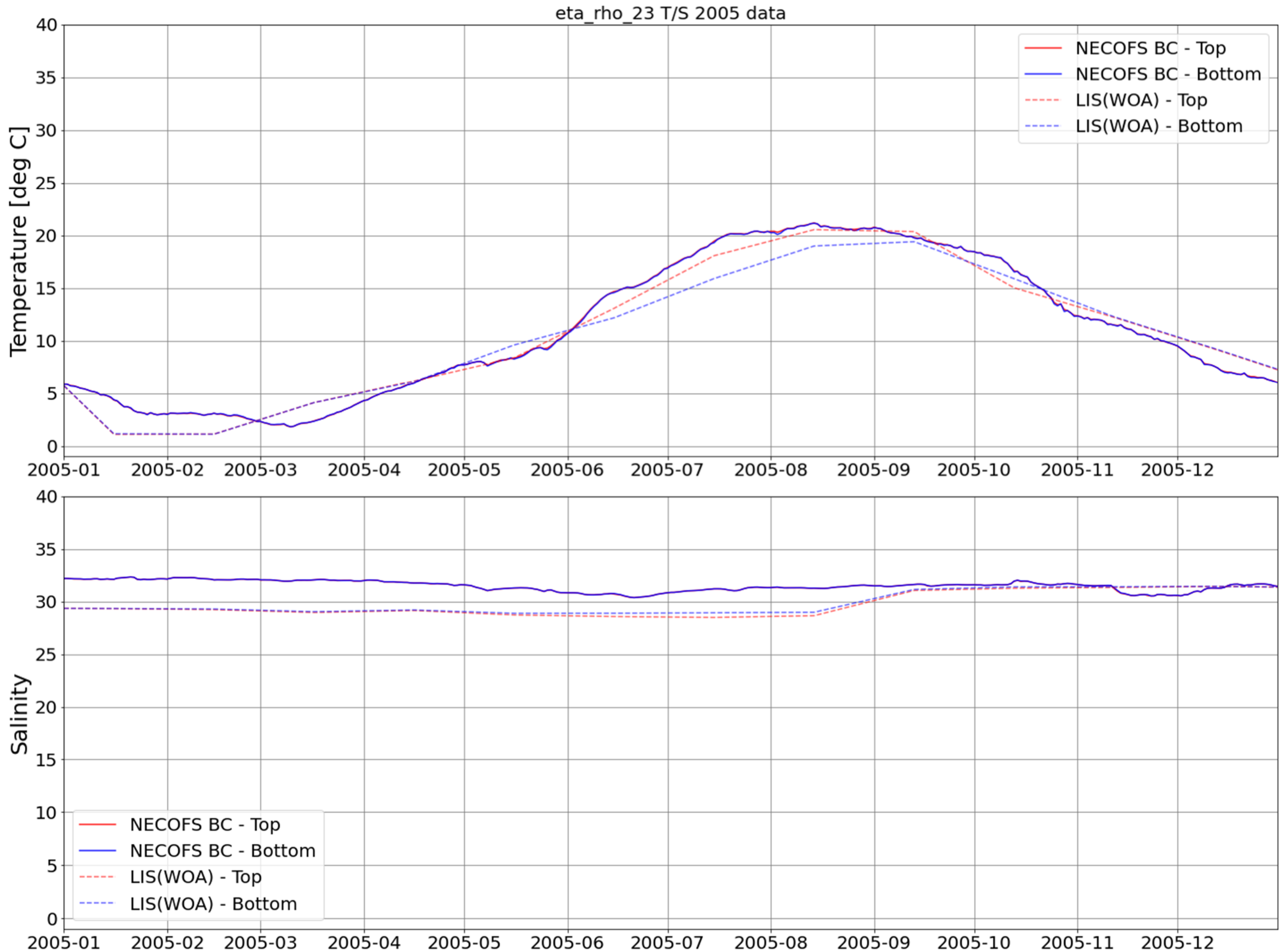


Figure 3. Example of Temperature and Salinity Assigned at the Model Boundary <u>(2005)</u>

c. Freshwater

Freshwater inputs define the source locations, volumes, and timing of freshwater discharges entering the model. These sources include rivers, water resource reclamation facilities (WRRFs) or wastewater treatment plants (WWTPs), combined sewer overflows (CSOs), direct runoff, stormwater, and groundwater.

Rivers

River flow model inputs were assigned based on data available at United States Geological Survey (USGS) gages in CT, NY, and NJ. Attachment 1 lists the rivers assigned in the model with available flow data at USGS gages (Figure 4). In locations without gages, or locations with data gaps, flows were estimated using similar rivers and adjusting from the USGS gage drainage area to the drainage area where flow estimates are needed (see Attachment 1). Some rivers were modified using the USGS StreamStats tool to generate flows for ungaged watershed areas in the Hudson River and East River (see Attachment 1). Table 2 presents the annual average river flows for the 10 largest rivers based on annual average flow and presented in Attachment 1 for all rivers included in the model. For CY05 and CY06, annual average river flows were very similar with the two largest flows originating from the Connecticut and Hudson Rivers.

The total drainage area entering LIS from CT, RI and NY (excluding NYC) is estimated as 16,180 mi^2. There are river flows assigned in the model from 24 rivers in CT, 1 river in RI, and 8 rivers in Westchester County and Long Island. These 33 river inputs account for 14,478 mi^2 and the estimated total drainage area is about 12% greater than the assigned river flow drainage area. A sensitivity to increasing the model assigned river flows by 12% in CT, RI, and NY resulted in minor decreases in salinity in LIS, primarily during the higher flow spring months. This flow increase will be used as part of future ROMS hydrodynamic model calibration improvements as the calibration process continues.

River temperatures were assigned based on available data from gages. The following USGS and NOAA gages were used to assign model river temperature inputs.

- USGS 01389005 Passaic River below Pompton River at Two Bridges, NJ
- USGS 01372058 Hudson River below Poughkeepsie, NY
- USGS 01193500 Salmon River near East Hampton, CT
- USGS 01196500 Quinnipiac River at Wallingford, CT
- NOAA 8518750 The Battery, NY

Temperature data gaps in the Passaic and Hudson Rivers were replaced by data from The Battery. Data gaps in the Quinnipiac River were replaced with data from the Salmon River or The Battery if the Salmon River had data gaps.

Rivers discharging into the Hudson River, East River and from the north shore of Long Island (including the Peconic River) were assigned temperatures from the Poughkeepsie, NY gage. Rivers in Connecticut were assigned temperatures from the Quinnipiac River gage. Rivers in NJ were assigned temperatures from the Passaic River, NJ gage.

All rivers were assigned a salinity of 0.0 practical salinity units (psu).

hdrinc.com 50 Tice Boulevard, Suite 210, Woodcliff Lake, NJ 07677-7654
(201) 335-9300

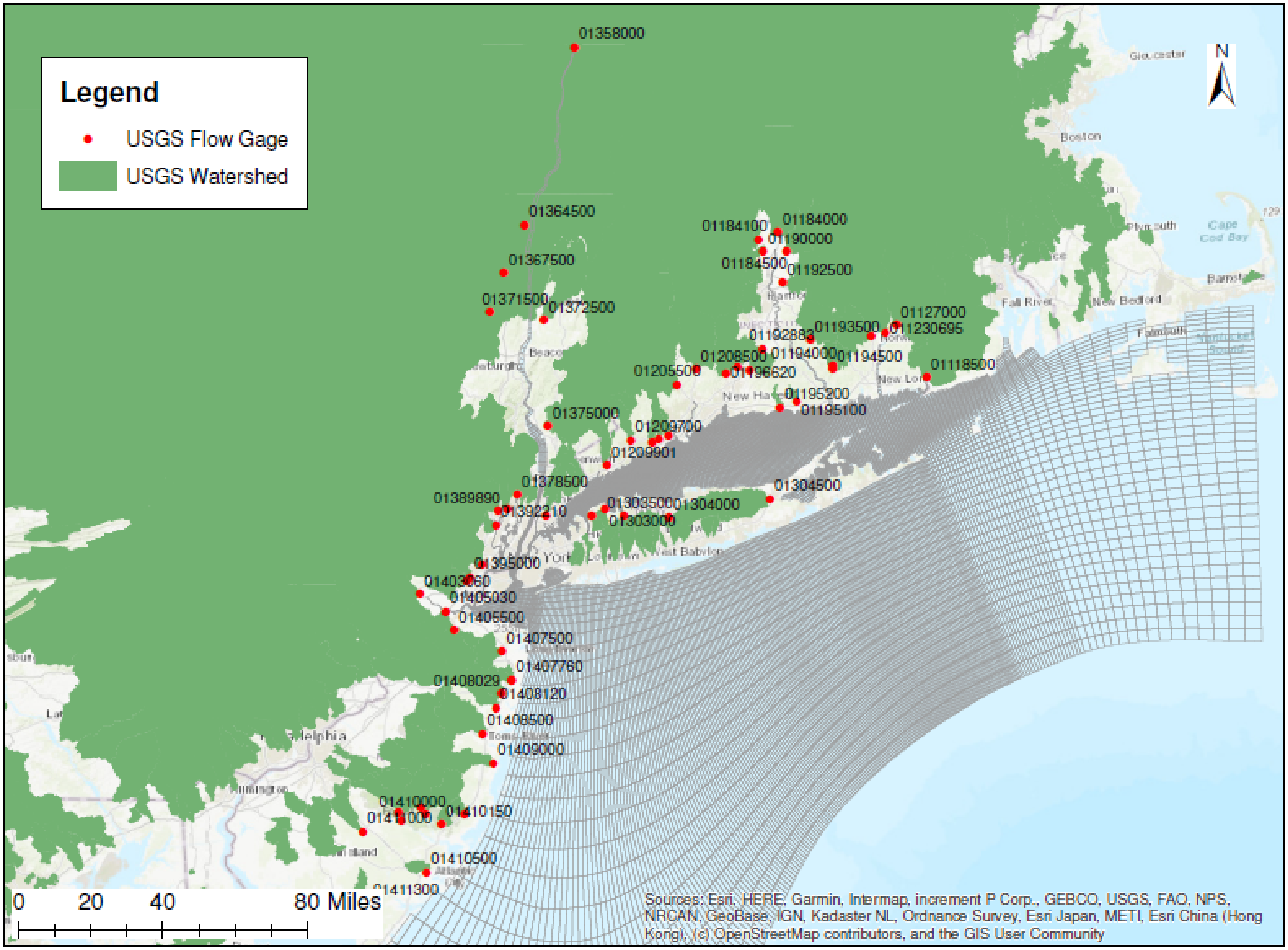


Figure 4. USGS Flow Gages used to Assign River Flows

Table 2. Ten Largest River Flows

River	State	2005 Annual Average (cfs)	2006 Annual Average (cfs)
Connecticut River at Thompsonville (01184000)	CT	23,206	23,571
Hudson River at Green Island (01358000)	NY	16,989	20,418
Housatonic River at Stevenson (01205500)	CT	3,548	3,655
Quinnebaug River at Jewett City, Shetucket River at Taftville & Yantic River at Yantic (01127000, 011230695, 01127500)	CT	3,189	3,140
Rondout Creek at Rosendale (01367500)	NY	2,758	2,507
Farmington River at Rainbow (01190000)	CT	1,403	1,784
Wallkill River at Gardiner (01371500)	NY	1,663	1,445
Passaic River at Dundee Dam at Clifton (01389890)	NJ	1,525	1,523
Raritan River below Calco Dam at Bound Brook (01403060)	NJ	1,391	1,387
Esopus Creek at Mount Marion (01364500)	NY	861	1,198

WRRFs

Freshwater flows from the New York City Department of Environmental Protection (DEP) WRRFs which were assigned in the model based on plant records supplied by DEP and each was assigned on a daily average basis. Flows from other non-DEP WRRFs were based on available plant records. Only WRRFs with flows greater than 1.0 MGD were included in the model. Figure 5 shows the location of the DEP WRRFs and Figure 6 presents the locations of the other non-DEP WRRFs assigned in the model. Attachment 2 presents the WRRF effluent flow locations assigned in the model along with annual average effluent flows for the assigned non-DEP WRRFs and approximate frequency of data availability. Table 3 presents the annual average effluent flows for DEP WRRFs and Table 4 presents the annual average effluent flows for other WRRFs with flows greater than 10 MGD. As with the CY05 and CY06 river flows, effluent flows for 2005 and 2006 were very similar.

Table 3. DEP WRRF Effluent Flows

DEP WRRF	2005 Annual Average (MGD)	2006 Annual Average (MGD)
Tallman Island	60	57
Hunts Point	133	129
Bowery Bay	119	109
Wards Island	211	218

DEP WRRF	2005 Annual Average (MGD)	2006 Annual Average (MGD)
Newtown Creek	230	236
Red Hook	31	34
North River	129	127
Port Richmond	32	32
Owls Head	103	105
Coney Island	93	89
26th Ward	59	58
Jamaica	86	88
Rockaway	21	23
Oakwood Beach	30	30

Table 4. Other WRRF Effluent Flows

WRRF	State	2005 Annual Average (MGD)	2006 Annual Average (MGD)
Passaic Valley Sewerage Commission (NJ0021016)	NJ	256	259
Middlesex County Utilities Authority (NJ0020141)	NJ	197	223
Bergen County Utilities Authority (NJ0020028)	NJ	86	85
Joint Meeting of Essex & Union Counties (NJ0024741)	NJ	67	70
South Shore Water Reclamation Facility (NY0026450)	NY	61	59
Greater New Haven Water Pollution Control Authority (CT0100366)	CT	33	34
Rahway Valley Sewerage Authority (NJ0024643)	NJ	31	31
Pfizer Groton (CT0000957)	CT	31	24
Bridgeport West Side Water Pollution Control Facility (CT0100056)	CT	26	27
Ocean County Utilities Authority Central Water Pollution Control Facility (NJ0029408)	NJ	23	22
Ocean County Utilities Authority Northern Water Pollution Control Facility (NJ0028142)	NJ	23	22

WRRF	State	2005 Annual Average (MGD)	2006 Annual Average (MGD)
City of Stamford Water Pollution Control Facility (CT0101087)	CT	16	18
Monmouth County Bayshore Outfall Authority (NJ0024694)	NJ	16	16
City of Norwalk Water Pollution Control Facility (CT0101249)	CT	12	15
North Hudson Sewerage Authority Adams Street Wastewater Treatment Plant (NJ0026085)	NJ	13	13
Cape May County Municipal Utilities Authority Wildwood/Lower Region Wastewater Treatment Facility (NJ0053007)	NJ	12	12
Linden Roselle Sewerage Authority (NJ0024953)	NJ	11	11
Two Rivers Water Reclamation Authority (NJ0026735)	NJ	10	10
North Hudson Sewerage Authority River Road Sewerage Treatment Plant (NJ0025321)	NJ	10	10

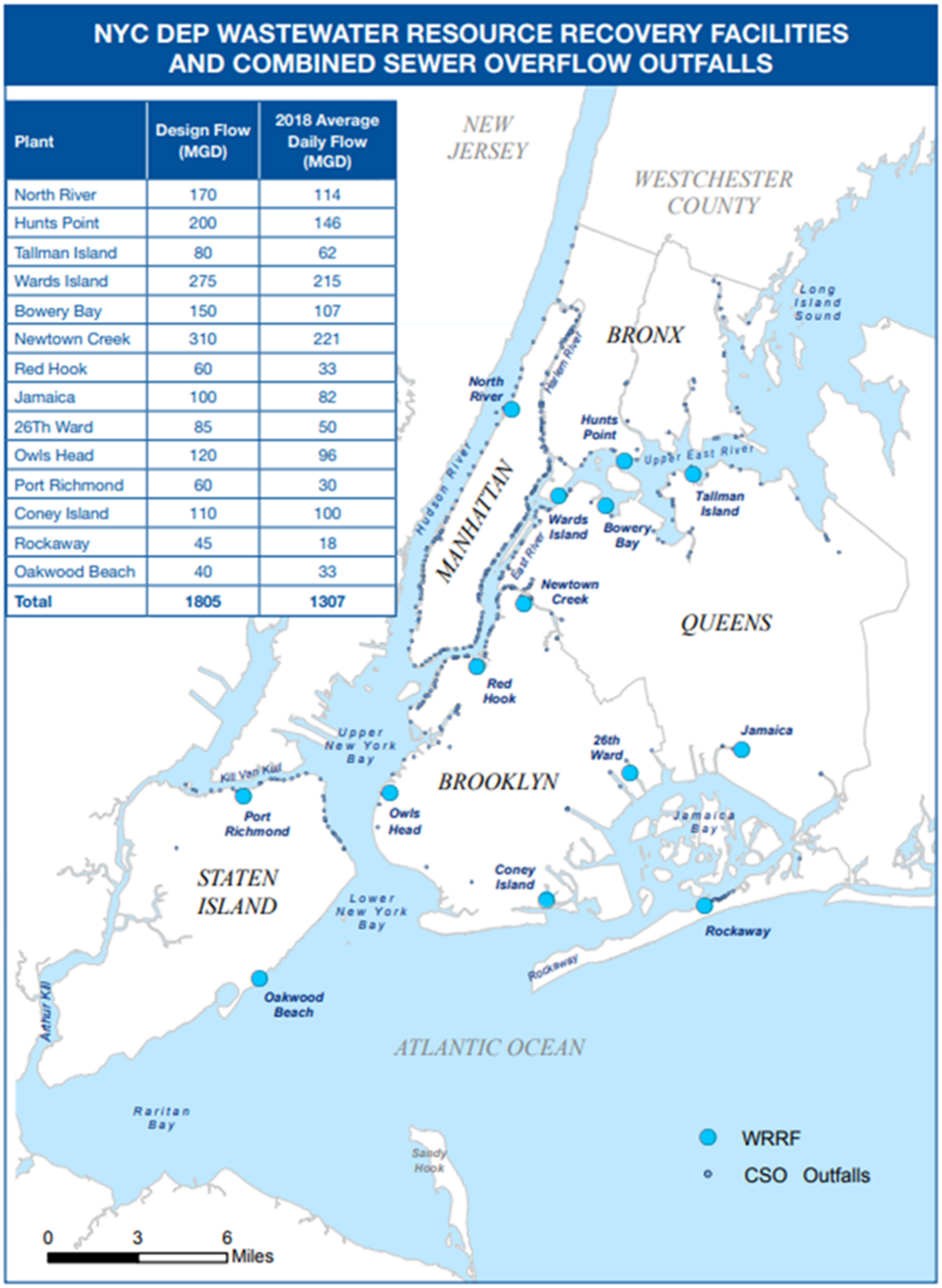
CSOs and Stormwater

In the modeling, stormwater includes flow from stormwater outfalls and direct runoff to a water body. Flows from DEP CSOs, stormwater and direct drainage were obtained from DEP InfoWorks model output. Flows were available for 13 of the 14 DEP WRRF sewersheds (12 models in total) which were used for existing conditions and were assigned on a daily basis. CSO and stormwater flows from the Oakwood Beach WRRF sewershed were based on an InfoWorks model run completed by HDR. Figure 7 presents the locations of the DEP and other NYC-area CSO locations in the left image.

The NY/NJ Harbor RAINMAN model (HydroQual, 2005) was used to provide flows for northern New Jersey and Westchester County, NY CSO and stormwater model inputs and flows were assigned on a daily basis. The RAINMAN model is based on a simplification of the EPA Storm Water Management Model (SWMM) but does not represent the sewer collection system. It has been applied in New York City and portions of New Jersey that result in discharges to NY/NJ Harbor. Flow is calculated as a function of rainfall, drainage area, and a runoff coefficient and completes a flow balance around CSO regulators and their capacities. Excess flow at the CSO regulators (i.e., not directed to a WRRF or downstream) discharges directly to an outfall. The advantage of this approach is that it is more site-specific per outfall and yet does not calculate time-consuming, dynamic hydraulic equations for flow routing. Rather, simple simulations of rainfall runoff, discharge to outfalls, and volumes captured for storage/treatment can be executed for large separate and combined collection systems for long-term simulations.

CT CSO flows were assigned as a constant flow based on Long Term Control Plans (LTCP) or Facility Plans for the cities of New Haven, Norwich, Bridgeport, and Hartford (CH2M 2018, CDM Smith 2020, CDM Smith 2020b, Norwich Department of Public Utilities 2015). When available, annual CSO volumes from typical year analysis were converted to constant annual flows. The Town of Bridgeport LTCP provided pre- and post-construction volumes that allowed for annual flows to be modified over the course of the calibration period.

Figures 7a and 7b present the locations of the CSO sources in the right image. Attachment 2 presents the CSO and stormwater flow locations assigned in the model.



