New York City Department of Environmental Protection

2024 Watershed Water Quality Annual Report

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List of Acronyms

Acronym	Definition
abs cm^{-1}	absorbance per centimeter
AI	Artificial intelligence
AmeriFlux	A network of ecosystem flux measurement sites
AWWA	American Water Works Association
BAP	Biological Assessment Profile
BWS	Bureau of Water Supply
CASTNET	Clean Air Status and Trends Network (a U.S. atmospheric monitoring program)
CAT/DEL	Catskill/Delaware System
CATALUM	Catskill Alum Chamber sampling location
CATIC	Catskill Influent Chamber sampling location
CATUEC	Catskill Upper Effluent Chamber sampling location
CCT	Corrosion Control Treatment
CFP	Croton Filtration Plant
CFR	Code of Federal Regulations
cfs	cubic feet per second
CFU	Colony-Forming Units
CHLA	Chlorophyll a
CLGH	Croton Lake Gate House
CONF	Confluent growth
CROGH	New Croton Reservoir Gatehouse
CWFP	Croton Water Filtration Plant
DAYCENT	Daily CENTURY Forest Growth Algorithm
DBP	Disinfection Byproducts
DBPfp	Disinfection Byproduct formation potential
DEL	Delaware system or watershed
DEL17	Delaware Aqueduct Shaft Building 17 sampling location
DEL18DT	Delaware Aqueduct Shaft Building 18 sampling location
DEL9	Delaware Aqueduct at entry to West Branch Reservoir
DEP	New York City Department of Environmental Protection
DOC	Dissolved organic carbon
DOM	Dissolved organic matter
DTO	Data and Technology Operations
EARCM	Ashokan Reservoir effluent sampling location
ELISA	Enzyme-Linked Immunosorbent Assay (used for detecting algal toxins)
EOH	East of Hudson

Acronym	Definition
EOS	End of season
EPA	See USEPA
EPT	Ephemeroptera, Plecoptera, Trichoptera (taxa groups)
ET	Evapotranspiration
EVI	Enhanced Vegetation Index (a measure of vegetation health)
EVI2	2-band Enhanced Vegetation Index
EWRM	Early Warning Remote Monitoring
FAD	Filtration Avoidance Determination
GAC	Granular activated carbon
GAM	General Additive Model (a statistical model used for predictive analysis)
GCM	Global Climate Model
GSM	Geosmin
HAB	Harmful algal bloom
HAWQS	Hydrologic and Water Quality System
HRU, HRUs	Hydrologic Response Unit(s) (smallest modeling units based on land use, soil type, and slope)
HUC-12	12-digit Hydrologic Unit Code (a watershed classification system)
ISO	International Organization for Standardization
KGE	Kling-Gupta Efficiency (a metric for evaluating hydrologic model performance)
LAI	Leaf Area Index (a measure of canopy density)
LSL	Lead service line
LSTM	Long Short-Term Memory (a deep learning technique)
LT2	Long-Term 2 Enhanced Surface Water Treatment Rule
MCD12Q2	MODIS Land Cover Dynamics Product Collection 6.1
MCL	Maximum contaminant level
$mg\ L^{-1}$	milligram per liter
MGD	Million gallons per day
MIB	2-methylisoborneol
ML	Machine learning
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MPVBC	Multiyear Precipitation Variability Bias Correction
MS	Matrix spike
NASEM	National Academies of Sciences, Engineering, and Medicine
NBI-P	Nutrient Biotic Index-Phosphorus
NCA	New Croton Aqueduct
NCDC	National Climatic Data Center

Acronym	Definition
ND	Non-detect
NEE	Net Ecosystem Exchange
nm	Nanometers
NOAA	National Oceanic and Atmospheric Administration
NOM	Natural organic matter
NR2	Neversink Reservoir Elevation Tap 2
NSE	Nash-Sutcliffe Efficiency (a model performance metric)
NTU	Nephelometric Turbidity Units
NWS	National Weather Service
NYC	New York City
NYCRR	New York Codes, Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OST	Operational Support Tool
PAC	Project Advisory Committee
PDF	Portable document format
PFAS	Per- and polyfluoroalkyl substances
PFBS	Perfluorobutanesulfonic acid
PFOA	Perfluorooctanoic acid
PFOS	Perfluoroctanesulfonic acid
PMA	Percent Model Affinity
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PU	Participating utility
PVC	Polyvinyl chloride
QC	Quality control
RAC	Research Advisory Council
RDAG	R Data Analysis Group
Reco	Ecosystem Respiration
RMSE	Root mean square error (a statistical measure of model accuracy)
RoboMon	Robotic monitoring
ROS	Regression on order statistics
ROV	Remotely operated vehicle
R-SWAT	A version of the Soil and Water Assessment Tool integrated with R software
RWBT	Rondout-West Branch Tunnel
SCADA	Supervisory control and data acquisition
SCUBA	Self-contained underwater breathing apparatus
Shaft 18	Delaware Aqueduct Shaft Building 18
SOR	Strategic Operations and Research

Acronym	Definition
SOS	Start of season
SPDES	State Pollutant Discharge Elimination System
SRR2CM	Schoharie Reservoir Release
SSM	Single sample maximum, also S/S/M
STF	Salinity Task Force
SUFI-2	Sequential Uncertainty Fitting algorithm version 2
SVOC	Semivolatile organic compound
SWAT	Soil Water Assessment Tool
SWTR	Surface Water Treatment Rule
T&O	Taste and odor
TASC-Forest	Terrestrial Aquatic Sciences Convergence-Forest Model
TDP	Total dissolved phosphorus
TDS	Total dissolved solids
TMDL	Total maximum daily load
TOC	Total organic carbon
TP	Total phosphorus
TSI	Trophic state index
TSS	Total suspended solids
TWI	Topographic Wetness Index – A measure indicating a location's likelihood of accumulating moisture
$\mu g\ L^{-1}$	microgram per liter
$\mu mhos\ cm^{-1}$	micromhos per centimeter
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UV	Ultraviolet
UV_{254}	Absorbance reading at 254 nm
VOC	Volatile Organic Compound
W2	CE-QUAL-W2, a two-dimensional hydrothermal and water quality model
WMP	Waterfowl Management Program
WOH	West of Hudson
WQ	Water Quality Directorate
WR&R	New York City Watershed Rules and Regulations
WRF	Water Research Foundation
WRTDS	Weighted Regression on Time, Discharge, and Season (statistical modeling package)
WWQMP	Watershed Water Quality Monitoring Plan
WWQO	Watershed Water Quality Operations

Acknowledgements

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Executive Summary

Chapter 1 Introduction

This report provides summary information about the watersheds, streams, and reservoirs that are the sources of New York City's drinking water. It is an annual report that provides a detailed description of the City's water resources, their condition during 2024, and compliance with regulatory standards. It is complementary to the New York City 2024 Drinking Water Supply and Quality Report (2024 Drinking Water Supply Quality Report), which is distributed to consumers annually to provide information about the quality of the City's tap water. Thus, the two reports together document water quality from its source to the tap.

The New York City Water Supply System provides drinking water to almost half the state's population, which includes over 8.5 million people in New York City and 1 million people in counties north of the City. The City's water is supplied from a network of 19 reservoirs and three controlled lakes. A summary of the number of sites, samples, and analyses that were processed in 2024 by the three upstate laboratories is provided. Grab sampling, robotic monitoring, and an early warning system are all employed. These data are used to guide system operations to provide high quality drinking water to the City.

Chapter 2 Water Quantity

In New York's Climate Division 2, which includes the West of Hudson (WOH) reservoirs, the 2024 precipitation total was 4.37 inches (111.00 mm) above the 20^{th}-century mean. In New York's Climate Division 5, which includes the East of Hudson (EOH) reservoirs, precipitation was 1.60 inches (40.64 mm) above the 20^{th}-century mean**.** In September and October, a drought occurred in the West of Hudson (WOH) and East of Hudson (EOH) watersheds, with lower rainfall totals observed for September and October relative to 30-year mean monthly rainfall. Patterns in streamflow reflect precipitation, with the drought in fall 2024 producing monthly streamflows that were in the bottom 25^{th} percentile of the long-term (30-year) monthly streamflow distribution. Reservoir storage remained within ~10% of long-term storage (1982 – 2024 Mean Percent Storage) until mid-September, after which storage declined to reach a maximum deficit of ~25% of the long-term storage due to drought conditions.

Chapter 3 Water Quality

Despite rainfall throughout the watersheds in the first part of 2024, turbidity levels in the Catskill/Delaware (CAT/DEL) reservoirs were mostly below their historical 25th percentile turbidity levels. At the start of 2024, there were typical (i.e., within the historical interquartile range) to low turbidity levels in the WOH streams, despite higher than historical monthly precipitation and streamflow in all WOH streams. Turbidity and streamflow were generally low to average from April through July across all WOH streams. In August, turbidity results were elevated at several streams following rain events. Dry conditions occurred in September and

continued through November with a drought warning implemented. Low WOH streamflow was observed at that time and generally coincided with lower stream turbidity levels. Streamflow returned to typical in December following several rain events across WOH in the second half of November and throughout December, and increased stream turbidity generally followed. Turbidity levels were also low in the Croton System with low to normal (within the historical interquartile range) turbidities generally observed throughout the year in most EOH streams despite elevated precipitation and streamflow during the first half of the year. Months where turbidity were elevated coincided with wet weather within days of sample collection. Though turbidity was sometimes elevated relative to historical levels, the maximum turbidity observed in the Croton streams all year was 8.5 NTU (KISCO3 in August), after 6 consecutive days of rainfall (4.16 inches) on the Croton Watershed, including on the day sampling took place.

In 2024, total coliform counts were elevated and often exceeded the historical 75th percentiles in most waterbodies of the CAT/DEL and Croton systems. All terminal reservoir basins remained "non-restricted" based on fecal coliforms for the coliform-restricted assessments. For non-terminal reservoir coliform-restricted evaluations based on total coliforms, eight of the 14 reservoirs evaluated had no exceedances of the total coliform standard. Except for West Branch Reservoir, fecal coliform counts were within or close to their historical interquartile ranges for most reservoirs of the Catskill/Delaware System (i.e., Cannonsville, Rondout). Elevated counts at West Branch are usually associated with sample collection within days of rain events. Though 2024 results were above the historical 75th percentile, West Branch had no elevated fecal coliform counts observed at or above 20 coliforms $100 mL^{-1}$. In the Croton System, fecal coliform counts were mostly elevated relative to historical levels. Runoff events and the degree of development in the Croton watersheds were likely responsible.

Phosphorus-restricted status for all WOH and EOH reservoirs remained the same as in the previous assessment. Cannonsville had the highest percentage of samples exceeding the 15 $\mu g\ L^{-1}$ total phosphorus (TP) single sample maximum benchmark (55% of all samples collected) in the Delaware System. Far fewer exceedances were observed at Pepacton (9%), Rondout (1%), and Neversink (2%). In the Catskill System, Ashokan West had few exceedances (1%) and Schoharie exceeded the benchmark in 23% of its samples. In the Croton System, TP exceedances were high throughout the watershed, with the lowest number of exceedances in Boyd Corners (50%) and Amawalk (62%). West Branch, with influences from the local watershed and the Delaware System, exceeded the benchmark in 21% of its samples.

Trophic state indices (TSI) are used to describe algal productivity of lakes and reservoirs. In 2024, TSI was higher than historical levels at Schoharie Reservoir, but slightly lower levels at Ashokan West and East basins. TSI levels in the Delaware System reservoirs were near historical median values, except for Neversink. TSI levels were generally within historical ranges in the Croton System reservoirs sampled in 2024. Both Croton Falls and Cross River, used for pumping operations during the Rondout West Branch Tunnel (RWBT) shutdown, had TSI levels lower

than historical levels. Other Croton System reservoirs experienced lower TSI in 2024 as well (New Croton, Muscoot, and East Branch reservoirs). Notably, multiple applications of the algaecide copper sulfate were applied to New Croton, Muscoot, Croton Falls, and Cross River reservoirs in 2024 from May through October which immediately reduced algal populations and likely prevented bloom establishment.

The New York State Department of Environmental Conservation (NYSDEC) and the New York City Department of Environmental Protection (DEP) finalized a memorandum of understanding (MOU) in 1997 governing several aspects of enforcement protocols in the New York City water supply watersheds. This report includes the information needed to satisfy the MOU requirement of the Addendum E report. In 2024, 75 sites were analyzed and compared to water quality guidance values. There were 15 sites where the mean value contravened the guidance values, and there were six sites that exceeded the spike threshold.

As per the Hillview Consent Decree and Judgement, DEP continued weekly protozoan monitoring at the Hillview Reservoir outflow (Site 3). *Cryptosporidium* was detected in five of 54 samples in 2024 with an annual mean concentration of 0.17 oocysts $50L^{-1}$ and detection rate of 9.3%. *Giardia* was detected in 19 of 52 samples, with an annual mean concentration of 0.57 cysts $50L^{-1}$ and detection rate of 35.2%. These were well within the historical ranges for both *Cryptosporidium* and *Giardia* detection rate. All Hillview samples tested for infectious *Cryptosporidium* by cell-culture immunofluorescent assay were negative.

DEP continued to monitor Amawalk, Muscoot, and New Croton reservoirs in 2024 to track the spread and density of zebra mussels (*Dreissena polymorpha*). DEP used multiplate and single set settlement polyvinyl chloride (PVC) substrates for adults, plankton samples to track veliger concentrations in New Croton Reservoir, and visual surveys of infrastructure using remotely operated vehicles (ROV) and SCUBA dives. In 2024, DEP constructed and deployed novel PVC multiplate substrates to augment historical PVC single set substrates. Significant expansion of the population was observed in 2024, with maximum settlement densities ranging from 656 to 184,064 m^{-2} (10 to 6292 m^{-2} in 2023), and veliger concentrations surpassing 106 L^{-1} (< 5 L^{-1} in 2023). An interdisciplinary working group within BWS (Bureau of Water Supply) continued to meet quarterly in 2024 to develop zebra mussel management and impact mitigation plans. DEP continues to implement recommendations made by the 2023 Water Research Foundation zebra mussel expert panel.

Water quality assessments of watershed streams based on resident benthic macroinvertebrate assemblages continued in 2024. DEP collected samples from 36 sites in 32 streams throughout New York City's watershed: 13 sites in the Croton System, 13 sites in the Catskill System, and 10 sites in the Delaware System. Two new approaches were used for comparisons to historical data, including (1) basing period of record means on Biological Assessment Profile (BAP) scores that include the Nutrient Biotic Index-Phosphorus (NBI-P)

metric, which was added to the statewide calculation in 2012, and (2) modifying BAP metrics to account for headwaters delineation for each district according to the NYSDEC criteria.

In the Croton System, of the 13 sites sampled in 2024, four sites were assessed as non-impaired, seven sites as slightly impaired, and two sites as moderately impaired. In the Catskill System, 10 of 13 sites were assessed as non-impaired and the remaining three sites were assessed as slightly impaired. Nine of 10 Delaware System sites were assessed as non-impaired, and one was assessed as slightly impaired.

To supplement required distribution system monitoring, DEP collects one sample at key sites throughout the upstate watersheds during the last quarter of the year to test for many volatile and semi-volatile organic compounds as well as the herbicide glyphosate. In 2024, no compounds were detected in these annual monitoring samples. Additionally, in 2024, most metal sample results were well below state and federal benchmarks. Antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and thallium were not detected at any monitored site in 2024.

Several enhanced monitoring studies were initiated in 2024 in response to water quality concerns or to better understand monitoring and management alternatives. The eight investigations reported include: the enhanced monitoring of the Cross River and Croton Falls pump stations, operated in support of the Rondout to West Branch Tunnel shutdown; targeted monitoring to identify taste and odor compounds; copper sulfate treatment monitoring; Cannonsville and Neversink storm event monitoring; forest fire impact monitoring at Sundown Forest; algal bloom monitoring; bench test pilot study for use of alum to reduce disinfection byproduct formation potential (DBP_{fp}); and, per- and polyfluoroalkyl substances monitoring.

Chapter 4 Kensico Reservoir

Kensico Reservoir is the terminal reservoir for the unfiltered Catskill/Delaware water supply. Monitoring of the outflow from Kensico takes place at site DEL18DT at Delaware Shaft 18. The City's high-frequency monitoring ensures that every effort is taken at this location to meet strict requirements for turbidity and fecal coliform concentrations set forth in the federal Surface Water Treatment Rule (SWTR). During 2024, all DEL18DT turbidity results were less than the SWTR 5 NTU limit and no fecal coliform results exceeded the SWTR 20 fecal coliforms $100mL^{-1}$ limit. As such, DEP met the SWTR turbidity and fecal coliform limit requirements for the monitoring year. The Waterfowl Management Program and operational decisions continued to be instrumental in keeping coliform bacteria concentrations well below the limits set by the SWTR. Turbidity curtain inspections are done by BWS Operations staff to perform the visual observations and provide Water Quality staff with inspection reports that contain information on condition, position, and suggested maintenance that Operations staff would perform. Overall, water quality from Kensico continued to be excellent during 2024.

In addition to routine monitoring, additional in-situ equipment was deployed to monitor two construction projects taking place near the shoreline of Kensico. This monitoring showed no impact to Kensico's water quality. One round of Storm Event sampling was also conducted in response to forecasted rain totals from tropical storm Debby. While the actual totals were much less than the predicted for Kensico, samples were still analyzed. There appeared to be no influence from the storm on DEL18DT water quality. Pathogen monitoring for 2024, as in previous years, showed seasonal variations in *Giardia* concentrations at the Kensico influents and effluent, with *Giardia* being most elevated during colder months. *Cryptosporidium* was also within its historical range for 2024.

Chapter 5 Water Quality Modeling

DEP's Water Quality Modeling Program uses models to quantify the impact of climate change, changes in land use, individual and grouped components of the watershed protection program, operation of the water supply system, and water demand on the quantity and quality of water delivered to the City.

In 2024, DEP continued to assess the degree of extreme climate conditions in the watershed using an aggregated index. The index combines several extreme climate indicators and compares to a reference period. DEP completed and refined the analyses of decadal scale variability in future extreme precipitation using four multi-model sets of downscaled climate products for WOH watershed. In 2024, DEP also began developing a method to analyze drought in the City's water supply. To that end, gridded estimates of climatic parameters like precipitation and temperature were extended across the WOH watershed region. The gridded climate dataset PRISM (Parameter-elevation Regressions on Independent Slopes Model) is available only from 1981 to the present; however, through efforts in 2024, the data were extended back to 1893. In 2024, DEP initiated a research project to assess the impact of climate variability on deciduous forest phenology in the WOH watershed region. Preliminary results indicated that the annual green-up and mid-green-up stages exhibit a slight upward trend (delays) across the watershed, while the annual peak stage shows a downward or advancing trend.

In 2024, DEP integrated the Daily CENTURY (DAYCENT) based forest growth algorithm into SWAT-Carbon (Soil and Water Assessment Tool-Carbon) model and renamed the integrated model as Terrestrial Aquatic Sciences Convergence-Forest (TASC-Forest) model. The TASC-Forest model can now simulate key forest processes, such as biomass and nutrient allocation, litterfall, death, and the transformation of various tree components into litter and soil carbon pools. A study was conducted to assess the effects of land use, climate, and atmospheric nitrogen deposition on stream nutrient dynamics in the urbanized Amawalk and forested Boyd Corners watersheds. In 2024, DEP explored the potential of using the Hydrologic and Water Quality System (HAWQS) for simulating inflows from the lower Delaware watersheds. HAWQS is a web-based, interactive modeling tool based on the SWAT framework, which eliminates the need for user-provided computational resources.

A machine learning (ML) model employing the XGBoost algorithm for assessing the vulnerability of septic systems in the WOH watersheds was tested in 2024. The model was trained using hydroclimatic, soil, and topographic data, supplemented by parcel data information as predictor variables. The model effectively identified the relative importance of predictors and predicted the likelihood of septic system failure with an average accuracy of 80% when validated against an independent testing dataset.

DEP is continuing to work on a multi-year project to develop DBP formation potential models for source water streams, fate and transport models for DBP precursors in reservoirs, and DBP model for the City's distribution system. In 2024, DEP began testing of two-dimensional hydrothermal and water quality model CE-QUAL-W2 (W2) for predicting UV_{254} in Ashokan Reservoir. The modeling analysis continues to support earlier findings that the nature of organic matter exported from the watershed and into the water supply is nearly refractory, i.e., resistant to biodegradation.

Several OST runs were conducted to guide operations of the Catskill Aqueduct and manage water quality in the aftermath of storms during December 2023-January 2024, and August 9-10, 2024. Additionally, runs were conducted to support RWBT outage (pre-, during, and post-outage) work.

Chapter 6 Further Research

BWS remains at the forefront of the industry through a complimentary array of programs including research undertaken within the bureau, participation in the Water Research Foundation (WRF), and interactions with national and international groups and universities such as the Cary Institute of Ecosystem Studies and Cornell University. In 2024, internal research initiatives included a drone working group, a salinity task force, and a monthly training for R statistical software. In 2024, BWS collaborated with The Water Research Foundation to hold a workshop on filtration planning.

Emerging and ongoing research is disseminated throughout the bureau in several ways. BWS developed and maintains the research inventory, a repository of all proposed, active, and completed research, with the assistance of the Research Advisory Council (RAC). In addition, BWS held an internal conference. In 2024, the conference theme was "The Delaware Aqueduct Repair Project." with more than 387 staff participating. In addition to the conference, BWS also highlights ongoing research or related activities with monthly "Thirsty Thursday" webinars. In 2024, 222 staff participated in four webinars.

1. Introduction

1.1 Water Quality Monitoring in the Watershed

This report provides information on the watersheds, streams, and reservoirs that are the sources of New York City's drinking water. The annual report provides the public, regulators, and other stakeholders with a detailed description of the City's water resources, their condition during 2024, and compliance with regulatory standards. It also provides an overview of operations and the use of field, laboratory, robotic, and continuous water quality monitoring data and models for the management of the water supply. This summary is complementary to the New York City 2024 Drinking Water Supply and Quality Report (available at: [2024-drinking-water-supply-quality-report.pdf (nyc.gov)]), which is distributed to consumers annually to provide information about the quality of the City's tap water. These two reports together document water quality from its source to the tap.

The New York City Water Supply System (Figure 1.1) provides drinking water to almost half the state's population, which includes over 8.5 million people in New York City and 1 million people in upstate counties, plus millions of commuters and tourists. New York City's Catskill/Delaware System is one of the largest unfiltered surface water supplies in the world. The City's water is supplied from a network of 19 reservoirs and three controlled lakes. The total watershed area for the system is approximately 1,972 square miles, extending over 125 miles north and west of New York City. This resource is essential for the health and well-being of millions and must be monitored, managed, and protected for the future. The mission of the Bureau of Water Supply (BWS) is to deliver a reliable and sufficient quantity of high-quality drinking water to protect public health and the quality of life for the City of New York. To gather and process the information needed to meet these goals, there is an ongoing program of water quality monitoring.

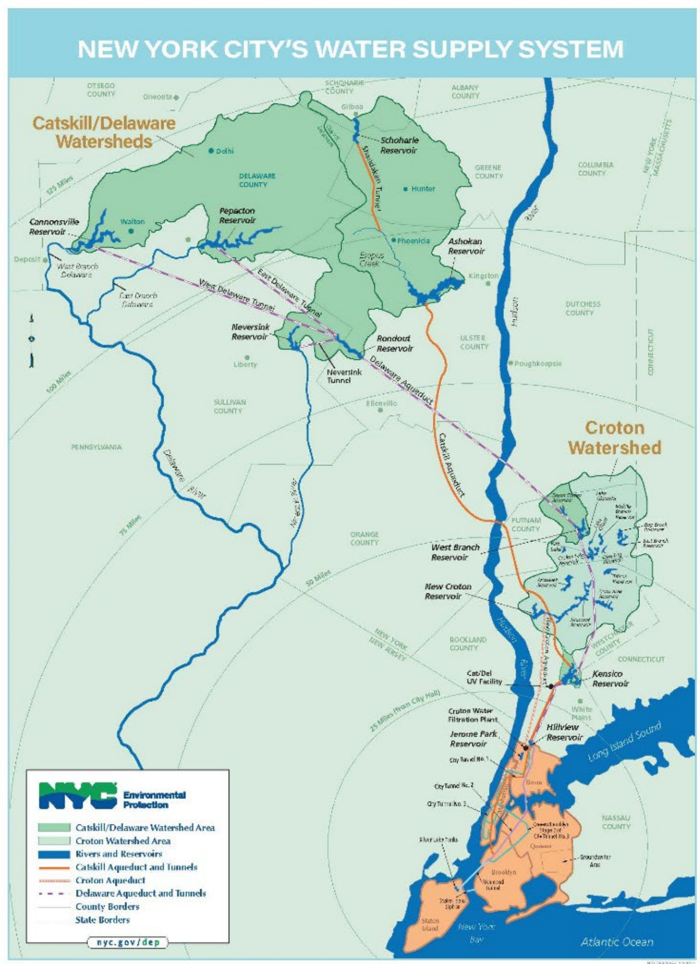

Figure 1.1 New York City Water Supply System.

The Directorate of Water Quality (WQ) oversees watershed monitoring through its Divisions of Water Quality North and South, operating primarily from three locations in upstate New York: Grahamsville, Kingston, and Hawthorne. Much of the information generated by field, laboratory, automated monitoring, and data analysis activities is presented here to provide an overview of watershed water quality in 2024, and to show how high-quality source water is reliably maintained through constant vigilance and operational changes. In addition to the work of WQ, DEP supplements its capabilities through contracts and interactions with other organizations (see Chapter 6 Innovation and Research).

1.1.1 Grab Sample Monitoring

Water quality of the reservoirs, streams, and aqueduct keypoints is monitored throughout the watershed to meet several objectives including regulatory compliance, water supply operations, and to demonstrate the effectiveness of watershed protection measures. The Watershed Water Quality Monitoring Plan (WWQMP; DEP 2024a) is DEP's comprehensive plan that describes the water quality monitoring conducted throughout the watershed. The sampling effort is continuously evaluated and tailored to meet specific DEP objectives. In 2024, DEP collected 13,073 samples from 320 watershed locations and performed nearly 251,114 analyses to support various water quality objectives.

1.1.2 Robotic Monitoring (RoboMon) Network

DEP's Robotic Monitoring (RoboMon) network provides high frequency, near real-time data that are essential for guiding water supply operations and supporting water quality modeling. Data are of particular importance when water quality conditions are changing rapidly, and operational responses may be required. In addition to water quality surveillance, these data are used as inputs to the Operations Support Tool (OST), reservoir and watershed models. Data generated by the RoboMon network have proven to be invaluable for the protection of the water supply during storm events, water quality special investigations, and the construction phase of water supply infrastructure projects that can potentially affect water quality. In 2024, nearly 2.5 million measurements were recorded from 24 sites (17 buoys and 7 stream sites). These automated water quality monitoring systems have become critical in managing the day-to-day operation of the water supply as we strive to reliably deliver the highest quality drinking water. Sites and associated parameters are included in Appendix A.

Except for the intake site near Delaware Shaft 18 at Kensico (Site 2BRK), DEP's robotic monitoring buoys are removed from the reservoirs before ice over. Because of the critical nature of monitoring turbidity at Ashokan Reservoir, DEP deploys two winter buoys on Ashokan. The units are positioned near the East and West Basin gatehouses which help guide operational decisions throughout the winter months. These buoys are typically installed in December and removed in April when the routine profiling buoys can be redeployed.

The only significant change in the robotic monitoring program during 2024, was deployment of two fixed depth buoys positioned near the intake of West Branch Reservoir to monitor turbidity upon restart of the Delaware Aqueduct following the RWBT shutdown.

1.1.3 Early Warning Remote Monitoring

The Early Warning Remote Monitoring (EWRM) team continued to operate a network of real-time, continuous, water quality monitoring stations at critical aqueduct monitoring locations. Instrumentation and sensors vary by site and are outlined in Appendix B. Data generated by this program are critical for the operation of the water supply, for fluoride residual monitoring, State Pollutant Discharge Elimination System (SPDES) monitoring, and for regulatory compliance including calculation of the inactivation ratio (IAR) for pathogens and viruses. Data from reservoir effluent chambers and gatehouses are also critical for making decisions about diversions, releases, and treatment operations. In addition to the instrumentation and parameters listed in Appendix B, the ToxProtect64 fish biomonitoring systems were operated at DEL18DT and CROGH sites in 2024 to provide rapid detection of contaminants that may not be detected by standard instrumentation. Neither site produced a water quality alarm signal in 2024.

In 2024, additional Ultraviolet Sensors (UVAS) were installed at the following Keypoints in the watershed: DEL17 (Kensico) and CATIC. These sensors provide continuous UV_{254} absorbance/transmittance measurements that can be used to make operational decisions based on the quality of various watershed sources. These specific sites were added to enhance DEP's understanding potential changes in DBPfp as a result of source water changes during the RWBT shutdown.

1.2 Tools for Optimizing Water Quality

1.2.1 Bureau of Water Supply Operational Reporting and Dashboards

WQ Data and Technology Operations (DTO) staff continued their collaboration with DEP's Bureau of Information Technology (BIT) and BWS Strategic Operations and Research (SOR) to enhance and refine the centralized data warehouse. This warehouse supports an increasing number of data-driven dashboards and reports using Microsoft's enterprise business intelligence platform, Power BI.

In 2024, there was a primary focus on addressing reporting and dashboard needs within the Distribution system. Additionally, there were several improvements across watershed related tools including updates to the near real-time dashboard screens for EWRM. Dashboard pages were re-engineered for consistency across both browser and mobile platforms, ensuring a streamlined and user-friendly experience (Figure 1.2).

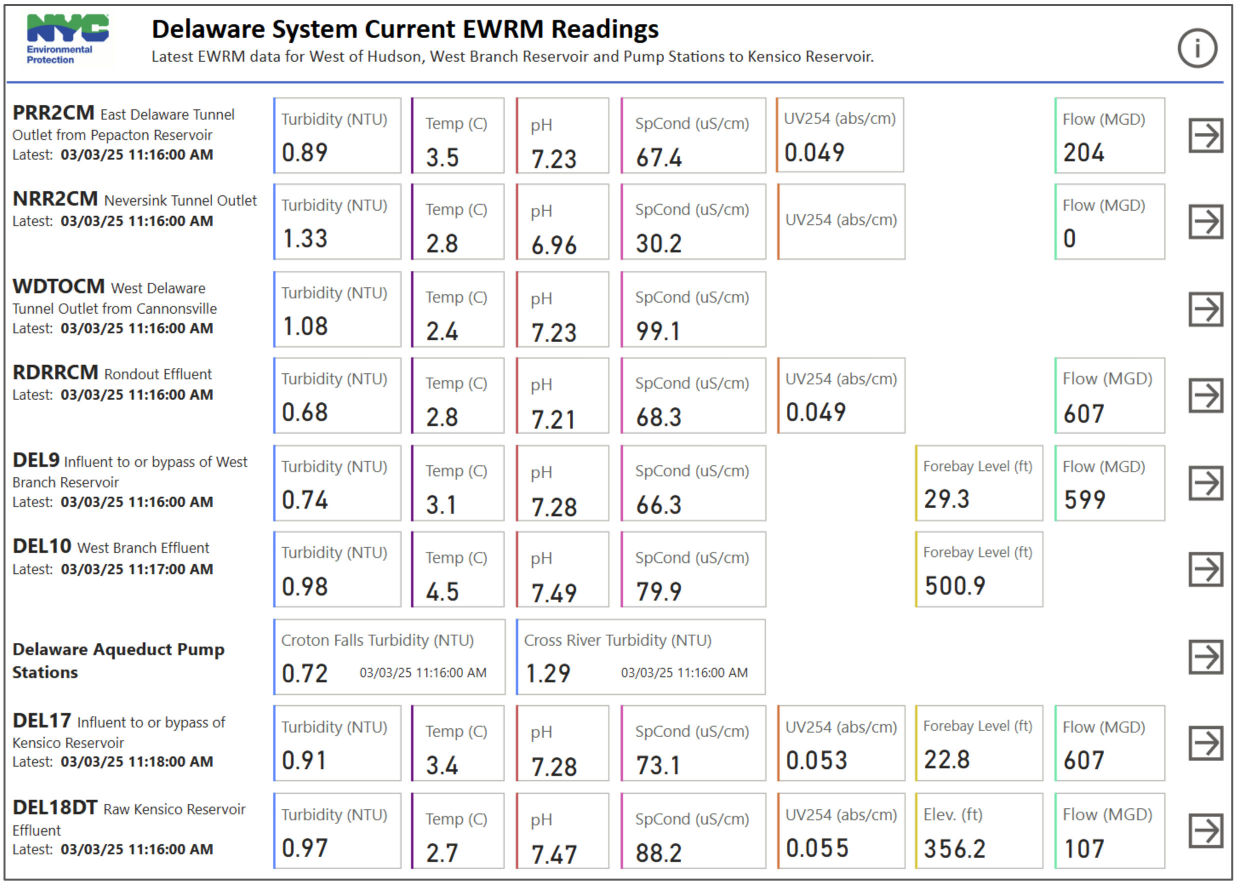

Figure 1.2 Delaware System Current EWRM Readings.

As part of ongoing improvements, DTO advanced two key projects related to EWRM data. First, the EWRM Field application was launched to record quality control and maintenance activities while EWRM staff are onsite (Figure 1.3). Data collected within this application help eliminate anomalous data often generated during maintenance periods, resulting in a cleaner and more reliable dataset for users.

Figure 1.3 EWRM Field Application showing QC and Maintenance Actions at an EWRM site.

Additionally, DTO collaborated on the BWS-led effort to consolidate SCADA-related data under the capital project DEL-360. A major goal of this initiative is to phase out the standalone Water Quality EWRM database by integrating data collection and storage within a unified Bureau-managed system. In 2024, DTO completed a systems comparison analysis between the two databases and initiated the data integration and migration process.

1.3 Operational Strategies

Catskill West of Hudson

In 2024, water quality in the Catskill System was excellent for most of the year. The elevation and location (East Basin/West Basin) of withdrawal and dividing weir operations at Ashokan Reservoir were adjusted as needed to divert the best quality water from the reservoir and to meet operational needs (e.g., lowering the West Basin to create a void to accept more runoff during large storm events) (Figure 1.4). The West Basin elevation remained below spill most of the year except for a few spill events due to storms during the winter and spring. At the end of 2023, a mid-December storm event led to tremendous runoff that raised the West Basin elevation almost eight feet over a period of two days (582.9’ on December 17, 2023 to 590.77’ on December 19, 2023). Management responded by operating Delaware Shaft 4 on December 22, 2023, introducing Delaware water into the Catskill Aqueduct in conjunction with reduced Ashokan Reservoir diversions to reduce turbidity levels diverted to Kensico Reservoir. This

system configuration was also utilized at the beginning of 2024, where the Shaft 4 interconnect was utilized from January 4, 2024, through January 14, 2024, and February 2, 2024, through February 14, 2024. During the 2024 winter/spring period the dividing weir was utilized consistently to move water from the West Basin into the East Basin. To prevent any potential 'short-circuiting' should turbidity spill west to east, the use of the dividing weir provides velocity that pushes West Basin water further out into the East Basin, giving it time to mix and settle. On April 15, 2024, an elevation change was made on the East Basin down to 522' drawing water from lower in the water column improving water quality diverted from Ashokan Reservoir.

After the active winter/spring period, operations were focused on executing the RWBT shutdown. The Shaft 4 interconnection remained offline until it was re-activated on July 20, 2024, to preserve Ashokan Reservoir water. In addition, the diversion at the Ashokan Reservoir was switched to the West Basin location in May, also to preserve East Basin water for the shutdown. Diversions continued to occur from the West Basin at the start of the shutdown, however due to lack of precipitation during the fall of 2024, the intake elevation was lowered twice due to the decrease in West Basin elevation. The West Basin draw continued until October 28, 2024, when a switch to the East Basin was required to maintain adequate flow to support the shutdown. The withdrawal continued from the East Basin the remainder of the year through the shutdown and after bailout of the shutdown on December 13, 2024.

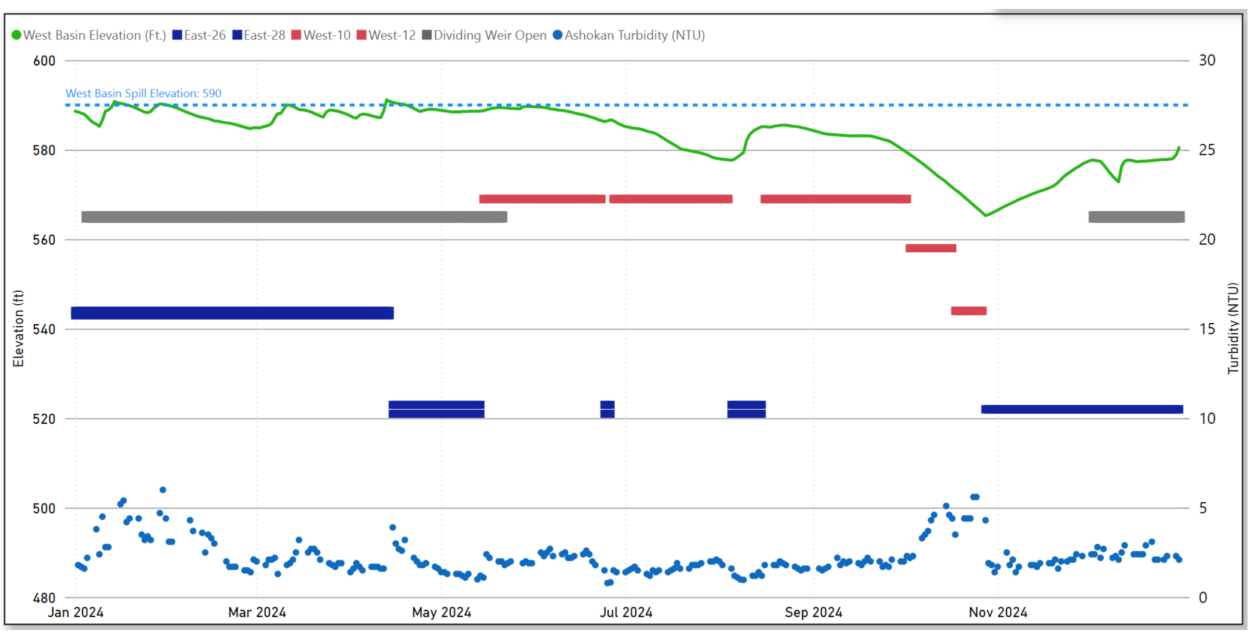

Figure 1.4 Ashokan diversion in relation to turbidity in 2024.

Delaware West of Hudson

For the majority of 2024, water quality in the Delaware System was excellent and unremarkable. However, the remnants of Tropical Storm Debby inundated Cannonsville and Pepacton reservoirs in early August. DEP typically minimizes the use of Neversink Reservoir due to elevated UV_{254}, but Neversink was favored over Cannonsville Reservoir throughout the month of August due to lower turbidity and UV_{254}. Pepacton Reservoir required an intake elevation change to a lower elevation following the storm to deliver the best quality water into Rondout Reservoir. Cannonsville Reservoir was brought back online at the end of August as water quality improved, with an intake elevation change to a higher elevation to further improve water quality. This configuration was held until the start of the RWBT shutdown. Diversions into Rondout Reservoir remained offline until mid-November 2024 as the Delaware System was preparing for restart of the RWBT in response to drought conditions. Rondout Reservoir elevation decreased to 822' during preparation for the RWBT shutdown with no impact on water quality. Prior to the restart, an intake elevation change was made at Cannonsville Reservoir necessitated by the low water elevation of the reservoir. Water quality remained excellent at Rondout Reservoir during refill following the RWBT shutdown; diversions from Rondout Reservoir re-started on December 13, 2024.

Catskill-Delaware East of Hudson

As part of the 2024 shutdown of the RWBT, and with written approval from the New York State Department of Health (NYSDOH), the Croton Falls and Cross River pump stations were operated. Croton Falls was used from October 1, 2024 to December 12, 2024. Cross River Pump Station was used from October 1, 2024 to November 21, 2024. The pump stations diverted up to 180 MGD from Croton Falls Pump Station and 60 MGD from Cross River Pump Station. Use of the pump stations during these exercises was summarized in an after-action report and submitted to NYSDOH.

In addition, Kensico Reservoir was operated in float mode on a few occasions in 2024: once in January to facilitate the installation of turbidity curtains around a section of the cove where construction activity had the potential to disturb soils, and once in March and twice in April in anticipation of high winds.

1.3.1 Croton Water Filtration Plant

The CWFP was operated from September 4 through December 31, 2024, in support of a RWBT shutdown.

2. Water Quantity

2.1 Introduction

The New York City Water Supply System is dependent on precipitation (rain and snow) and subsequent runoff to supply the reservoirs. As the water drains from the watershed, it is carried via streams and rivers to the reservoirs. The water is then moved via a series of aqueducts and tunnels to terminal reservoirs before it reaches the distribution system. The hydrologic inputs and outputs affect turbidity, nutrient loads, and water residence times, which are primary factors that influence reservoir water quality.

2.2 Watershed Precipitation

The average precipitation for each watershed was determined from daily readings collected from one precipitation gauge located in or near each watershed. The total monthly precipitation is the sum of the daily average precipitation values calculated for each reservoir's watershed. The 2024 monthly precipitation totals for each watershed are plotted along with the long-term (30-year) historical monthly averages (Figure 2.1). In September and October, a drought occurred in the West of Hudson (WOH) and East of Hudson (EOH) watersheds, with lower rainfall totals observed for September and October relative to 30-year mean monthly rainfall. The National Climatic Data Center's (NCDC) climatological rankings were queried to determine the 2024 rankings for New York (NCDC 2025). Overall total precipitation for New York State in 2024 was 44.31 inches (1,125.47 mm), which was 4.02 inches (102.1 mm) above the 20th-century mean (1901-2000) and the 26^{th} wettest year in the last 129 years (1895-2024). In New York's Climate Division 2, which includes the WOH reservoirs, the 2024 precipitation total was 4.37 inches (111.00 mm) above the 20th-century mean. In New York's Climate Division 5, which includes the EOH reservoirs, precipitation was 1.60 inches (40.64 mm) above the 20th-century mean.

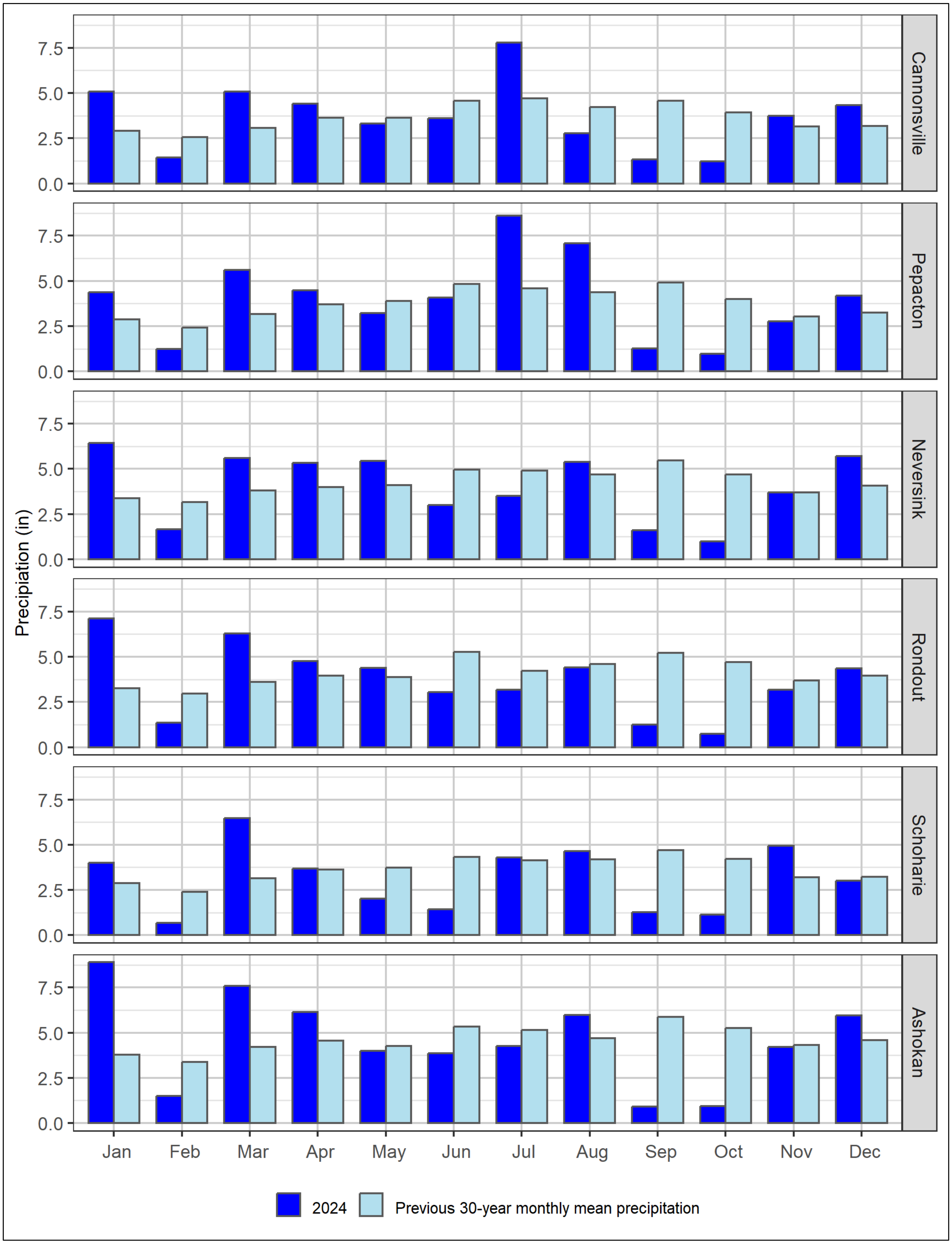

Figure 2.1 Monthly precipitation totals (2024) and long-term (30-year) historical mean monthly precipitation for West-of-Hudson (WOH) New York City watersheds.

2.3 Watershed Streamflow

Streamflow in a watershed can be affected by meteorological factors such as type of precipitation (rain, snow, and sleet), intensity, amount, duration, spatial distribution over the drainage basin, direction of storm movement, antecedent conditions, and resulting soil moisture and temperature. Physical characteristics of the watershed also affect streamflow. These include land use, vegetation, soil type, drainage area, basin shape, elevation, slope, topography, watershed orientation, drainage network pattern, and occurrence and area of ponds, lakes, reservoirs, sinks, and other features of the basin. Annual streamflow normalized by watershed area is a useful statistic to compare between watersheds and allows for comparisons of the hydrologic conditions in watersheds of varying sizes. It is calculated by dividing the annual flow volume by the drainage basin area, yielding a depth that would cover the drainage area.

Selected United States Geological Survey (USGS) stations were used to characterize streamflow in the different NYC Water Supply watersheds. Wappinger Creek is not located in the EOH system but is included here because it is in nearby Dutchess County and its longer period of record is more comparable to those found in the WOH system (Figure 2.2). The 2024 total monthly streamflow for each of the stations is shown as blue-green dots and historical 30-year streamflow data is provided in the boxplots.

For the 2024 water year (October 1, 2023 - September 30, 2024) New York State's computed annual runoff (streamflow per unit area) ranked as the 24th highest (80.8th percentile) over the last 125 years as determined by the USGS (http://waterwatch.usgs.gov/index.php?r=ny&m=statesum).

Figure 2.3 shows the 2024 mean daily streamflow, along with the minimum, maximum, and median daily streamflow for the previous 30 years, for the same USGS stations used to characterize annual areal-normalized streamflow. While the patterns generally reflect the monthly precipitation patterns, the higher time resolution of these plots are useful in that they identify shorter-term wet and dry periods as well as individual storms. The drought in fall 2024 can be seen by monthly streamflows that are in the bottom 25th percentile of the long-term monthly streamflow distribution (Figure 2.2).

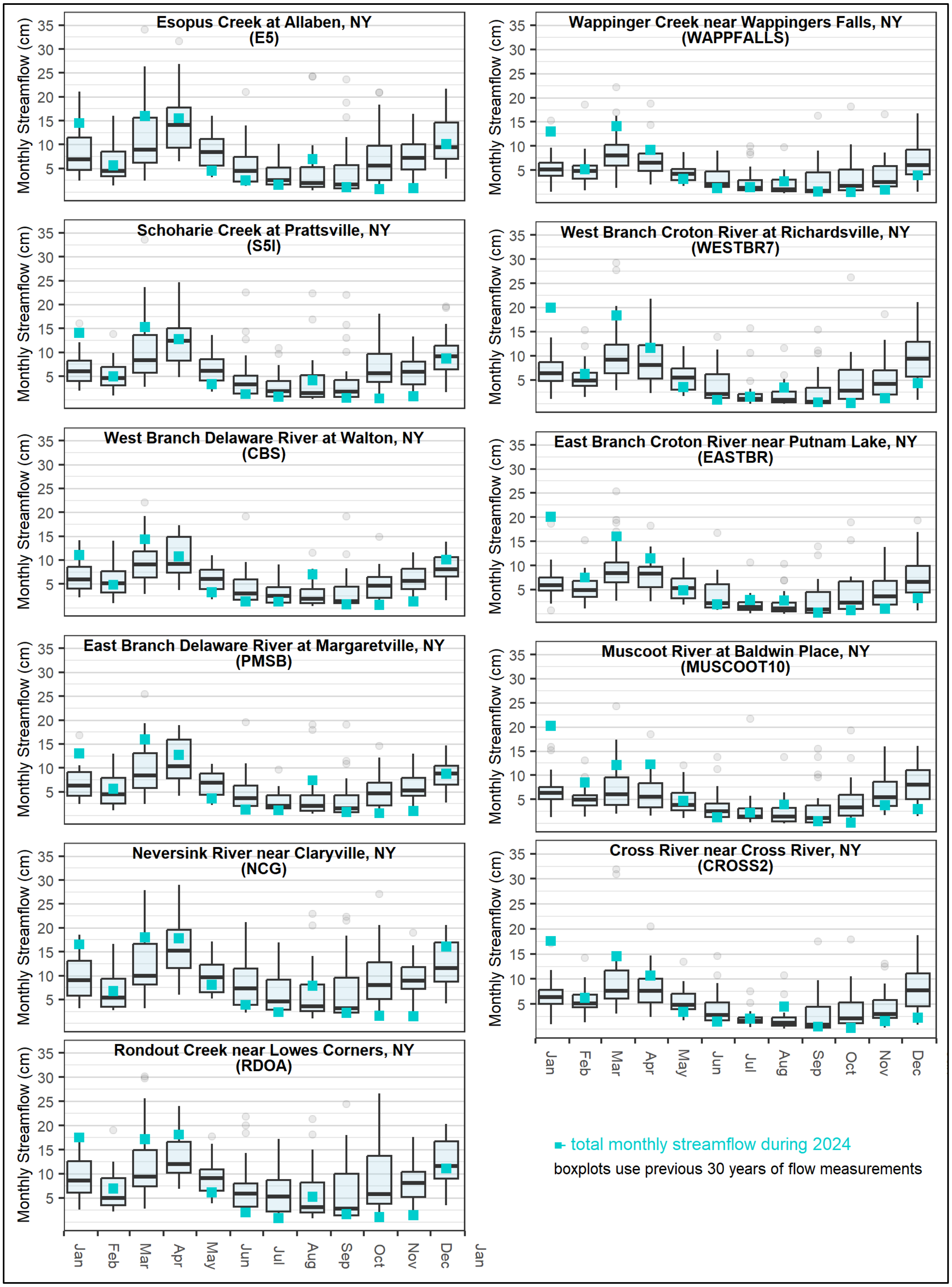

Figure 2.2 Historical areal-normalized streamflow (30-year boxplots) vs. 2024 monthly areal-normalized streamflow (blue-green squares). The gray circles indicate outliers (see Appendix C for a key to the boxplot).

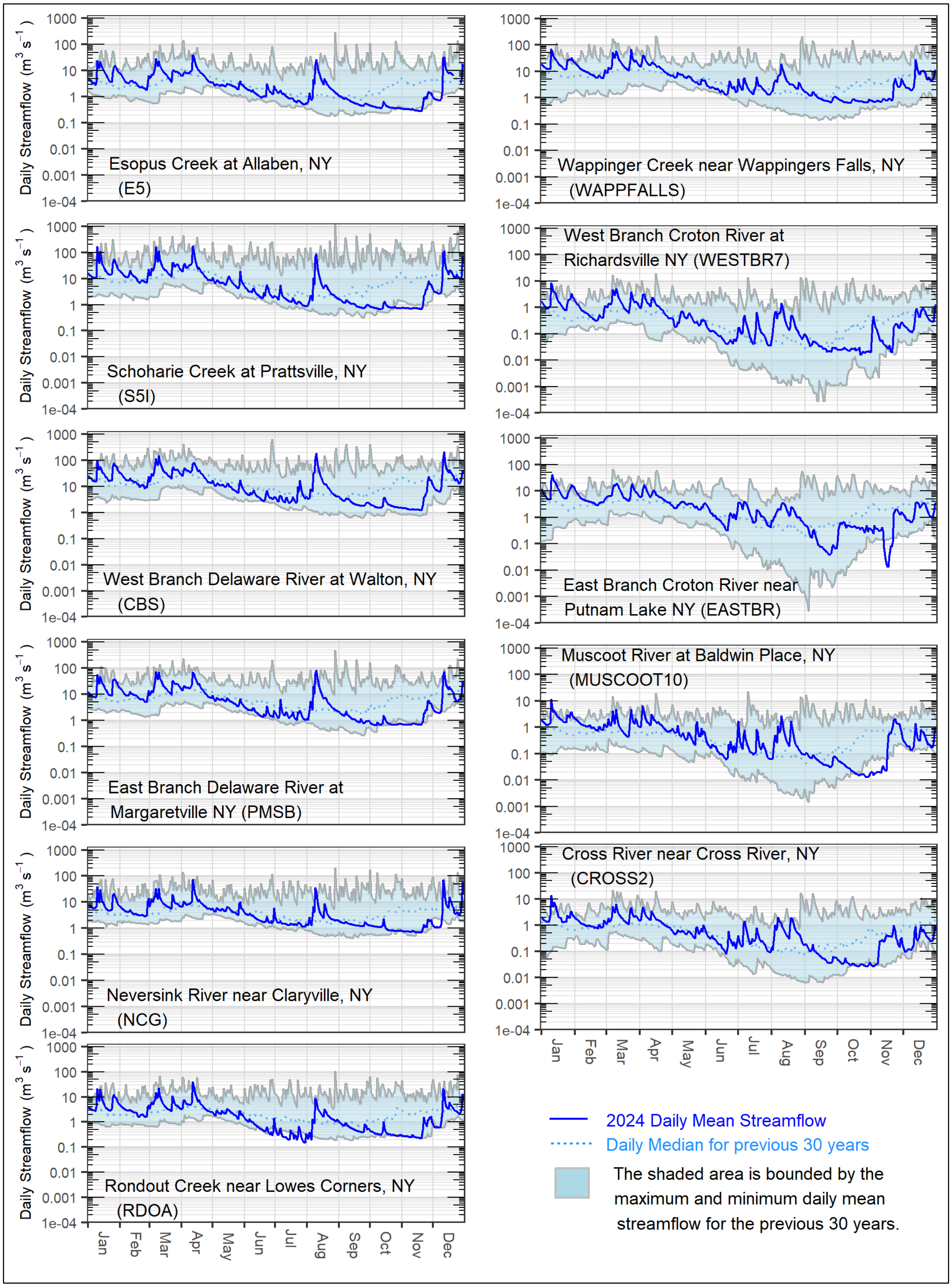

Figure 2.3 Daily mean streamflow for 2024 at selected USGS stations.

2.4 Reservoir Usable Storage

Ongoing daily monitoring of reservoir storage allows DEP to compare the system-wide storage in 2024 (including Kensico Reservoir) with average historical storage (Figure 2.4). Storage remained within ~10% of long-term storage (1982 – 2024 Mean Percent Storage) until mid-September, after which storage declined to reach a maximum deficit of ~25% of the long-term storage due to drought conditions.

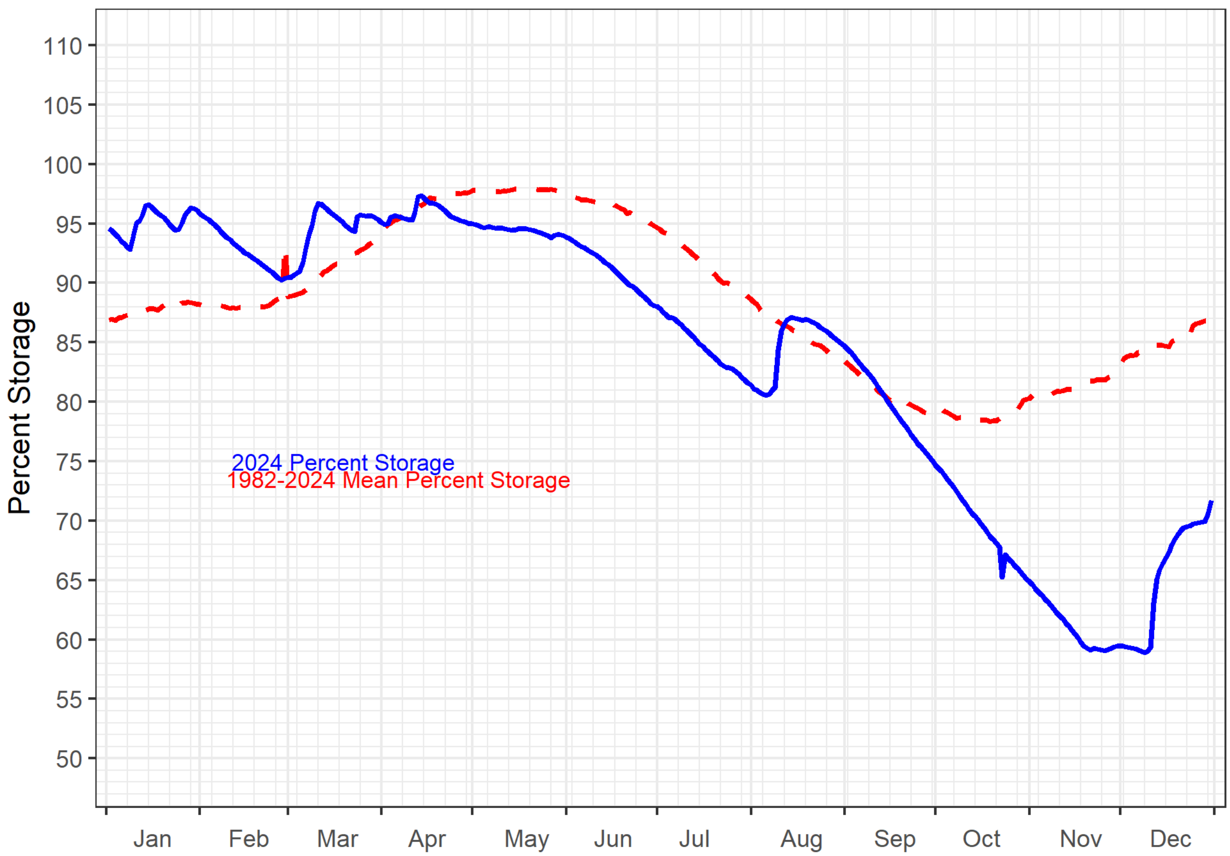

Figure 2.4 System-wide usable storage in 2024 compared to the average historical storage (1982-2022). Storage greater than 100% occurs when the water surface elevation is greater than the spillway elevation and reservoirs are spilling.

3. Water Quality

3.1 Monitoring Overview

Water quality samples are collected from designated sites at streams, reservoirs, and aqueduct locations throughout the NYC watershed (Appendix D). Routine stream samples considered in this report are typically collected on a monthly basis according to DEP's Watershed Water Quality Monitoring Plan (WWQMP) (DEP 2024a). Historically, reservoir samples are obtained from multiple sites and multiple depths with routine sampling frequencies of once per month. In 2024, the typical historical sample period of April through November was followed for all reservoirs. To ensure an impartial comparison with past data, reservoir historical data were adjusted to reflect the months and sites collected in 2024. If the historical data did not have adequate representation (at least 75% of the 2024 sample load) that particular year was excluded.

Aqueduct keypoint samples are collected year-round at frequencies that vary from daily, weekly, and monthly. Note that while Kensico Reservoir is usually operated as a source water, the reservoir can be bypassed so that Rondout or West Branch reservoirs can be operated as source waters. Regardless of reservoir operations, Delaware Shaft 18 (DEL18DT) remains the Surface Water Treatment Rule (USEPA 2006) compliance sampling site since all water flows through this location prior to delivery to Hillview Reservoir.

3.2 Reservoir Turbidity Patterns in 2024

Turbidity in reservoirs is comprised of both inorganic (e.g., clay, silt) and organic (e.g., plankton) particulates suspended in the water column. Turbidity may be derived from the watershed by erosion (storm runoff in particular) or generated within the reservoir itself (e.g., plankton, sediment resuspension). In general, turbidity levels are highest in the Catskill reservoirs (Schoharie and Ashokan) due to the occurrence of easily erodible lacustrine clay deposits found in these watersheds.

Despite rainfall throughout the watersheds in the first part of 2024, turbidity levels in the CAT/DEL reservoirs were mostly below their historical 25th percentile turbidity levels, except Pepacton Reservoir which had only slightly higher than historical levels. The difference between historical and 2024 turbidity levels at CAT/DEL reservoirs ranged from 0.03 NTU at Rondout to 4.6 NTU at Schoharie (see Figure 3.1). Several factors can contribute to lower turbidities. Snowmelt, which can be gradual in watersheds located west of the Hudson River, occurred from mid-March to early April with some rain-on-snow events occurring during this period. Large precipitation events occurred in January, March, and throughout the spring (>2 inches), primarily at Kensico, West Branch, Ashokan, and Rondout reservoirs, although remnants of Hurricane Debby impacted Pepacton and Cannonsville reservoirs in early August and temporarily increased turbidity levels in those reservoirs. The number of large precipitation events for the year remained fewer than the historical average for the Schoharie, Neversink, Pepacton and Cannonsville watersheds.

Localized precipitation events that occurred in December 2023 and January 2024 likely increased turbidity levels in the reservoirs, but since data used in Figure 3.1 is confined to the limnology sampling months of April through November 2024, their effects are not reflected in the plot. West Branch and Kensico reservoir's 2024 turbidity levels are largely reflective of operational best management practices (e.g., use of the Shaft 4 interconnect) for lowering turbidity levels from upstream sources. Rondout diversions, and to a much lesser extent releases from Boyd Corners, influence West Branch reservoir water quality, while Ashokan and Rondout/West Branch diversions influence that of Kensico reservoir.

Turbidity levels were also low in the Croton System, ranging from 0.1 to 0.6 NTU below historical median levels. Turbidity samples are not collected at Middle Branch, Diverting, Titicus, and Amawalk reservoirs and Figure 3.1 does not include results from East Branch and Bog Brook reservoirs or the controlled lakes at Gilead, Gleneida, and Kirk because their historical 10-year records are incomplete from mid-2019 through 2023 due to sample and workload reductions.