Plant	Design Flow (MGD)	2018 Average Daily Flow (MGD)
North River	170	114
Hunts Point	200	146
Tallman Island	80	62
Wards Island	275	215
Bowery Bay	150	107
Newtown Creek	310	221
Red Hook	60	33
Jamaica	100	82
26Th Ward	85	50
Owls Head	120	96
Port Richmond	60	30
Coney Island	110	100
Rockaway	45	18
Oakwood Beach	40	33
Total	**1805**	**1307**

Figure 5. NYCDEP WRRFs

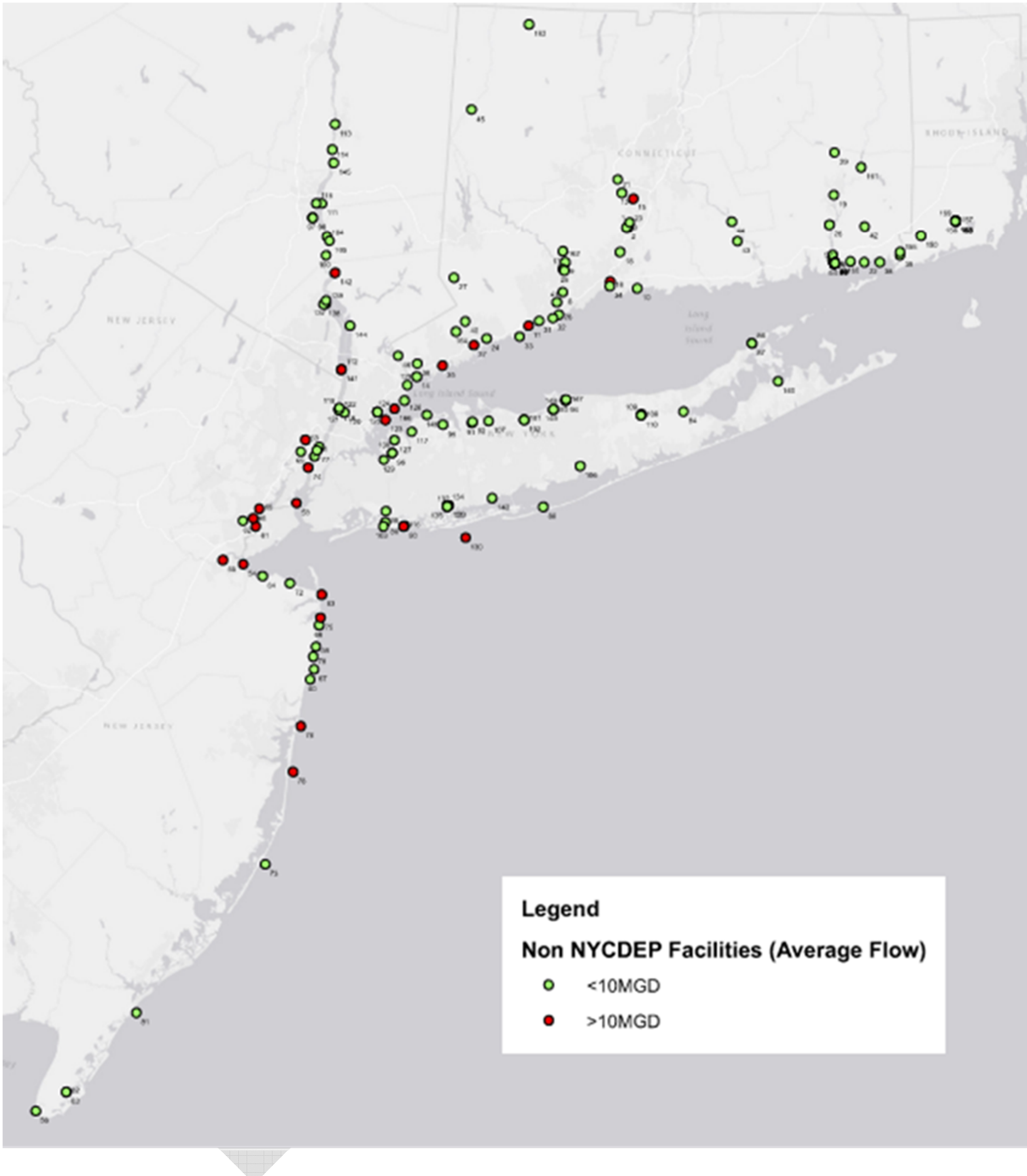


Figure 6. Non-NYCDEP Wastewater Treatment Plants within the Model Study Area

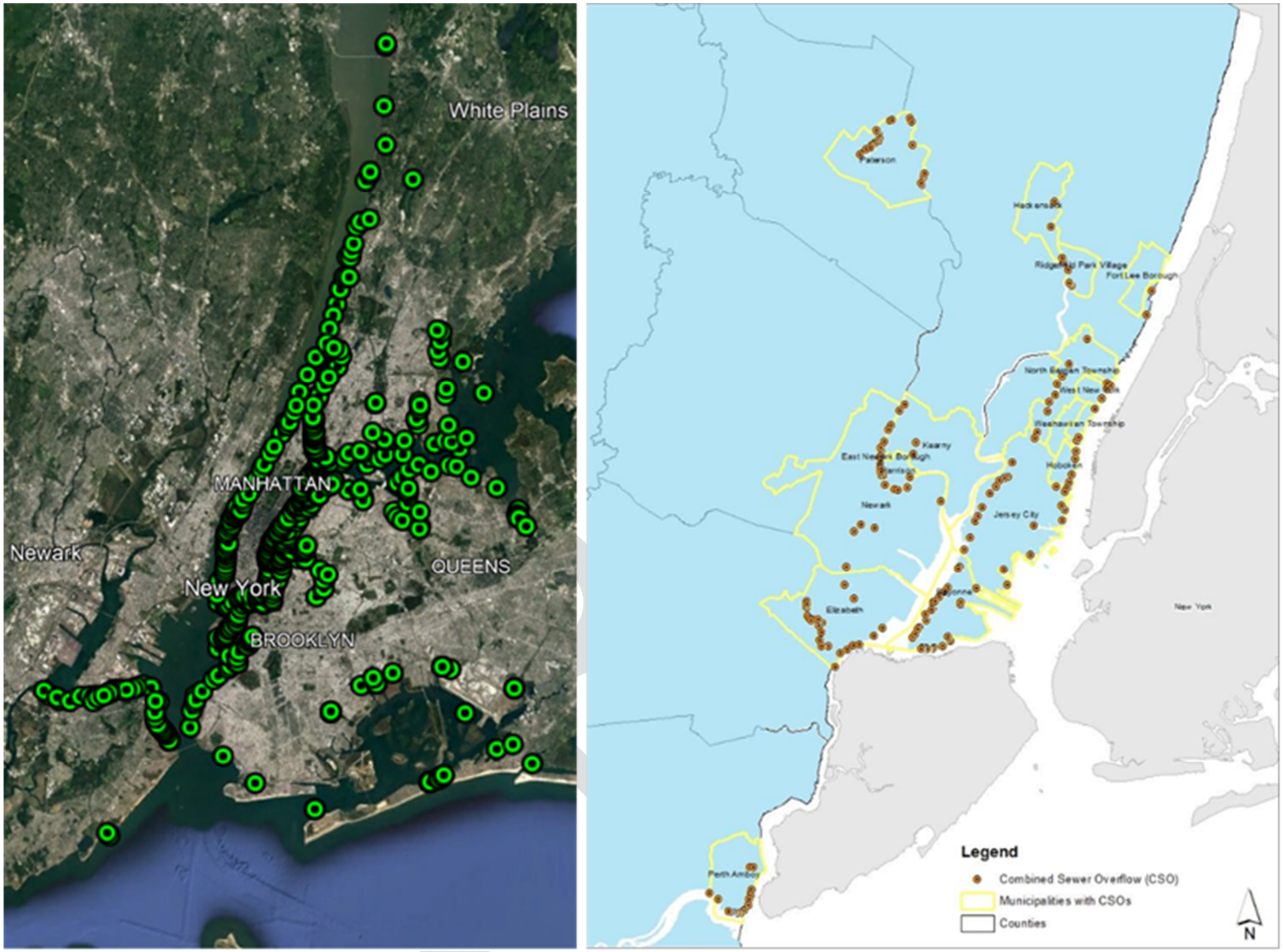


Figure 7a. Locations of CSO Sources

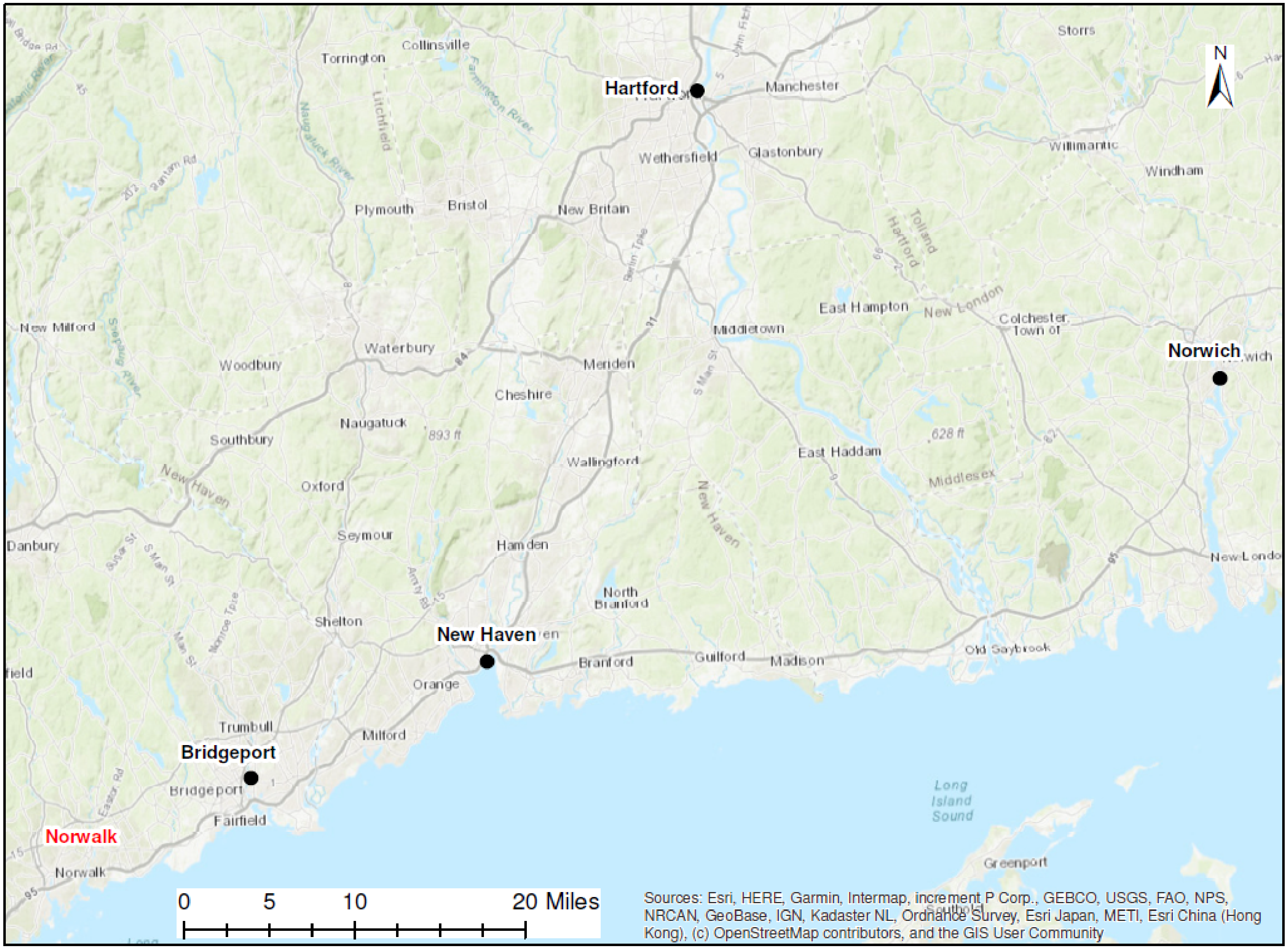


Figure 7b. Locations of CSO Sources in Connecticut

Power Plants

Power plant data were obtained from EPA PCS-ICIS databases, reviewed, and refined to facilities with a discharge flow greater than 5 MGD. This list was further narrowed by eliminating small facilities that discharge into large water bodies or coastal embayments (e.g., Atlantic Ocean, Barnegat Bay) that would not impact LIS or NYC waterways. These power plant discharges were not assigned in the ROMS model.

Two power plants were assigned in the ROMS model that discharge to the Connecticut River (NRG Middletown CT) and to LIS in Niantic Bay (Dominion Energy Millstone). The Dominion Energy Millstone Power Station is a once-through, non-contact cooling water facility that has an intake and discharge in Niantic Bay. This plant was assigned discharge flow ranges from about 1.2-2.2 billion gallons per day (BGD) over an annual cycle depending on plant operations and has a significant heat load. The discharge flow was also assigned a temperature that varied over the year from 15.8-32.0°C (60.5-89.7°F). Monthly discharge flows and temperatures were developed for a typical year based on available data and assigned for each modeled year.

Groundwater

Output from two USGS groundwater models were used to develop the groundwater flows assigned in the model: one for Connecticut (Barclay and Mullaney, 2021) and one for Long Island (Misut et al., 2021). The USGS Connecticut Groundwater model (Barclay and Mullaney, 2021) provided annual average groundwater flows for each of the hydrologic unit code 12 (HUC12) contributing drainage areas to LIS. The HUC12 shapefiles were used to track the flow from the HUC12 drainage area to one or more coastal segments within the LIS model grid. Groundwater flows from drainage areas that discharged to an area upstream of a USGS river gage used to assign river flow model inputs were not used.

The USGS Long Island model (Misut et al., 2021) provided a 2D spatial model grid along the Long Island coast with the groundwater flow that is entering LIS. This USGS groundwater model grid was then spatially joined to the LIS model grid, and the groundwater flows were applied to the nearest LIS model grid cell as input. The groundwater flows were assigned as annual averages. Figure 8 presents the model segments where groundwater flows were assigned.

Groundwater flows were not assigned to the East River, Hudson River, Jamaica Bay and NJ Coast. Estimates of groundwater flows from the East River, Hudson River and Jamaica Bay were about 60 cfs (39 MGD) and from the NJ Coast were about 101 cfs (65 MGD). Groundwater flows in these areas were not assigned as they represent a small fraction of the total river and point source flows entering these areas.

d. Meteorology

Meteorological data provides information on the atmospheric forcings on the surface of a waterbody that affect circulation, atmospheric temperature exchange, and density stratification. These model inputs include wind speed and direction, atmospheric pressure, relative humidity, air temperature, and shortwave solar radiation as impacted by cloud cover.

The North American Regional Reanalysis (NARR) (https://psl.noaa.gov/data/gridded/ data.narr.html) database provides smoothed data on a 0.25-degree resolution (~30 kilometers). These meteorological data have been applied for the DEP LTCP3 and Passaic Valley Sewerage Commission (PVSC) regional hydrodynamic models. NARR output was used to apply spatially variable meteorology as shown in Figure 9. Examples of meteorological inputs at station 60 are presented in Figure 10 for 2005 and in Figure 11 for 2006. Some NARR locations that are situated along the coastline and have major portions of their grid cell on land showed meteorological conditions that differed from adjacent locations in open water areas. The inputs for these areas were replaced by nearby open water NARR locations to avoid abrupt changes in meteorological inputs from grid cell to grid cell and to better represent open water conditions.

Two modifications were made to the NARR data as described below.

- A 20% reduction in the NARR shortwave solar radiation was applied. Wang et al. (2012) found that NARR output overestimated measured shortwave solar radiation in Delaware Bay by about 20%. In addition, shortwave solar radiation data from Brookhaven National Laboratory was compared to NARR output for 2019 and reductions ranged from 4-28% (18% average).
- NARR output at cells #62, #64, #65, #66, #67 and #69 were replaced with NARR output at cell #63; and NARR output at cells #58 and #61 were replaced with NARR output at cell #60. Some NARR output reflects meteorological conditions on land more than open water, so locations more indicative of land conditions were replaced by nearby open water NARR output.

e. Options and Constants

ROMS includes a number of options that can be applied. Table 5 shows a subset of the chosen constants and options used in the preliminary model calibration.

Table 5. ROMS Model Options

Input	Option
Vertical Layers	10
Horizontal Advection	3rd-Order Upstream Bias (U3)
Vertical Advection	4th-Order Centered Difference (C4)
Harmonic/Biharmonic Horizontal Diffusion	10 m^2/s (TNU2)
Background Vertical Mixing Coefficient	5E-06 m^2/s (AKT_BAK)
Upper Threshold Value for Computed Vertical Viscosity Coefficient	1E-03 m^2/s
Generic Length Scale Turbulent Closure Parameters (Turbulent Closure Scheme)	Default parameters for Mellor-Yamada 2.5 Turbulent Closure Scheme (k-kl)
Bottom Roughness Length Coefficient	0.002 and 0.05 m
Surface Roughness	0.005 m
Jerlov Water Type	Water Type III used to reflect available vertical PAR data in LIS

f. Jerlov Water Type

ROMS uses a Jerlov Water Type to control vertical light extinction through upper and lower layers of the water column. There are nine water type options available in ROMS, each with specific coefficients that define light penetration through the water column. The following equation is used in ROMS to represent light attenuation in the water column (Paulson and Simpson, 1977).

$$I_Z = I_0 \times \left[R \times e^{Z/\mu 1} + (1-R) \times e^{Z/\mu 2}\right]$$

where: I_Z – Light at depth Z (W/m^2)

I_0 – Light at the surface (W/m^2)

R – Fraction of surface light absorbed over top 5 meters of the water column

Z – Depth from surface (m)

μ_1 – absorption coefficient for solar wavelength band 1 as a function of the Jerlov water type (m)

μ_2 – absorption coefficient for solar wavelength band 2 as a function of the Jerlov water type (m)

Water Type III was applied using R = 0.78, μ_1 = 1.4; and μ_2 = 7.9 throughout the entire model study area. These values were based on light extinction coefficients of about 0.5/meter as estimated from available Connecticut Department of Energy and Environmental Protection (CTDEEP) vertical photosynthetically available radiation (PAR) data in LIS and as used in the original ECOM hydrodynamic mode of LIS. Figure 12 shows the vertical shape of the light attenuation applied in the model using the Jerlov Water Type III.

3. RCA Water Quality Model Inputs

a. Model State-Variables

The RCA water quality model includes 26 state-variables as listed in Table 6. The units for all model state-variables are mg/L. Other versions of RCA included a salinity state-variable as a check for the communication between the hydrodynamic and water quality models. In the current ROMS-RCA coupling, the models are run dynamically so the ROMS salinity is used directly by RCA to calculate the light extinction coefficient and dissolved oxygen (DO) saturation. The majority of these state-variables require concentrations or loads assigned to them from the various point and nonpoint sources. Unfortunately, state-variables in the model are not always measured, so these model inputs need to be derived from other measured parameters, estimated from similar sources, or estimated using best professional judgement and literature sources.

Note that organic phosphorus, nitrogen, and carbon are divided into particulate, dissolved, labile and refractory fractions. Organic carbon is further divided into two reactive fractions (reactive particulate organic carbon and reactive dissolved organic carbon). Use of these fractions acknowledges that not all organic compounds are broken down by bacteria at the same rate. For example, refractory dissolved organic carbon can remain in the water column for decades or more, labile dissolved organic carbon from a source such as stormwater (SW) can be oxidized in weeks, and reactive dissolved organic carbon from a Combined Sewer Overflow (CSO) can be oxidized in days. The data to assign these fractions are not always available, but the use of multiple fractions allows the model to better reproduce observed data. Table 7 presents the organic matter fractions used in SWEM for WWTPs, CSOs, SW and rivers. The SWEM organic matter fractions presented in this table are based on an analysis of data collected in the spring and summer of 1994 for the Interstate Sanitation Commission (currently the Interstate Environmental Commission). The reactivity study monitoring was completed at 21 WWTPs, 6 CSOs, 4 stormwater and 4 tributary sites and included 50-day incubation of samples for the estimation of the organic matter reactivity fractions. The documentation does not describe how the constituents were initially split into dissolved and particulate components. These fractions were re-evaluated and revised based on available data including original SWEM data, data used for the Jamaica Bay Eutrophication Model, CTDEEP stormwater data, and DEP MS4 stormwater data. Table 8 includes the updated fractions used in the RCA model.

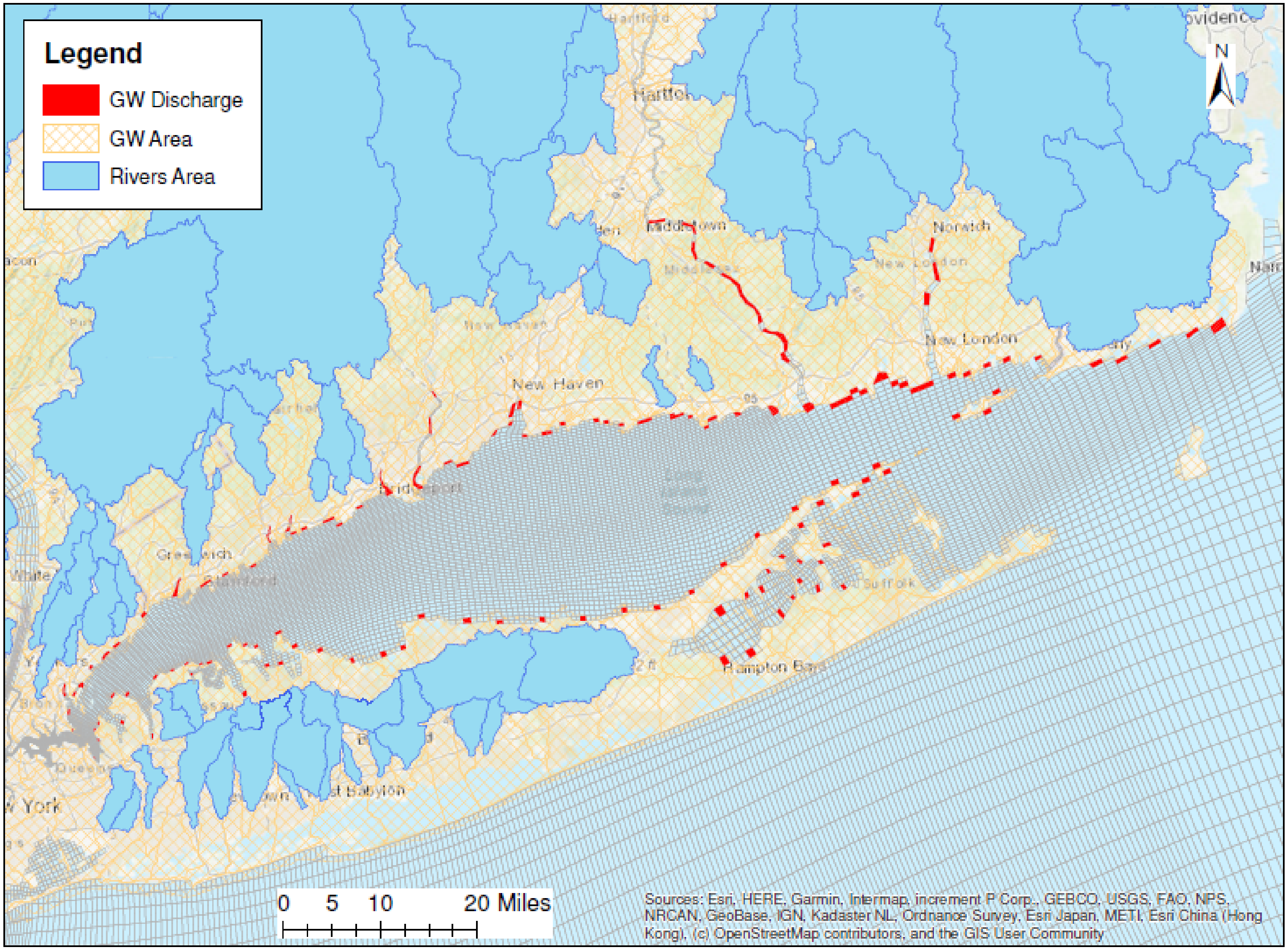


Figure 8. Model Locations where Groundwater Flow was Assigned

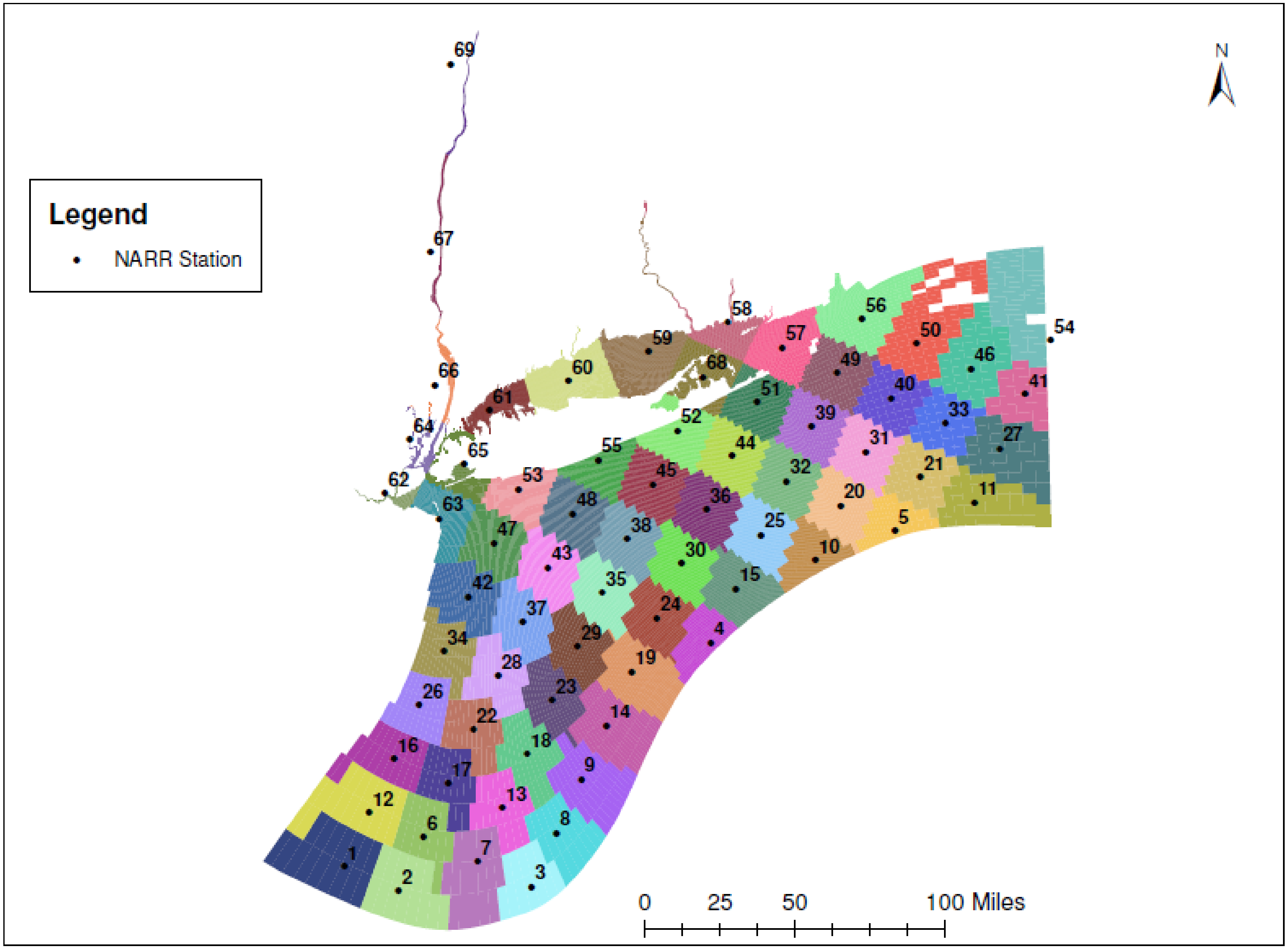


Figure 9. Spatial Distribution of NARR Meteorological Inputs

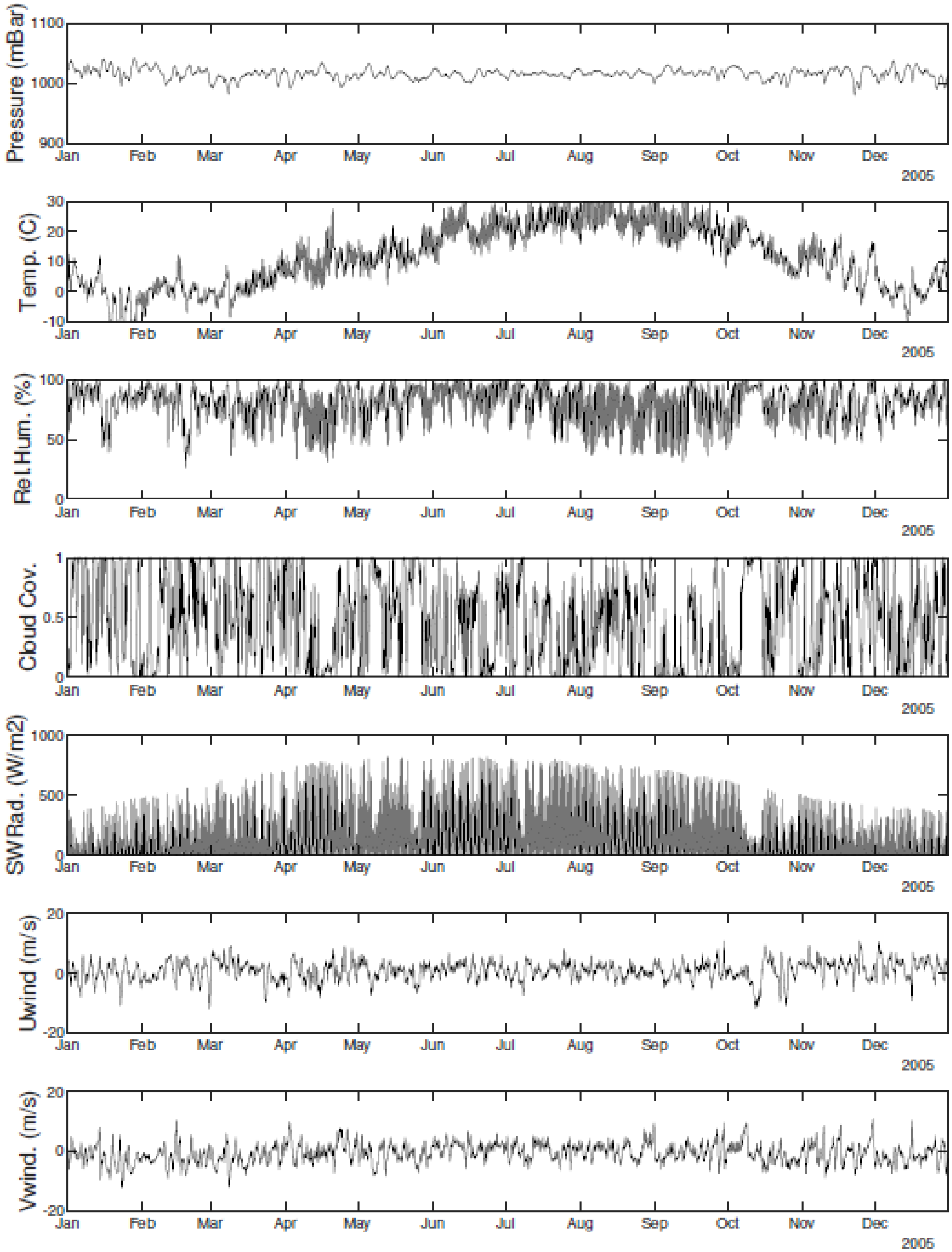


Figure 10. Example of NARR Meteorological Input at Station 60 in 2005

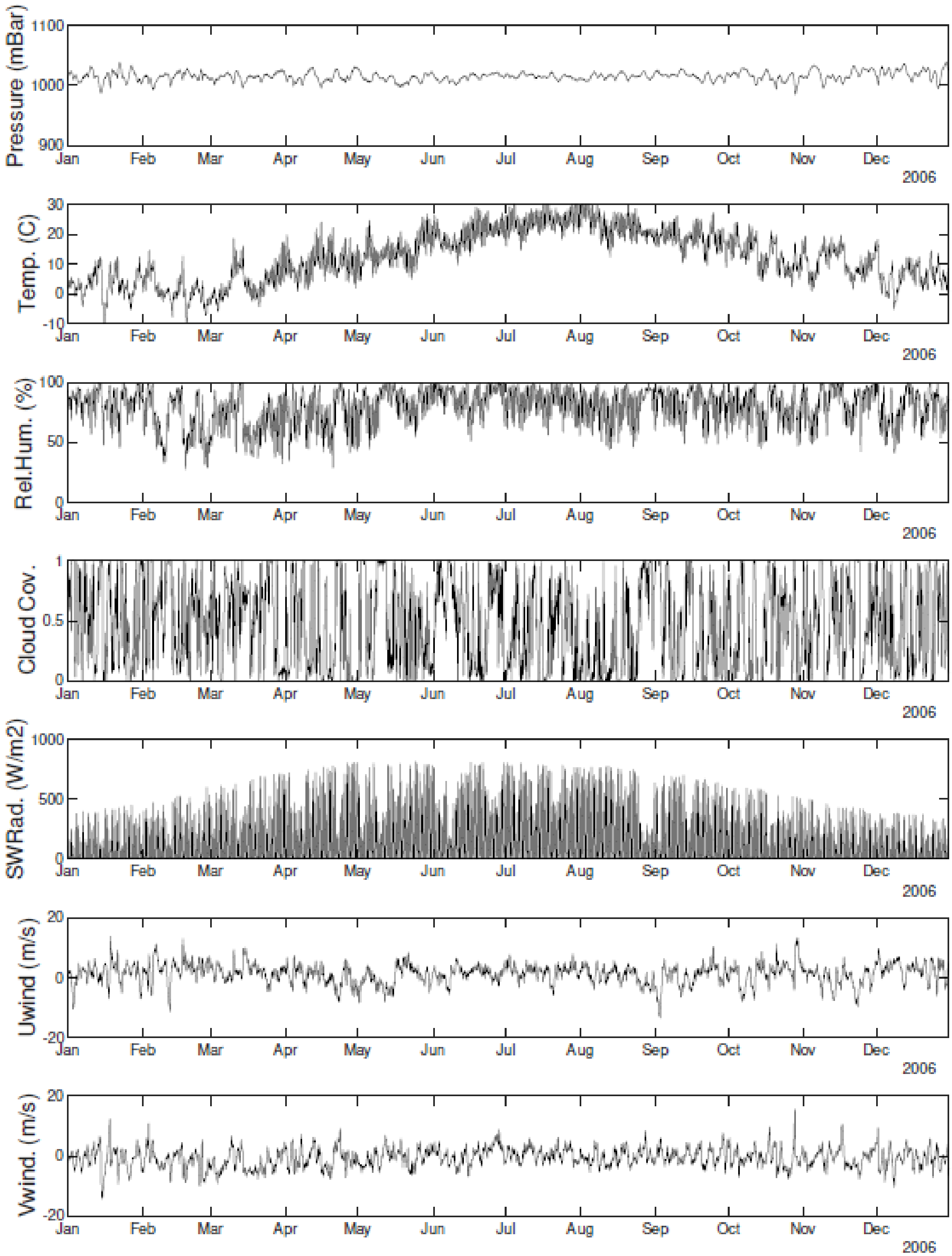


Figure 11. Example of NARR Meteorological Input at Station 60 in 2006

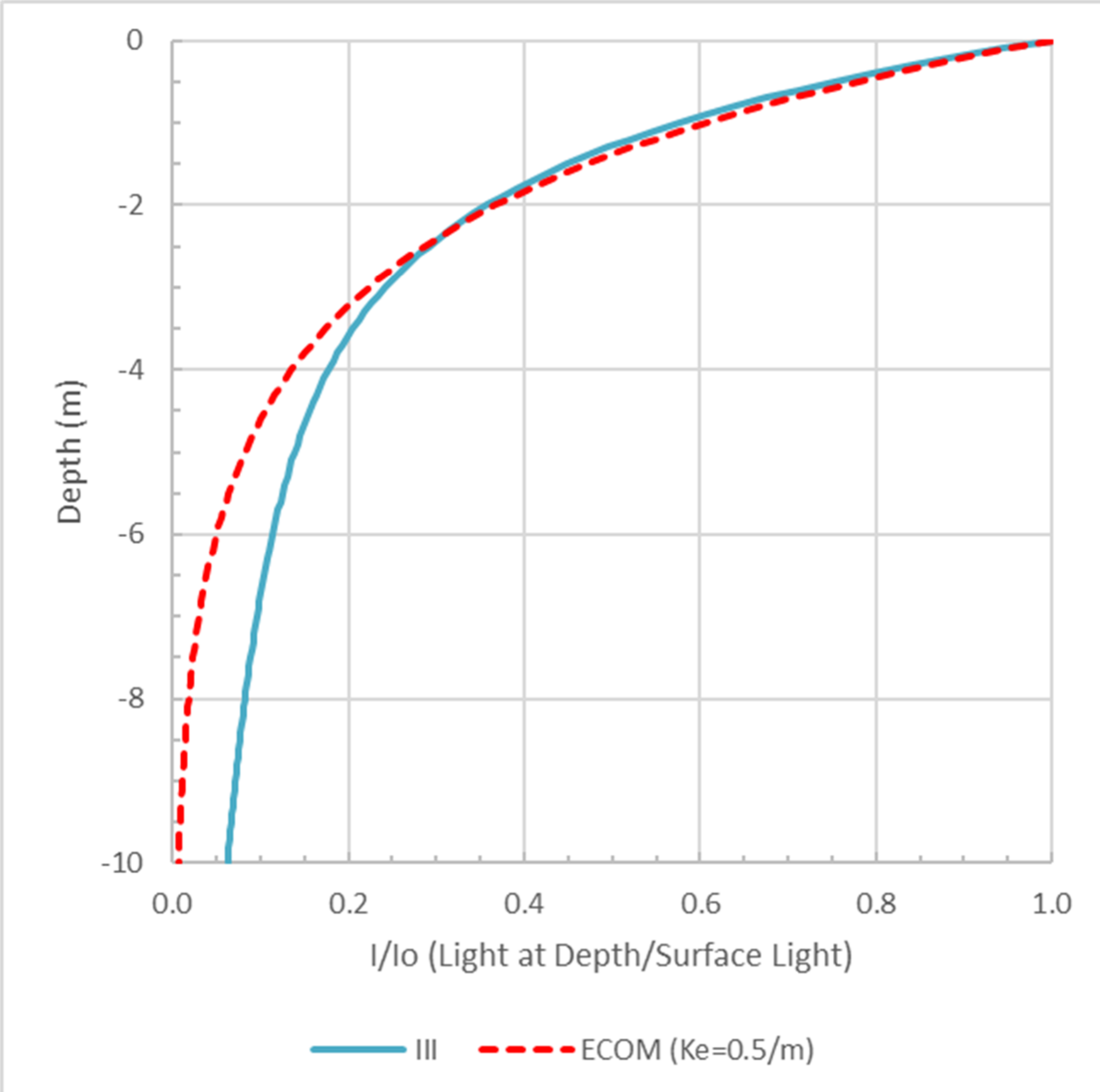


Figure 12. Model Light Attenuation for Jerlov Water Type III

Some state-variables in Table 6 do not require loads but are required as part of the eutrophication model kinetics used. Algal exudate dissolved organic carbon is produced by phytoplankton during photosynthesis. Dissolved oxygen equivalents represent hydrogen sulfide (in marine systems) that is released from the sediment during anoxic conditions and is tracked due to its ultimate impact on dissolved oxygen. In most cases, the phytoplankton state-variables are not included in the loads, but in some cases, they can be included as part of river loads. Biogenic silica is produced by phytoplankton during respiration and from zooplankton grazing, so it is not included as a load unless a phytoplankton load is included.

Loading sources that need to be accounted for in the RCA model include WRRFs or WWTPs, industrial treatment plants, power plants, CSOs, stormwater (MS4/direct runoff), rivers, groundwater, and atmospheric deposition. In this document, WRRFs and WWTPs have been split between DEP wastewater resource recovery facilities (WRRFs) and non-NYC WWTPs since the data come from different sources.

Table 6. RCA Model State-Variables

State-Variable	RCA Name	State-Variable	RCA Name
Total Suspended Solids	TSS	Algal Nitrogen + Ammonia Nitrogen	NH4T
Phytoplankton Carbon Group 1 (Winter)	PHYT1	Nitrite+Nitrate Nitrogen	NO23
Phytoplankton Carbon Group 2 (Summer)	PHYT2	Biogenic Silica	BSI*
Phytoplankton Carbon Group 3 (Spring)	PHYT3	Algal Silica + Available Silica	SIT
Refractory Particulate Organic Phosphorus	RPOP	Refractory Particulate Organic Carbon	RPOC
Labile Particulate Organic Phosphorus	LPOP	Labile Particulate Organic Carbon	LPOC
Refractory Dissolved Organic Phosphorus	RDOP	Refractory Dissolved Organic Carbon	RDOC
Labile Dissolved Organic Phosphorus	LDOP	Labile Dissolved Organic Carbon	LDOC
Algal Phosphorus + Dissolved Inorganic Phosphorus	PO4T	Algal Exudate Dissolved Organic Carbon	ExDOC*
Refractory Particulate Organic Nitrogen	RPON	Reactive Particulate Organic Carbon	RePOC
Labile Particulate Organic Nitrogen	LPON	Reactive Dissolved Organic Carbon	ReDOC
Refractory Dissolved Organic Nitrogen	RDON	Dissolved Oxygen Equivalents	O2EQ*
Labile Dissolved Organic Nitrogen	LDON	Dissolved Oxygen	DO
* - State-variable does not require load development.			

Table 7. SWEM Organic Matter Fractions by Source

Organic Matter Fraction	WWTP	CSO	SW	River
RPOC	0.30	0.50	0.70	0.75
LPOC	0.70	0.50	0.30	0.25
RDOC	0.25	0.50	0.70	0.75
LDOC	0.25	0.25	0.15	0.25

Organic Matter Fraction	WWTP	CSO	SW	River
ReDOC	0.50	0.25	0.15	0.00
RPON	0.30	0.50	0.70	0.75
LPON	0.70	0.50	0.30	0.25
RDON	0.30	0.50	0.70	0.75
LDON	0.70	0.50	0.30	0.25
RPOP	0.30	0.50	0.70	0.75
LPOP	0.70	0.50	0.30	0.25
RDOP	0.30	0.50	0.70	0.75
LDOP	0.70	0.50	0.30	0.25

Table 8. RCA Organic Matter Fractions by Source

Organic Matter Fraction	WWTP[1]	CSO	SW	River
RPOC	0.00	0.10	0.06	0.125
LPOC	0.17	0.10	0.27	0.375
RePOC	0.00	0.10	0.27	0.00
RDOC	0.13	0.23	0.07	0.125
LDOC	0.70	0.23	0.13	0.375
ReDOC	0.00	0.24	0.20	0.00
RPON	0.10	0.25	0.20	0.375
LPON	0.30	0.25	0.20	0.125
RDON	0.10	0.25	0.30	0.375
LDON	0.50	0.25	0.30	0.125
RPOP	0.10	0.42	0.30	0.375
LPOP	0.30	0.42	0.30	0.125
RDOP	0.10	0.08	0.20	0.375
LDOP	0.50	0.08	0.20	0.125

1 – Carbon fractions reflect non-NYCDEP WWTP only. NYCDEP carbon loads developed by another methodology.

b. Municipal Treatment Plants

Treatment plants generally have some of the best loading information available, but not all of the parameters needed by the model are monitored. Data are typically available on a daily to monthly basis and are required for DEP WRRFs, New York State, Connecticut, New Jersey and Rhode Island. Data sources include DEP, EPA (larger non-NYC WWTPs), States and owners.

SWEM Approach

The DEP WRRF and non-NYC WWTP discharges in SWEM were assigned on a monthly basis. Measured parameters generally included total phosphorus (TP), orthophosphate (PO4), total Kjeldahl nitrogen (TKN), ammonium (NH4), nitrite+nitrate (NO2+NO3), 5-day biochemical oxygen demand (BOD5) and DO. The measured concentrations were used to derive RCA model state-variables for assigning loads.

Updated Approach

DEP WRRFs

DEP effluent data for its 14 WRRFs were obtained, and the data files received included flow, 5-day carbonaceous biochemical oxygen demand (CBOD5), total suspended solids (TSS), TP, PO4, nitrite (NO2), nitrate (NO3), NH4, TKN, and DO. Most parameters are available on a daily basis, but CBOD5 is available on a weekly basis and the phosphorus parameters are measured every two-weeks. Figure 13 presents the locations of the 14 DEP WRRFs.

A similar approach for dividing the various measured parameters into the RCA model state-variables used for the original SWEM was used for RCA except that the various particulate/dissolved and labile/refractory fractions were revised.

Derivation of the labile organic carbon state-variable loads were re-evaluated, particularly the CBOD5 to organic carbon conversion, using a CBOD5 to CBODu ratio and available WRRF effluent TSS data to estimate LDOC and LPOC. Table 9 presents the current approach for assigning state-variable concentrations in ROMS-RCA.

The DEP WRRF loads were assigned on a daily basis, since many effluent parameters are available on a daily basis. For parameters not measured on a daily basis (e.g., weekly), the data were interpolated to daily for model input. Typically, the following DEP WRRF effluent sampling frequencies are available: daily for BOD5 and CBOD5; daily for nitrogen species except at Owls Head, Oakwood Beach, North River, and Port Richmond WRRFs, which are sampled once per week; weekly for DO; and 1-2 times per month for phosphorus species.

Table 9. Derivation of DEP WRRF State-Variable

State-Variable	State-Variable
RPOP = (TP – PO4) x Fp x Fr	TSS = TSS
LPOP = (TP – PO4) x Fp x Fl	NO23 = NO2+NO3
RDOP = (TP – PO4) x Fd x Fr	SIT = Constant

State-Variable	State-Variable
LDOP = (TP – PO4) x Fd x Fl	RDOC = 7.5
PO4T = PO4	CBODu estimated from $CBOD_5$; LDOC = CBODu/2.67
RPON = (TKN – NH4) x Fp x Fr	RPOC = 0
LPON = (TKN – NH4) x Fp x Fl	VSS = 0.80*TSS LPOC = 0.4*VSS
RDON = (TKN – NH4) x Fd x Fr	RePOC = 0
LDON = (TKN – NH4) x Fd x Fl	ReDOC 0
NH4T = NH4	DO = DO
Fp – fraction particulate, Fd – fraction dissolved (Fp+Fd=1) Fl – fraction labile, Fr – fraction refractory (Fl+Fr=1)	

Non-NYC WWTPs

Available effluent data were obtained from EPA's PCS-ICIS permit databases and were also received directly from EPA for CT WWTPs. Effluent data were reported monthly (https://www.epa.gov/enviro/pcs-icis-search). Queries were conducted to retrieve flow, temperature, BOD5, TSS, TP, PO4, NO2, NO3, NH4, TKN, TN and DO data. Flow, BOD5 and TSS were the most commonly available parameters. Nutrient data were less common with DO and temperature the least common.

The same calculations used to derive the RCA model state-variables from measured data used for DEP WRRFs will be used for the non-NYC WWTPs.

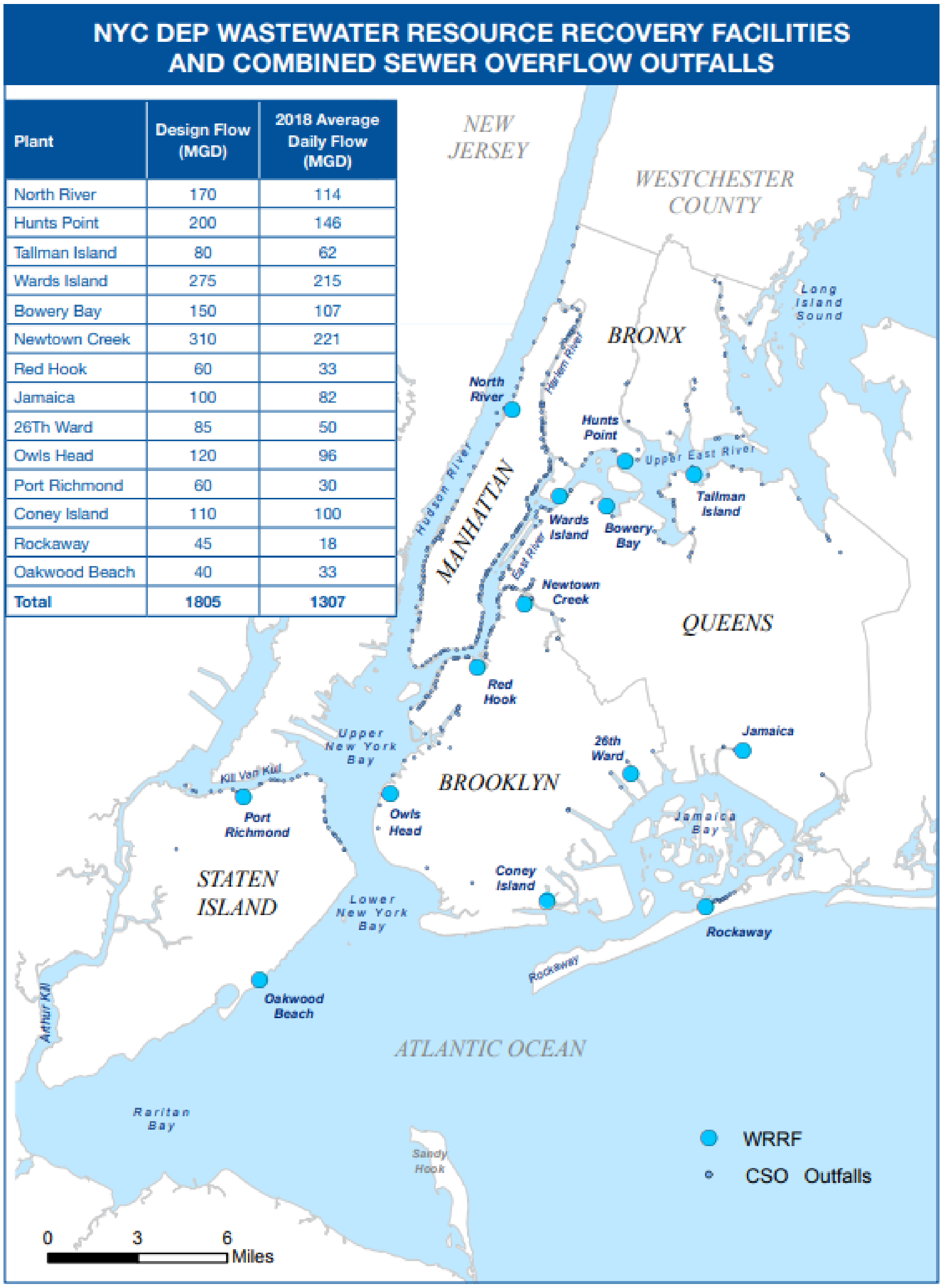
For some of the larger non-NYC facilities, additional (more frequent) effluent data that may not be reported in the PCS-ICIS permit databases were obtained from EPA, States and/or owners, if available. Table 10 lists the non-NYC WWTPs with average or permitted effluent flows greater than 10 MGD where additional data that is available more frequently (i.e., daily, weekly) was pursued.