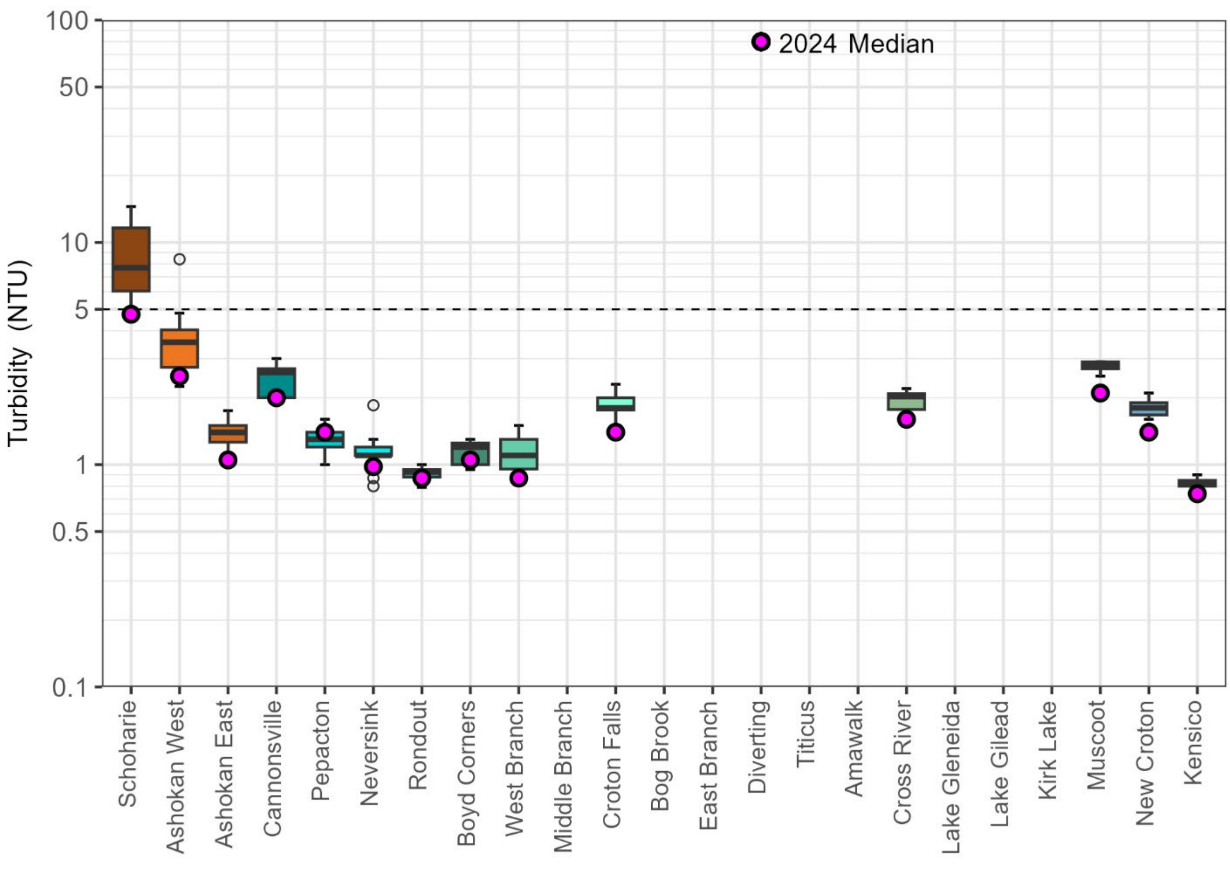

Figure 3.1 Annual median turbidity in NYC water supply reservoirs (2024 vs. 2014-2023), with the 2024 values displayed as a solid dot and outliers as open circles. The dashed line at 5 NTU represents the SWTR standard for source water as a reference.

3.3 Coliform-Restricted Basin Assessments in 2024

Coliform bacteria serve as indicators of potential pathogen contamination. To protect the City's water supply, the New York City Watershed Rules and Regulations (WR&R; DEP 2019) limit potential sources of coliform bacteria in the watershed area of water bodies classified as restricted. These regulations require the City to perform an annual review of its reservoir basins to make "coliform-restricted" determinations.

Coliform-restricted determinations are governed by four sections of the regulations: Sections 18-48(a)(1), 18-48(c)(1), 18-48(d)(1), and 18-48(d)(2). Section 18-48(c)(1) applies to terminal basins that include Kensico, West Branch, New Croton, Ashokan, and Rondout reservoirs. The coliform-restricted assessments of these basins conform to compliance with federally imposed limits on fecal coliforms collected from waters within 500 feet of the reservoir's aqueduct effluent chamber. Section 18-48(a)(1) applies to non-terminal basins and specifies that coliform-restricted assessments of these basins be based on compliance with New York State ambient water quality standard limits on total coliform bacteria (6 NYCRR Parts 701 and 703).

3.3.1 Terminal Basin Assessments

Table 3.1 provides coliform-restricted assessments for the five terminal reservoir basins. The results are based on 2024 fecal coliform data from a minimum of five samples each week over two consecutive six-month periods. If 10% or more of the coliform samples measured have values >20 fecal coliforms $100mL^{-1}$ and the source of the coliforms is determined to be anthropogenic (Section 18-48(d)(2)), the basin is classified as a "coliform-restricted" basin. All terminal reservoirs had fecal coliform counts below the 10% threshold and met the criteria for non-restricted basins for both six-month assessment periods in 2024.

Table 3.1 Coliform-restricted basin status as per Section18-48(c)(1) for terminal reservoirs in 2024.

Reservoir basin	Effluent keypoint	2024 assessment
Kensico	DEL18DT	Non-restricted
New Croton	CROGH[1,2]	Non-restricted
Ashokan	EARCM[2]	Non-restricted
Rondout	RDRRCM[2]	Non-restricted
West Branch	CWB1.5	Non-restricted

[1]Data from the corresponding alternate site used when the sample could not be collected at the primary site listed.
[2]Data from the elevation tap that corresponds to the level of withdrawal are included one day per week, and all other samples are collected at the specified effluent keypoint.

3.3.2 Non-Terminal Basin Assessments

Section 18-48(a)(1) of the WR&R requires that non-terminal basins be assessed according to 6 NYCRR Part 703 for total coliform. These New York State regulations are specific to the class of the reservoir. A minimum of five samples per month are required in each basin to be included in the assessment. If both the median value and more than 20% of the total coliform counts for a given month exceed the values ascribed to the reservoir class, then the results exceed the reservoir class standard, and the non-terminal reservoir is designated as restricted. Routine surveys are performed monthly, April through November. For 2024, several Croton reservoirs were not sampled for all eight-months due to low water elevations. This was caused by the Rondout-West Branch Tunnel shutdown and the extensive use of the Croton System from September through the end of the year. The water bodies not sampled eight times include Bog Brook, East Branch, Diverting, and Muscoot reservoirs and Kirk Lake. Two Catskill/Delaware System reservoirs, Schoharie and Neversink, also did not have samples collected at all eight routine sites due to draw-down and low water conditions, preventing safe access. Table 3.2 provides a summary of the 2024 coliform-restricted calculation results for the non-terminal reservoirs. Appendix E includes the details for coliform monthly medians and the percentage of values exceeding the relevant standard.

In 2024, eight reservoirs out of the evaluated 14 reservoirs and three controlled lakes had no exceedances for the Part 703 total coliform standard (Table 3.2). The highest number of exceedances occurred in Diverting Reservoir.

Total coliform bacteria originate from a variety of natural and anthropogenic (human-related) sources. However, Section 18-48(d)(1) states the source of the total coliforms must be proven to be anthropogenic before a reservoir can receive coliform-restricted status. No other data were collected that could definitively indicate an anthropogenic source.

Table 3.2 Coliform-restricted calculations for total coliform counts on non-terminal reservoirs in 2024.

Reservoir	Class[1]	Standard: Monthly Median / >20% (Total coliforms $100mL^{-1}$)	Months that exceeded the standard /months of data
Amawalk	A	2400/5000	0/8
Bog Brook	AA	50/240	1/7
Boyd Corners	AA	50/240	2/8
Cross River	A/AA	50/240	2/8
Croton Falls	A/AA	50/240	3/8
Diverting	AA	50/240	5/6
East Branch	AA	50/240	0/7
Kirk Lake	B	2400/5000	0/7
Lake Gilead	A	2400/5000	0/8

Reservoir	Class[1]	Standard: Monthly Median / >20% (Total coliforms $100mL^{-1}$)	Months that exceeded the standard /months of data
Lake Gleneida	AA	50/240	0/8
Middle Branch	A	2400/5000	0/8
Muscoot	A	2400/5000	0/7
Titicus	AA	50/240	1/8
Cannonsville	A/AA	50/240	3/8
Pepacton	A/AA	50/240	2/8
Neversink	AA	50/240	0/6
Schoharie	AA	50/240	2/7

[1] The reservoir class for each water body is set forth in 6 NYCRR Chapter X, Subchapter B. For those reservoirs that have dual designations, the higher standard was applied.

3.4 Reservoir Fecal and Total Coliform Patterns in 2024

Total coliforms are a broad-based category of coliform bacteria and include fecal coliforms, which only originate in the gut of warm-blooded animals, and other coliforms that typically originate in water, soil, and sediments. Coliform bacteria do not generally cause serious illness, but their presence can be used to infer that additional pathogenic organisms of fecal origin may be present in a sample.

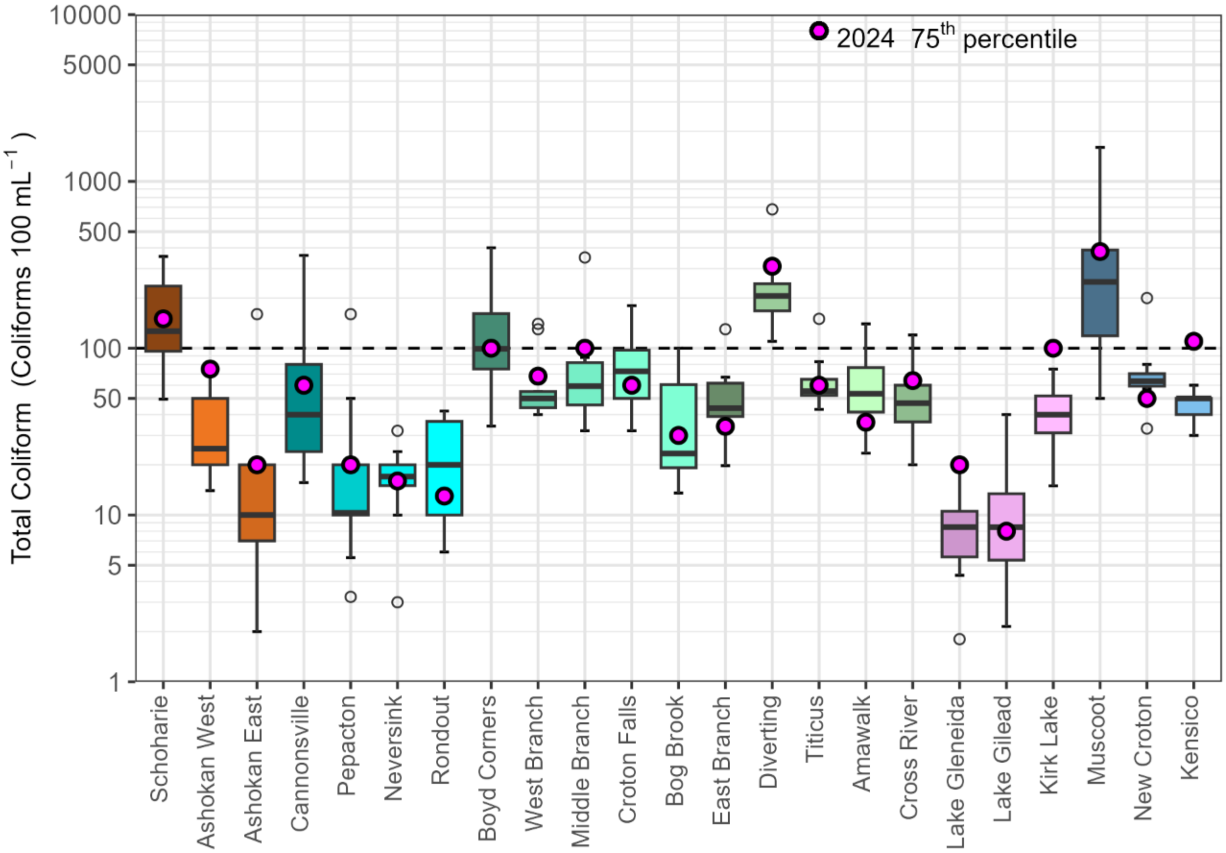

Figure 3.2 Annual 75th percentile of total coliforms in NYC water supply reservoirs (2024 vs. 2014-2023), with the 2024 75th percentile values displayed as a solid dot and outliers as open circles. The dashed line represents the SWTR standard for source water as a reference benchmark.

Reservoir total coliform results are presented in Figure 3.2 and reservoir fecal coliform results in Figure 3.3. According to the filtration avoidance criteria of the SWTR, fecal coliform concentrations must be ≤ 20 fecal coliforms $100mL^{-1}$ or total coliform concentrations must be ≤ 100 total coliforms $100mL^{-1}$ in at least 90% of the measurements from the last six months at the sample point immediately prior to the first point of disinfectant application. While this criterion does not apply to other sampling locations, lines at 20 fecal coliforms $100mL^{-1}$ and 100 total coliforms $100mL^{-1}$ are provided on the plots in this section as a point of reference. The centerline in the boxplot represents the median of the 75th percentile values rather than the 50th percentile or median of annual values. If a calculated annual 75th percentile results in a censored value or zero, it was estimated using the robust regression on statistics method (ROS) of Helsel and Cohn (1988).

In 2024, total coliform counts were elevated and often exceeded the historical 75th percentiles in most waterbodies of the CAT/DEL and Croton systems. The high counts are usually associated with June to August localized rain events. The largest excursions over historical levels were in the Croton System. Greater development (i.e., more impermeable surfaces) relative to the CAT/DEL System, combined with the frequent rain events are probable factors.

Except for at West Branch Reservoir, fecal coliform counts were within or close (i.e., Cannonsville, Rondout) to their historical interquartile ranges for most reservoirs of the CAT/DEL System. At West Branch, though 2024 results were above the historical 75 percentile, there were no elevated fecal coliform counts observed at or above 20 coliforms 100mL^{-1}. In most of the Croton System, fecal coliform counts were elevated relative to historical levels. Large precipitation events in the spring and again in the summer in July and August, contributed to runoff events. The degree of development in the Croton watersheds is also likely responsible.

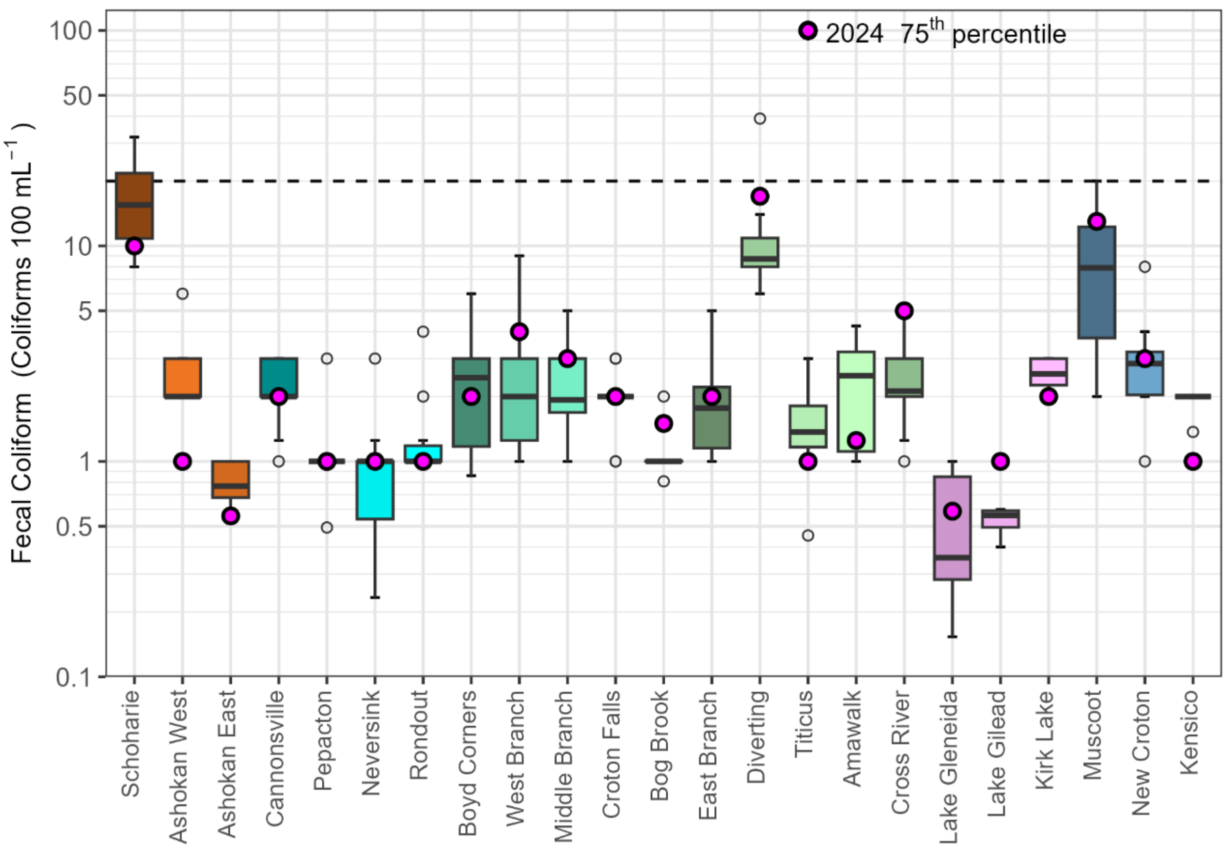

Figure 3.3 Annual 75th percentile of fecal coliforms in NYC water supply reservoirs (2024 vs. 2014-2023), with the 2024 75th percentile values displayed as a solid dot and outliers as open circles. The dashed line represents the SWTR standard for source water as a reference.

3.5 Phosphorus-Restricted Basin Assessments in 2024

The phosphorus-restricted basin status determination for 2024 is presented in Figure 3.4 and Table 3.3. Status is determined from two consecutive five-year assessments (2018-2022 and 2019-2023) using the methodology described in Appendix F. Reservoirs and lakes with a mean total phosphorus (TP) concentration that exceeds the benchmarks in the WR&R for both assessments are classified as restricted.

Phosphorus-restricted status for all West of Hudson and East of Hudson reservoirs remained the same as in the previous assessment. Figure 3.4 graphically shows the phosphorus-restricted basin status of the City's reservoirs and controlled lakes. Results from 2024 show a slight increase in the average five-year assessments in every system, except for Pepacton and Rondout reservoirs. Geometric means for individual years that contributed to the assessments are shown in Appendix F.

In 2024, Lake Gleneida was unintentionally sampled only twice during the growing season, making assessment of phosphorus-restriction status for 2024 unavailable, and, with 2024 annual data unavailable, the assessment of the five-year period did not meet the required three-year minimum and is also unavailable as a result.

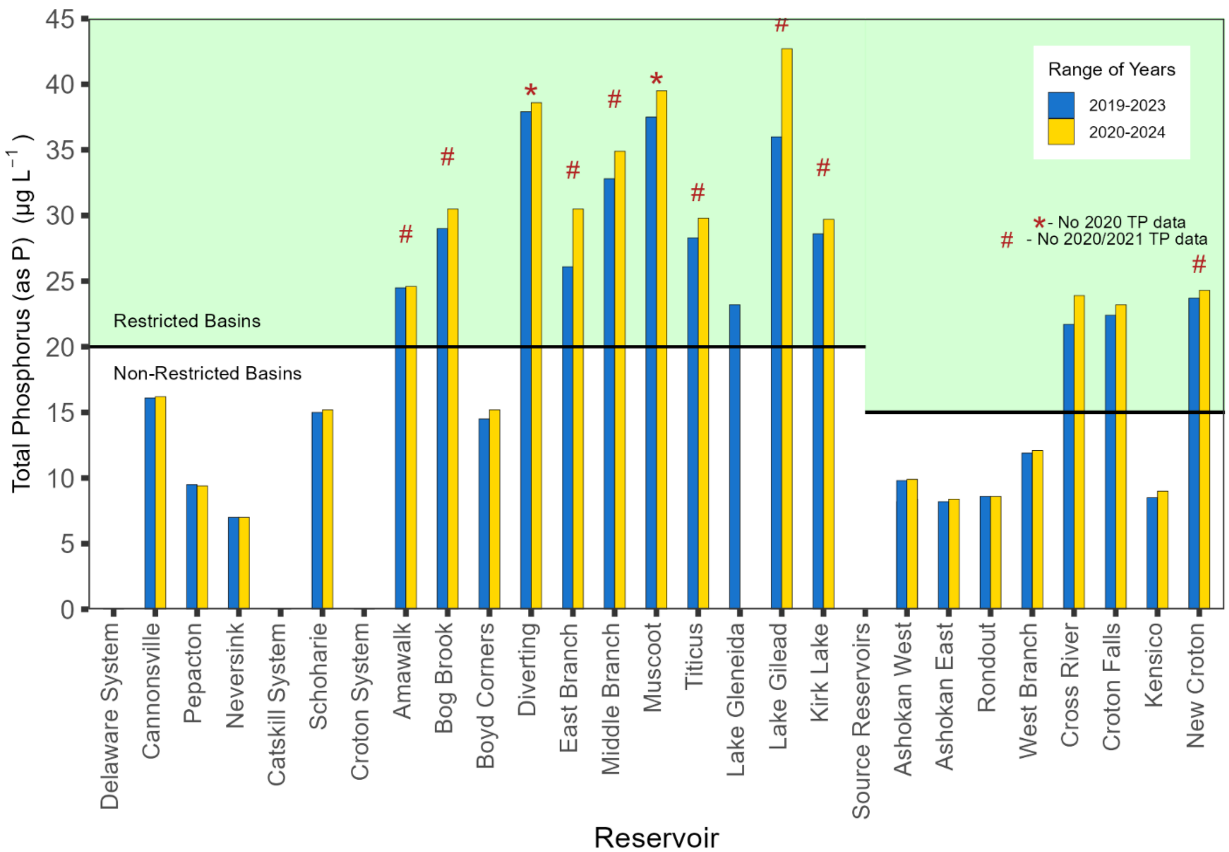

Figure 3.4 Phosphorus-restricted basin assessments. The horizontal solid lines at 20 µg L^{-1} and 15 µg L^{-1} represent the trophic guidance value for non-source and source waters, respectively.

Table 3.3 Phosphorus-restricted basin status for 2024.

Reservoir basin	2019-2023 Assessment[1,2] (µg L^{-1})	2020-2024 Assessment[1, 2] (µg L^{-1})	Phosphorus restricted status[3]
Non-Source Waters (Delaware System)			
Cannonsville	16.1	16.2	Non-restricted
Pepacton	9.5	9.4	Non-restricted
Neversink	7.0	7.0	Non-restricted
Non-Source Waters (Catskill System)			
Schoharie	15.0	15.2	Non-restricted
Non-Source Waters (Croton System)			
Amawalk	24.5	24.6	Restricted
Bog Brook	29.0	30.5	Restricted
Boyd Corners	14.5	15.2	Non-restricted
Diverting	37.9	38.6	Restricted
East Branch	26.1	30.5	Restricted
Middle Branch	32.8	34.9	Restricted
Muscoot	37.5	39.5	Restricted
Titicus	28.3	29.8	Restricted
Lake Gleneida	23.2	NA	Restricted
Lake Gilead	36.0	42.7	Restricted
Kirk Lake	28.6	29.7	Restricted
Source Waters (all systems)			
Ashokan West	9.8	9.9	Non-restricted
Ashokan East	8.2	8.4	Non-restricted
Rondout	8.6	8.6	Non-restricted
West Branch	11.9	12.1	Non-restricted
Cross River	21.7	23.9	Restricted
Croton Falls	22.4	23.2	Restricted
Kensico	8.5	9.0	Non-restricted
New Croton	23.7	24.3	Restricted

[1]Arithmetic mean of annual geometric mean total phosphorus concentration for 5-year period with S.E. (standard error of the mean) added to account for interannual variability.

[2] Reservoirs and lakes with sample reductions in 2020 and 2021 had a minimum of three years of data included in the calculation.

[3]The guidance value for non-source waters is 20 µg L^{-1} and for source waters is 15 µg L^{-1}.

3.6 Reservoir Total Phosphorus Patterns in 2024

In 2024, despite greater than average rainfall, annual median total phosphorous (TP) levels were at or below historical levels in six of nine CAT/DEL System reservoirs, including Kensico (Figure 3.5). Annual median increases were only observed at Pepacton (+1.0 µg L^{-1}) and Kensico (+2.0 µg L^{-1}). The TP patterns for the Catskill/Delaware System correlate well with patterns observed for turbidity (Figure 3.1) and fecal coliforms (Figure 3.3) in 2024. Kensico annual median TP was also elevated in 2024 compared to the ten-year history, but it was essentially unchanged from the last few years. Additional sources can include localized stream runoff from the Kensico watershed. Croton Falls and Cross River water was pumped into the Delaware Aqueduct exclusively from October 1 through November 21 and again from Croton Falls only on November 26 through December 12, 2024, as part of the RWBT shutdown. During the shutdown, the diversion from Rondout and West Branch reservoirs were stopped and only water from Croton Falls and Cross River, all of which are typically higher in TP relative to Rondout (Figure 3.5), was diverted into the Delaware Aqueduct.

In contrast, median 2024 TP in the Croton System reservoirs and controlled lakes was mostly elevated compared to historical levels. Reservoirs that historically are associated with conservation releases (e.g., Titicus and East Branch) but were drawn down in support of the RWBT shutdown indicate elevated TP. TP was at its highest or equivalent to its highest since 2014 in 12 of 14 Croton waterbodies. Development in the Croton watershed is greater than in the CAT/DEL System. Development is associated with more impermeable surfaces such as roads, parking lots and roofs which enhance runoff to streams. Development also provides more sources of TP (e.g., animal and human waste, fertilizers) in the watershed. Development in the Croton System, combined with the high frequency and magnitude of rain events, particularly from July through August 2024, are likely reasons for the elevated TP in 2024.

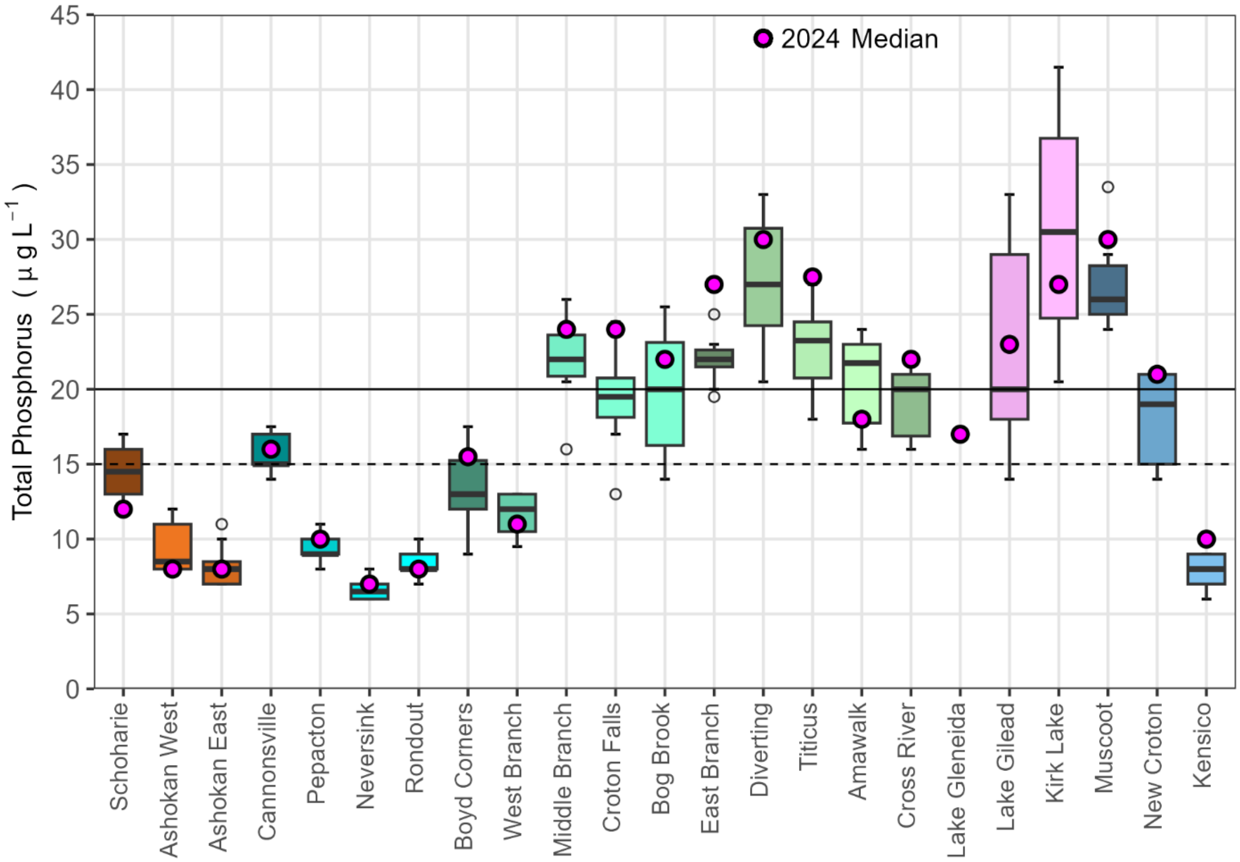

Figure 3.5 Annual median total phosphorus in NYC water supply reservoirs (2024 vs. 2014-2023), with the 2024 median values displayed as a solid dot and outliers as open circles. The horizontal dashed line at 15 µg L^{-1} refers to the NYC Total Maximum Daily Load (TMDL) guidance value for source waters. The horizontal solid line at 20 µg L^{-1} refers to the NYSDEC ambient water quality guidance value for reservoirs other than source waters.

3.7 Reservoir Comparisons to Benchmarks in 2024

The New York City reservoirs and water supply system are subject to the federal SWTR standards, New York State ambient water quality standards, and DEP's own guidelines. Water quality data for 2024 for the terminal reservoirs were evaluated by comparing the results to the water quality benchmarks listed in Table 3.4. Note that the benchmark values in this table are not necessarily applicable to all individual samples and medians described herein (e.g., SWTR limits for turbidity and fecal coliforms apply only to the source water point of entry to the system) and different values apply to Croton System reservoirs than to CAT/DEL reservoirs. Comparing the annual data to these benchmark values assists in assessing water quality status of the system and helps in identifying issues.

Comparisons of 2024 reservoir sample results to benchmark values are provided in Appendix G. Highlights of these benchmark comparisons of the reservoirs from 2024 are included below.

pH

Reservoir samples were generally in the circumneutral pH range (6.5-8.5) in 2024. In the Croton System, West Branch Reservoir samples below the circumneutral range reflected the characteristics of water transferred from the Delaware System, with a pH below 6.5 for 12% of samples collected. Exceedances above pH 8.5, an indicator of algal blooms, were relatively few, with the most exceedances in Lake Gilead (20% of samples collected) and at Titicus Reservoir (18% of samples collected). The West of Hudson reservoirs had a few exceedances above a pH of 8.5 when phytoplankton numbers were high. Samples below a pH of 6.5 occurred throughout the CAT/DEL reservoirs, reflecting the acidic characteristics of watershed soils and slow recovery from acid deposition (Stoddard et al. 1999). For Neversink Reservoir, 80% of samples were below pH 6.5. Fewer samples were below pH 6.5 for Schoharie Reservoir (8%) and Ashokan East and Ashokan West (22% and 19%, respectively). For Kensico Reservoir, 9% of samples were below a pH of 6.5, reflecting the influence of water transferred from West of Hudson reservoirs.

Table 3.4 Reservoir and controlled lake benchmarks as listed in the WR&R (DEP 2019).