The non-NYC WWTP loads were assigned on a daily, weekly or monthly basis depending on data availability. Smaller WWTPs loads were also included although most likely on a monthly loading basis. Figure 14 presents locations of the non-NYC WWTPs (municipal and industrial) where model inputs were developed.

c. Industrial Dischargers

SWEM Approach

The SWEM documentation for industrial dischargers is limited. Although there are a few, they do not contribute much to overall loadings to LIS. The equation used in SWEM to assign carbon to industrial dischargers is TOC = 0.6 x BOD5.



NYC DEP WASTEWATER RESOURCE RECOVERY FACILITIES AND COMBINED SEWER OVERFLOW OUTFALLS

Plant	Design Flow (MGD)	2018 Average Daily Flow (MGD)
North River	170	114
Hunts Point	200	146
Tallman Island	80	62
Wards Island	275	215
Bowery Bay	150	107
Newtown Creek	310	221
Red Hook	60	33
Jamaica	100	82
26Th Ward	85	50
Owls Head	120	96
Port Richmond	60	30
Coney Island	110	100
Rockaway	45	18
Oakwood Beach	40	33
Total	**1805**	**1307**

Figure 13. Location of DEP WRRFs
(Reproduced from DEP 2018 New York Harbor Water Quality Report)

Table 10. Non-NYC WWTPs with Flows Greater than 10 MGD

WWTP Name	Permit/Outfall Number	Average Flow (MGD)
Passaic Valley Sewerage Commissioners	NJ0021016 / 001	245.9
Yonkers Joint WWTP	NY0026689 / 001	120.0*

Middlesex County UA	NJ0020141 / 001	110.6
Bergen County UA	NJ0020028 / 001	78.3
Cedar Creek WPCP**	NY0026859 / 001	72.0*
Joint Meeting of Essex & Union Counties	NJ0024741 / 001	60.4
Middlesex County UA	NJ0020141 / 007	59.7
South Shore WRF	NY0026450 / 001	53.1
Rockland County Sewer District No. 1	NY0031895 / 001	29.0*
New Haven East WPCF	CT0100366 / 001	28.8
Rahway Valley SA	NJ0024643 / 001	28.0
Bridgeport West WPCF	CT0100056 / 001	23.8
Mamaroneck WPCF	NY0026701 / 001	23.2*
Northern WPCF	NJ0028142 / 001	22.7
Ocean County UA - Central	NJ0029408 / 001A	21.6
Stamford WPCF	CT0101087 /001	16.3
Monmouth County Bayshore Outfall Authority	NJ0024694 / 001	14.9
New Rochelle WPCF	NY0026697 / 001	13.6*
Norwalk WPCF	CT0101249 / 001	13.3
Adams Street WWTP	NJ0026085 / 001	12.9
Linden-Roselle SA	NJ0024953 / 001	11.4
Meriden WPCF	CT0100315 / 001	11.1
Two Rivers WRA	NJ0026735 / 001	10.1
Peekskill WWTF	NY0100803 / 001	10.0*
* - Permit flow ** - To include flow from the South Shore WRF (previously Bay Park STP)		

Updated Approach

Available effluent data were obtained from EPA's PCS-ICIS permit databases and are generally reported on a monthly basis. Queries were conducted to retrieve flow, temperature, BOD5, TSS, TP, PO4, NO2, NO3, NH3, TKN, TN and DO data. The data for industrial dischargers are generally sparser than for municipal dischargers. Organic nitrogen and phosphorus were split in a similar manner as WWTPs (i.e.,

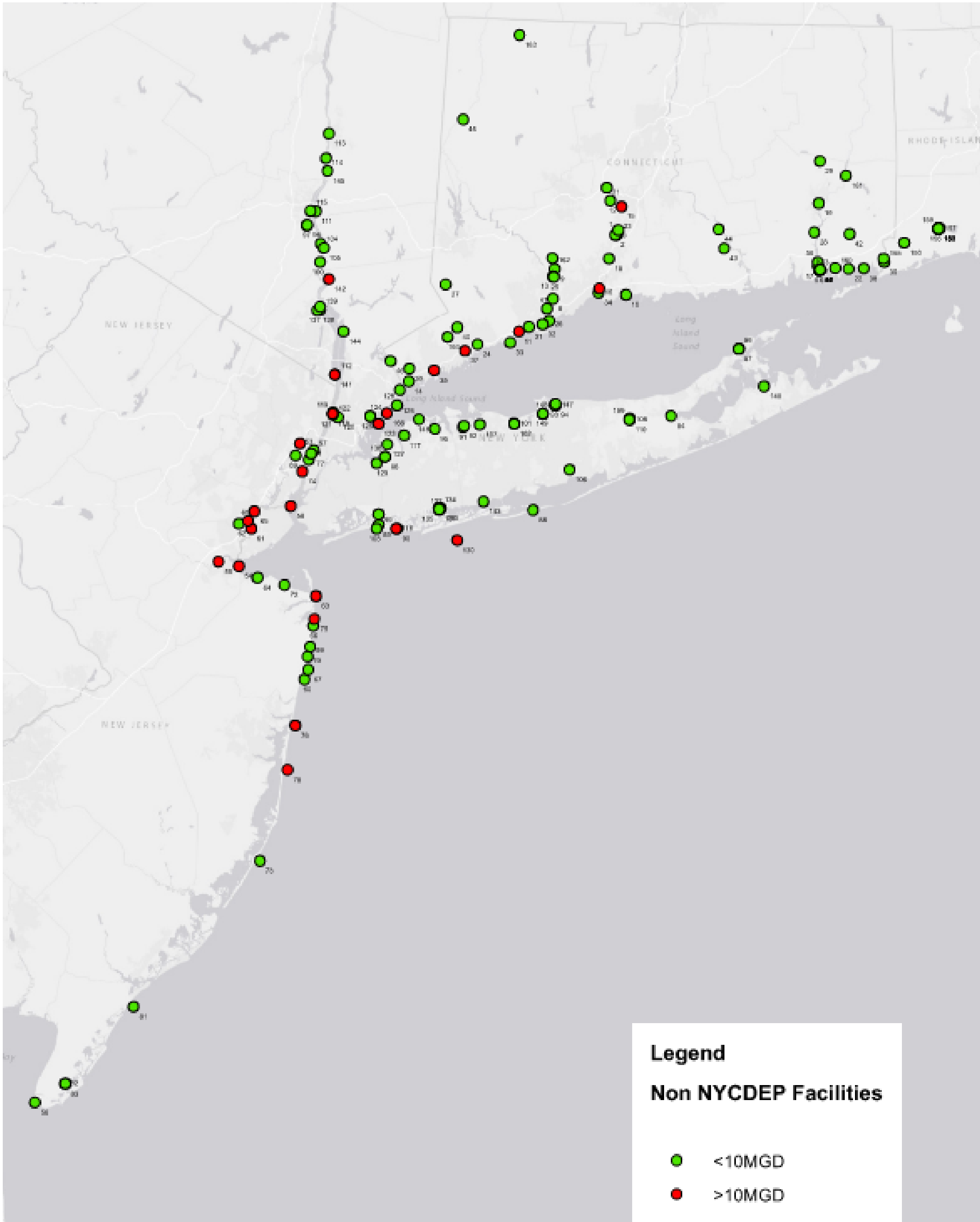


Figure 14. Non-NYC Treatment Plant Locations

using fraction particulate/dissolved and labile/refractory splits). The BOD5 conversion to organic carbon was based on the model assigned carbon oxidation rates to calculate a BOD5 to organic carbon ratio and any available effluent TSS, VSS, organic carbon and/or ultimate BOD data. Loads were assigned on a monthly basis.

d. Power Plants

SWEM Approach

SWEM did not include power plants in the model setup.

Updated Approach

The two power plants assigned in the RCA model were the NRG Middletown CT and Dominion Energy Millstone Power Stations (see Section 2c). These power plants primarily discharge heated non-contact cooling water and do not have any significant loadings of water quality parameters (e.g., nitrogen). No loadings of water quality parameters were assigned to the power plant discharges. It is possible that power plants can contribute to localized atmospheric loads but were not assigned and any potential loads were assumed to be reflected in the larger spatial atmospheric deposition loadings discussed below.

e. CSOs

Data sources include DEP and State/City Long Term Control Plans (LTCPs) or Facility Plans.

SWEM Approach

DEP CSO flows were calculated using the Rainfall Runoff Modeling Program (RRMP) II program, which is a simplified version of the Stormwater Management Model (SWMM). CSO concentrations were assigned using data collected during the SWEM monitoring program and log-mean concentrations of the data were used. Measurements included POP, DOP, PO4, PON, DON, NH4, NO2+NO3, dissolved silica (DSI), POC, DOC and DO. The assigned concentrations are presented in Table 11 and the state-variables were derived as presented in Table 12. Non-NYC CSO loads were not assigned in SWEM.

Updated Approach

DEP CSOs

DEP provided CSO flows as output from its InfoWorks models for 13 of the 14 WRRFs in NYC (CSO flows for the Oakwood Beach WRRF were developed by HDR). The provided CSO flows covered the 2003-2022 time period. CSO loads were calculated using the InfoWorks CSO flows and CSO concentrations presented in Table 13 as updated with additional data used in the SWEM WY89 and Jamaica Bay Eutrophication Model 1995-96 modeling. The CSO loads for model state-variables will be developed as presented in Table 12. As new data become available, the labile/refractory fractions in Table 12 will be re-evaluated.

New York State CSOs

Non-NYC CSOs in New York State are located along the Hudson River and around Staten Island as presented in Figure 15. Loads were assigned at these CSO locations based on available LTCPs.

Connecticut CSOs

Connecticut has six municipalities with CSOs: Bridgeport; Hartford; New Haven; Norwich; Norwalk; and Waterbury. Norwalk and Waterbury only have one CSO relief outfall at their respective WWTPs. Available LTCPs and Facility Plans were reviewed to estimate these CSO loads. Waterbury was determined to be upstream of the river gages used for its watershed, so it was not included. No information on Norwalk's one CSO was identified and, therefore, it was not assigned in the model. For the remaining CSO communities, annual average flows were calculated and the CSO concentrations used for the DEP CSOs were assigned to these flows to calculate loads.

New Jersey CSOs

The New Jersey CSO loads that are located in the LIS model domain were estimated based on available LTCP and Facility Plan information. Municipalities with CSOs include: Paterson; Hackensack; Ridgefield Park Village; Fort Lee Borough; North Bergen Township; West New York; Weehawken Township; Hoboken; Jersey City; Bayonne; Kearny; East Newark Borough; Harrison; Newark; Elizabeth; and Perth Amboy. Figure 15 presents the NJ CSO locations.

Table 11. SWEM CSO & SW Concentrations (WY95)

Parameter	CSO	SW
POP (mgP/L)	0.70	0.09
DOP (mgP/L)	0.13	0.02
PO4 (mgP/L)	0.60	0.08
PON (mgN/L)	3.02	0.37
DON (mgN/L)	1.63	0.40
NH4 (mgN/L)	4.44	0.24
NO2+NO3 (mgN/L)	0.49	6.33
DSI (mgSi/L)	1.71	1.77
POC (mgC/L)	41.5	7.32
DOC (mgC/L)	18.7	8.81
DO (mg/L)	3.8	6.3

Table 12. Derivation of CSO & SW State-Variables

State-Variable	State-Variable
RPOP = POP x Fr	NH4T = NH4
LPOP = POP x Fl	NO23 = NO2+NO3
RDOP = DOP x Fr	SIT = DSI
LDOP = DOP x Fl	RPOC = POC x Frp

State-Variable	State-Variable
PO4T = PO4	LPOC = POC x Flp
RPON = PON x Fr	RDOC = DOC x Frd
LPON = PON x Fl	LDOC = DOC x Fld
RDON = DON x Fr	ReDOC = DOC x Fred
LDON = DON x Fl	DO = DO
Fp – fraction particulate, Fd – fraction dissolved (Fp+Fd=1) Fl – fraction labile, Fr – fraction refractory (Fl+Fr=1) Frp – fraction refractory particulate, Flp – fraction labile particulate (Frp+Flp=Fp) Frd – fraction refractory dissolved, Fld – fraction labile dissolved, Fred – fraction reactive dissolved (Frd+Fld+Fred=Fd)	

Table 13. RCA CSO & SW Concentrations (CY05-06)

Parameter	CSO	SW
POP (mgP/L)	0.60	0.12
DOP (mgP/L)	0.12	0.08
PO4 (mgP/L)	0.40	0.12
PON (mgN/L)	1.40	0.42
DON (mgN/L)	1.40	0.70
NH4 (mgN/L)	1.70	0.40
NO2+NO3 (mgN/L)	0.50	0.80
DSI (mgSi/L)	1.80	1.80
POC (mgC/L)	15.0	9.0
DOC (mgC/L)	36.0	6.0
DO (mg/L)	5.0	6.0
TSS (mg/L)	125	50

f. Stormwater (MS4/Direct Runoff)

SWEM Approach

DEP stormwater flows were calculated using the RRMP II program, which is a simplified version of the Stormwater Management Model (SWMM). Stormwater concentrations were assigned using data collected during the SWEM monitoring program and log-mean concentrations of the data were used as presented in Table 11 with the state-variables calculated as presented in Table 12. Measurements included POP, DOP, PO4, PON, DON, NH4, NO2+NO3, DSI, POC, DOC and DO. Non-NYC stormwater flows were calculated based on runoff loads from the Long Island Sound Study.

Updated Approach

DEP Stormwater

DEP provided stormwater flow estimates from its InfoWorks models for 13 of the 14 WRRFs in NYC (SW flows for the Oakwood Beach WRRF were developed by HDR). The provided stormwater and direct runoff flows covered the 2003-2022 time period. Stormwater loads were calculated using the InfoWorks stormwater flows and stormwater concentrations presented in Table 13 as updated with additional data used in the SWEM WY89 modeling, Jamaica Bay Eutrophication Model 1995-96 modeling, ongoing DEP MS4 sampling, CTDEEP MS4 sampling and the national stormwater database. The stormwater loads for model state-variables were developed as presented in Table 12. As new data becomes available, the labile/refractory fractions in Table 12 will be re-evaluated.

New York State and New Jersey

New York State stormwater from areas around the Hudson River north of NYC and New Jersey were based on the NY/NJ Harbor RAINMAN model (HydroQual, 2005). Concentrations applied to calculated stormwater flows were based on the concentrations used for developing the DEP stormwater loads. The stormwater loads for model state-variables were developed as presented in Table 13. The labile/refractory fractions used in SWEM were re-evaluated based on available new data.

Additional guidance for estimating New Jersey stormwater loads were obtained from Baker et al. (2014), which includes USGS estimates of TN and TP loads into Barnegat Bay and Little Egg Harbor.

Connecticut, Westchester, and Long Island

Due to the sandy soils on LI, stormwater runoff and loads are small compared to groundwater flows and loads. Rainfall contributions to groundwater loads will be included in embayment load estimates as discussed in the Embayment Loads section. In areas where stormwater loads are considered significant (i.e., Connecticut, Westchester), stormwater loads will be included in embayment loads. When modeling the two stand-alone embayments (see description in LIS Model QAPP Section 1.4), local stormwater inputs may be more important and additional detail will be included in the stand-alone models.

g. Rivers

Data sources include the USGS and CTDEEP.

SWEM Approach

Daily USGS flows and monthly averaged measured concentrations were used to assign the river input loads for the SWEM WY95 modeling. For tributaries not monitored, concentrations were based on measured values at similar tributaries. Measured parameters included DOP, POP, PO4, NH4, TON, PON, DSI, DOC and POC. The state-variables were calculated as presented in Table 14. There are multiple state-variable equations presented in Table 14 because the state-variables can be derived differently depending on what measured parameters are available.

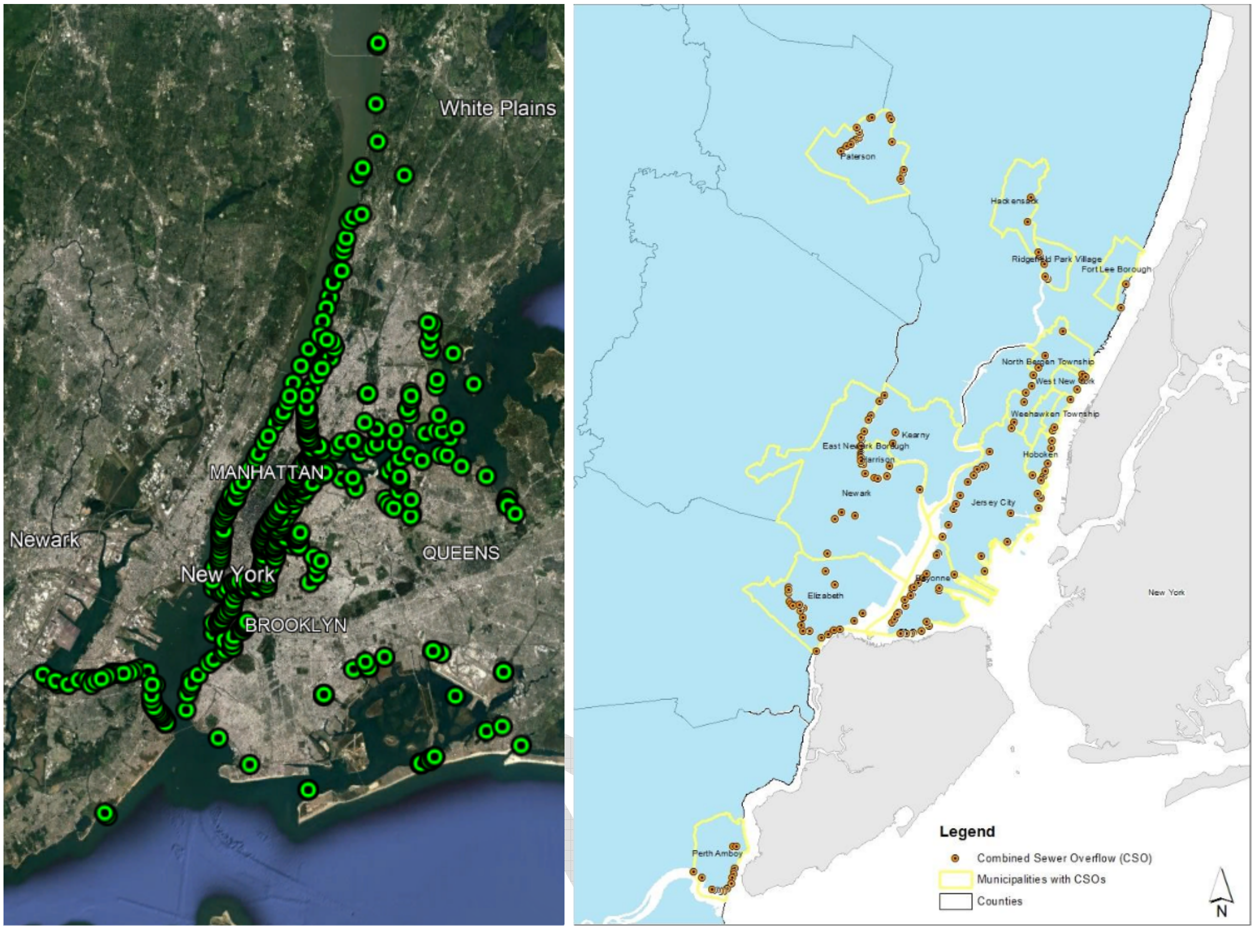


Figure 15. NY & NJ CSO Locations
(NY includes DEP CSOs, does not include CSOs north of Tarrytown)
Ref: NYSDEC & NJDEP

Updated Approach

River information was downloaded from the USGS with data availability varying widely for the river inputs needed. Downloaded parameters include flow, NH4, NO2+NO3, TKN, particulate nitrogen (PN), total organic nitrogen (TON), dissolved organic nitrogen (DON), total nitrogen (TN), TP, PO4, DSI, particulate carbon (PC), total organic carbon (TOC), DOC, POC, BOD5 and TSS. Table 15 summarizes the available data that was downloaded and Figure 16 presents the locations of the USGS gages where data was downloaded. Eight additional USGS gages were identified in Connecticut and New York and were also downloaded and processed. The eight gages are: Broad Brook at Broad Brook, CT (01184490); Farmington River at Tariffville, CT (01189995); Hockanum River near East Hartford, CT (01192500); Salmon River near East Hampton, CT (01193500); Mill Neck Creek at Mill Neck, NY (01303000); Cold Spring Brook at Cold Spring Harbor, NY (01303500); Nissequogue River near Smithtown, NY (01304000); and Glen Cove Creek at Glen Cove, NY (01302500).

River loads were based on the USGS LOADEST and/or WRTDS regression programs depending on data availability. Use of these two USGS load estimation programs depended on the amount of data available for completing the load regressions with the more rigorous regression routines in WRTDS requiring more data. During river load development, the availability of data was determined and guided the selection of whether LOADEST or WRTDS was used to develop river loads. In some cases, no data were available, and a constant concentration was applied. Constant concentrations tended to be applied in smaller rivers with a smaller contribution to the overall loading. Table 16 presents what approach was used for each river and each parameter. The LOADEST and WRTDS programs use USGS daily flow data and measured concentration data to create loads on a time increment specified by the user (e.g., daily). River loads were assigned on a daily basis and model state-variables derived as presented in Table 14.

Table 14. Derivation of River State-Variable

State-Variable	State-Variable
RPOP = (TP-PO4) x Fp x Fr	NH4T = NH4
LPOP = (TP-PO4) x Fp x Fl	NO23 = NO2+NO3
RDOP = (TP-PO4) x Fd x Fr	SIT = DSI
LDOP = (TP-PO4) x Fd x Fl	RPOC = POC x Fr RPOC = (TOC-DOC) x Fr RPOC = TOC x Fp x Fr
PO4T = PO4	LPOC = POC x Fl LPOC = (TOC-DOC) x Fl LPOC = TOC x Fp x Fl
RPON = TON x Fp x Fr RPON = PN x Fr RPON = (TKN-NH4) x Fp x Fr RPON = (TN-NH4-NO23) x Fp x Fr	RDOC = DOC x Fr RDOC = (TOC-POC) x Fr RDOC = TOC x Fd x Fr
LPON = TON x Fp x Fl LPON = PN x Fl LPON = (TKN-NH4) x Fp x Fl LPON = (TN-NH4-NO23) x Fp x Fl	LDOC = DOC x Fl LDOC = (TOC-POC) x Fl LDOC = TOC x Fd x Fl
RDON = TON x Fd x Fr RDON = DON x Fr RDON = (TKN-NH4) x Fd x Fr RDON = (TN-NH4-NO23) x Fd x Fr	DO = DO
LDON = TON x Fd x Fl LDON = DON x Fl LDON = (TKN-NH4) x Fd x Fl LDON = (TN-NH4-NO23) x Fd x Fl	TSS = TSS
Fp – fraction particulate, Fd – fraction dissolved (Fp+Fd=1) Fl – fraction labile, Fr -fraction refractory (Fl+Fr = 1) Frp – fraction refractory particulate, Flp – fraction labile particulate (Frp+Flp=Fp) Frd – fraction refractory dissolved, Fld – fraction labile dissolved, Fred – fraction reactive dissolved (Frd+Fld+Fred=Fd)	

The labile/refractory fractions used in SWEM were used and may be re-evaluated based on new data and during the calibration process. For the organic carbon state-variables, emphasis will be placed on reproducing measured BOD5 concentrations in water bodies during calibration. For rivers that lack water quality data, assigned concentrations were based on similar rivers on a case-by-case basis, as was done for SWEM input loads.

Table 15. Downloaded USGS River Data

State	USGS Gage #	Name	Major or Minor	Average flow (cfs)	Flow	NH34	NO23	TKN	PN	TON	DON	TN	OPO 4	TP	DP	BioSi	DSi	PC	TOC	DOC	POC	BOD	DO	TSS
CT	1184000	Connecticut River	Major	19458	C	C	C	C	I	C	C	C	C	C	C	N	C	I	I	I	I	N	C	N
	1205500	Housatonic River	Major	3029	C	I	C	C	I	I	I	C	I	C	C	N	C	I	I	I	N	N	C	N
	1127000	Quinebaug River	Major	1392	C	C	C	C	I	C	C	C	I	C	C	N	C	I	I	I	N	N	C	I
	1122500	Shetucket River	Major	801	C	C	C	C	I	N	N	C	C	C	N	N	I	N	I	N	N	N	C	I
	1118500	Pawcatuck River	Major	628	C	I	I	I	I	I	N	I	I	I	N	N	N	N	N	N	N	I	I	I
	1208500	Naugatuck River	Major	583	C	C	C	C	I	C	C	C	C	C	C	N	C	I	I	I	N	N	C	I
	1196500	Quinnipiac River	Major	248	C	C	C	C	I	C	C	C	C	C	C	N	C	I	I	I	N	N	C	I
	1209700	Norwalk River	Minor	61	C	I	C	C	I	I	I	C	C	C	C	N	C	I	I	I	I	N	C	N
NJ	1403060	Raritan River	Major	1291	C	I	I	I	N	N	N	N	I	N	N	N	N	N	N	I	N	N	I	I
		Raritan southbranch data				*C*	*C*	*C*	*I*	*C*		*C*	*C*	*C*			*I*		*C*			*I*	*C*	*C*
		Raritan northbranch data				*C*	*C*	*C*	*C*	*C*		*C*	*C*	*C*			*C*		*C*			*I*	*C*	*C*
	1389500	Passaic River	Major	1257	C	C	C	C	C	I	C	C	I	C	C	N	C	C	I	C	I	I	C	I
	1408500	Toms River	Major	222	C	I	I	I	I	N	I	I	I	I	I	N	I	I	N	I	I	I	I	I
	1409500	Batso River	Minor	128	I	I	I	I	I	N	I	I	I	I	I	N	I	I	N	I	I	I	I	I
	1391500	Saddle River	Minor	119	C	C	C	C	C	I	C	C	I	C	C	N	C	C	I	C	I	I	C	I
	1409400	Mullica River	Minor	110	C	I	I	I	N	N	N	I	I	I	N	N	N	N	I	I	N	I	I	I
	1411000	Great Egg Harbor River	Minor	94	C	I	I	I	N	N	N	N	I	N	N	N	N	N	I	I	N	N	I	I
	1410000	Oswego River	Minor	83	C	I	I	I	N	N	N	I	I	I	N	N	N	N	N	I	N	N	I	I
	1408000	Manasquan River	Minor	79	C	C	C	C	C	N	C	C	I	C	C	N	C	C	I	C	I	I	C	C
	1378500	Hackensack River	Minor	72	C	I	I	I	N	N	N	N	I	N	N	N	N	N	N	I	N	N	I	I
	1408120	Metedeconk River	Minor	65	C	I	I	I	N	N	I	I	I	I	N	I	I	N	N	I	I	I	I	I
	1407500	Swimming River	Minor	59	C	I	I	N	N	N	N	I	I	I	N	N	N	N	N	N	N	N	I	I
	1411300	Tuckahoe River	Minor	40	C	I	I	I	N	N	N	N	I	I	I	N	N	N	I	I	N	I	I	I
	1407705	Shark River	Minor	19	C	I	I	I	I	N	I	I	I	I	I	N	I	I	I	I	N	N	I	I
	1410150	East Branch Bass River	Minor	17	C	I	I	I	I	N	I	I	I	I	I	N	C	C	I	C	I	I	C	C
NY	1376500	Sawmill River	NA	NA	N	I	I	N	N	I	N	I	I	I	N	N	N	N	N	I	N	N	I	N
	1358000	Hudson River	Major	16680	C	I	I	I	I	I	I	I	I	I	N	N	N	I	I	I	N	I	I	I
	1371500	Wallkill River	Major	1299	C	I	I	I	N	N	N	N	I	N	N	N	N	N	N	N	N	N	I	I
	1367500	Rondout Creek	Major	701	C	I	I	I	N	N	N	N	I	I	I	N	I	N	I	I	N	N	I	I
	1364500	Esopus Creek	Major	653	C	I	I	I	N	N	N	N	I	N	N	N	N	N	N	N	N	N	I	I
	1375000	Croton River	Major	621	C	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	1372500	Wappinger Creek	Major	305	C	I	I	I	N	N	N	N	I	I	N	N	N	N	I	I	N	N	I	I
	1302020	Bronx River	Minor	78	I	I	I	I	N	I	N	I	I	I	N	N	I	N	N	I	N	N	I	I

C = Complete Data (2003-2020)
I = Incomplete Data
N = No Data Available from 2003-2020

Table 16. River Loading Method Used

	USGS Gage #	Name	NH3+ NH4_ mgLN	NO2+ NO3_ mgLN	TKN_ mgLN	PN_ mgL	TON_ mgL	DON _mgL	DN_ mgL	TN_ mgL	OPO 4_mg LP	TP_m gL	DP_ mgLP	TOC_ mgL	PC_m gL	DOC_ mgL	POC_ mgL	BioSi _mgL	TSi_ mgL	DSi_ mgL	BOD _mgL	CBO D_m gL	DO_ mgL	TSS_ mgL
CT	1118500	Pawcatuck Ri	W	W	W	L	W	C	C	W	L	W	C	C	C	C	C	C	C	C	L	C	L	L
	1122500	Shetucket Riv	L	W	W	C	W	C	C	W	W	W	C	C	C	C	C	C	C	C	C	C	L	C
	1127000	Quinebaug Ri	W	W	W	C	W	W	W	W	W	W	W	W	C	C	C	C	C	W	C	C	W	C
	1184000	Connecticut R	W	W	W	W	W	W	W	W	W	W	W	W	W	W	W	C	C	W	C	C	W	C
	1196500	Quinnipiac Ri	W	W	W	L	W	W	W	W	W	W	W	W	L	C	C	C	C	L	C	C	L	C
	1205500	Housatonic R	W	W	W	C	W	W	W	W	W	W	W	W	C	C	C	C	C	L	C	C	W	C
	1208500	Naugatuck Ri	W	W	W	C	W	W	W	W	W	W	W	W	C	C	C	C	C	W	C	C	W	C
	1209700	Norwalk Rive	L	W	W	W	W	W	W	W	L	W	W	W	W	W	L	C	C	L	C	C	L	C
NY	1302020	Bronx River	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	L	C
	1358000	Hudson River	L	W	L	C	L	C	C	L	L	L	C	L	C	L	C	C	C	C	C	C	L	L
	1364500	Esopus Creek	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	1367500	Rondout Cree	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	1371500	Wallkill River	L	L	L	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	L
	1372500	Wappinger C	L	L	L	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	1375000	Croton River	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
	1376500	Sawmill River	L	L	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
NJ	1378500	Hackensack R	C	C	W	C	C	C	C	C	W	C	C	C	C	W	C	C	C	C	C	W	L	W
	1389500	Passaic River	L	L	L	L	C	L	L	L	L	L	L	C	L	L	L	C	C	L	L	C	L	L
	1391500	Saddle River	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	C	C	L	L	C	L	L
	1403060	Raritan River	W	C	W	W	W	C	C	W	W	W	C	W	L	L	C	C	C	L	C	W	L	W
	1407500	Swimming Ri	C	L	C	C	C	C	C	L	L	L	C	C	C	C	C	C	C	C	C	C	L	L
	1407705	Shark River	C	L	C	C	C	C	C	L	L	L	C	C	C	C	C	C	C	C	C	C	L	L
	1408000	Manasquan R	L	L	L	L	C	L	L	L	C	L	L	C	L	L	L	C	C	L	C	C	L	L
	1408120	Metedeconk	L	W	L	C	C	C	L	W	W	W	C	L	C	L	C	L	L	L	L	L	L	W
	1408500	Toms River	L	L	L	L	C	L	L	L	C	L	L	C	L	L	L	C	C	L	L	C	L	L
	1409400	Mullica River	L	L	L	C	C	C	C	L	L	L	C	L	C	L	C	C	C	C	C	C	L	L
	1409500	Batso River	L	L	L	L	C	L	L	L	C	L	L	C	L	L	L	C	C	L	L	C	L	L
	1410000	Oswego River	C	L	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	L	C
	1410150	East Branch B	L	C	L	L	C	L	L	L	L	L	C	C	L	L	L	C	C	L	L	C	L	L
	1411000	Great Egg Ha	C	L	L	C	C	C	C	C	L	C	C	L	C	L	C	C	C	C	C	C	L	C
	1411300	Tuckahoe Riv	L	L	L	C	C	C	C	C	L	C	C	L	C	L	C	C	C	C	C	C	L	L
	1193500	Salmon River	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	L	C

L Loadest
W EGRET/WRTDS
C Constant Value in lieu of enough data

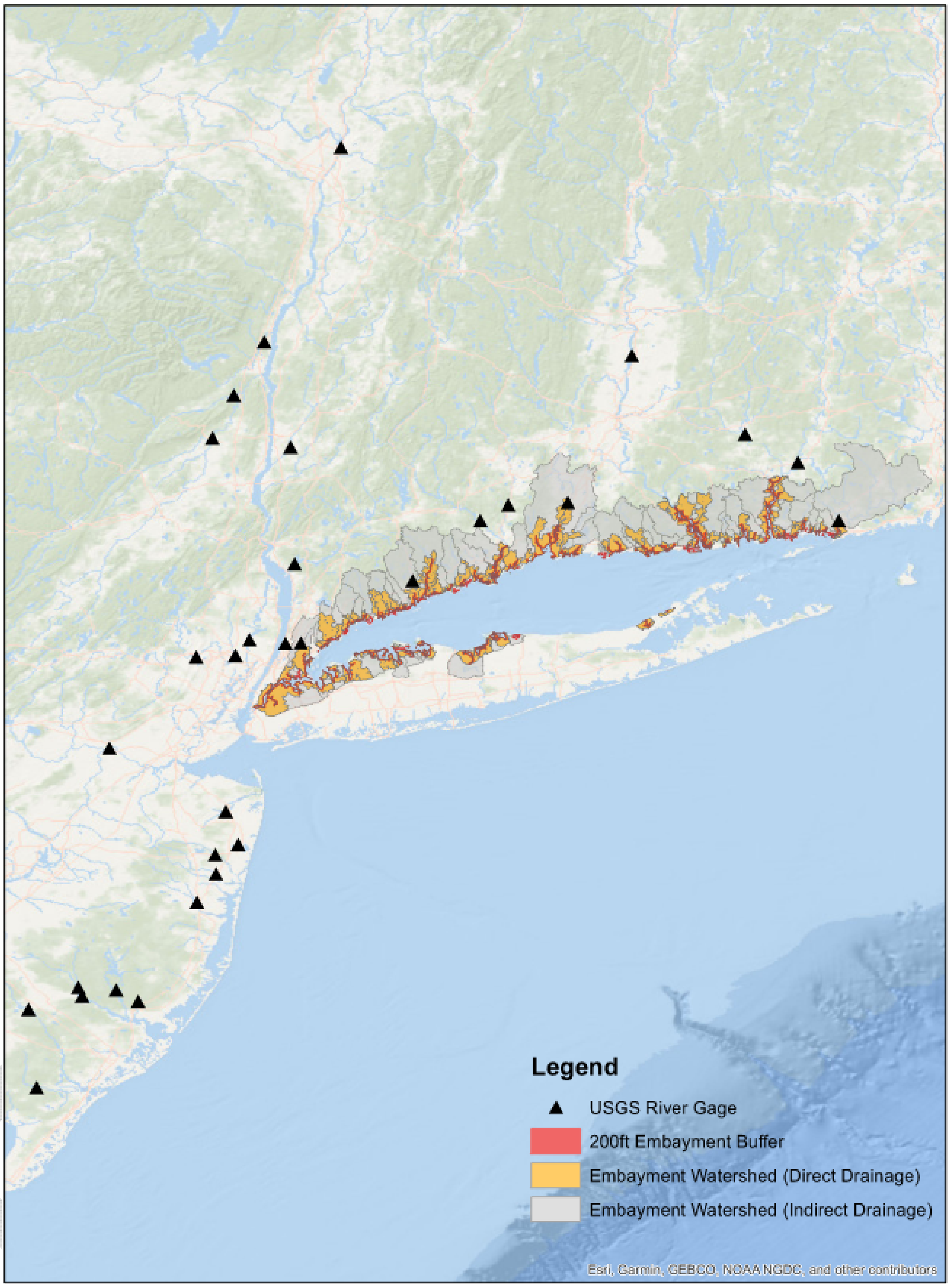


Figure 16. USGS Gage Locations with Available Data

h. Groundwater

Data sources include groundwater modeling from CDM Smith and/or USGS on Long Island, NYC and in Connecticut. Nitrogen load model (NLM) results are also available from Vaudrey et al. (2016) for Connecticut/New York embayments, Suffolk County Subwatersheds Wastewater Plan (2020) for Suffolk County embayments, and Nassau County Subwatersheds (2020) for Nassau County embayments.

SWEM Approach

No groundwater inputs were included.

Updated Approach

Groundwater Flows

The USGS has conducted groundwater modeling on Long Island and Connecticut (including Westchester County) to account for the flow that enters Long Island Sound (Misut et al., 2021, Barkley and Mullaney, 2021) via rivers and coastal areas for contributing watersheds. In addition, CDM Smith has completed groundwater modeling on Long Island in both Nassau and Suffolk Counties. The steady-state or long-term average groundwater flows from these studies were assigned spatially in the hydrodynamic model (ROMS) along the Long Island and Connecticut (including Westchester County) shorelines. For the open waters LIS model, the groundwater flows were assigned as annual inputs. For the stand-alone embayment modeling, the groundwater flows will most likely be assigned as seasonal or monthly inputs. The USGS is also conducting modeling to estimate groundwater nitrogen loads but these results are not expected until late 2023 and will not be available for use in this project. In areas other than LIS (e.g., East River, Hudson River, New Jersey coast) groundwater flow and loads will not be assigned because they are not expected to be significant.

Groundwater Loads (Not Associated with Embayments)

Some groundwater data exists for estimating concentrations used to calculate groundwater loads from Long Island, Connecticut and Westchester County areas not associated with an embayment (e.g., eastern end of the Long Island north shore). Concentrations for PO4, DON, NO3, DSI, DOC and DO were approximated from literature values. Literature sources included Tamborski (2016), Young et al. (2013, 2014, and 2016), Swanberg and Morgan (1978), Rahman et al. (2019), McDonough et al. (2019 and 2020), Scorca and Monti (2001), and Gobler and Sanudo-Wilhelmy (2001). Dissolved organic parameters were assigned as refractory state-variables. Table 17 presents the relationships that were used to derive model state-variables from the measured data and Table 18 presents the assigned concentrations. Loads for other model state-variables were not assigned.

Table 17. Derivation of Groundwater State-Variable

State-Variable	State-Variable
RDOP = estimated from PO4	NO23 = NO2+NO3
PO4T = PO4	SIT = DSI
RDON = DON	RDOC = DOC
NH4T = negligible	DO = DO

Table 18. Assigned Groundwater Concentrations

State-Variable	State-Variable
RDOP = 0.01 mg/L	NO23 = 3.0 mg/L
PO4T = 0.02 mg/L	SIT = 7.5 mg/L
RDON = 1.0 mg/L	RDOC = 1.7 mg/L

State-Variable	State-Variable
NH4T = 0.0 mg/L	DO = 6.0 mg/L

Embayment Loads (Nitrogen)

An embayment is defined as a recess in a coastline or indentation off a shoreline that forms a bay, harbor, or cove (e.g., Smithtown Bay, New Haven Harbor). NLMs exist for embayment subwatersheds along the Connecticut, New York and Long Island shorelines (e.g., Vaudrey et al., 2016; CDM Smith, 2020; and Stony Brook University, 2020). These existing NLMs will be used where available with potential adjustments as discussed below. NLMs use information about land use to calculate: (1) the nitrogen load released into a subwatershed from various sources; and (2) how much of the load ends up in the corresponding embayment. NLMs assume the transport mechanism for nitrogen entering an embayment from a subwatershed is primarily ground water. This is a good assumption for the coastal regions of Nassau and Suffolk Counties on Long Island.

In contrast with Nassau and Suffolk Counties, surface water runoff (stormwater) can be an important transport mechanism for nitrogen entering embayments in Westchester County and along the Connecticut shoreline. Where surface water runoff is the primary transport mechanism for nitrogen, nitrogen loads will be estimated in two steps. In the first step, surface water runoff will be estimated using a relationship between embayment watershed area and flow (e.g., Figure 17). Then, the surface water runoff estimates and available stormwater quality data (e.g., CTDEEP MS4 data, DEP MS4 Program) will be used to estimate nitrogen loads.

Groundwater and/or surface water runoff flows and nitrogen loads will be developed for the following areas: embayment subwatersheds in Suffolk County (6 areas); Nassau County (5 areas); Westchester County (5 areas); and Connecticut (35 areas). The delineation of these areas is still in progress but will be based on the embayment subwatershed delineations shown in Figure 18.

Annual average subwatershed flows and nitrogen loads for the embayments will be developed by year or for groupings of years for the Suffolk County areas based on the subwatershed delineations and groundwater modeling developed for Suffolk County's Subwatershed Wastewater Plan (SWP). The flows and nitrogen loads for the 2003-2018 time periods will be based on a steady-state run of the CDM Smith Suffolk County groundwater model under average precipitation and recharge conditions along with adjustments for population changes. The 2019-2022 flows and loads will be based on the flows and nitrogen loads from groundwater developed for the Suffolk County SWP.

Annual average subwatershed flows and nitrogen loads from groundwater will be developed by year or for groupings of years for the Nassau County areas based on the subwatershed delineations and groundwater modeling developed for Nassau County's SWP. The flows and nitrogen loads for the 2003-2018 time periods will be based on a steady-state run of the CDM Smith NYC groundwater model under average precipitation and recharge conditions along with adjustments for population changes. The 2019-2022 flows and loads will be based on the flows and nitrogen loads from groundwater developed for the Nassau County SWP.

Annual average subwatershed flows and nitrogen loads will be developed by year or for groupings of years for the Westchester County areas based on revisions to existing studies. The 2019-2022 flows and nitrogen loads will be based on subwatershed delineations to be obtained from others (e.g., HDR, USGS or UConn). Nitrogen loadings from unsewered areas will be based upon population estimates, and from estimates of fertilization and pets based upon the assumptions developed for Suffolk County's SWP. It is assumed that groundwater discharge from Westchester County will be a relatively insignificant component of the water balance to LIS and, therefore, not developed. The 2003-2018 flows and loads will be assigned as a proportion of the 2019-2022 loads based upon population increases.

Annual average subwatershed flows and nitrogen loads from surface water and /or groundwater will be developed by year or for groupings of years for coastal Connecticut areas based on revisions to existing studies. The 2019-2020 flows and nitrogen loads will be based on subwatershed delineations developed by others (e.g., CTDEEP); steady-state flows provided by on-going projects being conducted by the USGS (Barclay and Mullaney, 2021) and/or UConn (Vaudrey, et al., 2016); and nitrogen loading from groundwater developed for CTDEEP as part of the 2020 Phase II On-Site Wastewater Treatment Plants project, Vaudrey et al. (2016), and/or USGS estimates. For those subwatersheds that have not been characterized, nitrogen loads will be developed based upon land use within the watershed, and the nitrogen loads from wastewater, fertilizer and pets will be assigned based upon the assumptions developed as part of the Suffolk County SWP. The 2003-2018 flows and loads will be assigned as a proportion of the 2019-2020 loads based upon population increases.

Embayment Loads (Other Parameters)

Loads for the other model state-variables (i.e., RDOP, PO4T, RDON, NO23, SIT, RDOC, DO) will be estimated using the calculated surface water and/or groundwater flows, and available stormwater and groundwater data or literature sources. Alternately, if data is limited, loads for other model state-variables will be scaled to the calculated nitrogen loads for Long Island (Nassau and Suffolk Counties), Westchester, and Connecticut.

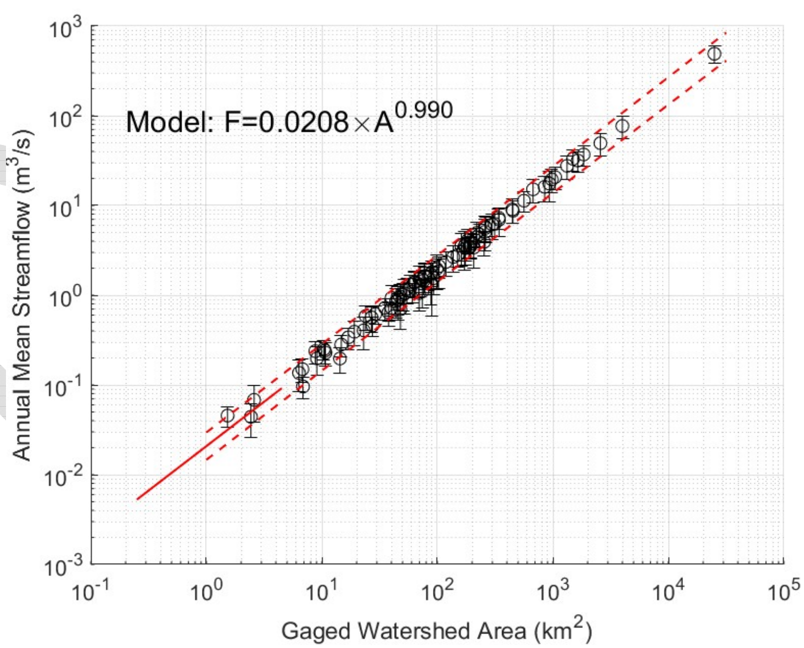


Figure 17. Flow versus Watershed Area for Connecticut USGS Gages (Vaudrey, 2021).