Analyte	Basis[1]	Croton System		Catskill/Delaware System	
		Annual Mean	Single Sample Maximum	Annual Mean	Single Sample Maximum
Alkalinity (mg L^{-1})	(a)	≥40.00		≥10.00	
Ammonia-N (mg L^{-1})	(a)	0.05	0.10	0.05	0.10
Dissolved chloride (mg L^{-1})	(a)	30.00	40.00	8.00	12.00
Chlorophyll *a (*mg L^{-1})	(a)	0.010	0.015	0.007	0.012
Color (Pt-Co units)	(b)		15		15
Dominant genus (ASU mL^{-1})	(c)		1,000		1,000
Fecal coliform (coliforms $100mL^{-1}$)	(d)		20		20
Nitrite + Nitrate (mg L^{-1})	(a)	0.30	0.50	0.30	0.50
pH (units)	(b)		6.5-8.5		6.5-8.5
Phytoplankton (ASU mL^{-1})	(c)		2,000		2,000
Dissolved sodium (mg L^{-1})	(a)	15.00	20.00	3.00	16.00
Soluble reactive phosphorus (µg L^{-1})	(c)		15		15
Sulfate (mg L^{-1})	(a)	15.00	25.00	10.00	15.00
Total dissolved solids (mg L^{-1})[2]	(a)	150.00	175.00	40.00	50.00
Total organic carbon (mg L^{-1})[3]	(a)	6.00	7.00	3.00	4.00
Total dissolved phosphorus (µg L^{-1})	(c)		15		15
Total phosphorus (µg L^{-1})	(c)		15		15
Total suspended solids (mg L^{-1})	(a)	5.00	8.00	5.00	8.00
Turbidity (NTU)	(d)		5		5

[1](a) WR&R (Appendix 18-B) – based on 1990 water quality results, (b) NYSDOH Drinking Water Secondary Standard, (c) DEP Internal standard/goal, (d) NYSDOH Drinking Water Primary Standard.
[2]Total dissolved solids was estimated by multiplying specific conductivity by 0.65 (van der Leeden, Troise, and Todd 1990).
[3]Dissolved organic carbon was used in this analysis since total organic carbon is not routinely analyzed at all sites.

Phytoplankton

Phytoplankton sampling summary statistics for 2024 are provided in Appendix G. There were few exceedances of the single sample maximum for phytoplankton. Catskill/Delaware Reservoirs generally had low mean values for total phytoplankton, with the highest means reported for Cannonsville and Neversink reservoirs (437 and 282 ASU mL^{-1}, respectively). West Branch and Kensico reservoirs, though influenced by Delaware System water, experienced higher mean total

phytoplankton in 2024 (722 and 458 ASU mL^{-1}, respectively). Among the Croton System reservoirs sampled, means varied, ranging from 519 to 1540 ASU mL^{-1}.

Chlorophyll and Dissolved Organic Carbon

Chlorophyll *a* concentration is a surrogate measure of algal biomass. Of the reservoirs sampled, there were eight reservoirs that exceeded the single sample maximum (SSM): Cannonsville (15%), Pepacton (3%), West Branch (6%), Boyd Corners (12%), East Branch (29%), Muscoot (26%), Croton Falls (29%), and New Croton reservoirs (9%). East Branch, Croton Falls, and Muscoot reservoirs exceeded the chlorophyll *a* mean value of 10.0 µg L^{-1}.

Dissolved organic carbon (DOC) is used as a surrogate measure for total organic carbon (TOC) for benchmark comparisons. In 2024, there was one exceedance of the single sample maximum benchmark of 4 mg L^{-1} at Cannonsville (1%) Reservoir. In addition, in 2024, there was one exceedance of the SSM benchmark of 7 mg L^{-1} at Muscoot (6%) Reservoir. Otherwise, there were no exceedances of the annual mean benchmark for DOC in any of the reservoirs sampled for DOC including the remainder of the CAT/DEL System, and source and potential source water reservoirs.

Chloride

In the Catskill/Delaware Systems, with an annual mean benchmark of 8.0 mg L^{-1}, exceedances for the chloride mean benchmark values in 2024 occurred in Cannonsville and Schoharie reservoirs (10.2 and 9.4 mg L^{-1}, respectively). Of the Croton System reservoirs sampled for chloride, exceedances of the annual mean benchmark of 30 mg L^{-1} occurred in Bog Brook, East Branch, Muscoot, Croton Falls, and New Croton reservoirs. West Branch and Kensico reservoirs exceeded the annual mean benchmark of 8 mg L^{-1} (12.5 and 9.8 mg L^{-1}, respectively). All chloride samples were well below the health secondary standard of 250 mg L^{-1}.

Turbidity

For the Delaware System reservoirs, few samples exceeded the SSM for Cannonsville (18%) and Pepacton (6%), with no exceedances occurring at Neversink and Rondout. As is historically the case for the Catskill System, Schoharie had the highest number of samples that exceeded the SSM with 46% of the samples. In addition, Schoharie was only one of two reservoir and lakes to exceed the mean annual value of 5 NTU with a value of 8.1 NTU. The Ashokan West Basin exceeded the benchmark SSM with 12% of its samples and the Ashokan East Basin with 2% of its samples. Turbidity in the Croton System had several instances of benchmark SSM exceedances. The highest was at Kirk Lake with 38% of the samples and a mean value of 5.3 NTU. Muscoot Reservoir was the next highest at 10%, followed by Boyd Corners (9%), Cross River (6%), East Branch (5%), Lake Gilead (4%), New Croton (4%), and Croton Falls (3%) reservoirs.

Nutrients

In the Delaware System, Cannonsville Reservoir had the greatest number of TP SSM, exceeding the 15 µg L^{-1} benchmark in 55% of all samples collected. Pepacton Reservoir had fewer

exceedances at 9%, Neversink Reservoir had 2%, and Rondout Reservoir had the lowest with 2%. In the Catskill System, the West Basin of Ashokan exceeded the benchmark with 1% of the samples collected and Schoharie exceeded the SSM in 23% of samples. In the Croton System, TP was high and exceeded the SSM throughout. The lowest percentage of SSM exceedances was at Amawalk (62%) and Boyd Corners (50%) reservoirs. West Branch Reservoir, with influences from the local watershed and the Delaware System, exceeded with 21% of its samples collected. The benchmark value for the bioavailable form of phosphorus (soluble reactive phosphorus or SRP) was exceeded at four reservoirs: Cross River (12%), East Branch (10%), Muscoot (6%), and New Croton (5%).

For nitrate/nitrite for the reservoirs sampled, only Croton Falls (22%), Muscoot (6%), and New Croton (3%) exceeded the SSM value. Ammonium exceeded at Cross River (33%), Muscoot (19%), New Croton (14%), Bog Brook (6%), Croton Falls (5%), Boyd Corners (5%), Schoharie (4%), Cannonsville (3%), and Kensico (1%) reservoirs.

Fecal Coliform Bacteria

There were no exceedances of the SSM of 20 fecal coliforms $100mL^{-1}$ at Ashokan West and East Basin, Rondout, Pepacton, Neversink, East Branch, Titicus, West Branch, and Croton Falls reservoirs, and Lake Gleneida, Lake Gilead, and Kirk Lake. The highest number of exceedances was at Diverting (23%), Schoharie (17%), and Muscoot (15%) reservoirs. For the remainder of the CAT/DEL reservoirs the SSM exceedances were low with 5% at Cannonsville Reservoir. For the Croton System the SSM was exceeded for Cross River (6%), Bog Brook (6%), Middle Branch (5%), New Croton (4%), Amawalk (2%), and Boyd Corners (2%) reservoirs. Kensico exceeded the SSM for 2% of the samples collected.

3.8 Reservoir Trophic Status in 2024

TSI are commonly used to describe the productivity of lakes and reservoirs. Four trophic state categories — oligotrophic, mesotrophic, eutrophic, and hypereutrophic — are used to separate and describe water quality conditions. Oligotrophic waters are low in nutrients, low in algal growth, and tend to have high water clarity. Eutrophic and hypereutrophic waters, on the other hand, are high in nutrients, high in algal growth, and low in water clarity. Mesotrophic waters are intermediate. The indices developed by Carlson (1977; 1996) use commonly measured variables (i.e., chlorophyll *a*, TP, and Secchi transparency) to delineate the trophic state of a body of water. TSI based on chlorophyll *a* concentration is calculated as:

$$TSI = 9.81 \times (\ln (CHLA)) + 30.6$$

where CHLA is the concentration of chlorophyll *a* in $\mu g\ L^{-1}$

The Carlson TSI ranges from approximately 0 to 100 (there are no upper or lower bounds) and is scaled so that values under 40 indicate oligotrophic conditions, values between 40 and 50

indicate mesotrophic conditions, and values between 50 and 70 indicate eutrophic conditions. Values beyond 70 indicate a hypereutrophic state. A low trophic state is desirable for water supplies because such reservoirs produce better water quality and better tasting water at the tap. Trophic state indices are generally calculated from data collected in the photic zone of the reservoir during the growing season (May through October). In 2024, chlorophyll *a* samples were collected from the Catskill/Delaware System as well as from the EOH Filtration Avoidance Determination (FAD) basins. No chlorophyll *a* samples were collected from most non-EOH FAD basins with the exception of Muscoot, East Branch, and Bog Brook reservoirs; Amawalk, Diverting, Middle Branch, and Titicus reservoirs, and Kirk Lake, Lake Gleneida, and Lake Gilead are not sampled for chlorophyll *a* or Secchi depth.

Historical (2014-2023) annual median TSI based on chlorophyll *a* concentration is presented in boxplots for all reservoirs in Figure 3.6. This analysis generally indicates that all West of Hudson reservoirs (including Kensico and West Branch) and Boyd Corners and Bog Brook reservoirs in East of Hudson fall into the mesotrophic category. East of Hudson reservoir Cross River typically straddles mesotrophic-eutrophic categories while New Croton, Muscoot, Croton Falls, and East Branch fall into the eutrophic range.

In 2024, not all reservoirs fell within historical interquartile ranges (Figure 3.6). In the Catskill System, TSI was higher than historical interquartile ranges in Schoharie Reservoir but within the historical maximum. Ashokan East and West basins were within historical interquartile ranges. TSI levels in the Delaware System reservoirs were near historical median values, except for Neversink, which is a low outlier. The annual calculation for Neversink was impacted by an inability to sample in October and November (unlike Cannonsville, Pepacton or Rondout) due to reservoir elevation. The dry summer of 2024, reduced run-off, the RWBT shutdown preparations draw-down, and resultant decrease in reservoir elevation, might suggest a reduction in overland phosphorus contributions and the suppression of algal blooms and subsequent chlorophyll *a* and biomass/productivity. A very slightly higher TSI was noted at Kensico Reservoir in 2024, though well within its historical range.

TSI levels were generally within historical ranges in the Croton System reservoirs sampled in 2024. Notably, both Croton Falls and Cross River, used for pumping operations during the RWBT shutdown, had TSI levels lower than historical levels. Other Croton System reservoirs experienced the same (New Croton, Muscoot, and East Branch). Several factors may be important. First, multiple applications of the algaecide copper sulfate were applied to New Croton, Muscoot, Croton Falls, and Cross River reservoirs in 2024 from May through October. All treated reservoirs had a TSI below historical medians, the history of which is made up of only about 20% treatment years. Following these treatments, algae populations were immediately reduced, preventing blooms along with subsequent improvements with chlorophyll *a* concentrations. Application dates, treatment area delineations and water quality results are available in the 2024 After Action Reports. A second factor was the continued use of the Croton System during the RWBT shutdown, which

became operational in September 2024 and remained on-line through the remainder of 2024. Water coming in from the reservoirs cascading down the Middle and East Branch of the Croton River includes East Branch, Bog Brook, Diverting, Middle Branch, Croton Falls, Titicus, Cross River and Muscoot reservoirs led to shorter reservoir residence times, high flushing from the cascading releases up-stream from one another, and overall increased flows. Prior to the RWBT shutdown, Croton Falls Reservoir also received water directly from West Branch Reservoir and benefitted from initial preparations for the RWBT shutdown. Boyd Corners and West Branch reservoirs were not in operation during the RWBT shutdown and, as a result, Boyd Corners had a decreased residence time which may have led to the slightly higher TSI than its historical median.

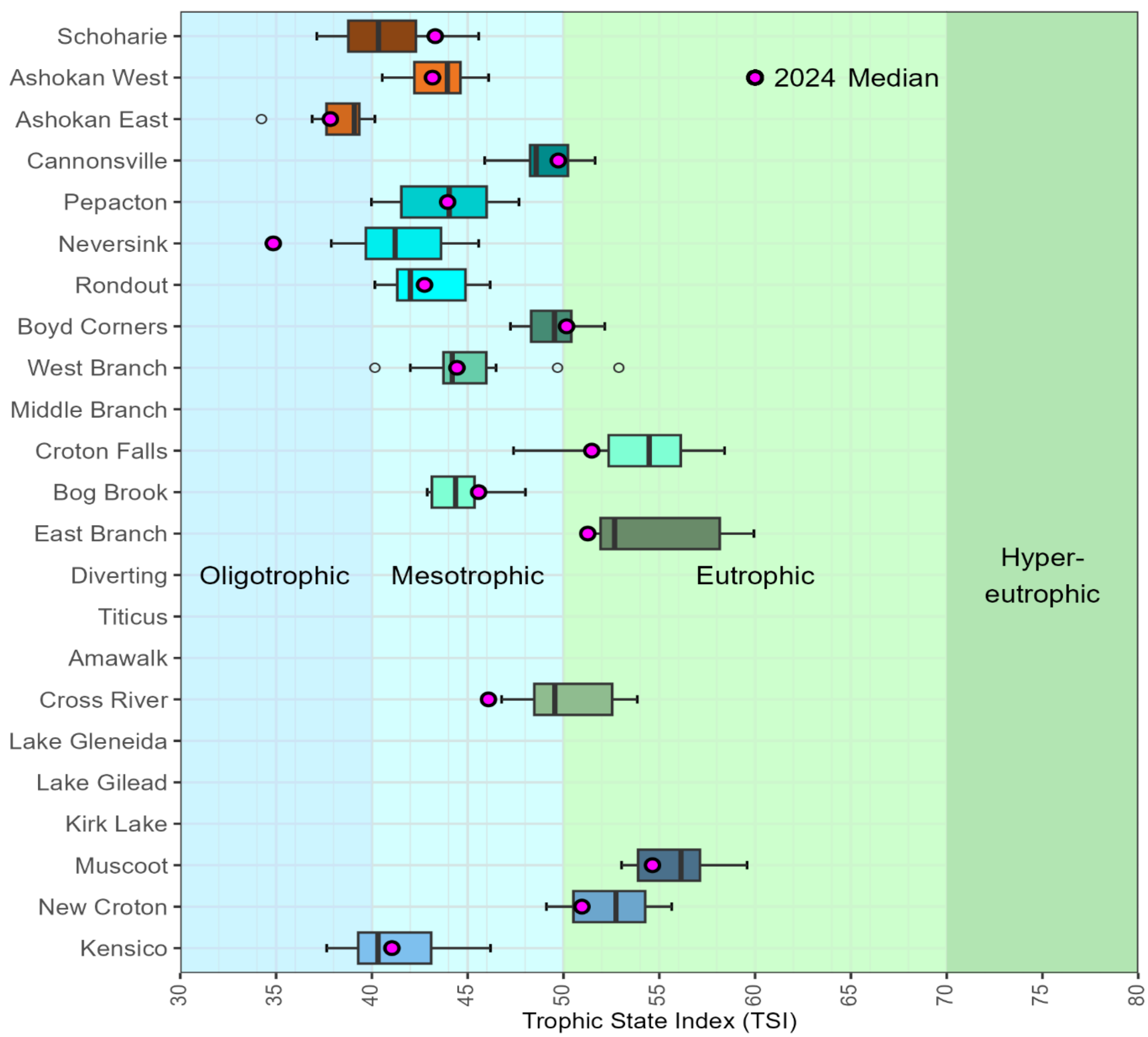

Figure 3.6 Annual median Trophic State Index (TSI) in NYC Water Supply reservoirs (2024 vs. 2014-2023), with the median displayed as a solid dot and outliers as open circles. In general, data were obtained from epilimnetic depths at multiple sites. Sample frequency is described in section 3.1. TSI is based on chlorophyll α concentrations.

3.9 Water Quality in the Major Inflow Streams in 2024

The stream sites discussed in this section are listed in Table 3.5, with locations shown in Figure 3.7, as well as Appendix D. These stream sites were chosen because they are immediately upstream from the six Catskill/Delaware System reservoirs and five of the Croton reservoirs. They represent the bulk of the water entering the reservoirs from their respective watersheds. The exception is New Croton Reservoir, whose major inflow is from the Muscoot Reservoir release. Kisco River and Hunter Brook are tributaries to New Croton Reservoir and represent water quality conditions in the New Croton watershed.

Water quality in these streams was assessed by examining those analytes considered to be the most important for the City's water supply. For streams, these are turbidity and fecal coliform bacteria (to maintain compliance with the SWTR), and TP (to control eutrophication).

The 2024 results presented here are based on routine grab samples generally collected once a month. The 2024 results are plotted by collection date and superimposed on the historical monthly boxplots which are centered on the 15th of the month. The figures in this section show the 2024 results with a boxplot of historical (2014-2023) monthly values for comparison.

Table 3.5 Site codes and site descriptions for the major inflow streams

Site code	Site description
S5I	Schoharie Creek at Prattsville, above Schoharie Reservoir
E16i	Esopus Creek at Boiceville bridge, above Ashokan Reservoir
CBS	West Branch Delaware River at Beerston, above Cannonsville Reservoir
PMSB	East Branch Delaware River below Margaretville Wastewater Treatment Plant, above Pepacton Reservoir
NCG	Neversink River near Claryville, above Neversink Reservoir
RDOA	Rondout Creek at Lowes Corners, above Rondout Reservoir
WESTBR7	West Branch Croton River, above Boyd Corners Reservoir
EASTBR	East Branch Croton River, above East Branch Reservoir
MUSCOOT10	Muscoot River, above Amawalk Reservoir
CROSS2	Cross River, above Cross River Reservoir
KISCO3	Kisco River, input to New Croton Reservoir
HUNTER1	Hunter Brook, input to New Croton Reservoir

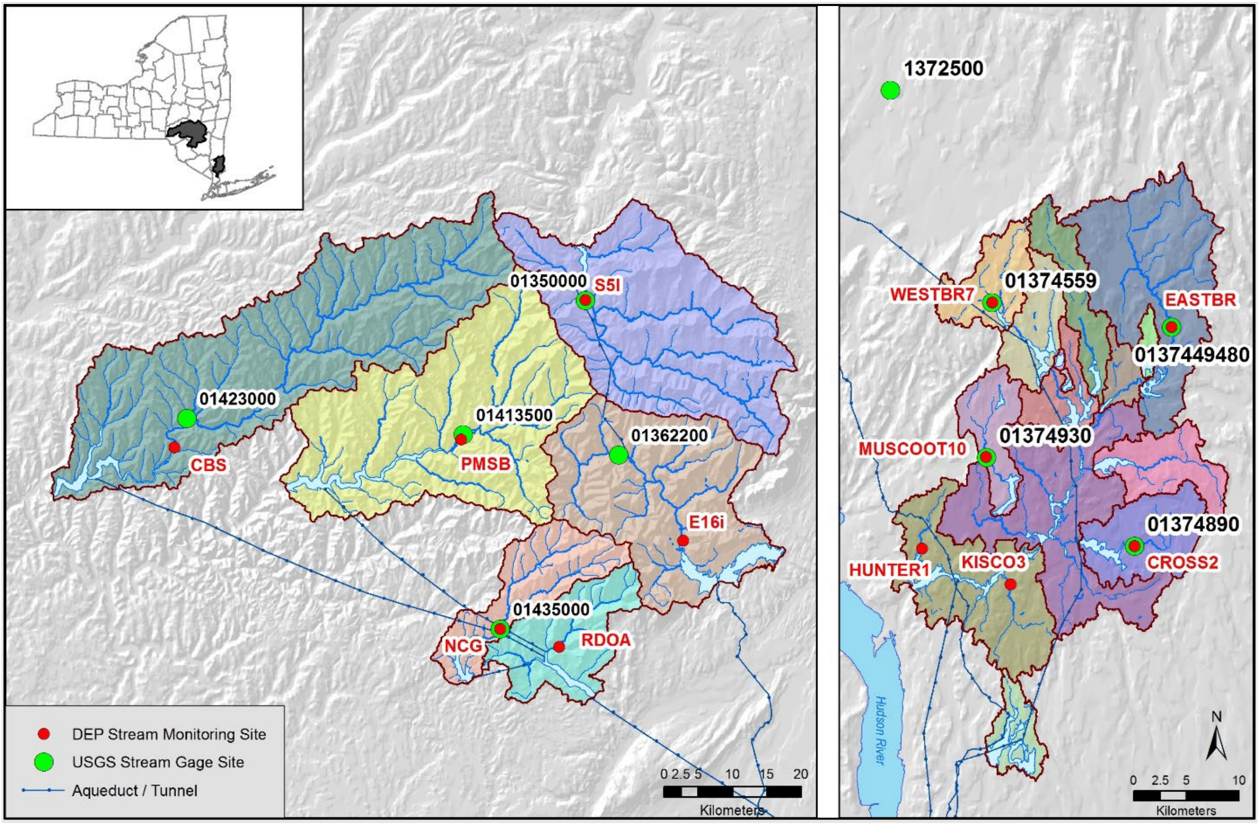

Figure 3.7 Locations of major inflow stream water quality sampling sites and USGS gage stations used to calculate areal-normalized streamflow values (see Section 2.3).

Turbidity

The year began in January with typical (i.e. within the historical interquartile range) to low turbidity levels in the WOH streams as shown in Figure 3.7, despite higher than historical monthly precipitation (Figure 2.1) and streamflow (Figure 2.2) in all WOH streams. January precipitation included several rain and snow events throughout the month. February was a drier month, with low precipitation in all WOH reservoirs but typical turbidity levels and streamflow. The elevated grab sample turbidity result at S5I on March 11 could be attributed to the 1.41 inches of rainfall on the Schoharie watershed on March 9. Turbidity at CBS was high in March, coinciding with higher than typical streamflow for the month. Turbidity and streamflow were generally low to average from April through July across all streams. August turbidity results were elevated at several streams following rain events: S5I peaked at 28 NTU on August 12, sampled after 1.28 inches of rain on the Schoharie watershed on August 9; RDOA had elevated turbidity on August 9 after 1.01 inches of rain on the Rondout watershed on the same day; and CBS had elevated turbidity on August 5 as 0.25 inches of rain was falling on the Cannonsville watershed. Dry conditions began in September and continued through November when a drought warning was implemented. Low WOH streamflow was observed during this time period, which generally coincided with lower stream turbidity levels. Streamflow returned to typical in December following several rain events across

WOH in the second half of November and throughout December, and increased stream turbidity generally followed. The maximum WOH stream turbidity observed all year occurred at E16I in December (60 NTU) and is likely due to the preceding increase in rainfall.

While annual summaries and regulations rely heavily on fixed frequency or more intense storm grab samples, operational decisions are based on data from robotic monitoring sources as well. The "Robomon" program of continuous near, real-time, in-situ monitoring for select locations is a better tool for operational decision making because temporary extreme peaks are identified that can be missed by the routine monthly grab sample or storm regimen. Table 3.6 lists the differences in timing and magnitude of the annual maximum grab and Robomon results.

Table 3.6 Maximum Annual Turbidity for Grab Samples and Robotic Monitoring

Stream Site	Annual Maximum Grab Turbidity (NTU)	Annual Maximum Robotic Monitoring Turbidity (NTU)	Value of Grab Nearest Robotic Max Turbidity (NTU)
CBS	200 on 12/11/24	7,800 on 12/27/24 @7:30PM	14 on 12/30/24
NCG	100 on 12/11/24	4,700 on 12/11/24 @6PM	100 on 12/11/24
RDOA	1.4 on 3/18/24	7,700 on 1/8/24 @ 1PM	0.66 on 1/8/24
S5i	46 on 1/25/24	2,500 on 8/9/24 @4:45PM	28 on 8/12/24
E16i	370 on 11/27/24	2,100 on 10/21/24 @ 14:45	2.7 on 10/21/24

Low to normal (within the historical interquartile range) grab turbidities were generally observed throughout the year in most EOH streams (Figure 3.8) despite elevated streamflow (Figure 2.2) during the first half of the year. Higher than historical maximum turbidities (excluding historical outliers) were recorded at EASTBR in January and November, HUNTER1 in February, July, and August, and KISCO3 and CROSS2 in August. Months where turbidity was elevated always coincided with wet weather within four days of sample collection. It is also important to note that even though turbidity was sometimes elevated relative to historical levels, the maximum turbidity observed in the Croton streams all year was only 8.5 NTU (KISCO3 in August), after 6 consecutive days of rainfall (4.16 inches) on the Croton Watershed, including on the day of sampling. Monitoring at EASTBR, MUSCOOT10, KISCO3, and HUNTER1 was reduced to quarterly beginning on August 13, 2024, due to staffing issues. Those streams were therefore only

sampled for turbidity, total phosphorus, and fecal coliform in November during the last quarter of 2024, except for MUSCOOT10 which was also sampled for those analytes in December.

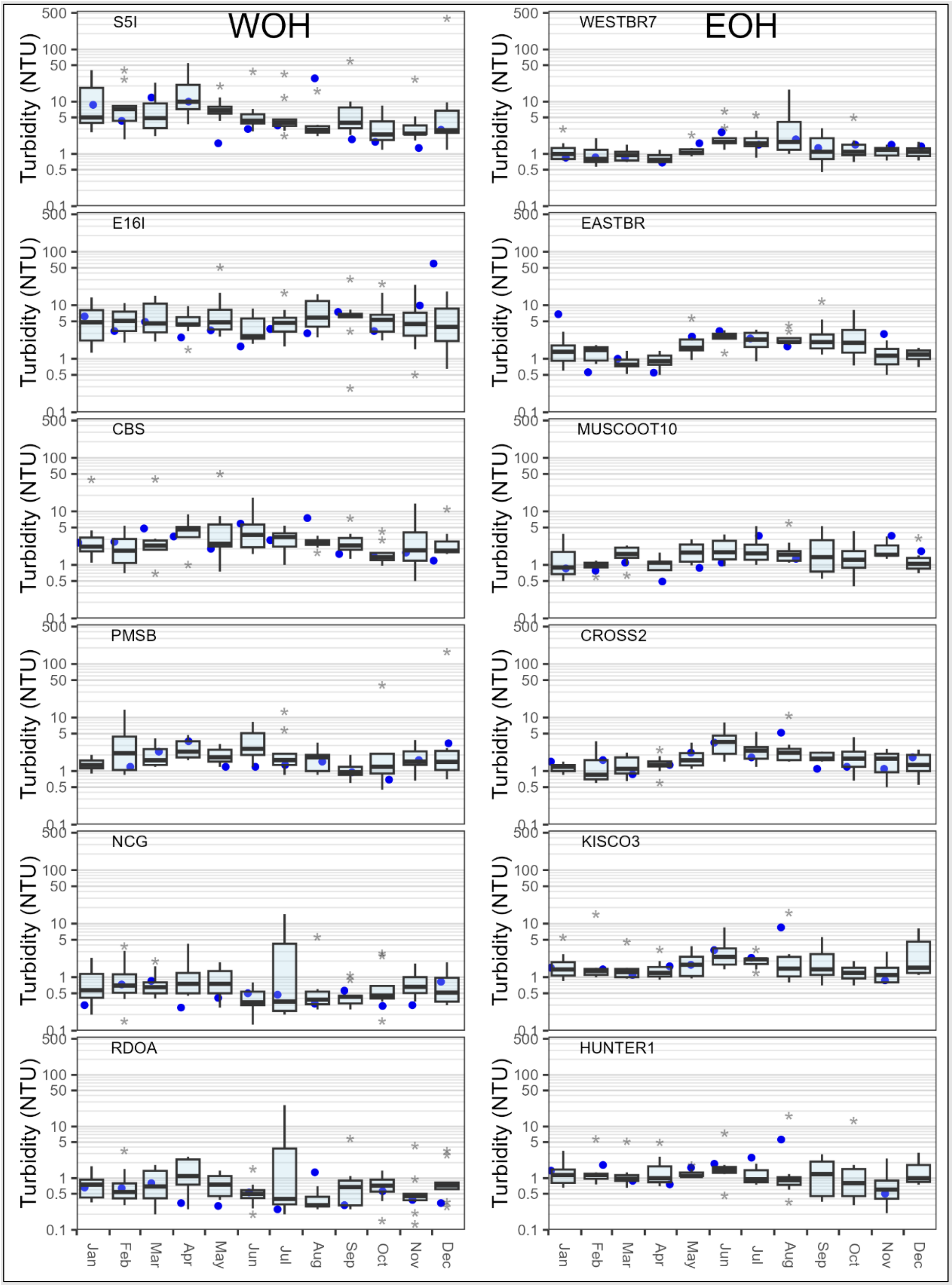

Figure 3.8 Turbidity values in 2024 from routine grab stream samples with a monthly boxplot of the historic (2014-2023) routine monthly samples. Note the y-axis is a log scale.

Total Phosphorus

The primary sources of phosphorus in the NYC water supply are from anthropogenic sources (i.e., septic effluent, fertilizer usage) and from natural sources (i.e., animal feces, microbial breakdown of plant material). Phosphorus is transported from the terrestrial environment to streams via rain and snowmelt events. Baseflow total phosphorus concentrations are generally higher in the EOH streams compared to the WOH streams due to greater development (i.e., more septic systems, more impervious surfaces to enhance transport) in the EOH watersheds.

In 2024, TP concentration results (Figure 3.9) in EOH generally continued to follow the historical seasonality trends, typically peaking in the summer. This trend was especially pronounced at KISCO3 and HUNTER1 in July and August, and at CROSS2 in August, when TP results were far above the historical 75th percentiles. TP results ranged from 107 to 206 µg L^{-1} and coincided with wet weather within five days of sample collection. Other EOH TP results were generally within or close to the historical interquartile ranges throughout the year. WOH TP continued to show a less pronounced seasonality trend and had mixed results relative to the historical medians throughout the year, although E16I generally trended low in the first half of the year and S5I trended high. CBS experienced a TP spike in February (62 µg L^{-1}) while other WOH streams had low TP results relative to historical medians. February was a dry month in WOH but followed a wet January that had several winter and rain storms throughout the month. The dry conditions leading to the drought warning in November coincided with low to normal TP values in the fall in WOH streams. E16I had TP (and turbidity) results far above the historical 75th percentiles in November and December following increased precipitation and streamflow in the second half of November through the end of 2024.

Fecal Coliform Bacteria

Like TP and turbidity, fecal coliform bacteria in the WOH and EOH main inflow streams were mostly within their historical monthly maximum and minimum ranges throughout 2024 and were below historical medians during the dry months of September and October (Figure 3.10). Excursions above monthly historical maximums were almost always linked to wet conditions just prior to sample collection. A fecal coliform benchmark of 200 coliforms 100mL^{-1} relates to the NYSDEC water quality standard for fecal coliforms (which is a monthly geometric mean of five samples) (6NYCRR §703.4b). Of the major inflow stream samples collected in 2024, KISCO3 and MUSCOOT10 exceeded the benchmark twice, and CBS, CROSS2, EASTBR, and HUNTER1 one time. Three of these exceedances, including the 9100 coliforms 100mL^{-1} result at CROSS2, occurred on August 7, 2024, after 6 consecutive days of rainfall on the Croton watershed.

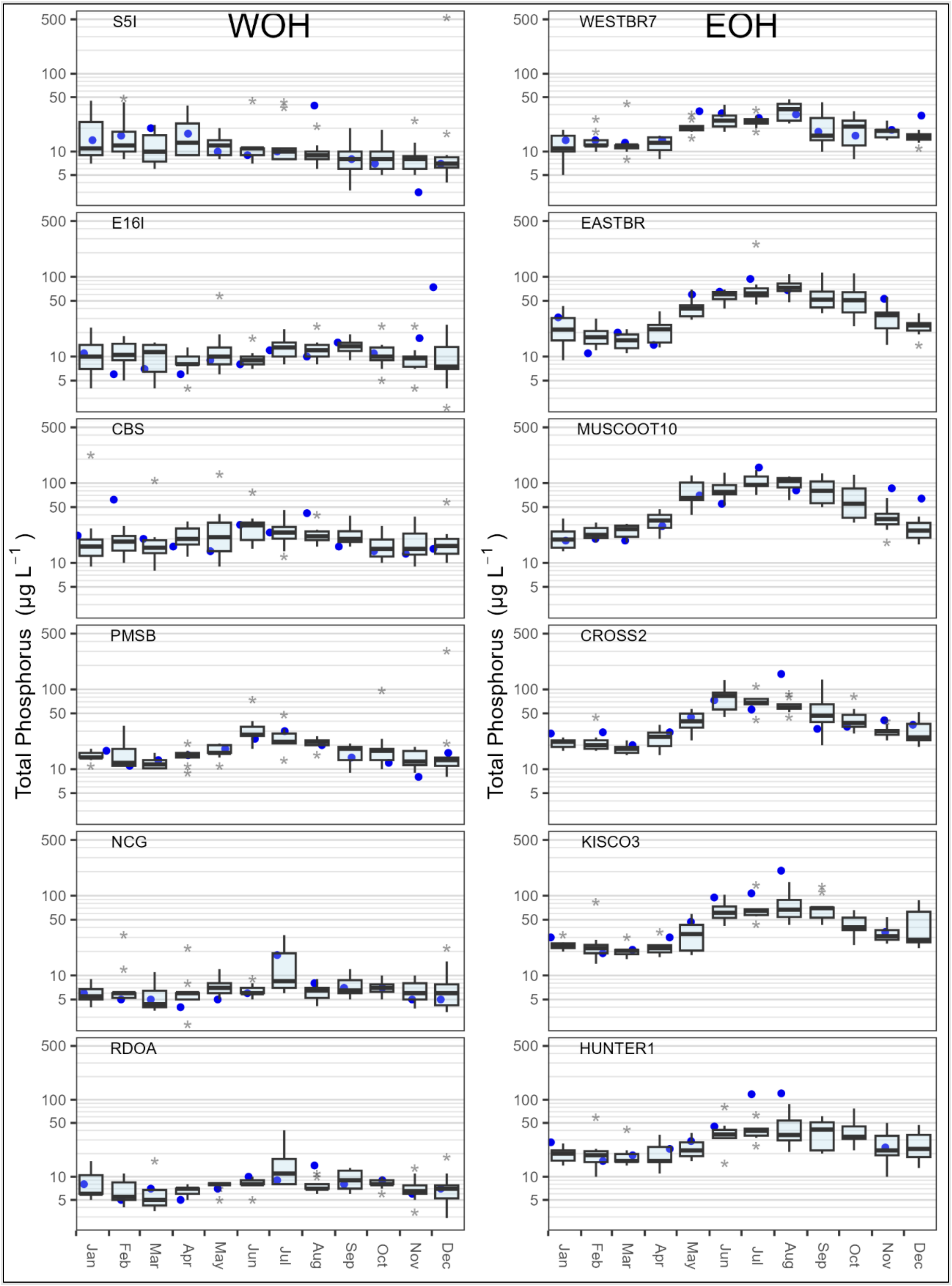

Figure 3.9 Total phosphorus values in 2024 from routine stream samples with a monthly boxplot of the historical (2014-2023) routine monthly samples. Note the y-axis is a log scale.

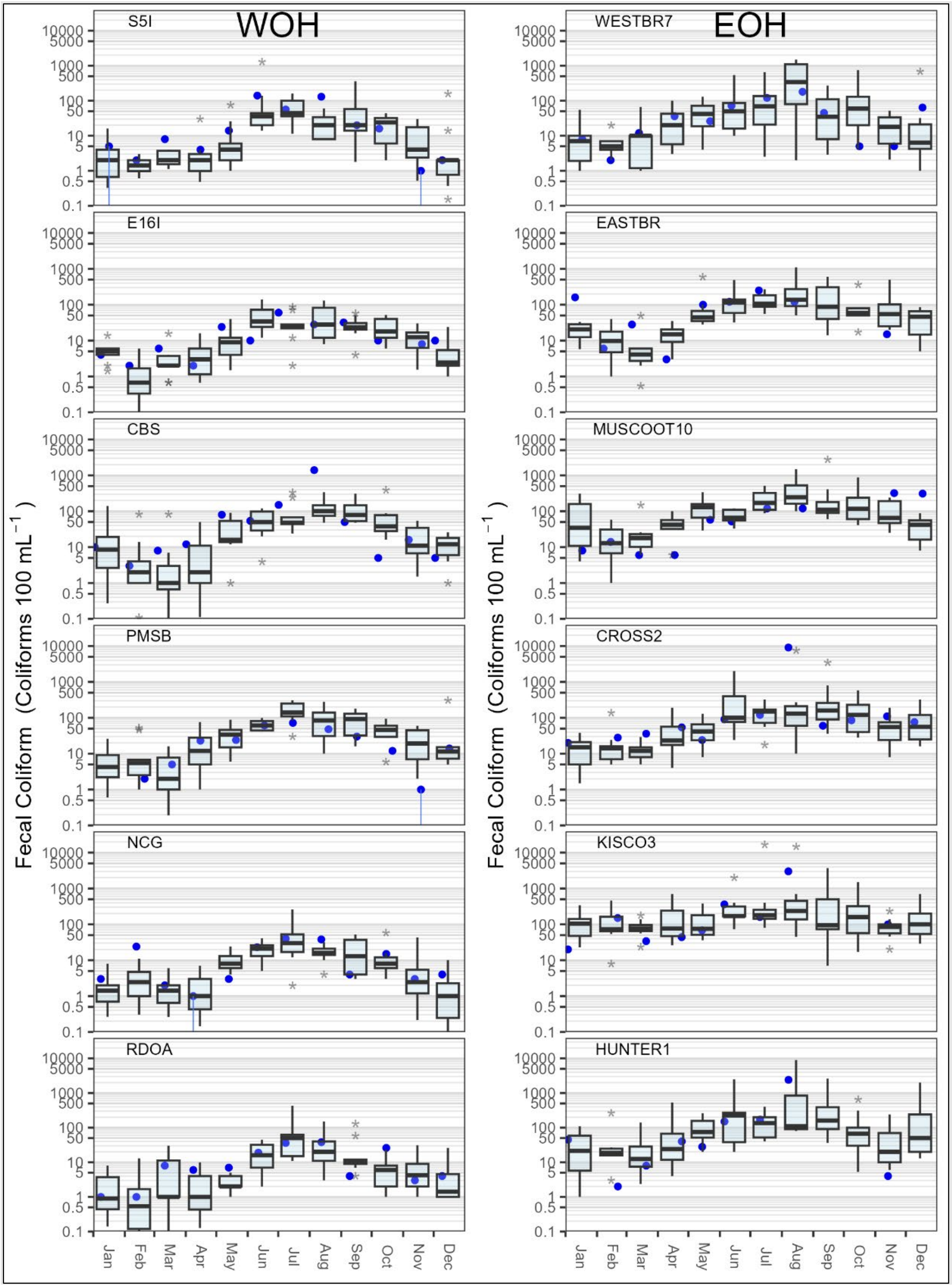

Figure 3.10 Fecal coliform values in 2024 from routine stream samples with a monthly boxplot of the historical (2014-2023) routine monthly samples. Note the y-axis is a log scale.

3.10 Stream Comparisons to Benchmarks in 2024

Select water quality benchmarks have been established for reservoirs and reservoir stems (any watercourse segment which is a tributary to a reservoir and lies within 500 feet of the full reservoir) in the WR&R (DEP 2019). In this section, the application of these benchmarks has been extended to 40 streams and reservoir releases to evaluate stream status in 2024. The benchmarks are provided in Table 3.7.

Table 3.7 Stream water quality benchmarks as listed in the WR&R (DEP 2019). The benchmarks are based on 1990 water quality results.

Analyte	Croton System		Catskill/Delaware Systems	
	Annual Mean	**Single Sample Maximum**	**Annual Mean**	**Single Sample Maximum**
Alkalinity (mg $CaCO_3$ L^{-1})	N/A	≥40.00	N/A	≥10.00
Ammonia-N (mg L^{-1})	0.1	0.2	0.05	0.25
Dissolved chloride (mg L^{-1})	35	100	10	50
Nitrite+Nitrate-N (mg L^{-1})	0.35	1.5	0.4	1.5
Organic Nitrogen [1]	0.5	1.5	0.5	1.5
Dissolved sodium (mg L^{-1})	15	20	5	10
Sulfate (mg L^{-1})	15	25	10	15
Total dissolved solids (mg L^{-1})[2]	150	175	40	50
Total organic carbon (mg L^{-1})[3]	9	25	9	25
Total suspended solids	5	8	5	8

[1] Organic nitrogen is not analyzed currently.

[2] Total dissolved solids are estimated by multiplying specific conductivity by 0.65(van der Leeden, Troise, and Todd 1990).

[3] Dissolved organic carbon was used in this analysis since TOC is not routinely analyzed at all sites.

Comparison of stream results to these benchmarks is presented in Appendix H along with site descriptions, which appear next to the site codes. Note that the Catskill/Delaware System criteria are applied to the release from West Branch Reservoir (WESTBRR) since that release usually is affected by Delaware System water. Below is a discussion of selected sites and analytes.

Alkalinity

Alkalinity is a measure of water’s ability to neutralize acids and is largely controlled by the abundance of carbonate rocks/surficial materials in a watershed and by the amount of precipitation the watershed receives. Elevated precipitation lowers alkalinity by diluting the cations that contribute to alkalinity while periods of drought can have a concentrating effect. Sufficient alkalinity ensures a stable pH in the 6.5 to 8.5 range, generally considered a necessary condition for a healthy ecosystem. Monitoring of alkalinity is also considered important to facilitate water treatment processes such as chemical coagulation, water softening, and corrosion control.

Watersheds of the CAT/DEL System vary in their capacity to neutralize acids. Low buffering capacity is typical of the surficial materials in the Ashokan, Rondout, and Neversink watersheds. Streams from these watersheds were below the alkalinity single sample benchmark of 10 mg L^{-1} in 76 of 120 samples collected in 2024. In contrast, higher buffering capacity is generally observed in the Cannonsville, Pepacton, and Schoharie watersheds. Here, only 10 of 156 stream samples were below the 10 mg L^{-1} benchmark. A benchmark of 40 mg L^{-1} is used for the Croton System streams; the higher benchmark reflects the much higher natural buffering capacity of this region. However, less buffering capacity does occur in the Boyd Corners and West Branch watersheds with samples from stream sites WESTBR7, BOYDR, HORSEPD12, and GYPSYTRL1, at times, below the single sample benchmark.

Chloride

The CAT/DEL System annual mean chloride benchmark of 10 mg L^{-1} was exceeded in eight of the 24 streams monitored in and associated with the CAT/DEL System with the highest mean, 29.8 mg L^{-1}, occurring at site NK6 on Kramer Brook in the Neversink watershed. In contrast to Kramer Brook, chloride concentrations in two additional monitored streams in the Neversink watershed, Aden Brook (NK4) and the Neversink River (NCG), were quite low, averaging 3.9 and 2.7 mg L^{-1}, respectively. The Kramer Brook watershed is very small (<1 square mile), is bordered by a state highway, and contains pockets of development, all of which contribute to the relatively high chloride levels. The single sample CAT/DEL chloride maximum benchmark of 50 mg L^{-1} was not exceeded in 2024.

Other CAT/DEL System streams exceeding the annual mean chloride benchmark of 10 mg L^{-1} included Bear Kill at S6I (20.5 mg L^{-1}) and the Schoharie Creek at Prattsville (12.6 mg L^{-1}), located within the Schoharie watershed; Trout Creek at C-7 (13.6 mg L^{-1}), Loomis Brook at C-8 (10.2 mg L^{-1}), and the West Branch of the Delaware River at CBS (15.9 mg L^{-1}), all tributaries to Cannonsville Reservoir; and Chestnut Creek at RGB (14.3 mg L^{-1}), a tributary to Rondout Reservoir. Two Pepacton streams, one at P-13 at Tremper Kill above Pepacton Reservoir and another at PMSB at the East Branch of the Delaware River near Margaretville (12.9 mg L^{-1}) exceeded the average annual benchmark in 2024. In general, higher chloride concentrations correlate with the percentage of impervious surfaces (e.g., roads, parking lots) in the watersheds (Mayfield and Van Dreason 2019).

The Croton System annual mean chloride benchmark of 35 mg L^{-1} was exceeded at nine of the 16 monitored Croton streams in 2024. The annual means exceeding the benchmark ranged from 35.7 mg L^{-1} at the East Branch of the Croton River above East Branch Reservoir (EASTBR), to 154.5 mg L^{-1} in Michael Brook above Croton Falls Reservoir (MIKE2). The mean 2024 chloride concentration for all 16 Croton streams was 53.3 mg L^{-1}, down from 61.8 mg L^{-1} in 2023. This concentration is still substantially higher than in the streams of the CAT/DEL System, which averaged 9.3 mg L^{-1}, slightly up from 8.6 mg L^{-1} in 2023. The single sample chloride benchmark is 100 mg L^{-1} for streams of the Croton System. In 2024, this benchmark was commonly exceeded at

Michael Brook at MIKE2 (154.5 mg L^{-1}) and at the Muscoot River above Amawalk Reservoir at MUSCOOT10 (121.1 mg L^{-1}). Road salt is considered the primary source of chloride in these systems, while secondary sources include septic system leachate, water softening brine waste, and wastewater treatment plant effluent. The much greater chloride concentrations in the Croton System are due to higher road and population densities in these watersheds (Van Dreason 2022). Given the common co-occurrence of chloride and sodium, it is not surprising that sodium benchmarks were exceeded in much the same pattern as chloride (Appendix H).

Total Dissolved Solids

The analysis of total dissolved solids (TDS) is a measure of the combined content of all inorganic and organic substances in the filtrate of a sample. Although TDS is not analyzed directly by DEP, it is commonly estimated in the water supply industry using measurements of specific conductivity. Conversion factors used to compute TDS from specific conductivity relate to the water type ("ISO 7888: Water Quality—Determination of Electrical Conductivity" 1985; Singh and Kalra 1975). For NYC waters, specific conductivity was used to estimate TDS by multiplying specific conductivity by 0.65 (van der Leeden, Troise, and Todd 1990).

In 2024, 15 of 24 CAT/DEL streams had at least one value greater than the TDS single sample maximum of 50 mg L^{-1}. These same streams, plus WESTBRR, also exceeded the TDS annual mean benchmark of 40 mg L^{-1}. TDS in CAT/DEL streams were correlated with chloride, and chloride accounted for 81 percent of the variation in TDS (Figure 3.11). All excursions of the SSM were associated with chloride concentrations that exceeded approximately 9.5 mg L^{-1}.

The Croton stream TDS were strongly correlated to chloride concentrations (Figure 3.12). The much higher Croton TDS is mostly due to greater road density and deicer usage in the Croton watersheds. The TDS SSM of 175 mg L^{-1} was exceeded in 13 of 16 streams while the annual mean benchmark of 150 mg L^{-1} was exceeded in 11 of 16 Croton streams in 2024. Nine stream sites, AMAWALKR, LONGPD1, CROFALLSVC, BOGEASTBRR, DIVERTR, EASTBR, KISCO3, MIKE2, and MUSCOOT10, exceeded the mean benchmark standard most of the year.

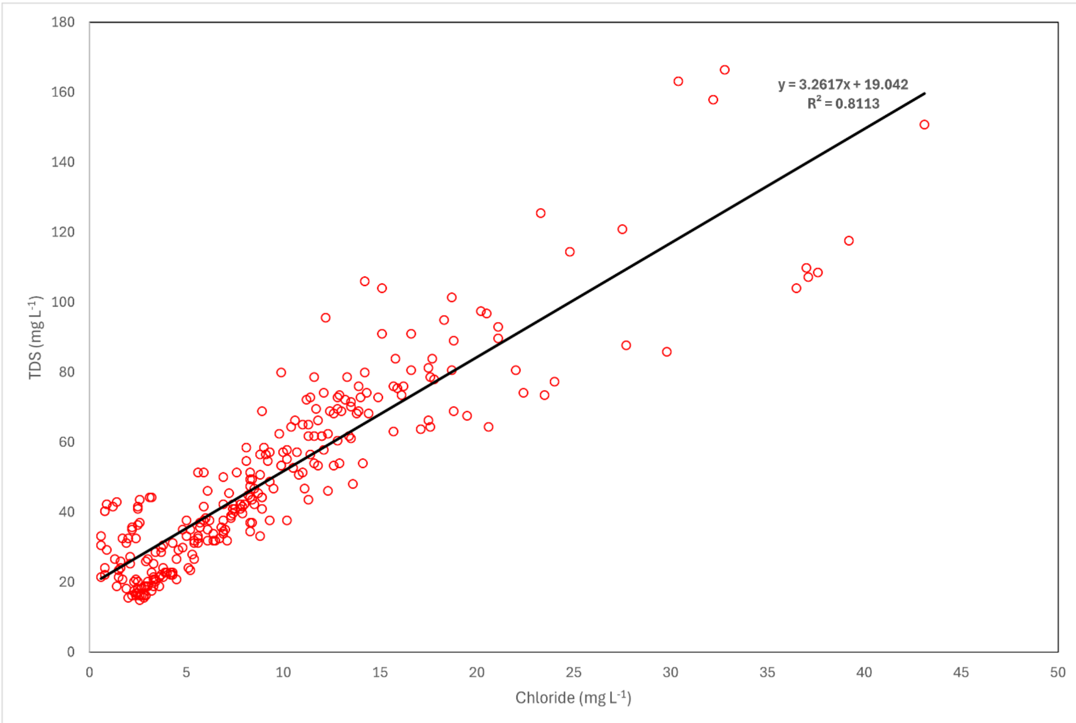

Figure 3.11 TDS versus chloride for Catskill/Delaware System streams in 2024.

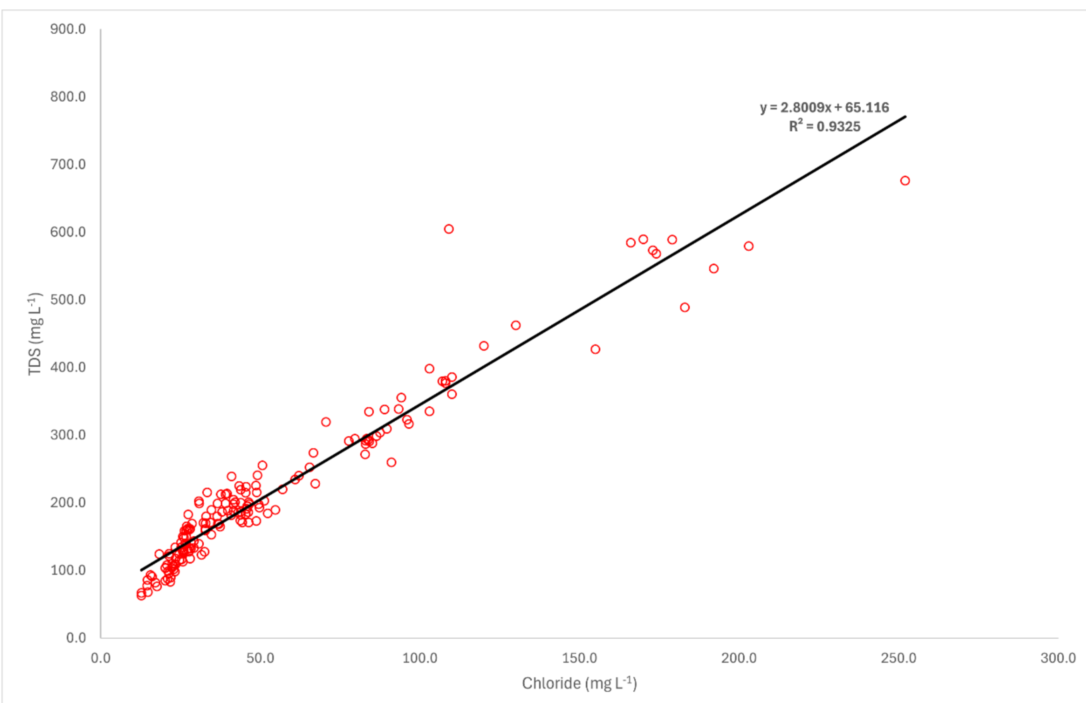

Figure 3.12 TDS versus chloride for Croton System streams in 2024.

Nitrogen

Nitrogen results were generally below benchmarks in the CAT/DEL System in 2024. Only S6I, Bear Kill at Hardenburgh Falls, exceeded the single sample nitrate benchmark of 1.5 mg L^{-1}. The mean annual benchmark of 0.40 mg L^{-1} was exceeded at S6I (0.67 mg L^{-1}) and at the West Branch of the Delaware River at CBS (0.55 mg L^{-1}). Likely sources for nitrate at CBS are fertilizers associated with the relatively high agricultural activity in this basin, and multiple wastewater treatment plants that discharge to the river.

Michael Brook at MIKE2 (7.19 mg L^{-1}) and the Kisco River at KISCO3 (0.56 mg L^{-1}), were the only Croton streams to exceed the nitrate-nitrite annual mean benchmark of 0.35 mg L^{-1} in 2024. The single sample nitrate-nitrite benchmark of 1.5 mg L^{-1} was exceeded at Michael Brook for 83% of the samples collected. The highest concentration was 16.21 mg L^{-1}, occurring in November, when the Croton System was experiencing drought conditions, and was therefore most likely due to low stream flow volume. Possible nitrogen sources are plentiful given the relatively high development in the Michael Brook and Kisco River watersheds, including inputs from local wastewater treatment plants.

All ammonia results were within the single sample maximum benchmark of 0.25 mg L^{-1} and the mean annual benchmark of 0.05 mg L^{-1} in the CAT/DEL System in 2024. Ammonia was only detected in 18 of the 288 collected from all CAT/DEL streams, and detected concentrations were relatively low, ranging from 0.02 to 0.16 mg L^{-1}. In the Croton System, only BOYDR (0.30 mg L^{-1}), CROSSRVVC (0.44 mg L^{-1}), and TITICUSR (0.21 mg/L^{-1}) had one instance each where the ammonia SSM of 0.20 mg L^{-1} was exceeded. These exceedances occurred in October or November during low precipitation timeframes.

Sulfate

Neither the sulfate SSM (15 mg L^{-1}) nor the annual mean (10.0 mg L^{-1}) benchmarks were exceeded in the CAT/DEL streams in 2024. Individual sample results ranged from 1.9 to 11.1 mg L^{-1} with a collective average of 3.4 mg L^{-1}. In the Croton System in 2024, Michael Brook above Croton Falls Reservoir at MIKE2 exceeded the SSM of 25 mg L^{-1} (172 mg L^{-1} in February and 25.7 mg L^{-1} in November), as well as the annual mean standard benchmark of 15 mg L^{-1} (49.2 mg L^{-1}). Sulfate is a common ingredient in personal care products (e.g., soaps, shampoos, and toothpaste) and mineral supplements that can be introduced to waterbodies in the household waste stream. Note that USEPA does not consider sulfate to be a health risk and has only established a secondary maximum contaminant level of 250 mg L^{-1} as a benchmark for aesthetic consideration (i.e., salty taste).

Dissolved Organic Carbon

DOC was used in this analysis instead of total organic carbon since the latter is not routinely analyzed as part of the DEP monitoring program. Previous work has shown that DOC constitutes

most of the organic carbon in stream and reservoir samples. The DOC single sample benchmark of 25 mg L^{-1} and annual mean benchmark of 9.0 mg L^{-1} were not surpassed by any stream in the CAT/DEL or Croton systems in 2024. In the CAT/DEL System, single sample results ranged from 0.6 to 7.9 mg L^{-1} and stream annual means ranged from 0.9 to 3.4 mg L^{-1}. DOC is generally higher in the Croton System compared to the CAT/DEL System (although both systems are well below DOC benchmarks) due to a higher occurrence of wetlands in the Croton watersheds. The annual mean DOC in the Croton System ranged from 2.9 to 5.3 mg L^{-1} in 2024, and the highest single sample DOC, 10.1 mg L^{-1}, occurred at CROSS2, above Cross River Reservoir.

3.11 Water Quality Evaluation for New York State (MOU Addendum E)

In September 1997, NYSDEC and DEP finalized a Memorandum of Understanding (MOU) governing several aspects of enforcement protocols in the New York City water supply watersheds. Sections 3.11.1 and 3.11.2 fulfill the requirements to report and describe the results of the MOU Addendum E analysis and to document any other water quality concerns.

3.11.1 Data Analysis

The means of the analytes required for Addendum E were calculated for each site and compared to the stream water quality guidance values listed in Table 3.8. Values below the detection limit were converted to one-half the detection limit for the purpose of calculating mean values. The median is used for total coliform and the geometric mean is used for the fecal coliform evaluations. Coliform values listed as "CONF" in the dataset, including Cannonsville stream site CBS, were not used in the summary statistics for each sampling site because they could not be converted into a numerical value. To determine the compliance of streams with Addendum E pH standards ($6.5 \leq pH \leq 8.5$), this protocol converts pH values to hydrogen ion concentrations, calculates the mean, and compares the mean to the pH standards also expressed as hydrogen ion concentrations (*i.e.*, $3.1623 \times 10^{-7} \geq [H^+] \geq 3.1623 \times 10^{-9}$).

Table 3.8 Water quality guidance values used to compare routine stream monitoring data for Addendum E.

Parameter	Guidance Value
pH $[H^+]$	6.5 £ pH £ 8.5 [3.1623×10^{-9} £ $[H^+]$£ 3.1623×10^{-7}]
fecal coliform bacteria	200 CFU 100mL^{-1}
total coliform bacteria	2400 CFU 100mL^{-1}
total phosphorus	50 µg L^{-1}
dissolved oxygen	6 mg L^{-1}
total ammonia (NH_3+NH_4-N)	2 mg L^{-1}
nitrate-nitrite (NO_3+NO_2-N)	10 mg L^{-1}

3.11.2 Water Quality Results

In 2024, samples collected at 75 sites were analyzed and compared to water quality guidance values. Table 3.9 lists sites where either the mean value contravened water quality standards, or data from a site included more than two "spikes" in one or more of the seven

parameters tested. A "spike" is defined by Addendum E as an ambient water quality concentration found to be above the guidance value by three standard deviations of the mean at a given site. There were 15 sites at which the mean value of any analyte contravened the Table 3.8 guidance values, and six sites exceeded the spike threshold for any analyte (see the fifth column of Table 3.9). For information regarding the biomonitoring impairment ratings during 2024, see 3.14.

Table 3.9 Routine stream sampling sites with contraventions of water quality guidelines in 2024.

Reservoir Basin	Site	Mean contravened water quality guidelines	Analytes exceeding spike threshold	Number exceeding spike threshold	Spike threshold contra-vention
Kensico Basin					
Kensico	E10	TP	Ammonia	1	No
	E9	TP	Fecal coliform	1	No
	MB-1	TP	none	0	
	N5-1	TP	Fecal coliform	1	No
		TP	Total coliform	1	No
New Croton System					
Amawalk	MUSCOOT10	TP	none	0	
New Croton	KISCO3	TP	none	0	
	STONE5	TP	none	0	
Catskill System					
Ashokan	AEHG	pH (acid)	Fecal coliform	1	No
Schoharie	SBKHG	pH (acid)	Fecal coliform	1	No
Delaware System					
Pepacton	PROXG	TP	none	0	
Neversink	NCG	pH (acid)	TP	1	No
	NK4	pH (acid)	none	0	
	NK6	pH (acid)	none	0	

Reservoir Basin	Site	Mean contravened water quality guidelines	Analytes exceeding spike threshold	Number exceeding spike threshold	Spike threshold contra-vention
Rondout	RDOA	pH (acid)	none	0	
	RRH	pH (acid)	none	0	

3.12 Hillview Reservoir Pathogen Monitoring

Hillview Reservoir Outflow (Site 3)

Giardia and *Cryptosporidium* are monitored weekly at Hillview Reservoir Site 3 as required by the Hillview Administrative Order on Consent. Results are summarized in Table 3.10. *Cryptosporidium* was detected in five of 54 samples in 2024, with an annual mean concentration of 0.17 oocysts $50L^{-1}$ and detection rate of 9.3%. *Giardia* was detected in 19 of 52 samples, with an annual mean concentration of 0.57 cysts $50L^{-1}$ and detection rate of 35.2%. These are well within the historical ranges for both *Cryptosporidium* (0 - 11.1% and 0-2 oocysts $50L^{-1}$) and *Giardia* detection rate (9.3 - 42.3% and 0-6 cysts $50L^{-1}$). Sample results for 2024 are presented in Figure 3.13 and Figure 3.14. Matrix spike (MS) recoveries are shown in Table 3.11. All MS samples were analyzed internally using EPA Method 1623.1. MS *Cryptosporidium* recovery passed method limits in all but two of the samples collected. MS *Giardia* recovery passed method limits in all twelve samples collected. All infectivity results were negative.

Table 3.10 Hillview Site 3 protozoan detections from 2020 to 2024.

	Cryptosporidium		***Giardia***	
Year	**Detects**	**% Detect**	**Detects**	**% Detect**
2020	2	3.8%	17	32.7%
2021	4	7.7%	15	28.8%
2022	3	5.8%	12	23.1%
2023	2	3.8%	5	9.6%
2024	5	9.3%	19	35.2%

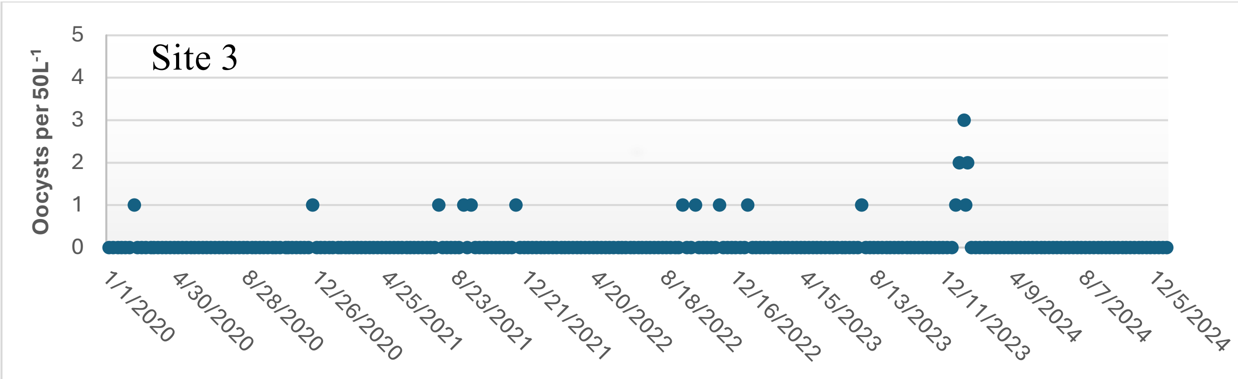

Figure 3.13 Hillview Site 3 Cryptosporidium (2020-2024).