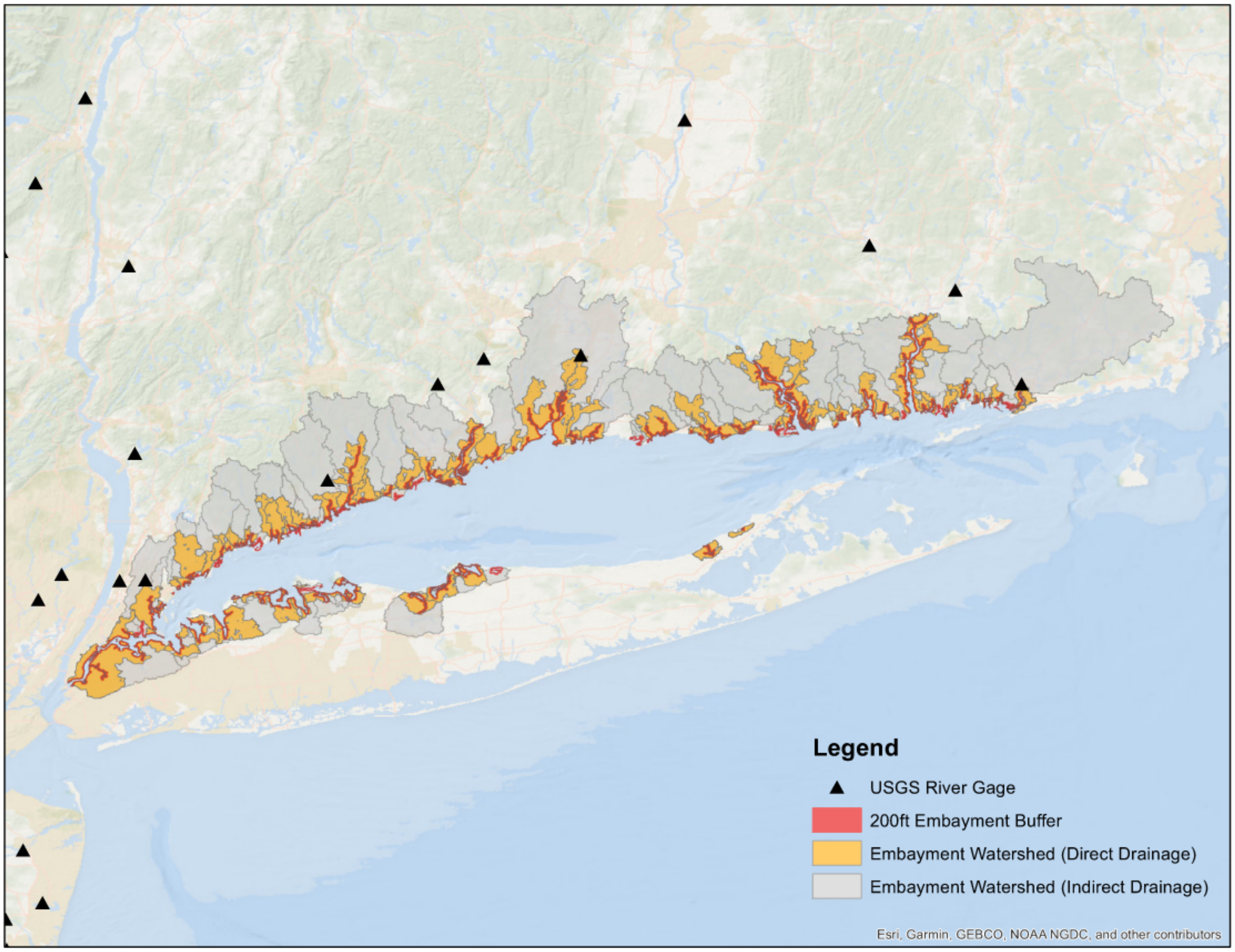


Figure 18. LIS Embayment Subwatershed Areas (Vaudrey et al., 2016)

i. Atmospheric

Data sources include NOAA, SWEM monitoring and literature.

SWEM Approach

For SWEM, wet-fall measurements of DOC, PO4, NH4, NO2+NO3, silicate, DON and DOP were collected. Spatially averaged maximum likelihood estimate (MLE) concentrations were calculated and assigned on a monthly basis. Precipitation was based on LaGuardia, Bridgeport, and Groton airports. Dry-fall measurements of NH4 and NO2+NO3 were also available from 1991 to 1993 and used in assigning SWEM model inputs.

Updated Approach

The National Atmospheric Deposition Program (NADP) (NTN Data (wisc.edu)) has monitoring data for NH4, NO3, and TN that were used to estimate dry and wet atmospheric deposition loads along with rainfall data. EPA's Community Multiscale Air Quality Modeling System (CMAQ) output were also used to supply NH4 and NO3 deposition rates for developing atmospheric deposition loads and were compared to the loads developed using the NADP data. The dry and wet atmospheric deposition loads were assigned as annual averages and varied by year. Spatially varying inputs were developed for nitrogen and spatially constant inputs were developed for other parameters. Figures 19 and 20 present the NADP and CMAQ locations where atmospheric deposition information was available.

Atmospheric deposition measurements for other parameters are very limited. HDR was guided by

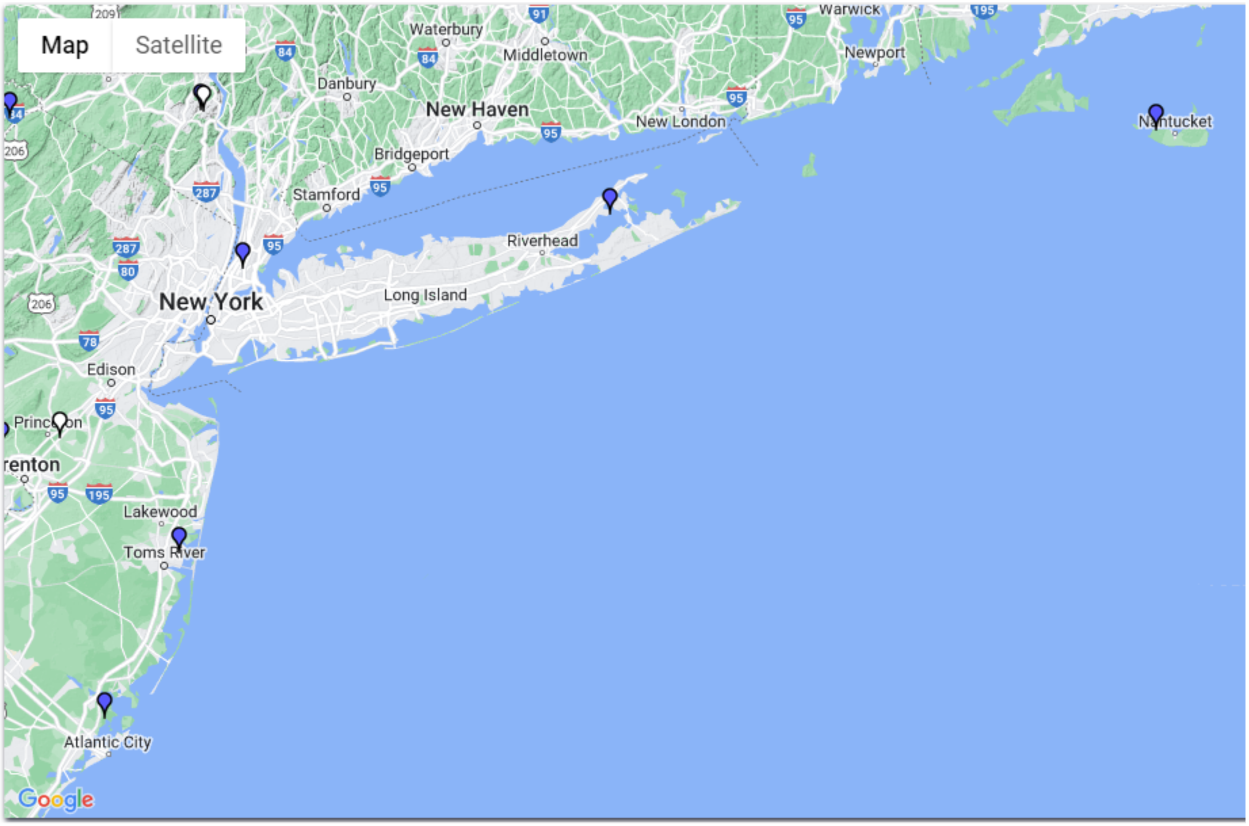


Figure 19. NADP Atmospheric Deposition Information Locations

previous measurements used for SWEM and the Jamaica Bay Eutrophication Study. Additionally, literature values were reviewed to bound potential deposition concentrations as noted in: Decina et al., 2018; Gao et al., 2007; Iavorivska et al., 2016; Iavorivska et al., 2017; Mahowald et al., 2008; and Tipping et al., 2014.

Results from SWEM sampling suggested that DON comprised 10 to 20% of the nitrogen deposition, so DON was estimated from the CMAQ deposition as DON = 0.175 x (NH4 + NO3). TN was then estimated as TN = DON + NH4 + NO3. Since the other deposition rates were limited, they were estimated by ratios to TN based on SWEM measured concentrations as shown in Table 19. The fractions assigned for each constituent, as shown in Table 20 were based on SWEM fractions or literature values, when available. Iavorivska (2016) estimated that 40% of atmospheric DOC deposition was labile. Estimates of atmospheric deposition rates and concentrations for phosphorus and carbon vary and were often not measured along with nitrogen, making the estimates of ratios uncertain. Since nitrogen is often the limiting nutrient in LIS, the other atmospheric loads are not viewed as being as critical.

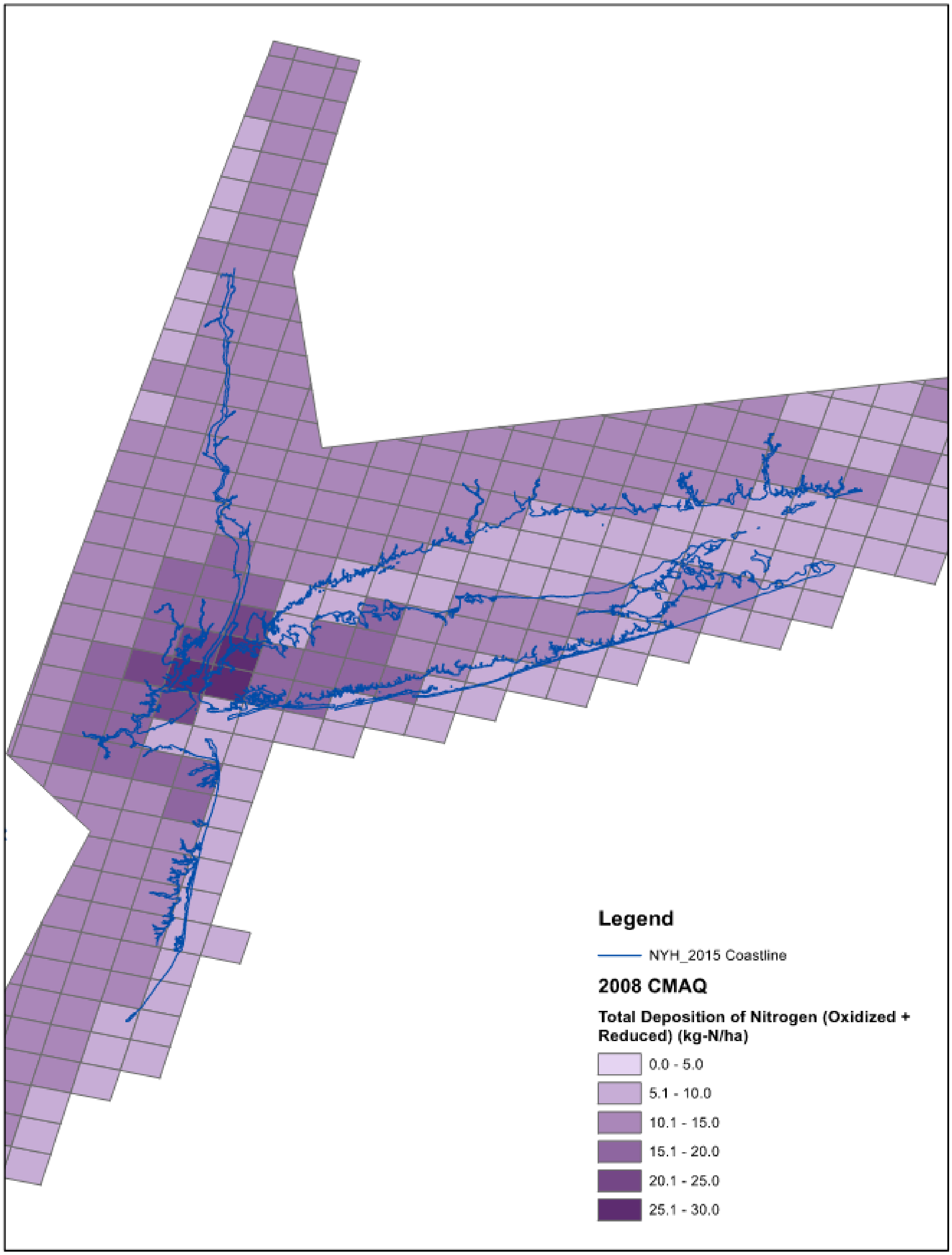


Figure 20. CMAQ Atmospheric Deposition Information Locations

Table 19. Ratios Assigned to Atmospheric Loading Rates

State-Variable
TP = TN/50
DSI = TN/25
TOC = 1.9 x TN

Table 20. Methodology Use to Assign Atmospheric Loading Rates

State-Variable	State-Variable
LDOP = 0.5 x TP	NO23 = CMAQ (NO3)
PO4T = 0.5 x TP	SIT = DSI
LDON = DON	RDOC = 0.6 x DOC
NH4T = CMAQ (NH3)	LDOC = 0.4 x DOC

j. Boundary Conditions

Although offshore boundary condition inputs are not considered a loading source to the model, they do represent an important model input and will be discussed. Offshore boundary condition inputs are assigned along the ocean boundary of the model and need to be specified for RCA model state-variables in addition to water elevation, temperature, and salinity in the ROMS model. Figure 21 presents the new LIS model grid with the offshore boundary condition input cells highlighted in yellow.

SWEM Approach

The SWEM modeling used data collected at nine Battelle water quality stations to assign monthly boundary conditions. The process of defining labile/refractory fractions is not documented in the SWEM report but were determined by reviewing the model input files.

Updated Approach

Offshore boundary condition data are not available for all years of the new modeling time period from 2003-2022. The World Ocean Atlas 2018 (WOA18) data (Garcia et al., 2019) was used to define some of the offshore boundary condition inputs in RCA. The WOA18 has objectively analyzed climatological monthly mean ocean data at different depths on both quarter- and one-degree longitude/latitude grids (Figure 22) based on data collected during the 2005-2017 time period (A5B7). The monthly mean concentrations were used to define boundary condition inputs for DO, NO3, PO4 and DSI. An example of the available data at location 8 (see Figure 22) is shown in Figure 23. Data are binned into 5-meter vertical increments for the first 100 meters and then in 25-meter vertical increments to 500 meters. This figure presents the surface data (at 0 meters) and data at 100 meters averaged over the 2005-2017 time period. The WOA18 monthly mean data were also used for the years outside of the available WOA18 data time period (e.g., 2003-2004 and 2017-2022). A review of the DO data suggested the deeper DO measurements were not accurate and surface DO, PO4, NO3, and DSI concentrations from WOA18 were applied for all depths at the model boundary.

Model-data comparisons at monitoring stations located in offshore areas (e.g., CTDEEP station M3) were used to evaluate the impact of the assigned boundary conditions and to guide interannual adjustments that may be needed to reproduce the offshore monitoring data. This approach was also used to help in defining model boundary conditions for other water quality parameters not provided in the WOA18 database (e.g., organic nitrogen, phosphorus, and carbon). Table 21 presents the concentrations currently being assigned at the model boundary condition input locations. These concentrations may be adjusted as additional years are included in the model calibration.

In summary, the WOA18 data were used to guide RCA model offshore boundary condition input setup along with the use of other offshore monitoring data within the model domain (e.g., CTDEEP station M3), monitoring data collected for SWEM development, and best professional judgment.

Table 21. RCA State-Variable Boundary Condition Concentrations

State-Variable	Concentration (mg/L)	State-Variable	Concentration (mg/L)
TSS	5.0	NH4T	Phyt N
PHYT1	0.1	NO23	NO3 (WOA)
PHYT2	0.1	BSI	0.125
PHYT3	0.1	SIT	DSi (WOA) + Phyt Si
RPOP	0.004	RPOC	0.05
LPOP	0.0	LPOC	0.05
RDOP	0.01	RDOC	2.0
LDOP	0.0	LDOC	0.7
PO4T	PO4 (WOA) + Phyt P	ExDOC	0.0
RPON	0.01	RePOC	0.0
LPON	0.0	ReDOC	0.0
RDON	0.10	O2EQ	0.0
LDON	0.0	DO	DO (WOA Surface)

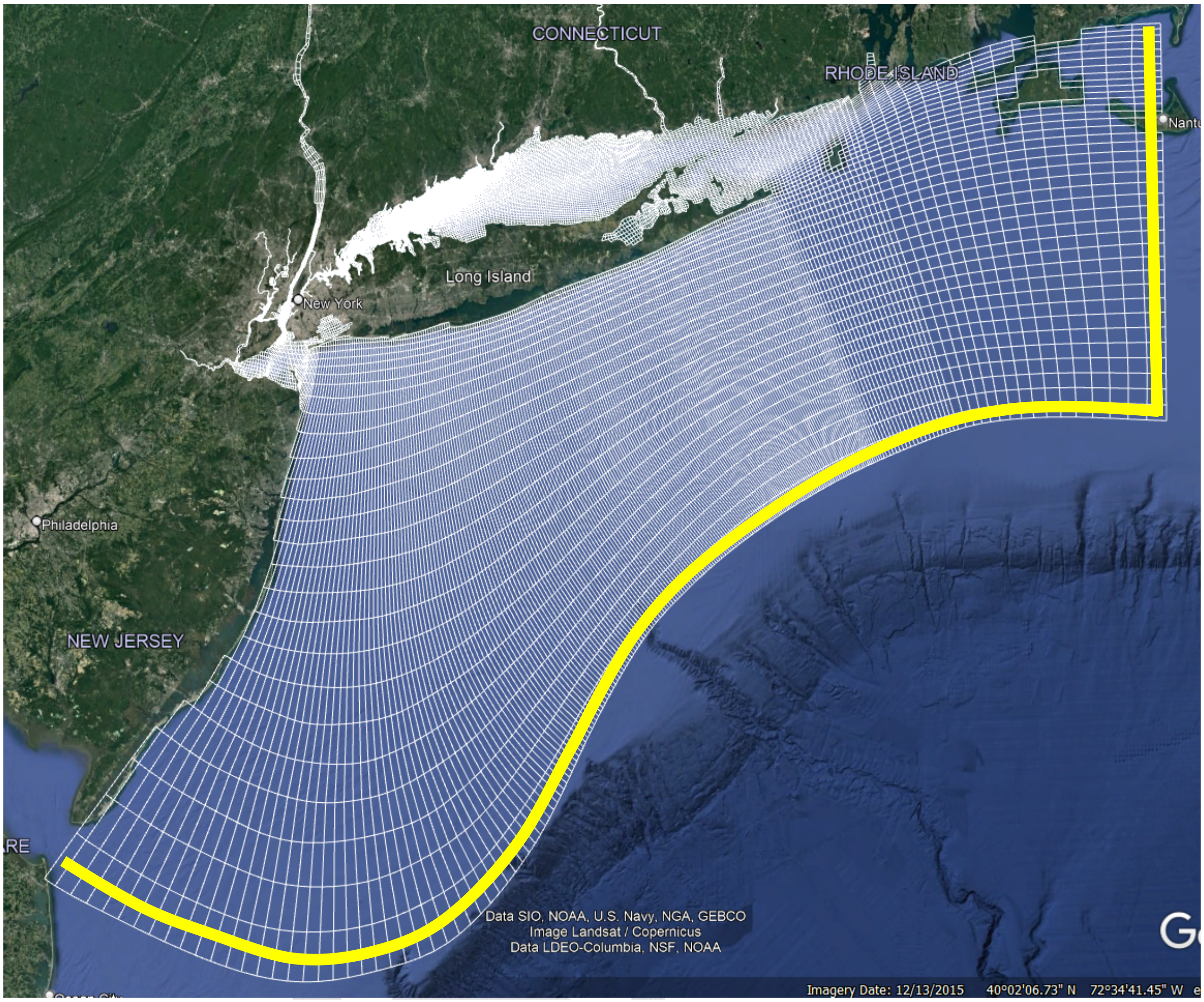


Figure 21. New LIS Model Grid with Offshore Boundary Condition Locations (Yellow Cells)

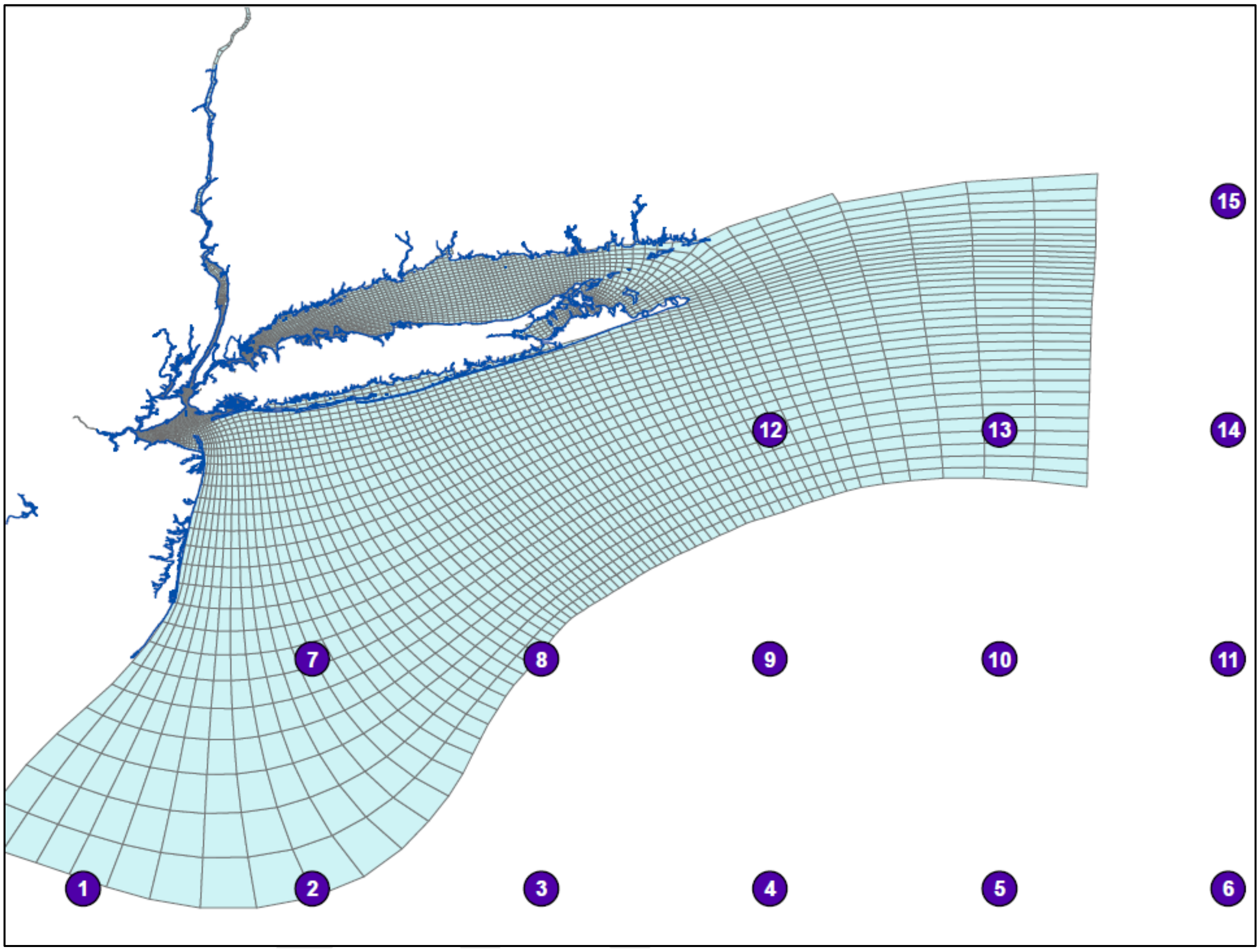


Figure 22. WOA18 1-Degree Grid for Climatological Means (circled numbers) & SWEM Model Grid

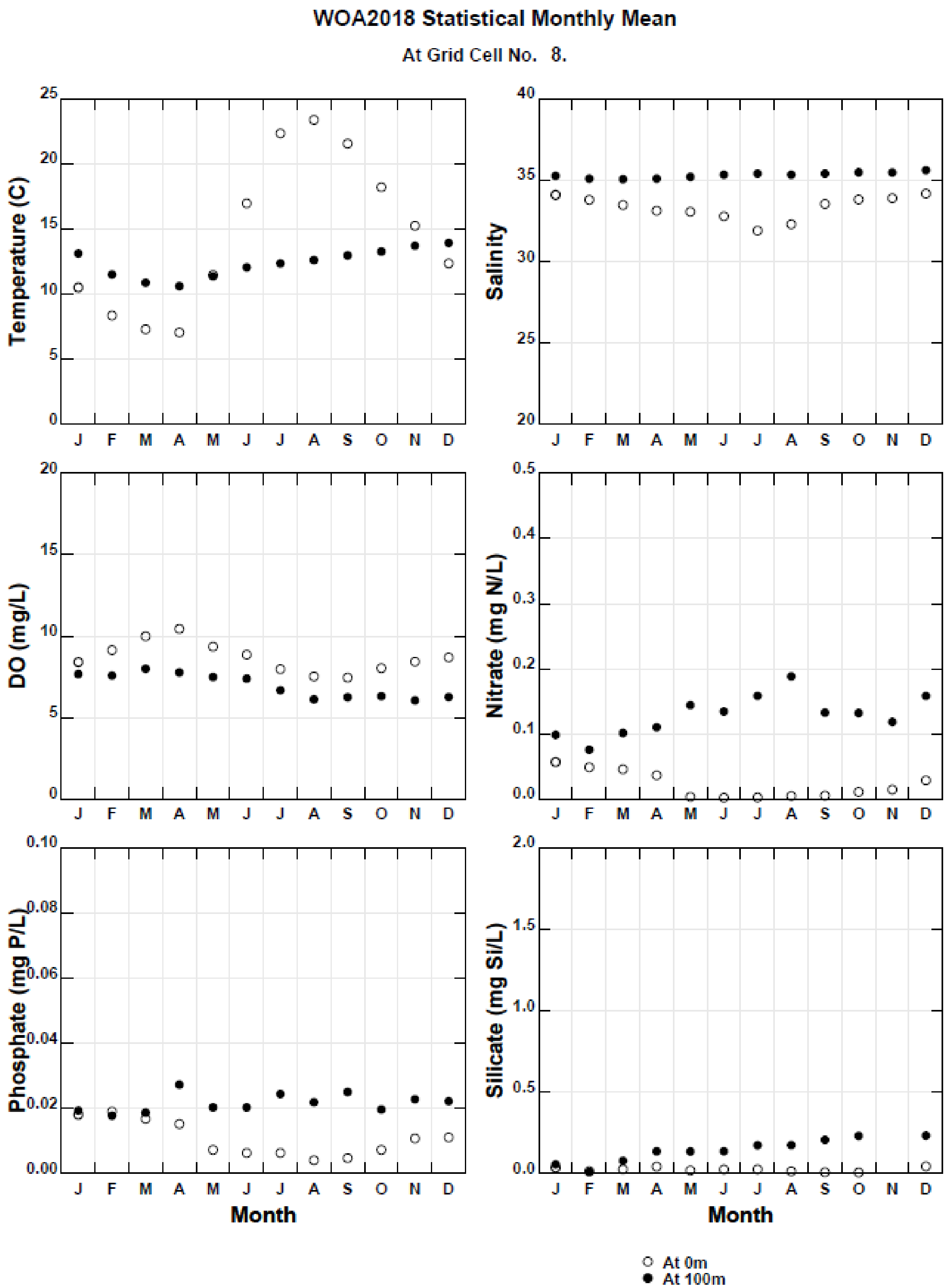


Figure 23. Example of WOA18 Offshore Data (Average Values over 2005-2017 Time Period)

4. References

Baker, R.J., C.M., Wieben, R.G. Lathrop, and R.S. Nicholson, 2014. Concentrations, loads, and yields of total nitrogen and total phosphorus in the Barnegat Bay-Little Egg Harbor watershed, New Jersey, 1989–2011, at multiple spatial scales: U.S. Geological Survey Scientific Investigations Report 2014–5072, 64 p., http://dx.doi.org/10.3133/sir20145072.

Barclay, J.R., and J.R. Mullaney, 2021. Simulation of groundwater budgets and travel times for watersheds on the north shore of Long Island Sound, with implications for nitrogen-transport studies: U.S. Geological Survey Scientific Investigations Report 2021–5116, 84 p., https://doi.org/ 10.3133/ sir20215116.

CDM Smith, 2020. DRAFT Facilities Plan for the West and East Side Wastewater Treatment Plants. Water Pollution Control Authority (WPCA). City of Bridgeport, CT. November 2020.

CDM Smith, 2020b. 2018 Integrated Long-Term CSO Control Plan Summary. The Metropolitan District. Hartford, Connecticut. May 2020.

CH2M, 2018. City of New Haven Combined Sewer Overflow Long-Term Control Plan Update. Prepared for Greater New Haven Water Pollution Control Authority. December 2016. Revised March 2018.

Swanberg, C.A. and P. Morgan, 1978. The Linear Relation Between Temperatures Based on the Silica Content of Groundwater and Regional Heat Flow: A New Heat Flow Map of the United States. Pageoph, Vol. 117 (1978/79), Birkhauser Verlag, Basel.

Decina, S. M., P. H., Templer, and L.R., Hutyra, 2018. Atmospheric Inputs of Nitrogen, Carbon, and Phosphorus across an Urban Area: Unaccounted Fluxes and Canopy Influences, Earth's Future, 6, 134–148, https://doi.org/10.1002/2017EF000653.

Garcia, H.E., T.P. Boyer, O.K. Baranova, R.A. Locarnini, A.V. Mishonov, A. Grodsky, C.R. Paver, K.W. Weathers, I.V. Smolyar, J.R. Reagan, D. Seidov, and M.M. Zweng, 2019. World Ocean Atlas 2018: Product Documentation. A. Mishonov, Technical Editor.

Gao, Y., M.J. Kennish, and A. M. Flynn., 2007. Atmospheric Nitrogen Deposition to The New Jersey Coastal Waters and Its Implications. Ecological Applications, 17(5) Supplement, 2007, pp. S31–S41.

Gobler, C.J. and S.A. Sanudo-Wilhelmy, 2001. Temporal variability of groundwater seepage and brown tide blooms in a Long Island Embayment. Mar. Ecol. Prog. Ser. Vol. 217:299-309, 2001.

HydroQual, 2005. Application of RAINMAN to New York/New Jersey Harbor. Submitted to NY/NJ Harbor Estuary Program Pathogen Work Group. Interim Report, 9/2005.

Iavorivska, L., E. W. Boyer, D. R. DeWalle., 2016. Atmospheric deposition of organic carbon via precipitation. Atmospheric Environment 146 (2016) 153-163.

Iavorivska, L., E. W. Boyer, and J. W. Grimm., 2017. Wet atmospheric deposition of organic carbon: An underreported source of carbon to watersheds in the northeastern United States, J. Geophys. Res. Atmos., 122,3104–3115, doi:10.1002/2016JD026027.

Jia, Y. and M.M. Whitney, 2019. Summertime Connecticut River Water Pathways and Wind Impacts. Journal of Geophysical Research: Oceans, 124, 1897-1914.

Mahowald, N., T. D. Jickells, A. R. Baker, P. Artaxo, C. R. Benitez-Nelson, G. Bergametti, T. C. Bond, Y. Chen, D. D. Cohen, B. Herut, N. Kubilay, R. Losno, C. Luo, W. Maenhaut, K. A. McGee, G. S. Okin, R. L. Siefert, and S. Tsukuda, 2008. Global distribution of atmospheric phosphorus sources, concentrations and deposition rates, and anthropogenic impacts. Global Biogeochemical Cycles, Vol. 22, GB4026, doi:10.1029/2008GB003240, 2008.

McDonough, L.K., I.R. Santos, M.S. Andersen, D.M. O'Carroll, H. Rutlidge, K. Meredith, P. Oudone, J. Bridgeman, D.C. Gooddy, J.P.R. Sorensen, D.J. Lapworth, A.M. MacDonald, J. Ward, and A. Baker, 2020. Changes in global groundwater organic carbon driven by climate change and urbanization. Nature Communications. https://doi.org/10.1038/s41467-020-14946-1.

Misut, P.E., N.A. Casamassina, and D.A. Walter, 2021. Delineation of areas contributing groundwater and travel times to receiving waters in Kings, Queens, Nassau, and Suffolk Counties, New York: U.S. Geological Survey Scientific Investigations Report 2021–5047, 61 p., https://doi.org/ 10.3133/ sir20215047.

Norwich Department of Public Utilities, 2015. Environmental Impact Evaluation. Combined Sewer Overflow Long Term Control Plan. Project Number 14765. October 15, 2015.

Rahman, S., J.J. Tamborski, M.A. Charette, and J.K. Cochran, 2019. Dissolved silica in the subterranean estuary and the impact of submarine groundwater discharge on the global marine silica budget. Marine Chemistry. 208 (2019) 29-42.

RESPEC, 2021. Simulation Plan for The Connecticut Statewide Watershed Modeling. Topical Report RSI-3094. Prepared for the Connecticut Department of Energy and Environmental Protection.

Scorca, M.P. and J. Monti, Jr., 2001. Estimates of Nitrogen Loads Entering Long Island Sound from Ground Water and Streams on Long Island, New York, 1985-96. U.S. Geological Survey. Water-Resources Investigations Report 00-4196.

Stony Brook University, 2020. Nitrogen Load Modeling for Nassau County Subwatersheds. Prepared for NYSDEC. School of Marine and Atmospheric Sciences. 2/2020.

Suffolk County Department of Health Services and CDM Smith, 2020. Suffolk County Subwatersheds Wastewater Plan. 7/2020.

Tamborski, J.J. 2016. Submarine Groundwater Discharge into Long Island Sound. Stony Brook University Ph.D. Dissertation.

Tipping, E., S. Benham, J.F. Boyle, P. Crow, J. Davies, U. Fischer, H. Guyatt, R. Helliwell, L. Jackson-Blake, A.J. Lawlor, D.T. Monteith, E.C. Rowe, and H. Tobermana, 2014. Atmospheric deposition of phosphorus to land and freshwater. Environmental Science: Processes & Impacts.

Vaudrey, J.M.P., C. Yarish, J.K. Kim, C. Pickerell, L. Brousseau, J. Eddings, and M. Sautkulis, 2016. Connecticut Sea Grant Project Report: Comparative Analysis and Model Development for Determining the Susceptibility to Eutrophication of Long Island Sound Embayments. Project Number R/CE-34-CTNY. 46p.

Vaudrey, J.M.P., 2021. Development of a Statewide Embayment Modeling Scheme for Connecticut. Draft Task Deliverable as Part of RESPEC Project with CTDEEP (Contract Award No. 19PSX0167). 12/20/2021.

Whitney, M.M. and D.L. Codiga, 2011. Response of a Large Stratified Estuary to Wind Events: Observations, Simulations, and Theory for Long Island Sound. Journal of Physical Oceanography, Volume 41, 1308-1327.

Young, C., K.D. Kroeger, and G. Hansen, 2013. Limited denitrification in glacial deposit aquifers having thick unsaturated zones (Long Island, USA). Hydrogeology Journal (2013) 21:1773-1786.

Young, C., Hanson, G., T. Wong, N. Stark, J. Durand, R. Paulsen, and J. Wanlass, 2014. Sources and Fate of Nitrogen in North Shore Embayment's. Project R/CTP-44-NYCT.

Young, C., J. Durand, J. Rapaglia, and H. Bokuniewicz. Submarine Discharge of Nitrate Rich Groundwater into Port Jefferson Harbor, Long Island, NY. Stony Brook University. NY Sea Grant.

Young, C., J.B. Martin, and G.N. Hanson. Controls on Nitrous Oxide Production in, and Fluxes from a Coastal Aquifer in Long Island, NY, USA, 2016. Journal of Marine Science and Engineering. 2016, 4, 71.

1

Methods Used to Assign Model River Inputs

List of rivers with USGS gage data assigned in the model

- USGS 01209700 Norwalk River at South Wilton, CT
- USGS 01208500 Naugatuck River at Beacon Falls, CT
- USGS 01205500 Housatonic River at Stevenson, CT
- USGS 01196500 Quinnipiac River at Wallingford, CT
- USGS 01184000 Connecticut River at Thompsonville, CT
- USGS 01127000 Quinebaug River at Jewett City, CT
- USGS 011230695 Shetucket River at Taftville, CT
- USGS 01192500 Hockanum River near East Hartford, CT
- USGS 01127500 Yantic River at Yantic, CT
- USGS 01193500 Salmon River near East Hampton, CT
- USGS 01194500 East Branch Eightmile River near North Lyme, CT
- USGS 01194000 Eightmile River at North Plain, CT
- USGS 01195100 Indian River near Clinton, CT
- USGS 01192883 Coginchaug River at Middlefield, CT
- USGS 01196561 Muddy River near East Wallingford, CT
- USGS 01196620 Mill River near Hamden, CT
- USGS 01184100 Stony Brook near West Suffield, CT
- USGS 01208950 Sasco Brook near Southport, CT
- USGS 01208873 Rooster River at Fairfield, CT
- USGS 01208925 Mill River near Fairfield, CT
- USGS 01118500 Pawcatuck River at Westerly, RI
- USGS 01358000 Hudson River at Green Island NY
- USGS 01372500 Wappinger Creek near Wappingers Falls NY
- USGS 01375000 Croton River at New Croton Dam Nr Croton-On-Hudson NY
- USGS 01371500 Wallkill River at Gardiner NY
- USGS 01367500 Rondout Creek at Rosendale NY
- USGS 01364500 Esopus Creek at Mount Marion NY
- USGS 01303500 Cold Spring Brook at Cold Spring Harbor NY
- USGS 01302500 Glen Cove Creek at Glen Cove NY
- USGS 01303000 Mill Neck Creek at Mill Neck NY
- USGS 01304500 Peconic River at Riverhead NY
- USGS 01304000 Nissequogue River near Smithtown NY
- USGS 01209901 Rippowam River at Stamford, CT
- USGS 01302020 Bronx River at NY Botanical Garden at Bronx NY
- USGS 01411300 Tuckahoe River at Head of River NJ
- USGS 01410500 Absecon Creek at Absecon NJ
- USGS 01411000 Great Egg Harbor River at Folsom NJ
- USGS 01409400 Mullica River near Batsto NJ
- USGS 01410000 Oswego River at Harrisville NJ
- USGS 01409810 West Branch Wading River near Jenkins NJ
- USGS 01410150 East Branch Bass River near New Gretna NJ
- USGS 01409280 Westecunk Creek at Stafford Forge NJ
- USGS 01408120 North Branch Metedeconk River near Lakewood NJ
- USGS 01408029 Manasquan River near Allenwood NJ
- USGS 01407705 Shark River near Neptune City NJ

- USGS 01407760 Jumping Brook near Neptune City NJ
- USGS 01407500 Swimming River near Red Bank NJ
- USGS 01409500 Batsto River at Batsto NJ
- USGS 01408500 Toms River near Toms River NJ
- USGS 01409000 Cedar Creek at Lanoka Harbor NJ
- USGS 01395000 Rahway River at Rahway NJ
- USGS 01405030 Lawrence Brook at Westons Mills NJ
- USGS 01403060 Raritan River Below Calco Dam at Bound Brook NJ
- USGS 01391500 Saddle River at Lodi NJ
- USGS 01389890 Passaic River at Dundee Dam at Clifton NJ
- USGS 01378500 Hackensack River at New Milford NJ

Estimation method for rivers with flow data gaps

- Shetucket R. estimated by Quinnebaug R. x 512.0/713.0
- Eightmile R. estimated by East Bound Eightmile R. x 20.10/22.30
- Muddy R. estimated by Coginchaug R. x 8.880/29.80
- Rooster R. estimated by Sascobrook R. x 10.60/7.380
- Mill R. at Fairfield estimated by Sascobrook R. x 28.60/7.380
- Glen Cove R. estimated by Coldspring R. x 14.40/7.830
- Mill Neck R. estimated by Coldspring R. x 8.580/7.830 + 5.0 (estimated baseflow)
- Nissequogue R. estimated by Peconic R. x 27.00/74.70 + 32.0 (estimated baseflow)
- Bronx R. estimated by Rippowam R. x 38.40/34.00
- Absecon R. estimated by Tuckahoe R. x 17.90/30.80
- West Branch Wading R. estimated by Oswego R. x 84.10/72.50
- Westecunk R. estimated by Bass R. x 15.80/8.110
- Batsto R. estimated by Oswego R. x 67.80/72.50 + 10.0 (estimated baseflow)
- Cedar Creek R. estimated by Toms R. x 53.30/123.0
- Dundee Dam estimated by Passaic R. at Little Falls x 805.0/762.0

Estimation method for rivers with no flow data available

- Farmington R. estimated by Naugatuck R. x 590./260.
- Scantic R. estimated by Hockanum R. x 98.2/73.4
- Neck R. estimated by Indian R. x 6.55/5.68
- Elizabeth R. estimated by Rahway R. x 18.0/40.9
- Robinsons R. estimated by Rahway R. x 21.6/40.9
- South R. estimated by Lawrence R. x 94.6/44.9
- Third R. estimated by Saddle R. x 11.8/54.6
- Second R. estimated by Saddle R. x 11.6/54.6

Rivers/creeks/streams modified using application of the USGS StreamStats tool (prepared by Manhattan College) to generate the flows for all of the ungaged watershed areas/tributaries entering the Hudson River below Albany and into the East River

- Esopus Creek
- Wallkill River
- Rondout Creek

- Wappinger Creek
- Croton River
- Poesten Kill
- Wynants Kill – East
- Wynants Kill – West
- Hannacrois Creek Total - West & East
- Kinderhook Creek
- Roeliff Jansen Kill
- Saw Kill – West
- Saw Kill – East
- Landsman Kill – West
- Landsman Kill – East
- Fishkill Creek & Quassaic Creek – West
- Quassaic Creek – East
- Moodna Creek
- Peekskill Hollow Creek – East
- Peekskill Hollow Creek – West
- Ossining & Gory Brook
- Nyack Brook
- Irvington and Dobbs Ferry
- Sparkhill Creek & Tall Man Park
- Hutchinson River
- New Rochelle Creek
- Mamaroneck River
- Blind Brook
- Catskill Creek
- Normans Kill
- Saw Mill River
- Tallman Park Creek

		Annual Average Flow (cfs)				Annual Average Flow (cfs)	
State	River	2005	2006	State	River	2005	2006
CT	Connecticut River 01184000	23206	23571	NY	Bronx River 01302020	70	87
NY	Hudson River 01358000	16989	20418	NY	Quassaic Creek East	94	96
CT	Housatonic River 01205500	3548	3655	NJ	Hackensack River 01378500	88	71
NY	Rondout Creek 01367500	2758	2507	CT	Coginchaug River 01192883	85	89
NJ	Passaic River 01389890	1525	1523	NJ	Rahway River 01395000	62	66
CT	Quinnebaug River 01127000	1746	1692	NJ	North Branch Metedeconk River 01408120	73	71
CT	Farmington River 01190000	1403	1784	CT	Norwalk River 01209700	70	88
NY	Wallkill River 01371500	1663	1445	NY	Wynants Kill West	76	66
NJ	Raritan River 01403060	1391	1387	NJ	Lawrence Brook 01405030	63	62
CT	Shetucket River 011230695	1254	1215	NJ	Swimming River 01407500	63	70
NY	Kinderhook Creek	1075	867	CT	Mill River 01196620	64	74
NY	Catskill Creek	992	880	NY	Mamaroneck River	68	55
NY	Esopus Creek 01364500	861	1198	CT	East Branch Eightmile River 01194500	52	67
NY	Croton River 01375000	809	827	NY	Nissequogue River 01304000	53	57
RI	Pawcatuck River 01118500	777	824	CT	Rippowam River 01209901	62	71
CT	Naugatuck River 01208500	618	786	CT	Eightmile River 01194000	47	60
NY	Roeliff Jansen Kill	563	455	CT	Mill River 01208925	44	59
NY	Moodna Creek	468	407	NY	Saw Mill River	53	54
NY	Wappinger Creek 01372500	482	389	NJ	Tuckahoe River 01411300	37	40
NY	Hannacrois Creek Total West	417	362	NY	Peconic River 01304500	42	58
NY	Normans Kill	378	328	NJ	Robinsons Branch 01396000	33	35
NY	Fishkill Creek	350	358	NY	Hutchinson River	44	36
NY	Quassaic Creek West	351	305	NJ	Westecunk Creek 01409280	31	37
CT	Quinnipiac River 01196500	299	360	NJ	Elizabeth River 01393500	27	29
NJ	Toms River 01408500	231	230	NY	New Rochelle Creek	36	29
CT	Salmon River 01193500	242	300	NJ	Third River 01392210	28	29
NY	Peekskill Hollow Creek East	233	238	NY	Irvington & Dobbs Ferry	32	32
CT	Scantic River 01184500	241	236	NJ	Second River 01392500	28	29
CT	Yantic River 01127500	190	233	NY	Gory Brook	30	31
NY	Landsman Kill East	234	189	NY	Blind Brook	29	23
NY	Poesten Kill	205	166	CT	Stony Brook 01184100	27	24
NY	Wynants Kill East	205	166	NY	Ossinning Brook	23	24
NY	Saw Kill East	193	156	NJ	Shark River 01407705	20	22
CT	Hockanum 01192500	180	176	NJ	Absecon Creek 01410500	21	23
NJ	West Branch Wading River 01409810	80	143	NJ	East Branch Bass River 01410150	15	17
NJ	South River 01405500	133	131	NY	Sparkhill Creek	21	22
NJ	Saddle River 01391500	132	135	CT	Rooster River 01208873	18	24
NY	Peekskill Hollow Creek West	136	134	CT	Muddy River 01196561	20	21
NJ	Mullica River 01409400	109	128	CT	Sasco Brook 01208950	16	20
NY	Landsman Kill West	141	123	CT	Neck River 01195200	14	14
NJ	Cedar Creek 01409000	105	116	NJ	Jumping Brook 01407760	12	11
NJ	Batsto River 01409500	102	91	NY	Nyack Brook	12	12
NJ	Great Egg Harbor River 01411000	88	94	CT	Indian River 01195100	12	12
NY	Saw Kill West	116	101	NY	Mill Neck Creek 01303000	9	11
NY	Hannacrois Creek Total East	114	92	NY	Glen Cove Creek 01302500	7	8
NJ	Manasquan River 01408029	95	95	NY	Cold Spring Brook 01303500	3	5
NJ	Oswego River 01410000	69	87	NY	Tallman Park Creek	4	4