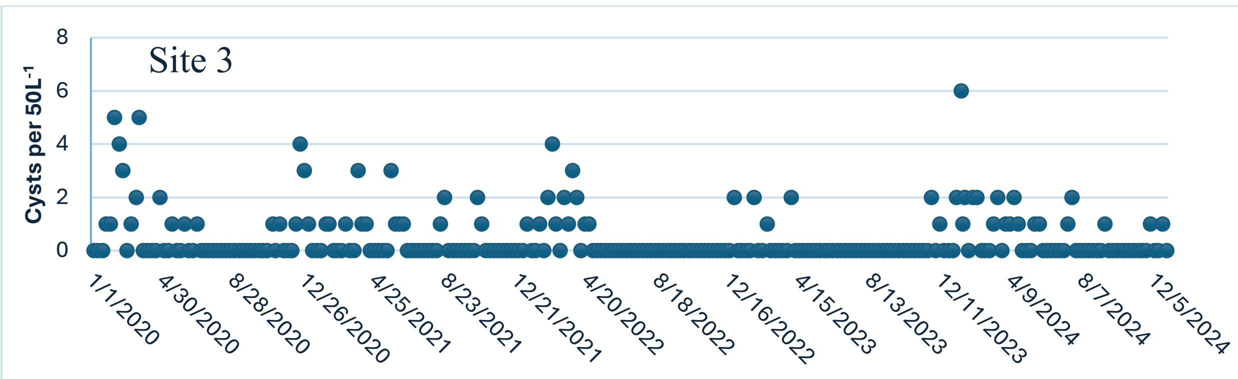

Figure 3.14 Hillview Site 3 Giardia (2020-2024).

Table 3.11 Hillview Site 3 Matrix Spike Recovery 2024.

Date*	***Cryptosporidium* % Recovery ($50L^{-1}$)**	***Giardia* % Recovery ($50L^{-1}$)**
1/16/2024	64	78
1/19/2024	73	58
2/12/2024	58	78
3/11/2024	81	66
4/15/2024	62	61
5/13/2024	40	37
6/10/2024	49	44
7/15/2024	37	36
8/12/2024	29	39
9/16/2024	42	53
10/21/2024	50	57
11/18/2024	70	54
12/16/2024	20	62

3.13 Zebra Mussel Monitoring

A high intensity precipitation event in 2021 introduced zebra mussels to Amawalk Reservoir from Lake Mahopac. Zebra mussels then spread to Muscoot and New Croton reservoirs, where adults and veligers were found in low densities throughout 2022. DEP monitored Amawalk, Muscoot, and New Croton reservoirs in 2021 and 2022, and expanded the program to include Croton Falls, Cross River and Titicus reservoirs in 2023 and 2024. No zebra mussels have been found outside of Amawalk, Muscoot, and New Croton reservoirs.

DEP's monitoring includes multiplate or single set artificial PVC substrates to track adult zebra mussel presence and density, plankton samples to track veliger concentrations in New Croton Reservoir, and visual surveys of infrastructure using remotely operated vehicles (ROV) and SCUBA dives. In 2024, DEP constructed and deployed novel PVC multiplate substrates to augment historical PVC single set substrates. Significant expansion of the population was observed in 2024 relative to 2023, with maximum settlement densities ranging from 656 to 184,064 m^{-2}, (10 to 6292 m^{-2} in 2023), and veliger concentrations surpassing 106 L^{-1} (< 5 L^{-1} in 2023).

ROV surveys of the intake screens near the New Croton Dam in 2023 revealed low level infestation, and SCUBA dive surveys of infrastructure at Gatehouse 1 at the dam revealed varying densities of zebra mussel infestation. ROV surveys of the intake screens near the New Croton Dam in 2024 revealed minimal infestation of the screens but significant densities on the nearby intake piping were removed by SCUBA divers. In 2023, no mussels were found in the first 100 meters of the New Croton Aqueduct (NCA), but divers removed zebra mussels found at the Croton Lake Gate House (CLGH). Divers returned to the CLGH in 2024 and scraped significant densities of zebra mussels from the chamber walls and ceilings and pumped the shells out to a filtered dumpster for removal a week later.

ROV surveys of the intake towers and screens at Amawalk Reservoir in both 2023 and 2024 revealed large colonies of zebra mussels inhabiting the intake towers that were not impacting the screens to a significant degree. A September 2023 ROV survey of the walls of Jerome Park Reservoir in the vicinity of Gatehouse 5, and the outfall of the NCA found no zebra mussels. A boat survey in May 2024 of the walls, mooring buoy, and anchor line at Jerome Park Reservoir also found no zebra mussels. The south raw water wet well at the Croton Filtration Plant was also inspected in May of 2024 and no zebra mussels were found. An August 2024 inspection of Gatehouse 1 of the NCA in the north Bronx also found no zebra mussels.

An interdisciplinary working group within BWS continued to meet quarterly in 2024 to develop zebra mussel management and impact mitigation plans. DEP is continuing to implement recommendations made by the 2023 Water Research Foundation zebra mussel expert panel and will continue to evaluate and adapt its response as the population progresses.

3.14 Stream Biomonitoring

Macroinvertebrate biomonitoring assessments are collected and analyzed according to statewide protocols developed by the New York State Stream Biomonitoring Unit (NYSDEC 2021). Five metrics, each a different measure of biological integrity, are calculated and averaged to produce a multi-metric Biological Assessment Profile (BAP) score ranging from 0-10. These scores correspond to four levels of stream impairment (non-impaired, 7.5-10; slightly impaired, 5-7.5; moderately impaired, 2.5-5; severely impaired, 0-2.5). The five metrics used in the analysis are species richness (total number of taxa); EPT richness (unique species of Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies)); HBI (Hilsenhoff Biotic Index, an index of taxa tolerance to organic pollution); PMA (Percent Model Affinity, a measure of how the subsampled assemblage compares to an assemblage found in ideal conditions); and NBI-P (Nutrient Biotic Index-Phosphorus, an index of species tolerance to phosphorus input). To add context, 2024 results are compared to the period-of-record mean scores and to the previous sampling event score.

In 2024, DEP collected samples from 36 sites in 32 streams throughout New York City's watershed: 13 sites in the Croton System, 13 sites in the Catskill System, and 10 sites in the Delaware System (for site locations, see Appendix I). Sites are sampled on a three-year rotating schedule. To remain consistent with NYSDEC (NYSDEC 2021) protocols, two new approaches were used for comparisons to historical data:

1. Period of record means are based on BAP scores that include the NBI-P metric, which was added to the statewide calculation in 2012.
2. Headwaters have been delineated for each district according to the NYSDEC criteria (NYSDEC 2021) and require a modification to BAP metrics.
    a. Croton River Watershed: Headwater streams are those with a drainage area of less than 16 km2 from the sampling point. Statewide BAP scores are multiplied by a flat modifier of 1.3.
    b. Catskill and Delaware Watersheds: Headwaters streams are those with a drainage area of less than 16 km2 and an elevation greater than 366 m. NBI-P is replaced by an additional Percent Model Affinity based on functional feeding group (PMA-FFG) for statewide BAP score calculation.

East of Hudson – Croton System

Of the 13 sites sampled in 2024, four sites (101, 128, 131, 133) were assessed as non-impaired, seven sites (102, 107, 108, 123, 124, 141, 150) as slightly impaired, and two sites (104, 117) as moderately impaired. BAP scores for four sites (Hallocks Mill Brook (104), Whippoorwill Creek (117), Cross River (123), Tonetta Brook (141)) were lower than their respective period of record means (Figure 3.15).

Site 104 (Hallocks Mill Brook, HMILL7) had the lowest BAP score (4.51) of the 2024 EOH sites, comparable with its mean BAP score of 4.89 since 2014 (n=3). Metrics that contributed to the

lower BAP score included low species richness (13) and unique EPT taxa (7), dissimilarity to PMA models (36%), and NBI-P consistent with eutrophic conditions (6.68). Almost 50% of taxa identified in the subsample were somewhat tolerant *Stenelmis* spp. riffle beetles and *Cheumatopsyche* spp. caddisflies. However, intolerant mayfly species from the genus *Isonychia* and *Maccaffertium modestum* were identified, as well. Overall, the assemblage identified at this site does not vary considerably from historical records that date back to 1994. DEP will return to this site in 2027 and continue to monitor other sites on Hallocks Mill Brook for the next two sampling seasons to determine if more appropriate or representative habitat is available.

At site 117 (Whippoorwill Creek, WHIP), the BAP score (4.94, moderately impaired) was the lowest for the period of record, which consists of 11 sampling events since 1997. The macroinvertebrate assemblage was overwhelmingly species of collector-filter functional feeding groups (83%), likely affecting the results for PMA (36%). However, the subsample also contained intolerant taxa including 10 *Maccaffertium modestum* and one *Glossosoma* sp. caddisfly.

The updated headwater analysis as per NYSDEC protocols (NYSDEC 2021) was performed in 2024 and retroactively applied to historical records for comparison at six sites: 102 (Angle Fly Brook, ANGLE5), 124 (Plum Brook, PLUM2), 131 (Gypsy Trail Brook, GYPSYTRL1), 133 (Long Pond Stream, LONGPD1), 141 (Tonetta Brook), and 150 (tributary to Croton Falls Reservoir). This is a flat multiplier of 1.3 applied to the BAP score. All headwater sites were assessed at slightly/non-impaired and above their mean for the period of record, except for 141 which was 0.97 below its mean and 1.94 below the last sampling event.

DEP will continue to monitor additional sites on streams with results in moderately impaired or lower categories.

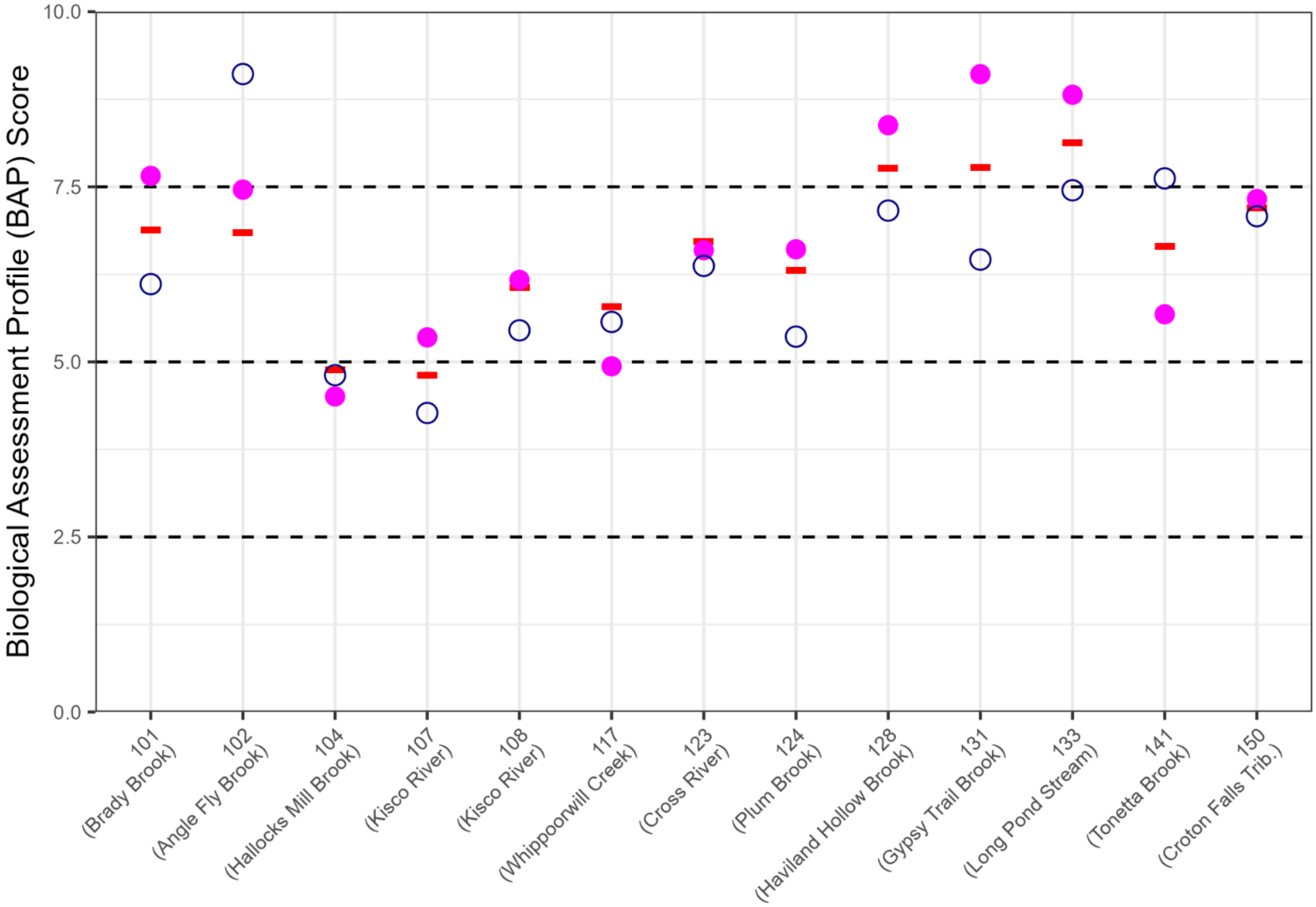

Figure 3.15 Biological Assessment Profile scores for East-of-Hudson biomonitoring sites sampled in 2024. Magenta symbols represent the 2024 score, navy symbols represent the previous sampling event score, and the period of record mean is indicated by a red bar.

West of Hudson – Catskill and Delaware Systems

In the Catskill System, 10 of 13 sites (202, 207, 213, 215, 218, 243, 246, 253, 269, 270) were assessed as non-impaired. The remaining three sites (206, 227, 232) were assessed as slightly impaired (Figure 3.16). All sites were assessed at levels close to their historical means and previous sampling event, except for site 232. Two new sites were sampled in 2024: 269 on the Batavia Kill at S10-LC; and 270 on the Panther Kill.

An updated headwater analysis as per NYSDEC protocols (NYSDEC 2021) was performed in 2024 and retroactively applied to historical records for comparison at two sites: 232 (Seneca Hollow) and 270 (Panther Kill). Although the 2024 BAP score at site 232 was lower than historical scores (6.93 vs. mean of 8.37), the sample contained an abundance of intolerant *Pteronarcys* sp. (stoneflies), suggesting that water quality was not a limiting factor. Site 232 is on a steep mountain

stream with shallow pools between high-gradient drops, and low flows limited the amount of appropriate riffle habitat for sampling.

Newly added site 270 had the highest 2024 BAP score at 9.10. This site provides a regional, high-elevation headwater reference due to relatively undisturbed conditions and previous external reports of rare mayfly species that are proposed to be tracked under the upcoming State Wildlife Action Plan: *Acentrella barbarae* (Baetidae) and *Siphlonurus barbarous* (Siphlonuridae). Neither species was detected in the 2024 subsample.

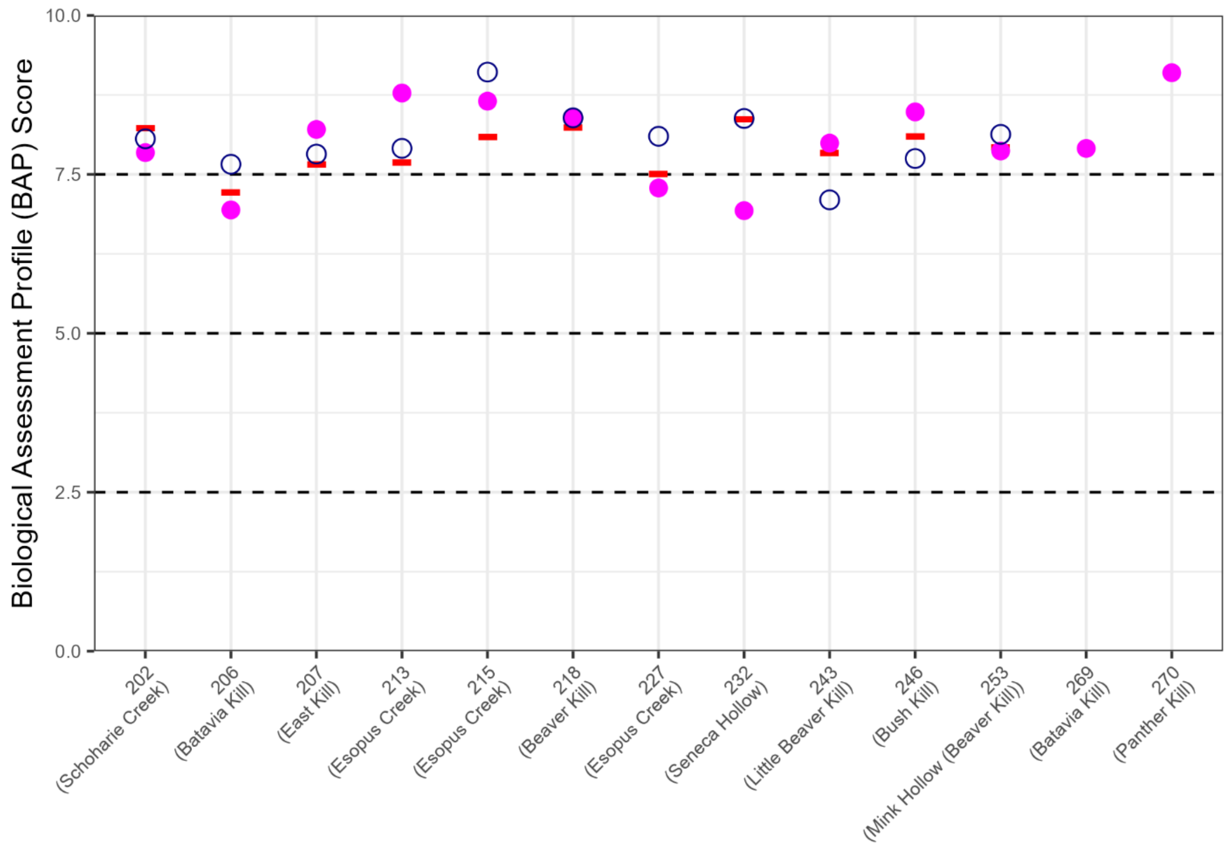

Figure 3.16 Biological Assessment Profile scores for Catskill biomonitoring sites sampled in 2024. Magenta symbols represent the 2024 score, navy symbols represent the previous sampling event score, and the period of record mean is indicated by a red bar.

Nine of the 10 Delaware System sites (302, 312, 323, 324, 327, 328, 335, 342, 349) were assessed as non-impaired, and site 341 was assessed as slightly impaired (Figure 3.17). Consistent with results from previous sampling events, the macroinvertebrate assemblages for most Delaware sites are speciose and hold high numbers of sensitive EPT taxa. Only site 341 (Emory Brook) scored in the slightly impaired category (7.38 BAP), with a score lower than its period of record mean (7.46 BAP) and previous sampling event (8.23 BAP, 2016). Site 328 (Red Brook, RK) contained one of the highest species richness counts in the program's history, with 37 unique

species in the 118-count subsample. This included 11 *Psilotreta labida* (Odontoceridae), an intolerant caddisfly.

Changing flows and stream conditions throughout September may have affected sampling efficacy at some Catskill and Delaware sites. The specific sampling location for site 227 (Esopus Creek, AEWDL) was moved approximately 75 meters upstream to the closest appropriate riffle due to accessibility issues at the original sampling area. Site 337 (BELLE5) was scheduled for collection but cancelled due to insufficient flow.

DEP will continue to monitor additional sites in Catskill and Delaware streams and revisit 2024 sites within the next three years.

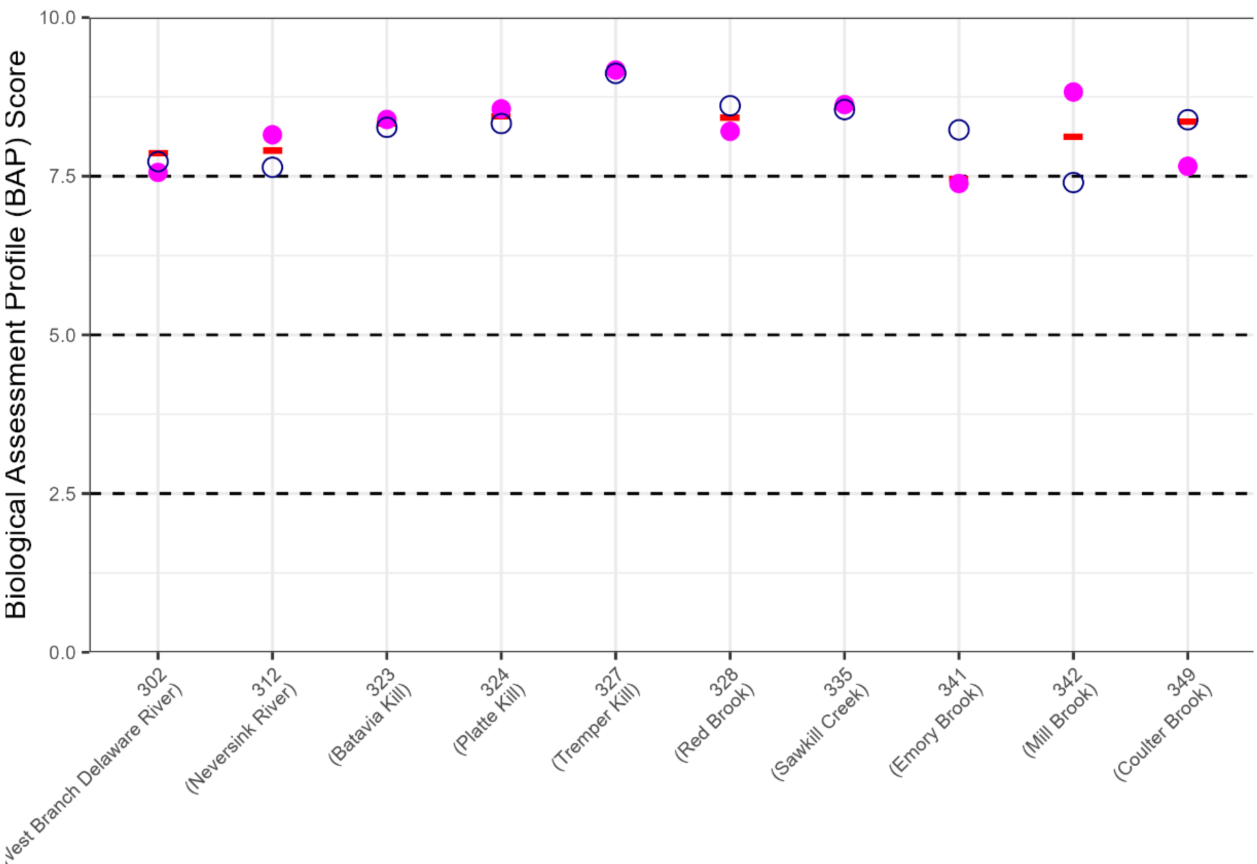

Figure 3.17 Biological Assessment Profile scores for Delaware biomonitoring sites sampled in 2024. Magenta symbols represent the 2024 score, navy symbols represent the previous sampling event score, and the period of record mean is indicated by a red bar.

3.15 Supplemental Contaminant Monitoring

3.15.1 Volatile (VOC) and Semi-volatile Organic (SVOC) Compounds

To supplement required distribution system monitoring, DEP collects one sample at key sites throughout the upstate watersheds during the last quarter of the year to test for many volatile and semi-volatile organic compounds as well as the herbicide glyphosate. The list of compounds is provided in Appendix J and the sites sampled are provided below in Table 3.12. The compounds analyzed in 2024 were generally the same as what was analyzed in 2023, and all samples were shipped to a contract lab for analysis. In 2024, no compounds were detected in these annual monitoring samples.

Table 3.12 Sampling sites for VOC, SVOC, and glyphosate monitoring.

Site Code*	Site Description	Reason for Site Selection
	East of Hudson	
CROGH	Croton Gate House	Croton Aqueduct intake
CWB1.5	West Branch at Delaware Shaft 10	Represents West Branch water
DEL18DT	Delaware Shaft 18	Delaware intake on Kensico
	West of Hudson	
EARCM	Ashokan Intake	Represents Ashokan water
NRR2CM (NR2)	Neversink Intake	Represents Neversink water
PRR2CM (PR1)	Pepacton Intake	Represents Pepacton water
SRR2CM	Schoharie Intake monitoring site	Schoharie water entering Esopus
RDRRCM (RR2)	Rondout Intake	Represents Rondout water
WDTOCM (CR2)	West Delaware Tunnel Outlet	Represents Cannonsville water

*If a diversion is off-line at the collection time, the sample is drawn from the upstream reservoir elevation tap that corresponds to the tunnel intake depth as if that reservoir were on-line. In 2024 sampled elevation taps are indicated in parentheses.

3.15.2 Metals Monitoring

Supplemental, noncompliance sampling of the Catskill, Delaware, and Croton systems is conducted to determine background concentrations for a variety of metals as outlined in Table 3.13 and Table 3.14. These metals are monitored quarterly at the keypoint sites listed in Table 3.13 or at the appropriate elevation tap if an aqueduct is offline. In 2024, elevation tap CR2 was sampled in place of WDTOCM in May and November, and elevation tap CRO1B was sampled in place of CROGH in February, May, and August. The elevation tap NR2 was sampled in place of NRR2CM in May and November, and elevation tap RR2 was sampled in place of RDRRCM in November. DEL9 and DEL10 were not sampled in November due to the Rondout West Branch Tunnel shutdown.

Table 3.13 Keypoint sampling sites for trace and other metal occurrence monitoring.

Reservoir Basin	Site(s)
West of Hudson	
Catskill System	
Ashokan	EARCM[1]
Schoharie	SRR2CM[1]
Delaware System	
Cannonsville	WDTOCM[1] (CR2)
Pepacton	PRR2CM[1] (PR1)
Neversink	NRR2CM[1] (NR2)
Rondout	RDRRCM[1] (RR2)
East of Hudson	
Kensico	CATALUM, DEL17, DEL18DT, DEL19LAB
New Croton	CROGH[1] (CRO1B)
West Branch	DEL9, DEL10, CWB1.5

[1]Elevation tap samples will be collected when the reservoir is offline.

Data are reviewed on an annual basis and compared to the standard as stipulated in USEPA National Primary and Secondary Drinking Water Standards (Table 3.14) and the health (water source) based standard stipulated in the NYSDEC Water Quality Regulations, Title 6, Chapter X, Part 703.5 (Table 3.15).

Table 3.14 USEPA National Primary and Secondary Drinking Water Quality Standards.

Analyte	Primary Standard (µg L^{-1})	Secondary Standard (µg L^{-1})
Silver (Ag)	-	100
Aluminum (Al)	-	50-200
Arsenic (As)	10	-
Barium (Ba)	2,000	-
Beryllium (Be)	4	-
Cadmium (Cd)	5	-
Chromium (Cr)	100	-
Copper (Cu)	1,300	1,000
Iron (Fe)	-	300
Mercury (Hg)	2	-
Manganese (Mn)	-	50
Nickel (Ni)	-	-
Lead (Pb)	15	-
Antimony (Sb)	6	-
Selenium (Se)	50	-
Thallium (Tl)	0.5	-
Zinc (Zn)	-	5,000

Table 3.15 Water quality standards for metals from NYSDEC Title 6 regulations.

Analyte	Type	Standard (µg L^{-1})
Silver (Ag)	Health (Water Source)	50
Arsenic (As)	Health (Water Source)	50
Barium (Ba)	Health (Water Source)	1,000
Cadmium (Cd)	Health (Water Source)	5
Chromium (Cr)	Health (Water Source)	50
Copper (Cu)	Health (Water Source)	200
Mercury (Hg)	Health (Water Source)	0.7
Manganese (Mn)	Health (Water Source)	300
Nickel (Ni)	Health (Water Source)	100
Lead (Pb)	Health (Water Source)	50
Antimony (Sb)	Health (Water Source)	3
Selenium (Se)	Health (Water Source)	10

In 2024, most metal sample results were well below state and federal benchmarks. Antimony, arsenic, beryllium, cadmium, chromium, lead, mercury, selenium, silver, and thallium were not detected at any monitored site in 2024.

Nickel was detected just above the detection limit (1.0 µg L^{-1}) once each at four sites. Concentrations ranged from 1.1-1.4 µg L^{-1}, all well below the NYSDEC regulation (Title 6, Chapter X, Part 703.5) of 100 µg L^{-1}. Barium was detected in all 54 samples, ranging from 6.5 µg L^{-1} at EARCM to 29.8 µg L^{-1} at NR2. Copper was detected in 42 of 54 samples with concentrations ranging from 1.0 µg L^{-1} to 23 µg L^{-1}. A portion of these concentrations is likely associated with plumbing fixtures at the keypoint monitoring locations. Zinc was detected in 3 of 54 samples with detected values ranging from 10.1 µg L^{-1} to 23.5 µg L^{-1}, both collected at CR2. All detected barium, copper, and zinc results were below their respective standards.

Secondary standards for manganese, aluminum, and iron were occasionally surpassed in 2024. Secondary standards are voluntary, unenforceable guidelines recommended by the EPA to help water suppliers in managing cosmetic and aesthetic considerations in their drinking water. The manganese secondary standard of 50 µg L^{-1} was exceeded four times at SRR2CM (71 µg L^{-1} - 233 µg L^{-1}), and once at EARCM (92 µg L^{-1}), CR2 (57 µg L^{-}1), PR1 (911 µg L^{-}1), NR2 (111 µg L^{-1}), RR2 (103 µg L^{-1}), CATALUM (72 µg L^{-1}), DEL17 (227 µg L^{-1}), and CROGH (72 µg L^{-1}). The aluminum secondary standard of 50 µg L^{-1} was exceeded four times at SRR2M (197 µg L^{-1} - 291 µg L^{-1}), and once at EARCM (82.5 µg L^{-1}), CR2 (108 µg L^{-1}), NRR2CM (53.7 µg L^{-1}), and NR2 (54.4 µg L^{-1}). The iron secondary standard of 300µg L^{-1} was exceeded twice at SRR2CM (329 µg L^{-1}, 405 µg L^{-1}), and once at DEL17 (525 µg L^{-1}). The elevated results for iron, manganese, and aluminum at SRR2CM are likely due to suspended clay particles, a common occurrence in water from Schoharie Reservoir. While iron, aluminum, and manganese exceedances may pose aesthetic concerns (e.g., taste, staining), they are not considered a health risk.

3.16 Enhanced Monitoring

Enhanced monitoring was initiated throughout 2024 to support operations and to evaluate monitoring and management alternatives.

3.16.1 Pump Station Monitoring

In support of the RWBT shutdown, the Croton Falls and Cross River pump stations began operating on October 1, 2024, to augment Ashokan Reservoir diversions into Kensico Reservoir. Enhanced monitoring began on September 9, 2024, and was conducted in accordance with the Water Quality Monitoring Plan for Croton Falls and Cross River Pump Station Operations (September 2024) to satisfy Section 5.1 of the Revised 2017 FAD. These data were submitted to NYSDOH on September 24, 2024, with a request for approval to operate the pumping station. Approval was granted by NYSDOH on September 25, 2024, and no water quality issues were

observed during their operation. Details of the enhanced monitoring were provided to NYSDOH in an after-action report.

3.16.2 Taste and Odor Monitoring

Taste and odor (T&O) compounds such as geosmin (GSM) and 2-methyisoborneol (MIB) can be detected in drinking water at concentrations as low as 10 ng L^{-1}. DEP monitors consumer complaints in the distribution system via the NYC 311 system, and water quality calls are categorized based on the type of water quality complaint. When GSM or MIB concentrations are greater than the 10 ng L^{-1} threshold, musty water quality consumer complaint calls may increase. DEP uses water quality consumer complaint data in conjunction with GSM and MIB data to monitor and manage T&O events. DEP has been monitoring for GSM and MIB in the Croton System since autumn 2019.

A total of 551 samples were collected for GSM and MIB analysis at a total of 36 sites in 2024. These samples were collected in support of copper sulfate treatment in select reservoirs and the operation of the Croton Water Filtration Plant and the Croton Falls and Cross River pump stations. There were no taste and odor events in 2024.

3.16.3 Copper Sulfate Treatment Monitoring

In preparation for the RWBT shutdown, DEP continued copper sulfate treatments within Croton System reservoirs to control algal populations that can produce taste and odor compounds. Croton Falls, Cross River, Muscoot, and New Croton reservoirs were treated with copper sulfate based on the results of ongoing water quality monitoring. Total copper, photosynthetic production, phytoplankton presence and abundance, and MIB and GSM monitoring were conducted before and after treatment.