2

WRRF/CSO/Stormwater Flows Assigned in the Model

DEP WRRFs

WRRF-26	WRRF-BB	WRRF-CI	WRRF-HP	WRRF-JA
WRRF-NC	WRRF-NR	WRRF-OH	WRRF-PR	WRRF-RH
WRRF-RO	WRRF-TI	WRRF-WI		

Other WRRFs by NPDES Permit Number

CT0000086	CT0000957	CT0024759	CT0100013	CT0100048	CT0100056
CT0100161	CT0100234	CT0100242	CT0100366	CT0100382	CT0100404
CT0100412	CT0100501	CT0100617	CT0100684	CT0100714	CT0100749
CT0100935	CT0101010	CT0101036	CT0101044	CT0101079	CT0101087
CT0101184	CT0101249	CT0101419	CT0101656	CTMIU0192	CTP000083
NJ0020028	NJ0020141	NJ0020371	NJ0020591	NJ0021016	NJ0024520
NJ0024562	NJ0024643	NJ0024694	NJ0024708	NJ0024741	NJ0024783
NJ0024872	NJ0024953	NJ0025038	NJ0025241	NJ0025321	NJ0025356
NJ0026018	NJ0026085	NJ0026735	NJ0028142	NJ0029084	NJ0029408
NJ0035343	NJ0053007	NY0020061	NY0021342	NY0021750	NY0022144
NY0022462	NY0023523	NY0025976	NY0026051	NY0026255	NY0026271
NY0026310	NY0026450	NY0026620	NY0026719	NY0026778	NY0026841
NY0108324	NY0206644	RI0100064			

DEP CSO/SW Outfalls

26-004	26-003	26-005	26--61	26--62	26--83	26--84
26--85	26--86	26--87	26--88	26--89	26--90	26--91
26--92	26--93	26--94	26--95	26--96	26--97	26--98
26--99	BB-005	BB-007	BB-008	BB-026	BB--48	BB--50
BB--51	BB--52	BB--53	BB--54	BB--55	BB--58	BB--59
BB--60	BB--61	BB--62	BB--63	BB--64	BB--65	BB--66
BB--67	BB--68	BB--69	BB--70	BB--71	BB--72	BB--73
BB--74	BB--75	BB--76	BB--77	BB--78	BB--79	BB--80
BB--82	BB--83	BB--84	BB--85	BB--86	BB--87	BB--88
BB--89	BB-200	BB-202	BB-370	BB-506	BB-510	BB-512
BB-519	BB-522	BB-524	BB-528	BB-532	BB-537	BB-601
BB-602	BB-603	BB-606	BB-607	BB-609	BB--CF	BB--93
BB--94	BB--95	BB-LG01	BB-LG02	BB-LG03	BB-LG04	BB-LG05
BB-LG5A	BB-LG06	BB-LG6A	BB-LG07	BB-LG08	BB-LG10	BB-LG11
BB-LG12	BB-LG13	BB-LG1A	BB-LGA	BB-LKD	BB-047	BB-006
BB-016	BB-017	BB-018	BB-021	BB-022	BB-023	BB-024
BB-025	BB-027	BB-028	BB-029	BB-009	BB-030	BB-031
BB-046	BB-033	BB-032	BB-034	BB-035	BB-036	BB-037
BB-041	BB-002	BB-003	BB-010	BB-040	BB-004	BB-042
BB-013	BB-043	BB-014	BB-015	BB-011	BB-012	BB-045
BB--49	BB-103	BB-502	BB-503	BB-604	CI-111	CI-113
CI-417	CI-425	CI-428	CI-430	CI-431	CI-432	CI-446
CI-455	CI--54	CI--55	CI--56	CI--57	CI--58	CI--59
CI--60	CI-601	CI-602	CI-603	CI-604	CI-659	CI-605
CI-607	CI-608	CI-609	CI--61	CI-610	CI-611	CI-612
CI-613	CI-614	CI-615	CI-616	CI-617	CI-618	CI-619
CI--62	CI-620	CI-621	CI-622	CI-623	CI-624	CI-625
CI-626	CI-627	CI-628	CI-629	CI--63	CI-630	CI-631
CI-632	CI-633	CI-634	CI-636	CI-637	CI-639	CI--64
CI-640	CI-640d	CI-641	CI--65	CI-653	CI-654	CI-655
CI-656	CI-657	CI--66	CI-661	CI-660	CI-662	CI-663
CI-664	CI-665	CI-666	CI-668	CI-669	CI-670	CI-671

CI-672	CI-673	CI-674	CI-676	CI-677	CI-678	CI--68
CI-682	CI-683	CI--69	CI--70	CI--71	CI--72	CI--73
CI--74	CI--75	CI--76	CI--77	CI--78	CI--79	CI--80
CI--82	CI--83	CI--84	CI--85	CI--86	CI--87	CI--88
CI--89	CI--90	CI--91	CI--92	CI--93	CI--94	CI--95
CI--96	CI--97	CI--98	CI--99	CI-0U1	CI-CIT	CI-006
CI-005	CI-004	HP-006	HP-029	HP-015	HP-010	HP-008
HP-005	HP--37	HP--38	HP--39	HP--40	HP--41	HP--42
HP--43	HP--44	HP--45	HP--46	HP--47	HP--48	HP--49
HP--50	HP--51	HP--52	HP--53	HP--54	HP--55	HP--56
HP--57	HP--58	HP--59	HP--60	HP--61	HP--62	HP--63
HP--64	HP--65	HP--66	HP--67	HP--68	HP--69	HP--70
HP--71	HP--72	HP--73	HP--74	HP--75	HP--76	HP--77
HP--78	HP--79	HP--80	HP--81	HP--82	HP--83	HP--84
HP--85	HP--86	HP--88	HP--89	HP--90	HP--91	HP--92
HP--93	HP--94	HP--95	HP--96	HP--97	HP--98	HP--99
HP-004	HP-007	HP-012	HP-013	HP-014	HP-031	HP-033
HP-105	HP-106	HP-109	HP-205	HP-502	HP-504	HP-505
HP-506	HP-507	HP-511	HP-602	HP-606	HP-610	HP-614
HP-623	HP-625	HP-626	HP-627	HP-630	HP-631	HP-633
HP-635	HP-636	HP-637	HP-638	HP-640	HP-641	HP-643
HP-644	HP-645	HP-839	HP-899	HP-943	HP-022	HP-021
HP-020	HP-019	HP-016	HP-011	HP-025	HP-002	HP-003
HP-017	HP-018	HP-009	HP-026	HP-023	HP-024	JA-003a
JA-003	JA--60	JA--61	JA--62	JA--63	JA--64	JA--65
JA--66	JA--67	JA--74	JA--75	JA--77	JA--78	JA--79
JA--81	JA--82	JA--83	JA-006	JA-007	JA--80	JA-114
JA-115	JA-116	JA-117	JA-523	JA-530	JA-601	JA-603
JA-604	JA-605	JA-607	JA-609	JA-615	JA-617	JA-618
JA-620	JA-624	JA-636	JA-639	JA-649	JA-652	JA-653
JA-654	JA-655	JA-656	JA-657	JA-658	JA-659	JA-802
JA-806	JA-877	JA-005	JA-888	JA-999	NC-077	NC-003
NC-004	NC-006	NC-007	NC-008	NC-010	NC-012	NC-013
NC-014	NC-015	NC-019	NC-021	NC-022	NC-023	NC-024
NC-025	NC-026	NC-027	NC-082	NC-083	NC--26	NC--29
NC--30	NC-506	NC-513	NC--60	NC--61	NC--62	NC-624
NC-625	NC-629	NC--63	NC-630	NC-631	NC-635	NC-636
NC--64	NC--65	NC--66	NC--67	NC--68	NC--69	NC--70
NC--71	NC--72	NC--73	NC--74	NC--75	NC--76	NC--77
NC--78	NC--83	NC--84	NC-029	NC--27	NC--28	NC--31
NC-510	NC-511	NC-514	NC-632	NC-637	NC--79	NC--81
NC--82	NC-047	NC-004M	NC-005M	NC--90	NC--48	NC--49
NC--50	NC--51	NC--52	NC--53	NC--54	NC--55	NC--56
NC--57	NC--58	NC--59	NC--85	NC--86	NC--87	NC--88
NC--89	NC--91	NC--92	NC-005	NC-011	NC-016	NC-017
NC-018	NC-020	NC-028	NC-030	NC-031	NC-032	NC-033
NC-034	NC-035	NC-036	NC-037	NC-038	NC-039	NC-040
NC-041	NC-042	NC-043	NC-044	NC-045	NC-046	NC-048
NC-049	NC-050	NC-051	NC-052	NC-053	NC-054	NC-055
NC-056	NC-057	NC-058	NC-059	NC-060	NC-061	NC-062
NC-063	NC-064	NC-065	NC-066	NC-067	NC-068	NC-069
NC-070	NC-071	NC-072	NC-073	NC-074	NC-075	NC-076
NC-078	NC-080	NC-081	NC-087	NR--60	NR--61	NR--62
NR--63	NR--64	NR--65	NR--66	NR--67	NR--68	NR--69
NR--70	NR--71	NR--72	NR--73	NR--74	NR--75	NR--76
NR--77	NR--78	NR-501	NR--79	NR-027	NR-006	NR-018
NR-045	NR-017	NR-016	NR-014	NR-013	NR-012	NR-055
NR-011	NR-010	NR-009	NR-008	NR-007	NR-005	NR-004
NR-003	NR-002	NR-044	NR-043	NR-042	NR-041	NR-040

NR-039	NR-038	NR-046	NR-037	NR-036	NR-035	NR-034
NR-033	NR-047	NR-032	NR-031	NR-030	NR-048	NR-029
NR-028	NR-052	NR-026	NR-025	NR-024	NR-023	NR-022
NR-049	NR-050	NR-021	NR-020	NR-019	OH-015	OH--12
OH-344	OH-415	OH-419	OH-514	OH-519	OH-556	OH-590
OH-606	OH--61	OH--62	OH--63	OH--64	OH--65	OH--66
OH--67	OH--68	OH--69	OH--70	OH--71	OH--72	OH--73
OH--74	OH--75	OH--77	OH--78	OH--91	OH--79	OH--92
OH--80	OH--93	OH--81	OH--94	OH--82	OH--95	OH--83
OH--96	OH--84	OH--97	OH--85	OH--86	OH--87	OH-875
OH--88	OH--89	OH--90	OH-902	OH--U1	OH--U2	OH--U3
OH--U4	OH--U5	OH-021	OH-403	OH-607	OH-616	OH-003
OH-004	OH-005	OH-006	OH-007	OH-017	OH-018	OH-019
OH-020	OH-023	OH-024	OH-002	PR-002	PR-003	PR-004
PR-005	PR-006	PR-007	PR-008	PR-009	PR-010	PR-011
PR-013	PR-014	PR-015	PR-016	PR-017	PR-018	PR-019
PR-020	PR-021	PR-023A	PR-024	PR-025	PR-026	PR-027
PR-028	PR-029	PR-030	PR-031	PR-032	PR-033	PR-034
PR-035	PR-036	PR-037	PR-104	PR-133	PR-134	PR-135
PR-137	PR-140	PR-141	PR-145	PR-149	PR-152	PR-162
PR-180	PR-181	PR-187	PR-189	PR-190	PR-503	PR-603
PR-612	PR-613	PR-621	RH--60	RH--61	RH--62	RH--63
RH--64	RH--65	RH--67	RH-501	RH-505	RH-508	RH-510
RH-511	RH-610	RH-611	RH-002	RH-614	RH-028	RH--66
RH--71	RH--72	RH-329	RH-393	RH-523	RH-524	RH-525
RH-601	RH-857	RH-029	RH-030	RH-031	RH-035	RH-025
RH-024	RH-023	RH-022	RH-019	RH-021	RH-020	RH-018
RH-016	RH-014	RH-013	RH-011	RH-010	RH-012	RH-009
RH-008	RH-007	RH-006	RH-005	RH-003	RH-036	RH-037
RH-038	RH-033	RH-040	RH-034	RO--61	RO-029	RO-031
RO-006	RO-007	RO-030	RO-004	RO-005	RO-008	RO-009
RO-010	RO-011	RO-012	RO-014	RO-015	RO-017	RO-016
RO--60	RO--62	RO--63	RO--01	RO--02	RO--03	RO--04
RO--05	RO--06	RO--07	RO--08	RO--09	RO--10	RO--11
RO--12	RO--13	RO--14	RO--15	RO--16	RO--17	RO-130
RO-610	RO-614	RO-617	RO-618	RO-619	RO-620	RO-622
RO-624	RO-625	RO-627	RO-629	RO-630	RO-631	RO-632
RO-633	RO-634	RO-635	RO-636	RO-637	RO-638	RO-640
RO-641	RO-642	RO-648	RO-649	RO-651	RO-652	RO-653
RO-656	RO-657	RO-658	RO-659	RO-660	RO-661	RO-669
RO-670	RO-671	RO-672	RO-675	RO-676	RO-677	RO-678
RO-679	RO-680	TI--61	TI--62	TI--63	TI--64	TI--65
TI--67	TI-670	TI-673	TI--68	TI--69	TI--71	TI--73
TI--78	TI--80	TI--81	TI--82	TI--83	TI--84	TI--85
TI-501	TI-505	TI-516	TI-524	TI-543	TI-545	TI-546
TI-548	TI-551	TI-561	TI-562	TI-567	TI-601	TI-608
TI-609	TI-610	TI-614	TI-621	TI-623	TI-625	TI-628
TI-629	TI-631	TI-633	TI-638	TI-639	TI-641	TI-642
TI-643	TI-649	TI-654	TI--41	TI--50	TI--42	TI--43
TI--44	TI--45	TI--46	TI--47	TI-658	TI-659	TI-662
TI-668	TI--52	TI--53	TI--54	TI--55	TI-009	TI-015
TI-004	TI-023	TI-011	TI--60	TI--70	TI--74	TI--75
TI--76	TI--77	TI-604	TI-611	TI-615	TI-619	TI-630
TI-634	TI-655	TI-656	TI-660	TI-665	TI-006	TI-012
TI-013	TI-024	TI-1208	TI-603	TI-616	TI-617	TI-618
TI-624	TI-646	TI-653	TI-661	TI-666	TI-671	TI-674
TI-675	TI-676	TI-007	TI-005	TI-008	TI-010	TI-014
TI-016	TI-017	TI-018	TI-019	TI-020	TI-022	TI-003
WI-977	WI-908	WI-184	WI-826	WI-507	WI-870	WI-189

WI-832	WI-102	WI-105	WI-821	WI-840	WI-049	WI-609
WI-610	WI-614	WI-883	WI-887	WI-002	WI-003	WI-004
WI-005	WI-006	WI-007	WI-008	WI-009	WI-010	WI-011
WI-012	WI-013	WI-014	WI-015	WI-016	WI-017	WI-018
WI-019	WI-043	WI-021	WI-022	WI-023	WI-024	WI-025
WI-026	WI-027	WI-028	WI-029	WI-030	WI-031	WI-032
WI-033	WI-034	WI-035	WI-036	WI-037	WI-038	WI-039
WI-040	WI-041	WI-042	WI-044	WI-045	WI-046	WI-047
WI-048	WI-050	WI-051	WI-052	WI-068	WI-067	WI-066
WI-065	WI-075	WI-064	WI-062	WI-061	WI-060	WI-059
WI-058	WI-057	WI-056	WI-072	WI-071	WI-070	WI-069
WI-063	WI-073	WI-078	WI-077	WI-076	WI-055	WI-054
WI-053	WI-207	WI-936	WI-950	WI-951	WI-982	WI-984

NJ SW Outfalls

BY-001	BY-003	BY-006	BY-007	BY-008	BY-009	BY-010	BY-011	BY-012	BY-013
BY-014	BY-015	BY-016	BY-017	BY-018	BY-019	BY-020	BY-021	BY--61	BY--62
BY--63	BY--64	BY--65	BY--66	BY--67	BY--68	BY--69	EL-001	EL-002	EL-006
EL-007	EL-008	EL-009	EL-010	EL-011	EL-012	EL-013	EL-014	EL-016	EL-017
EL-021	EL-022	EL-025	EL-026	EL-028	EL-029	EL-030	EL-031	EL-032	EL-034
EL-035	EL-037	EL-038	EL-039	EL-040	EL-042	EL--60	EL--61	EL--62	EL--63
EW--60	EW--61	FL-001	FL-002	FL-003	FL--61	FL--62	FL--63	GU-001	GU--60
HK-001	HK-002	HK--60	HK--61	HK--62	HK--63	JE-001	JE-002	JE-004	JE-006
JE-007	JE-008	JE-009	JE-010	JE-012	JE-013	JE-014	JE-015	JE-016	JE-018
JE-019	JE--60	JE--61	JE--62	JE--63	JE--64	JW-001	JW-002	JW-003	JW-004
JW-006	JW-007	JW-008	JW-009	JW-010	JW-011	JW-013	NB-003	NB-004	NB-005
NB-006	NB-007	NB-008	NB-009	NB-011	NB-014	NB--60	NB--61	NB--62	NB--63
NB--64	NJ--10	NJ--11	NJ--12	NJ--13	NJ--14	NJ--15	NJ--17	NJ--18	NJ--19
NJ--20	NJ--21	NJ--22	NJ--23	NJ--24	NJ--25	NJ--26	NJ--27	NJ--28	NJ--29
NJ--30	NJ--31	NJ--33	NJ--34	NJ--37	NJ--38	NJ--39	NJ--40	NJ--41	NJ--42
NJ--43	NJ--44	NJ--45	NJ--46	NJ--47	NJ--48	NJ--49	NJ--50	NJ--51	NJ--52
NJ--54	NJ--55	NJ--56	NJ--57	NJ--58	NJ--59	NJ--60	NJ--61	NJ--62	NJ--63
NJ--64	PA-002	PA-003	PA-004	PA-005	PA-006	PA-007	PA-008	PA-009	PA-010
PA-011	PA-013	PA-014	PA-015	PA-016	PA-017	PA--60	PA--61	PA--62	PA--63
PA--64	PV-029	PV-032	PV-033	PV-034	PV-037	PV-038	PV-039	PV-040	PV-041
PV-042	PV-043	PV-044	PV-045	PV-046	PV-047	PV-048	PV-049	PV-050	PV-051
PV-052	PV-053	PV-054	PV-055	PV-056	PV-057	PV-058	PV-059	PV-060	PV-061
PV-062	PV-083	RP-001	RP-002	RP-003	RP-004	RP-005	RP-006	RP--60	RP--61
RP--62	RP--63	RP--64	RP--65	WN-001	WN--60				

			Annual Average Flow (MGD)					Annual Average Flow (MGD)	
NPDES	Name	Frequency	2005	2006	NPDES	Name	Frequency	2005	2006
NJ0021016	Passaic Valley Sewerage Commissoners	Daily	256.2	259.5	NJ0020591	Bergen County UA - Edgewater Boro MUA	Monthly	3.6	3.9
NJ0020141	Middlesex County UA	Bi-weekly	197.5	222.9	CT0100404	North Haven WPCF	Weekly	3.4	3.7
NJ0020028	Bergen County UA	Monthly	85.8	84.6	NJ0024783	Long Branch SA	Monthly	3.7	2.5
NJ0024741	Joint Meeting of Essex & Union Counties	Daily	66.6	69.7	NJ0035343	Cape May County MUA - Ocean City	Monthly	3.1	3.2
NY0026450	South Shore WRF (formerly Bay Park STP)	Monthly	61.2	59.4	NJ0025038	Seacaucus MUA - Koelle Blvd	Monthly	3.2	3.3
CT0100366	New Haven East WPCF	Bi-weekly	32.9	34.0	NY0026620	Glen Cove	Monthly	3.6	3.6
NJ0024643	Rahway Valley SA	Daily	30.7	31.1	CT0100242	Groton Town WPCF	Weekly	3.4	3.5
CT0100056	Bridgeport West WPCF	Bi-weekly	26.0	27.1	NJ0029084	North Bergen MUA - Woodcliff	Monthly	2.6	2.9
NJ0028142	Northern Water Pollution Cont Facility	Bi-weekly	23.0	22.4	NY0026719	Blind Brook WPCF	Monthly	2.7	3.9
NJ0029408	Ocean County UA - Central	Bi-weekly	23.3	22.2	NY0026271	Poughkeepsie (T) Arlington WWTP	Monthly	3.0	2.9
CT0101087	Stamford WPCF	Bi-weekly	15.7	18.3	CT0100714	Shelton WPCF	Weekly	2.7	2.6
NJ0024694	Monmouth Cnty Bayshore Outfall Authority	Bi-weekly	15.8	15.7	RI0100064	Westerly WWTF	Monthly	2.8	2.8
CT0101249	Norwalk WPCF	Bi-weekly	12.3	14.9	NY0026778	Port Washington	Monthly	2.6	2.8
NJ0026085	Adams Street WWTP	Daily	12.9	13.5	NJ0025241	Asbury Park WTP	Monthly	2.4	2.3
NJ0053007	Wildwood/Lower Region WTF	Monthly	12.3	12.0	CT0100013	Ansonia WPCF	Weekly	2.4	2.7
NJ0024953	Linden-Roselle SA	Monthly	10.8	10.9	CT0101184	Groton City WPCF	Weekly	2.0	2.0
CT0000957	Pfizer	Monthly	31.3	23.8	CT0100749	Milford Beaver Brook WPCF	Weekly	2.1	2.2
NJ0026735	Two Rivers Water Reclamation Authority	Daily	10.4	10.3	CT0100161	Derby WPCF	Weekly	1.6	1.7
NJ0025321	River Road (West New York) WWTP	Monthly	9.9	10.4	NY0206644	SUNY	Monthly	1.7	1.8
CT0100234	Greenwich American Centre	Monthly	9.1	9.4	CT0100684	Westport WPCF	Weekly	1.9	2.0
CT0101044	Fairfield WPCF	Weekly	8.5	9.5	CT0100935	Montville WPCF	Weekly	1.8	2.1
CT0101036	Stratford WPCF	Bi-weekly	7.8	8.2	NY0026841	Belgrave	Monthly	1.6	1.5
NJ0024708	Bayshore RSA	Bi-weekly	8.5	8.4	CT0000086	Cytec	Monthly	1.9	1.9
NY0026255	Poughkeepsie STP	Monthly	7.0	6.6	CT0100501	Seymour WPCF	Weekly	1.5	1.6
NJ0026018	Ocean County UA - Southern	Monthly	7.4	7.6	NJ0020371	Cape May Co MUA - Cape May	Monthly	1.3	1.2
NJ0025356	Middletown Twp SA	Monthly	8.2	8.1	NY0026051	Orangetown SD #2 STP	Monthly	0.0	0.0
CT0100382	New London WPCF	Bi-weekly	8.7	8.2	NY0026310	Newburgh WWTP	Monthly	0.0	7.6
CT0101010	Bridgeport East WPCF	Bi-weekly	8.2	9.1	NY0021342	Huntington	Monthly	0.0	0.0
CT0101656	Milford Housatonic WPCF	Weekly	6.5	8.8	NY0020061	Riverhead Sewer District WWTF	Monthly	0.8	0.9
CT0101079	West Haven WPCF	Bi-weekly	7.7	7.4	NY0021750	Port Jefferson	Monthly	0.9	0.9
NJ0024562	South Monmouth Regional SA	Monthly	6.2	5.9	NY0022144	Cornwall WWTP	Monthly	0.0	0.0
NJ0024872	Neptune Twp SA STP	Monthly	5.4	5.2	NY0023523	Greater Atlantic Beach WWTP	Monthly	0.6	0.6
NJ0024520	Township of Ocean SA	Monthly	6.2	5.5	NY0022462	Cedarhurst (V) WPCP	Monthly	0.7	0.8
CT0100617	Wallingford WPCF	Weekly	0.6	6.6	CTP000083	Pfizer	Monthly	0.0	0.0
CT0100048	Branford WPCF	Weekly	4.0	4.2	CT0101419	School Sisters of Notre Dame	Monthly	0.0	0.0
CT0100412	Norwich WPCF	Weekly	5.0	5.0	CT0024759	PL 612 Wheelers Farms Limited Partnership	Monthly	0.0	0.0
NY0108324	Ossining WWTP	Monthly	3.1	5.4	CTMIU0192	Pfizer	Monthly	0.0	0.0
NY0025976	Beacon WPCP	Monthly	3.9	3.8					