Copper sulfate was applied from a contractor boat using an on-board tank and calibrated pumping system to disperse the copper sulfate at 0.3 mg L^{-1}. In total, there were four treatments each at Croton Falls and Cross River reservoirs, six treatments at New Croton Reservoir, and seven treatments at Muscoot Reservoir. All treatment applications successfully depressed algal growth within the treated portion of the water column. The details of these treatments are outlined in after-action reports submitted to NYSDOH and NYSDEC.

3.16.4 Cannonsville and Neversink Storm Event Monitoring

In 2024, there were 13 total storm events monitored in the Cannonsville and Neversink basins. Storm event monitoring was captured for nine events at the Cannonsville Reservoir major inflow site, CBS (Figure 3.18) and another four events at the Neversink Reservoir major inflow site, NCG (Figure 3.19). Samples for DBPfp were collected at NCG and CBS twice monthly throughout the year. The WWQMP requires DBPfp sample collection during storm events three times a year, in the spring, summer, and fall. In 2024, four events were captured for CBS, and three events were captured for NCG. Special case DBP events are sometimes collected during large discharge events.

It's worth noting that a DBP event is an enhanced nutrient storm event that collects additional DBP analytes. One large storm event collection between August 9 and 10 was missed at CBS because of a power outage to the stream hut equipment.

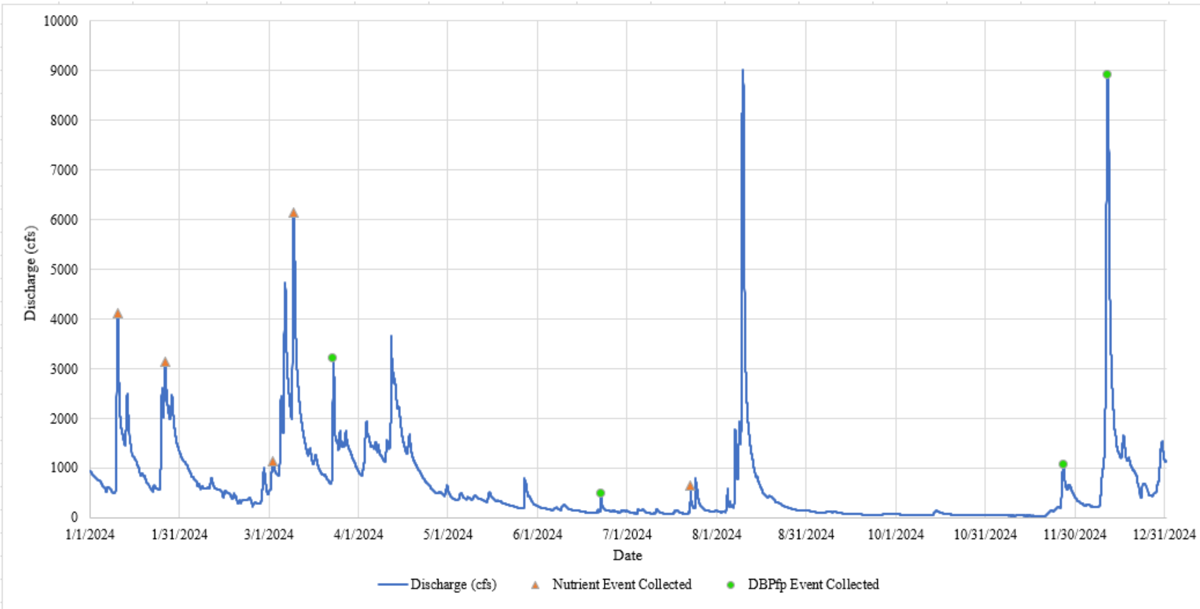

Figure 3.18 2024 Discharge and Storm Event Collection at USGS West Branch Delaware River at Walton, NY, upstream of site CBS.

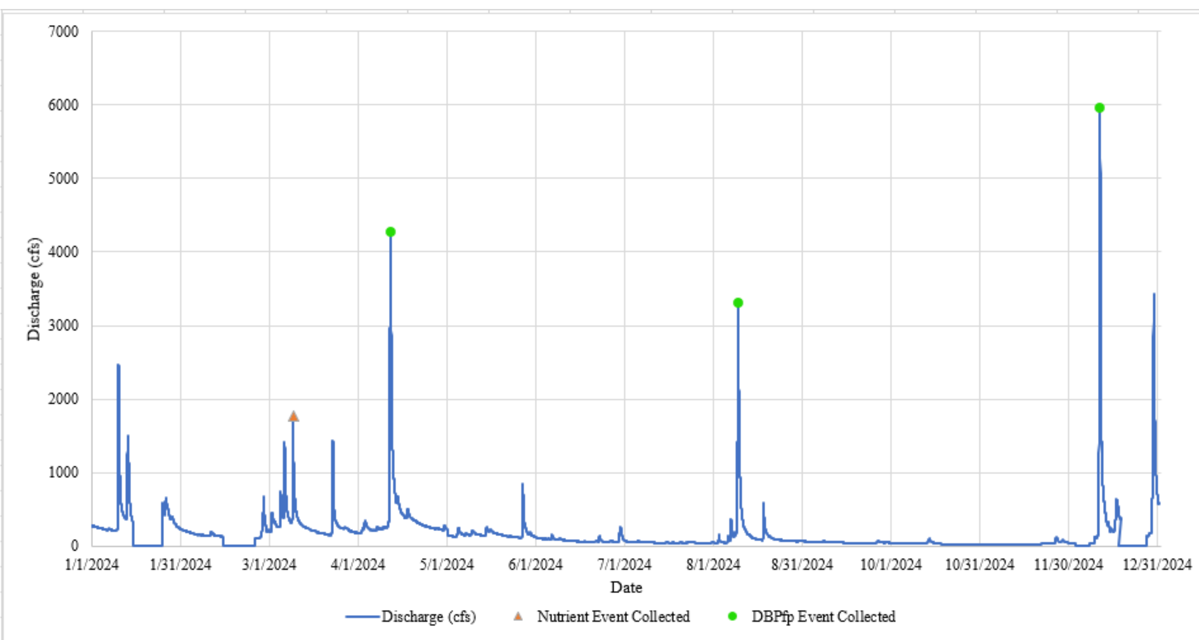

Figure 3.19 2024 Discharge and Storm Event Collection at USGS Neversink River Near Claryville, NY at site NCG.

The highest flow storm event monitored in 2024 occurred from December 9 through December 16 at CBS which resulted in 2.85 inches of precipitation and an instantaneous flowrate of 8,890 ft^3 sec^{-1} on December 12 at 4:30 a.m. (Figure 3.18). The mean daily discharge for this event was 7,130 ft^3 sec^{-1}, an order of magnitude above the historical mean daily discharge for the 74 years of record (709 ft^3 sec^{-1}). This storm event produced maximum DBPfp concentrations of 1,259 µg L^{-1} for HAA5 and 795 µg L^{-1} for THM (Figure 3.20), far above the 6-year average concentrations of 290 µg L^{-1} for HAA5 and 184 µg L^{-1} for THM. Similarly at site NCG, the same storm event produced maximum DBPfp concentrations of 2,263 µg L^{-1} for HAA5 and 1,306 µg L^{-1} for THM (Figure 3.21). These results reflect the large influx of natural organic matter (NOM) during storm events. The extended dry period between September and December (Figure 3.19), with little chance for excess NOM runoff is one potential reason for the large spike in DBPfp concentrations during the December storm event. For reference and long-term trend analysis, Figure 3.20 and Figure 3.21 show DBPfp concentrations over the past six years in relation to discharge flow.

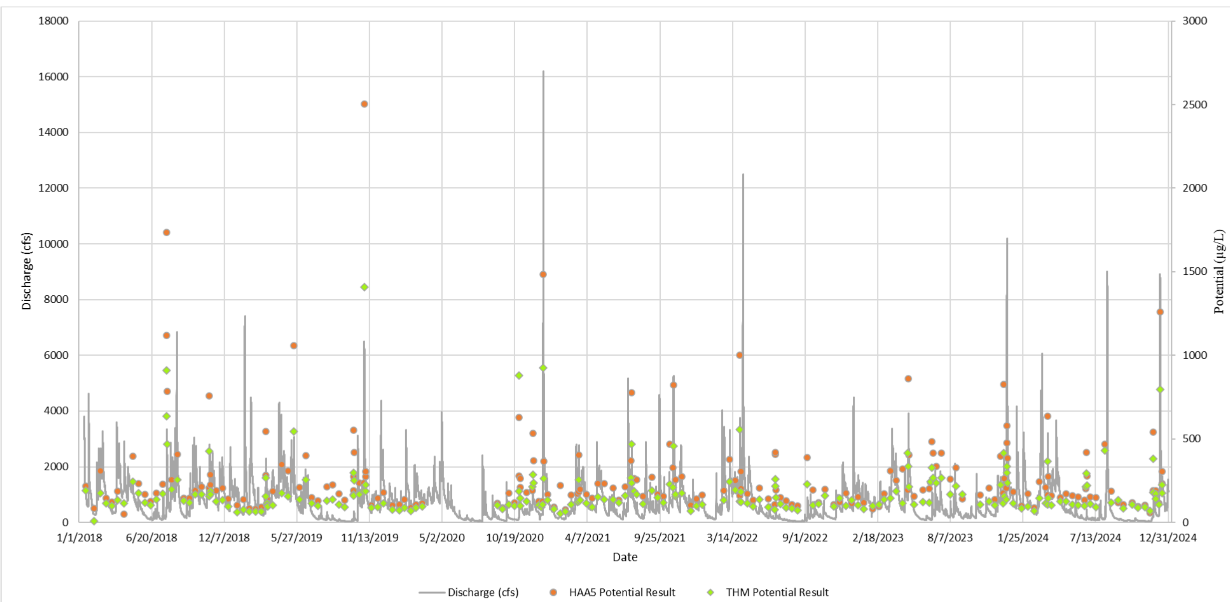

Figure 3.20 Discharge flow measurements from January 2018 to December 2024 at USGS West Branch Delaware River at Walton, NY and CBS HAA5/THM formation potential results.

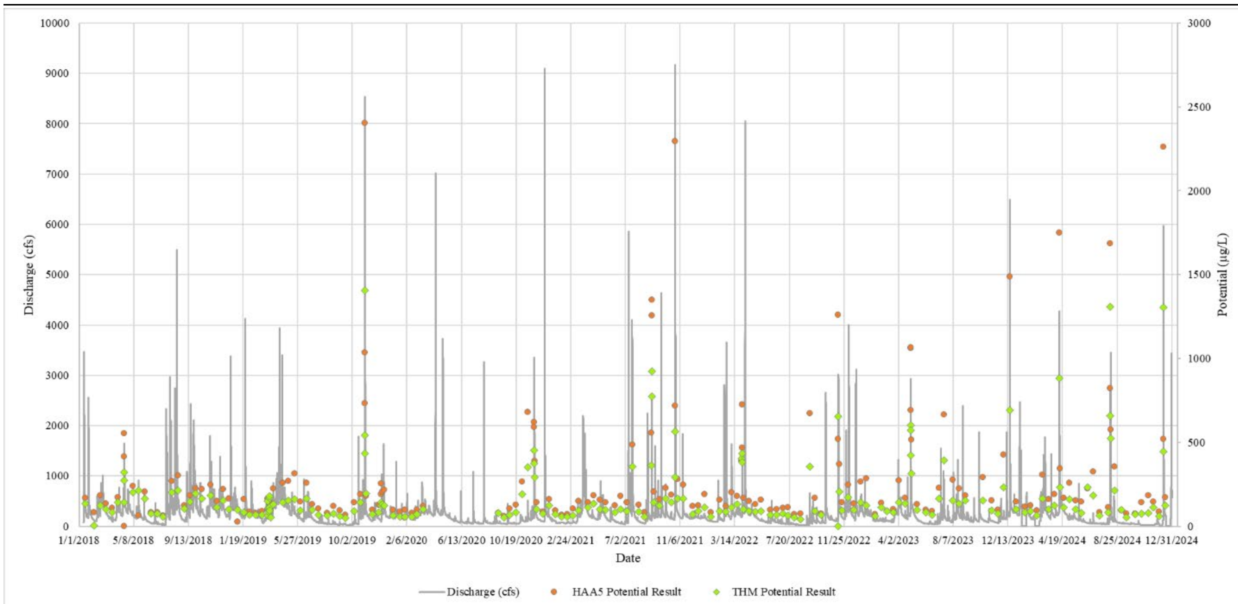

Figure 3.21 Discharge flow measurements from January 2018 to December 2024 at USGS Neversink river at Claryville, NY and NCG HAA5/THM formation potential results.

Major storm events also impact the levels of organic matter within the reservoirs. UV_{254} is a practical indicator of dissolved organic compounds contributing to DBPfp and is therefore sampled weekly at Cannonsville and Neversink reservoir outlets at sites CR2 and NR2. As shown in Figure 3.22 and Figure 3.23, there is a delayed (14 to 21 days) but persisting spike in UV_{254} results at reservoir sites after large stream discharges from storm events. Similar to DBPfp, drier periods immediately prior to large storm events may create a larger spike in UV_{254} values in the reservoir. For example, the UV_{254} reading at the NR2 tap on December 9, 2024, was 0.051 abs cm^{-1}. Following the first significant precipitation event since August 2024, occurring on December 11, 2024, the UV_{254} reading increased to 0.068 abs cm^{-1} fourteen days later, on December 23, 2024. (Figure 3.23)

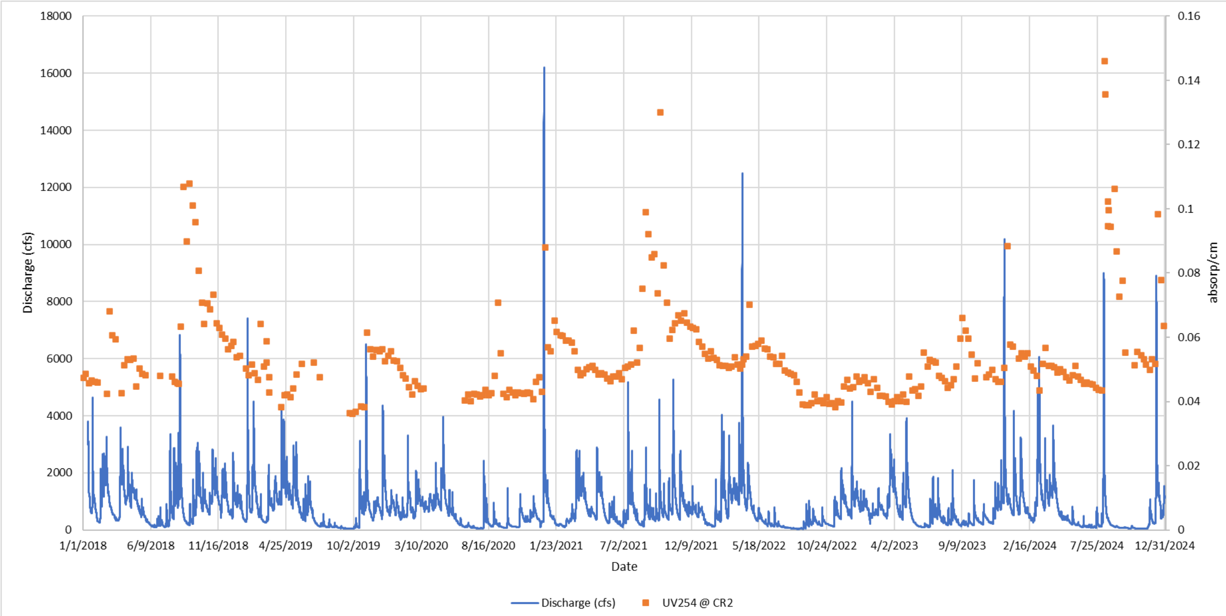

Figure 3.22 Discharge at CBS from January 2018 to December 2024 and UV_{254} readings at site CR2.

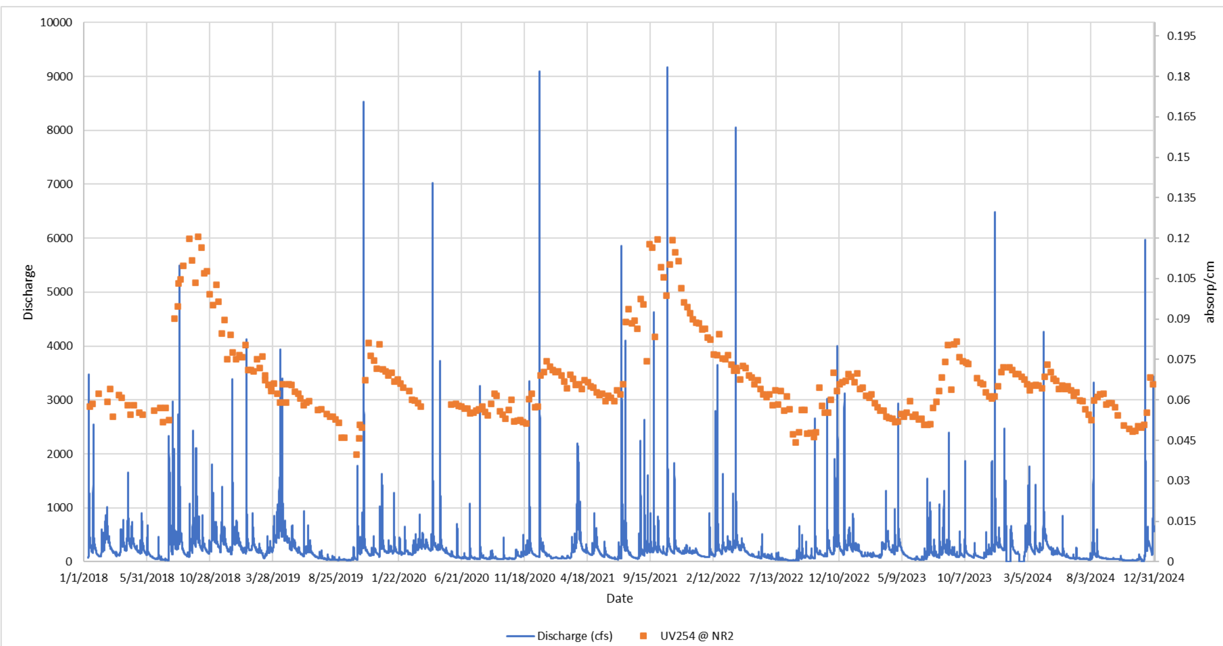

Figure 3.23 Discharge at NCG from January 2018 to December 2024 and UV_{254} readings at site NR2.

3.16.5 Sundown Forest Fire Monitoring

Between November 8 and November 12, 2024, Sundown Forest experienced a 600-acre forest fire. The Rondout Creek is a direct input stream to the Rondout Reservoir, which runs through the Sundown Forest (Figure 3.24). Rondout Reservoir, a terminal reservoir for the Delaware System, sometimes requires additional monitoring during various weather events.

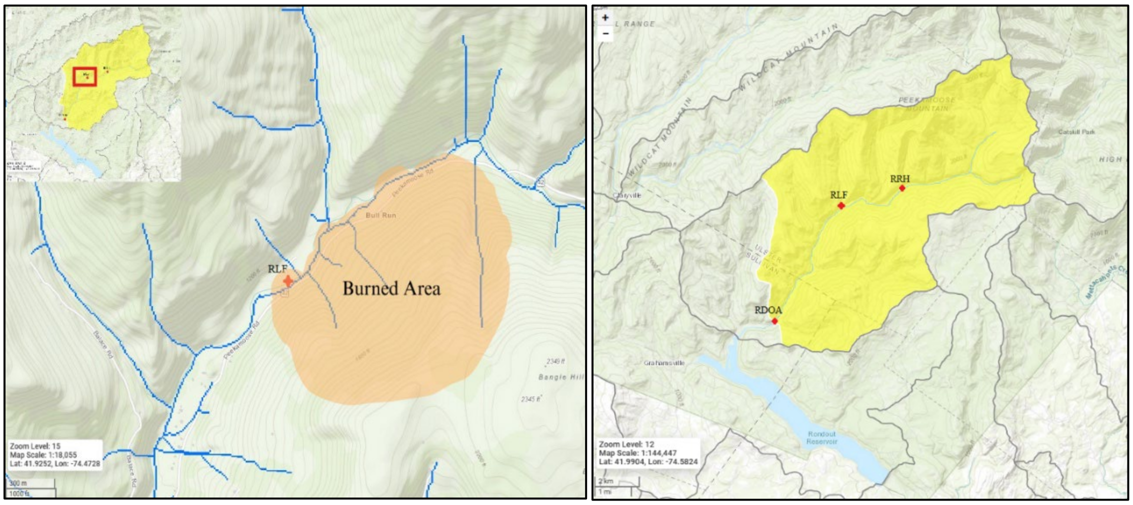

Figure 3.24 USGS watershed delineation of stream site RDOA, locations of stream sites, and the approximate location the burned area in Sundown Forest.

As a precautionary measure, a request was made by Water Quality Operations North to sample locations upstream of the fire burn area, at the fire burn area, and downstream of the fire burn area on November 21. These sites are described and named correspondingly as: above the burn area, Rondout Creek above Blue Hole at Peekamoose, NY (RRH); at the burn area, Rondout Lower Field DEC campground (RLF); and downstream ofthe burn area, Rondout Creek near Lowes Corners (RDOA). Figure 3.24 shows a map of the sampling locations properly labeled; the yellow area is the delineated watershed area for RDOA. RLF (Table 3.16) was selected as the burn area site because the field team recognized a large burn area near the stream and no wildfire damage above RLF. The November 21 sampling occurred during a rain event in order to catch any runoff from the fire burn area. A week prior to the sampling request, on November 12, the regularly scheduled monthly sampling was performed at Rondout Creek above the fire burn area (RRH) and below the fire burn area (RDOA). The fire was extinguished just prior to the November 12 sampling. The October sampling of RRH and RDOA are also included in Table 3.16 as a baseline for comparison.

Table 3.16 Analyte sampling results for investigated sites RRH, RLF, and RDOA.

Site	Date	Field Conductance (umhos/cm)	Nitrogen, Total (as N) (mg/L)	Nitrogen, Total Dissolved (as N) (mg/L)	Organic Carbon, Dissolved (mg/L)	Organic Carbon, Total (mg/L)	pH	Temperature (C)	Turbidity (NTU)	UV-254 (absorb/cm)	HAA5 Potential (µg/L)	THM Total Potential (µg/L)
RRH	10/15/24	N/A	0.16	0.13	1.5	N/A	5.64	8.8	<0.1	N/A	N/A	N/A
RRH	11/12/24	N/A	0.17	0.20	1.0	N/A	6.46	9.0	2.5	N/A	N/A	N/A
RRH	11/21/24	22	0.28	0.26	2.1	1.5	6.14	8.3	0.38	0.037	160	89

Site	Date	Field Conductance (umhos/cm)	Nitrogen, Total (as N) (mg/L)	Nitrogen, Total Dissolved (as N) (mg/L)	Organic Carbon, Dissolved (mg/L)	Organic Carbon, Total (mg/L)	pH	Temperature (C)	Turbidity (NTU)	UV-254 (absorb/cm)	HAA5 Potential (µg/L)	THM Total Potential (µg/L)
RLF	11/21/24	25	0.23	0.23	1.0	0.9	6.36	8.2	0.25	0.021	94	56

Site	Date	Field Conductance (umhos/cm)	Nitrogen, Total (as N) (mg/L)	Nitrogen, Total Dissolved (as N) (mg/L)	Organic Carbon, Dissolved (mg/L)	Organic Carbon, Total (mg/L)	pH	Temperature (C)	Turbidity (NTU)	UV-254 (absorb/cm)	HAA5 Potential (µg/L)	THM Total Potential (µg/L)
RDOA	10/15/24	N/A	0.14	0.11	1.0	N/A	5.98	9.9	0.56	0.018	N/A	N/A
RDOA	11/12/24	N/A	0.14	0.10	0.7	N/A	6.66	10.4	0.38	0.013	N/A	N/A
RDOA	11/21/24	34	0.16	0.16	1.0	0.8	6.46	9.5	0.47	0.016	66	43

The results shown in Table 3.16 represent no significant difference between any of the sampling dates. The THM and HAA5 potential results, though not routinely sampled at the investigated sites, are generally lower than the typical reported values at RDRRCM. For context, the average HAA5 and THM levels at Rondout Reservoirs draft elevations were 84 µg L^{-1} and 135 µg L^{-1}, respectively, during the November/December sampling period.

3.16.6 Algal Bloom Monitoring

DEP monitors reservoir and aqueduct diversions when a surface bloom is visibly present or when routine phytoplankton monitoring indicates elevated levels of cyanobacteria. This proactive watershed monitoring was initiated following the May 2015 USEPA issuance of a 10-Day Drinking Water Health Advisory for cyanobacterial toxins. This algal bloom monitoring requires staff scientists in the field to photograph the bloom, estimate the bloom size and extent in the waterbody, and collect a surface sample (0 meters) for analysis of phytoplankton genus, chlorophyll *a*, and algal toxins (ELISA – EPA Method 546). The ELISA test is conducted if cyanobacteria counts are greater than 1,000 ASU mL^{-1}. If ELISA results are greater than 0.3 µg L^{-1}, the sample is sent to a contract lab for a suite of cyanotoxins via LC/MS/MS analysis at the discretion of management. In addition, to more accurately report blooms to the NYSDEC HAB Reporting Page, DEP began cyanobacteria presence/absence testing on July 18, 2024 to confirm and only report blooms that contained cyanobacteria. If the bloom does contain cyanobacteria, a harmful algal bloom report may be submitted, at management discretion, to the NYSDEC online using a User Trained Report Form so the bloom can be reported on their website.

Harmful Algal Blooms (HABs) occur when toxin-producing algae grow excessively in a body of water. Blooms cannot be determined to be definitively harmful by simply looking at them. For several years, DEP has conducted cyanotoxin monitoring and has actively supported New York State Department of Environmental Conservation (NYSDEC) HAB reporting. NYSDEC's program primarily uses visual observation for reporting and does not currently incorporate any follow up testing conducted by DEP. Table 3.17 provides a listing of algal bloom notifications made by DEP to DEC based on visual and/or cyanobacteria presence observations in 2024 (NYSDEC 2024). During the 2024 season, there were 20 blooms that were investigated at various locations across the watershed.

Table 3.17 Algal bloom monitoring investigation(s) during 2024

Date	**Reservoir**	**Location**	**NYSDEC HAB Report**	**Phytoplankton**	**ELISA ($\mu g\ L^{-1}$)**	**Algal Toxins**
6/11/24	Cannonsville	20'x20' area near boat launch	Submitted 6/12/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A
6/13/24	Kensico	Confined to site 4BRK and DEL18 cove area	Submitted 6/13/24	No cyanobacteria present	N/A	No detections; analyzed as precaution
6/18/24	Ashokan	East Basin near gatehouse 150' x 60' at Site 4EAE	Submitted 6/18/24	Cyanobacteria > 1,000 ASU mL^{-1}	0.32	N/A; bloom dissipated and drawing from West Basin
6/20/24	Rondout	Near intake at site 1RR	Submitted 6/20/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A
7/9/24	Cannonsville	Entire upper end of reservoir	Submitted 7/9/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A

Date	Reservoir	Location	NYSDEC HAB Report	Phytoplankton	ELISA (µg L^{-1})	Algal Toxins
8/5/24	Kensico	Site 6 BRK	No submission	No cyanobacteria present	N/A	N/A
8/15/24	Middle Branch	Site 3CMB	Submitted 8/19/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A
8/15/24	Diverting	Site CD	Submitted 8/19/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A
8/19/24	Croton Falls	Site 5CCF	No submission	No cyanobacteria present	N/A	N/A
9/9/24	Ashokan	Site 3EAW	No submission	Cyanobacteria present	<0.30	N/A
9/11/24	Cannonsville	Site 6WDC to site 4WDC	Submitted 9/13/24	Cyanobacteria > 1,000 ASU mL^{-1}	1.3	N/A
9/12/24	Middle Branch	boat launch area	No submission	Cyanobacteria present	N/A	N/A
9/12/24	Diverting	boat launch area	No submission	Cyanobacteria present	N/A	N/A
9/16/24	Bog Brook	Site 1CBB	Submitted 9/16/24	Cyanobacteria present	N/A	N/A
10/9/24	Cannonsville	Site 6WDC	Submitted 10/17/24	Cyanobacteria > 1,000 ASU mL^{-1}	<0.30	N/A
10/21/24	Middle Branch	Boat launch area	No submission	Cyanobacteria present	N/A	N/A
10/22/24	Pepacton	Site 6EDP	Submitted 10/29/24	Cyanobacteria present	N/A	N/A
10/26/24	East Branch	East Branch boat launch	Submitted 10/25/24	Cyanobacteria present	N/A	N/A

Date	Reservoir	Location	NYSDEC HAB Report	Phytoplankton	ELISA ($\mu g\ L^{-1}$)	Algal Toxins
10/26/24	Bog Brook	Site 0.5CBB boat launch area	Submitted 10/25/24	Cyanobacteria present	N/A	N/A
11/14/24	Cannonsville	Site 6WDC	Submitted 11/18/24	Cyanobacteria present	N/A	N/A

3.16.7 Delaware (Blended Supply) Alum Treatment Study

Under normal operating conditions, using water with lower organic content is considered a best practice to reduce DBP formation in treated water. During the planned shutdown of the RWBT, Shaft 17 delivered water from Cross River and Croton Falls reservoirs to Kensico Reservoir. Water from these reservoirs contains higher levels of disinfection byproduct precursors than the water typically delivered through Shaft 17. Since this blended supply contains higher organic content, DEP conducted alum jar tests June 5, 2024 through September 18, 2024 to evaluate the DBPfp impacts on delivery Croton System water to Kensico Reservoir. The jar tests were conducted with alum at optimal (30 mg/L) and practical (20 mg/L) doses. These doses resulted in an average of 64% and 53% reductions in UV_{254}, 47% and 33% reductions in trihalomethane formation potential (THM_{fp}), and 63% and 51% reductions in haloacetic acid formation potential ($HAA5_{fp}$), respectively.

The study data indicated optimal and practical dosing to achieve effective UV254 reductions. Using this information, approval was requested to conduct a full-scale pilot study to treat with alum at DEL17 during the RWBT shutdown to lower the DBP precursors entering Kensico Reservoir.

3.16.8 Per and Polyfluoroalkyl Substances (PFAS) Monitoring

DEP continued to monitor for per and polyfluoroalkyl substances (PFAS) in 2024 with quarterly monitoring at the CAT/DEL and Croton systems source water monitoring locations, and annual monitoring at Kensico tributaries E9, E10, E11, and Kensico Reservoir limnology Site 6 (6BRK0). In addition to quarterly and annual monitoring, DEP conducted PFAS monitoring on November 20, 2024, at the Croton Falls Reservoir and Cross River Reservoir effluent valve chamber locations, CROFALLSVC and CROSSRVVC respectfully. This monitoring occurred during the RWBT shutdown operation in the fall of 2024 while the Croton Falls and Cross River pump stations were actively pumping their respective reservoir water into the Delaware Aqueduct.

Consistent with previous years (2019-2023), the outflow of Kensico Reservoir (DEL18DT) had no detections of PFAS compounds. Monitoring of the outflow of New Croton Reservoir (CROGH) or its intake elevation tap location when offline (CRO1B) resulted in low level detections of certain compounds (Table 3.18). Although not drinking water, results were well below the New York State Drinking Water Maximum Contaminant Levels (MCLs) for PFOS and PFOA (0.010 µg L^{-1} each).

The Kensico limnology sample collected from site 6BRK0 (Rye Lake) on August 14, 2024, had no detections of PFAS compounds. Detections for samples collected at the three tributary sites (E9, E10, and E11), also collected on August 14, 2024, are provided in Table 3.19.

Table 3.18 PFAS results from New Croton Reservoir outflow (CROGH) or tap (CRO1B), 2024 (µg L^{-1}).

PFAS compound	Method	March 20 CRO1B	June 20 CRO1B	August 15 CRO1B	October 24 CROGH
Perfluorobutanesulfonic acid (PFBS)	EPA 533	0.0022	0.0021	0.0020	0.0020
	EPA 537.1	0.0020	<0.0020	<0.0020	
Perfluorobutanoic acid (PFBA)	EPA 533	<0.0020	<0.0020	<0.0020	0.0028
Perfluorohexanoic acid (PFHxA)	EPA 533	<0.0020	<0.0020	<0.0020	0.0020
	EPA 537.1	<0.0020	<0.0022	<0.0020	
Perfluorooctanoic acid (PFOA)	EPA 533	0.0033	0.0031	0.0031	0.0038
	EPA 537.1	0.0032	0.0029	0.0030	
Perfluoroctanesulfonic acid (PFOS)	EPA 533	0.0027	0.0026	0.0027	0.0033
	EPA 537.1	0.0022	0.0022	0.0024	
Perfluoropentanoic acid (PFPeA)	EPA 533	0.0021	<0.0020	<0.0020	0.0025

Table 3.19 PFAS results for stream sites E9, E10 and E11 August 14, 2024 ($\mu g\ L^{-1}$).

PFAS compound	E9	E10	E11
1H,1H,2H,2H-perfluorooctane sulfonic acid (6:2 FTS)	<0.0020	0.013	0.0069
Perfluorobutanesulfonic acid (PFBS)	0.0023	0.0056	0.0045
Perfluorobutanoic acid (PFBA)	0.0079	0.012	0.015
Perfluoroheptanesulfonic acid (PFHpS)	<0.0020	0.0028	<0.0020
Perfluoroheptanoic acid (PFHpA)	0.0039	0.018	0.016
Perfluorohexanesulfonic acid (PFHxS)	<0.0020	0.075	0.028
Perfluorohexanoic acid (PFHxA)	0.0051	0.0031	0.024
Perfluorononanoic acid (PFNA)	0.0023	0.012	0.0098
Perfluorooctanesulfonic acid (PFOS)	0.0094	0.093	0.029
Perfluorooctanoic acid (PFOA)	0.0011	0.033	0.022
Perfluoropentanesulfonic acid (PFPeS)	<0.0020	0.0074	0.0037
Perfluoropentanoic acid (PFPeA)	0.0065	0.046	0.039

4. Kensico Reservoir

4.1 Kensico Reservoir Overview

Kensico Reservoir in Westchester County is the terminal reservoir for the City's raw source water from the Catskill/Delaware water supply. Protection of this reservoir is critically important to prevent water quality degradation and to maintain the Filtration Avoidance Determination. To ensure these goals are met, DEP has a routine water quality monitoring strategy for Kensico aqueducts, streams, and the reservoir that is documented in the Watershed Water Quality Monitoring Plan (WWQMP; DEP 2024a). These sampling program groups are shown in Figure 4.1. The WWQMP prescribes monitoring to maintain compliance with all federal, state, and local regulations; enhance the capability to make current and future predictions of watershed conditions and reservoir water quality; and ensure delivery of the best water quality to consumers through ongoing high frequency surveillance.

Table 4.1 summarizes the approximate number of water quality samples collected within the Kensico watershed during 2024. These routine sample counts include monitoring from five programs within the Kensico watershed which have returned to pre-pandemic sampling levels.

Table 4.1 Summary of Routine Kensico Water Quality Samples collected in 2024.

Kensico sampling programs	Turbidity	Bacteria	*Giardia/ Crypto-sporidium*	Phyto-plankton	Other Analyses
SWTR Turbidity compliance	2,197				
Keypoint effluent	366	366	54	162	2,501
Keypoint influent	529	523	109	108	3,838
Reservoir	446	330		97	2,707
Streams	113	109	102		1,553

Since compliance with the Safe Drinking Water Act Surface Water Treatment Rule (SWTR; USEPA 1989) and Long Term 2 Enhanced Surface Water Treatment Rule (LT2; USEPA 2006) is required to maintain the Filtration Avoidance Determination, fecal coliform and turbidity are critical aspects of Kensico water quality monitoring and the focus of analysis within this chapter. Fecal coliform and turbidity results during 2024 consistently met compliance requirements for water leaving Kensico Reservoir. The predominantly low fecal coliform results are in large part due to a combination of the ongoing success of the Waterfowl Management Program discussed in Section 4.4.1 and effective operational decisions.

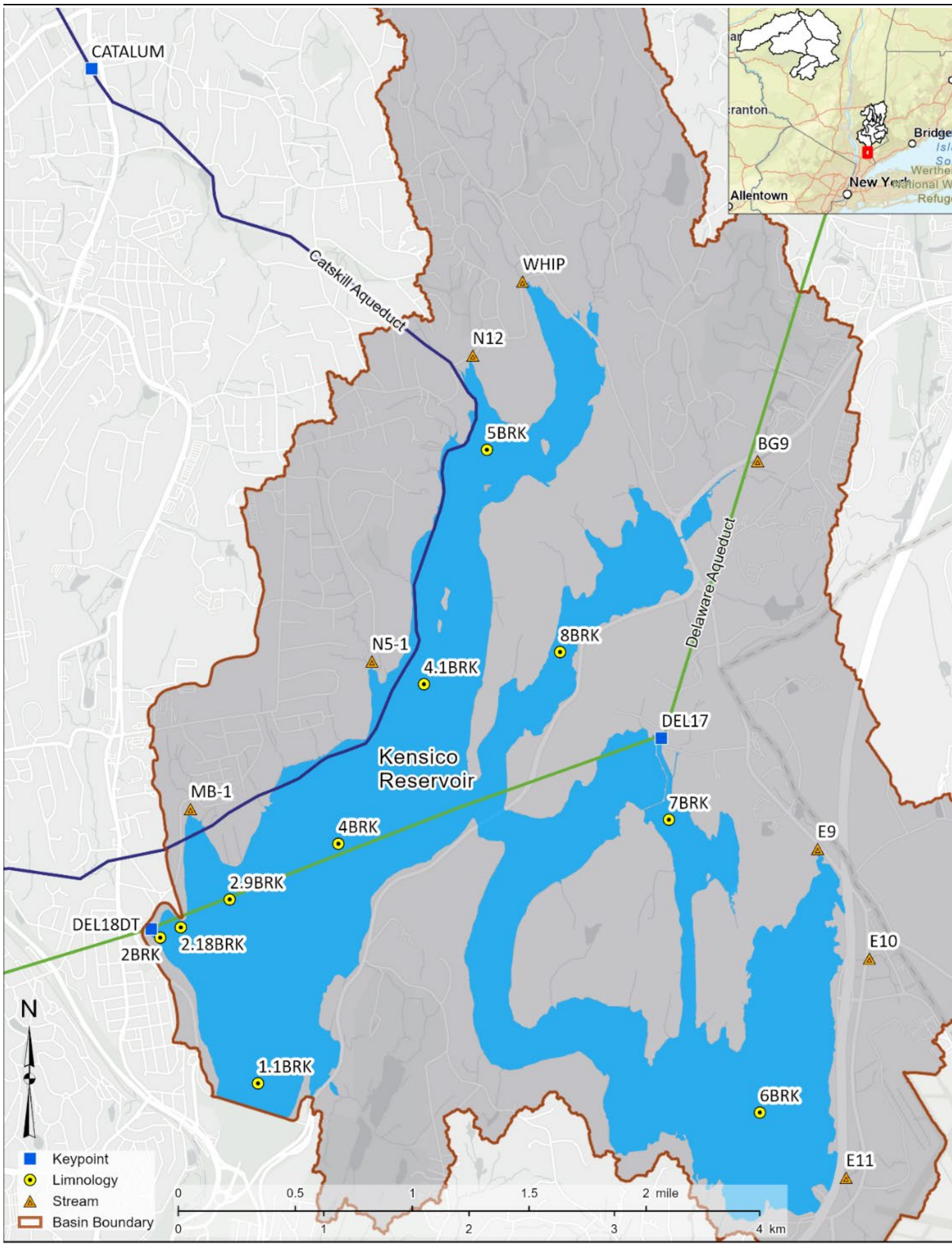

Figure 4.1 Kensico Reservoir showing limnological, hydrological, and keypoint sampling sites; and aqueducts.

4.2 Reservoir Raw Water Quality Compliance

4.2.1 Kensico Reservoir Keypoint Data

DEP routinely conducts water quality compliance monitoring at the Kensico Reservoir aqueduct keypoint sites. The CATALUM and DEL17 influent keypoints represent water entering Kensico Reservoir from the upstate reservoirs of the Catskill/Delaware System via the Catskill and Delaware aqueducts, respectively. The monitoring for CATALUM and DEL17 includes requirements defined by the Catskill Influent Chamber (CATIC) and Delaware Aqueduct (DEL17)

SPDES permits, NY-026-4652 and NY-026-8224, respectively. The DEL18DT effluent keypoint represents water entering the Delaware Aqueduct Shaft 18 facility via reservoir, float, or bypass operational mode at a point just prior to disinfection, after which the water travels down to Hillview Reservoir and into the distribution system. Table 4.2 outlines the routine grab sample monitoring that occurred at three aqueduct keypoint locations for 2024.

Analytical results from all three keypoint locations are used as an indicator of water quality entering and leaving Kensico Reservoir. These data are utilized to optimize operational strategies to ensure the delivery of the best quality water to Hillview Reservoir. Operational strategies are also informed by the continuous monitoring instrumentation for temperature, pH, conductivity, and turbidity at all three locations in near-real time.

Table 4.2 Water quality monitoring plan for Kensico Reservoir aqueduct keypoints via routine grab samples for 2024.

Site	**Fecal and Total Coliforms, Turbidity, Specific Conductivity, Scent, Apparent Color**	**Field pH, Temperature**	**Turbidity**	**Phytoplankton**	**UV_{254}**	**Total Phosphorus**	**Dissolved Organic Carbon**	**Giardia & Cryptosporidium**	**Alkalinity, Ammonia, NOx, Orthophosphate, TDP, Total Suspended Solids, TN, TDN, Chlorophyll *a***	**Anions, Major Metals, Trace Metals, Fe, Mn, Hg**
CATALUM	5D	5D		W	W	W	W	W	M	Q
DEL17	5D	5D		W	W	W	W	W	M	Q
DEL18DT	*+7D	7D	*4H	3D	W	M	W	W	M	Q

4H – Sampled every four hours 3D – Sampled three days per week M – Sampled Monthly
7D – Sampled seven days per week W – Sampled Weekly Q – Sampled Quarterly
5D – Sampled five days per week. * SWTR Compliance
+For fecal coliform, a minimum of 5 samples per week are required and samples must be taken every day that the turbidity exceeds 1.49 NTU. DEP voluntarily samples 7 days per week.

Additional sampling was conducted for various events during the year as follows:

- October 9, 2024 phytoplankton/*Chrysosphaerella* detection.
- Alum treatment from October 15, 2024 to October 30, 2024 required additional sampling to be conducted at CATALUM for the following parameters: pH, temperature, total suspended solids (TSS), turbidity, total and dissolved aluminum, total phosphorus. Weekly sampling at 5BRK was done at 3- and 5-meter depths for the following: pH, turbidity, TSS, total and dissolved aluminum.

Annual median and single sample maximum for turbidity and fecal coliform are included as a partial assessment of the overall water quality for 2024 and can be compared to the previous year (Table 4.3). Assessment of individual 2024 routine grab samples for each of the Kensico aqueduct locations was conducted graphically (Figure 4.2, Figure 4.3, and Figure 4.4) by comparing results to SWTR limits. Influent sites (DEL17 and CATALUM) are not subject to the SWTR limits, so the SWTR limit line is provided for reference purposes.

Table 4.3 Kensico keypoint fecal coliform and turbidity metric results.

Analyte	**Kensico Sampling Location**	**Median**		**Single Sample Maximum**	
		2023	**2024**	**2023**	**2024**
Fecal coliform (coliforms $100mL^{-1}$)	CATALUM	<1	<1	35	E4
	DEL17	1	2	E95	E76
	DEL18DT	1	1	35	31
Turbidity (NTU)	CATALUM	1.7	1.9	5.4	10
	DEL17	0.8	0.8	2.7	3.7
	DEL18DT	0.8	0.8	1.5	2.1

The CATALUM (Figure 4.2) turbidity and fecal coliform results were similar to the previous year's values. Overall, CATALUM results were below the fecal coliform and turbidity reference limits except when following a precipitation event in the Ashokan watershed or an operational change. Alum usage had a notable impact on turbidity in October. For DEL17, all turbidity results were less than 5 NTU (Figure 4.3) and thirteen fecal coliform results exceeded the 20 fecal coliform $100mL^{-1}$ reference limit, each following a precipitation event. The start of the 2024 RWBT shutdown and pumping station operations are apparent in the turbidity figures for DEL17 in October.

For 2024 DEL18DT (Figure 4.4), all turbidity results were less than 5 NTU and no fecal coliform results exceeded the SWTR criteria that no more than 10% of source water samples exceed 20 fecal coliform $100mL^{-1}$ over the previous six-month period. During the period January through March, 0.55% of the DEL18DT fecal coliform samples exceeded the SWTR 20 fecal coliforms $100mL^{-1}$ limit for the six-month period due to an exceedance in October 2023 factoring into this calculation. From April to December 2024 there was no exceedance of the SWTR 20 fecal coliforms $100mL^{-1}$ limit.

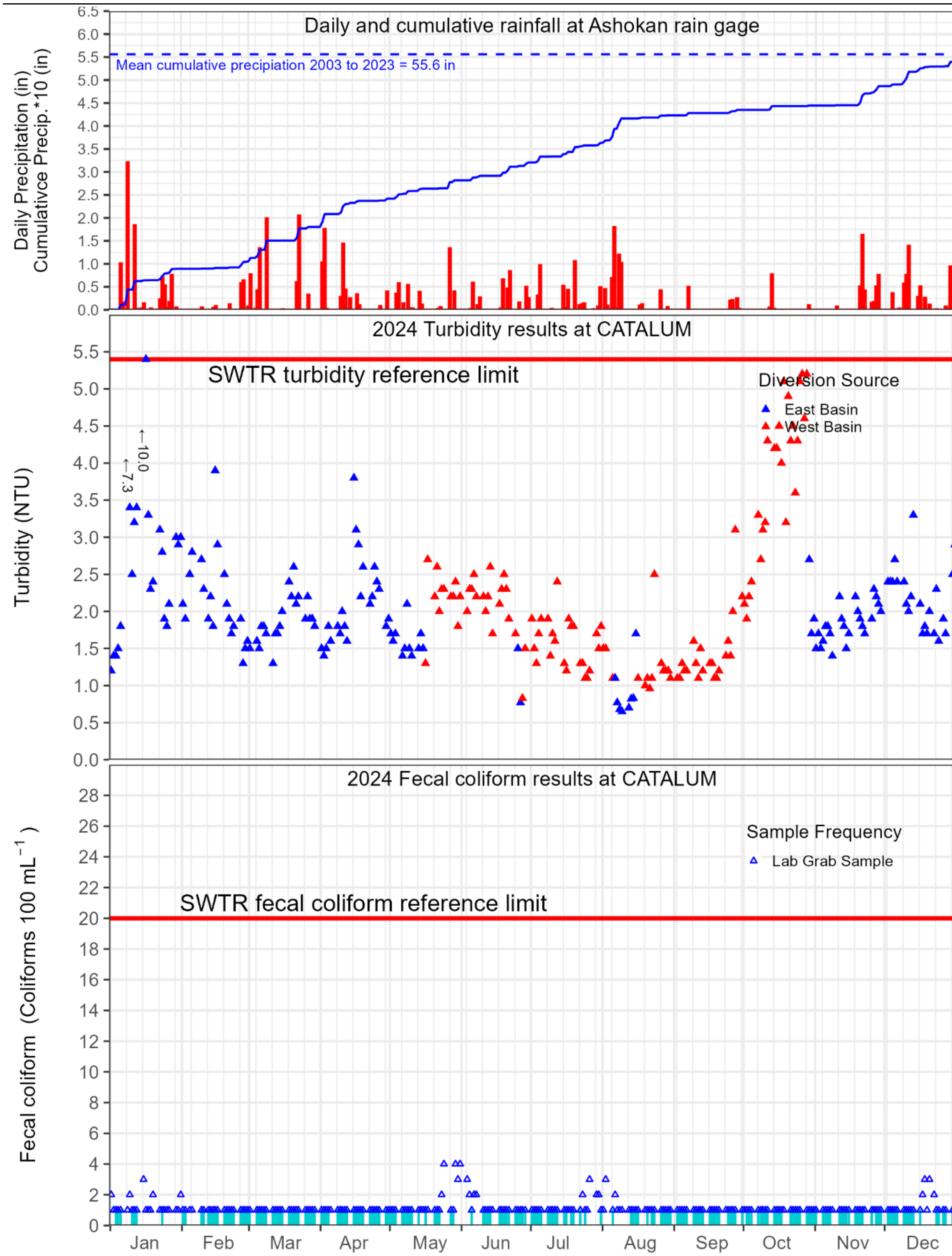

Figure 4.2 Five-day-per-week turbidity and fecal coliform grab samples at CATALUM. Drop lines indicate censored values.

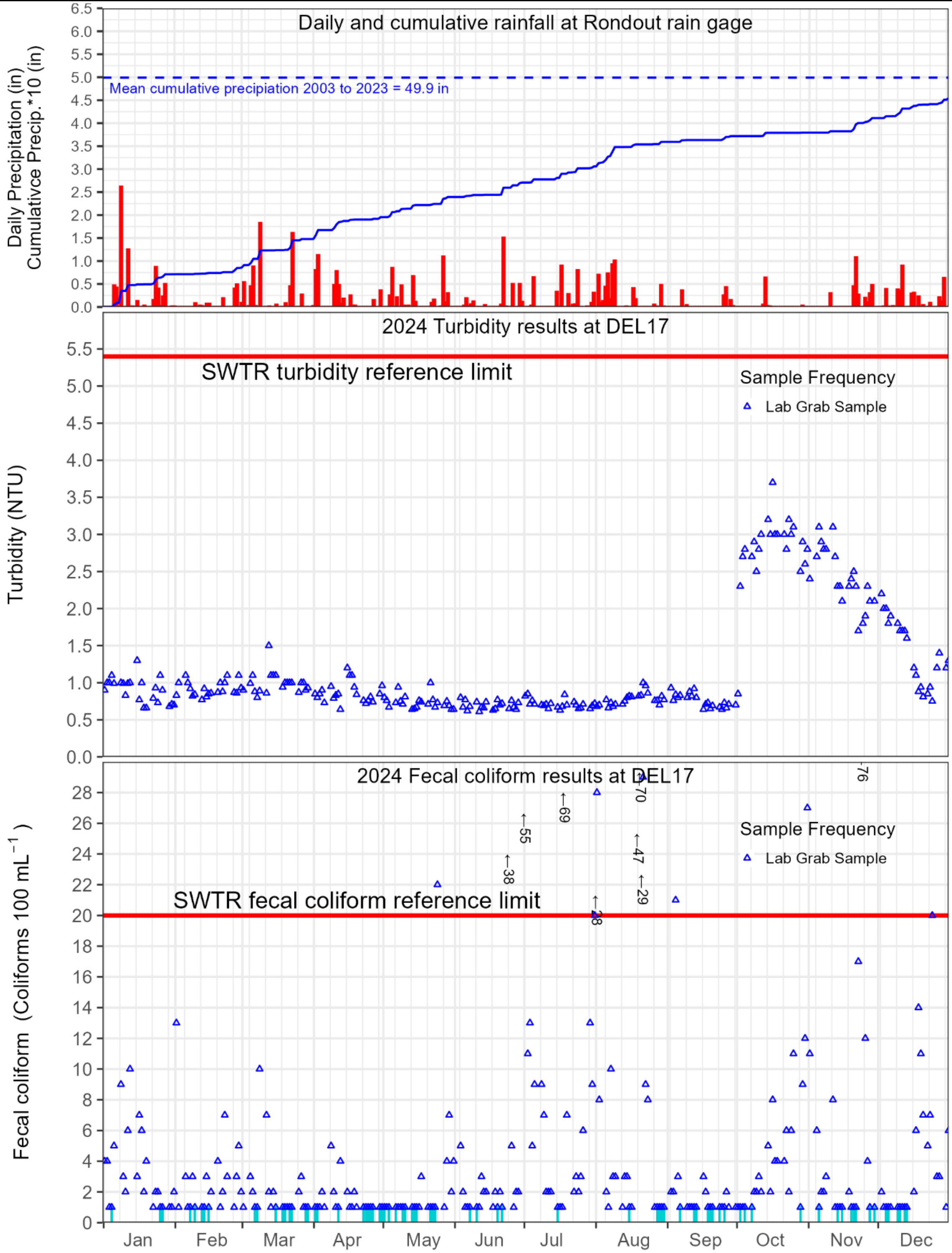

Figure 4.3 Five-day-per-week turbidity and fecal coliform grab samples at DEL17. Drop lines indicate censored values.

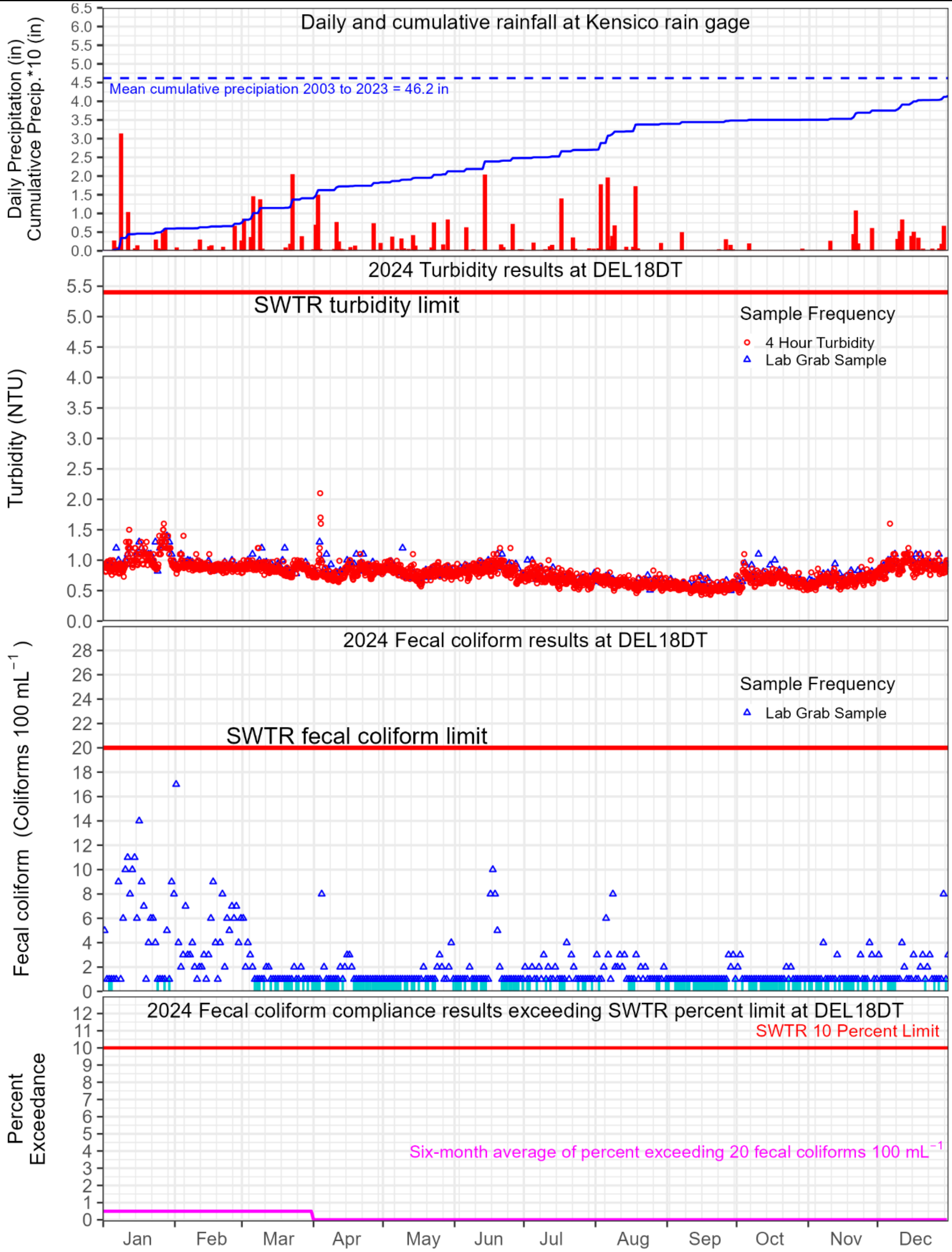

Figure 4.4 Seven-day-per-week turbidity and fecal coliform grab samples at DEL18DT. Drop lines indicate censored values.

4.2.2 Keypoint Pathogen Data

Samples collected for protozoan analyses in 2024 were analyzed by Method 1623.1 with EasyStain® and heat dissociation. In addition, samples were collected and analyzed by a cell culture immunofluorescent assay to monitor for infectious *Cryptosporidium* in water leaving Hillview Reservoir. Kensico outflow results are posted weekly on DEP's website (https://data.cityofnewyork.us/Environment/DEP-Cryptosporidium-And-Giardia-Data-Set/x2s6-6d2j) and reported annually in this report.

DEP completed its monitoring requirements for the Long Term 2 Enhanced SWTR (LT2; USEPA 2006) in 2018; however, the calculation procedure described in the LT2 is performed annually by DEP to measure results against the thresholds. For the period of 2023-2024, there were a total of 106 samples collected at the Delaware outflow of Kensico Reservoir at Site DEL18DT. The *Cryptosporidium* mean of monthly means for this 24-month period was 0.0053 oocysts L^{-1}.

In 2024, 17 Kensico inflow samples (CATALUM and DEL17) were positive for *Cryptosporidium,* for a combined inflow detection rate of 15.6%. This is within the annual historical range from 0.9% to 20.5%, with inflow concentrations ranging from 0 to 3 oocysts $50L^{-1}$. Concentrations for the Kensico and Croton outflows (DEL18DT and CROGH) or equivalent tap (CRO1B/CRO1T) ranged from 0 to 4 oocysts $50L^{-1}$.

For *Giardia*, 77 Kensico inflow samples (CATALUM and DEL17) were positive for *Giardia*, for a combined inflow detection rate of 70.6%. Concentrations ranged from 0 to 29 cysts $50L^{-1}$. Concentrations for the outflow (DEL18DT and CROGH) ranged from 0 to 14 cysts $50L^{-1}$. Results are presented in Table 4.4, Figure 4.5, and Figure 4.6. As in previous years, there were seasonal variations in *Giardia* concentrations at the Kensico inflows and outflow, with seasonally elevated *Giardia* concentrations during the colder months.

Table 4.4 *Cryptosporidium* and *Giardia* - Kensico and New Croton keypoints.

Analyte	Site	Number of Positive Samples	Detection Rate (%)	Mean Count[2]	Maximum Count
Cryptosporidium (Oocysts $50L^{-1}$)	CATALUM (n=53)	6	11.3	0.15	2
	DEL17 (n=56)	11	19.6	0.29	3
	DEL18DT (n=54)	13	24.1	0.43	4
	CROGH[1] (n=4)	0	0	0.00	0
Giardia (cysts $50L^{-1}$)	CATALUM (n=53)	31	58.5	1.34	9
	DEL17 (n=56)	46	82.1	4.95	29
	DEL18DT (n=54)	32	59.3	2.11	14
	CROGH[1] (n=4)	2	50	1.00	1

[1]May include alternate sites sampled to best represent outflow during “off-line” status. In 2024, CRO1B was substituted for CROGH during the first, second and third quarters.

[2]Sample volumes not exactly equal to 50L are calculated to per L concentrations and then normalized to 50L for determination of means. Zero values are substituted for non-detect values when calculating means.

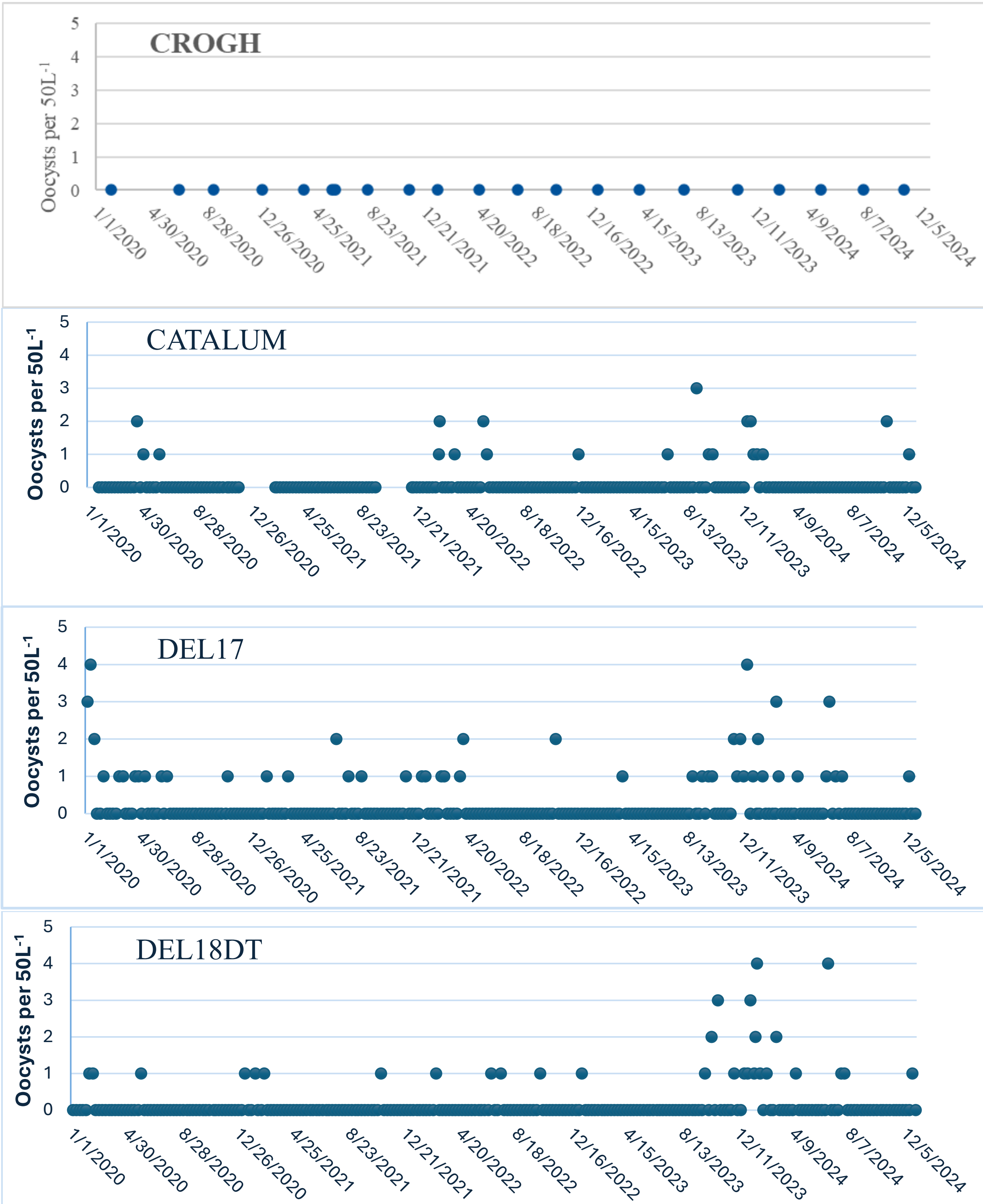

Figure 4.5 Kensico keypoint *Cryptosporidium* 2020-2024.

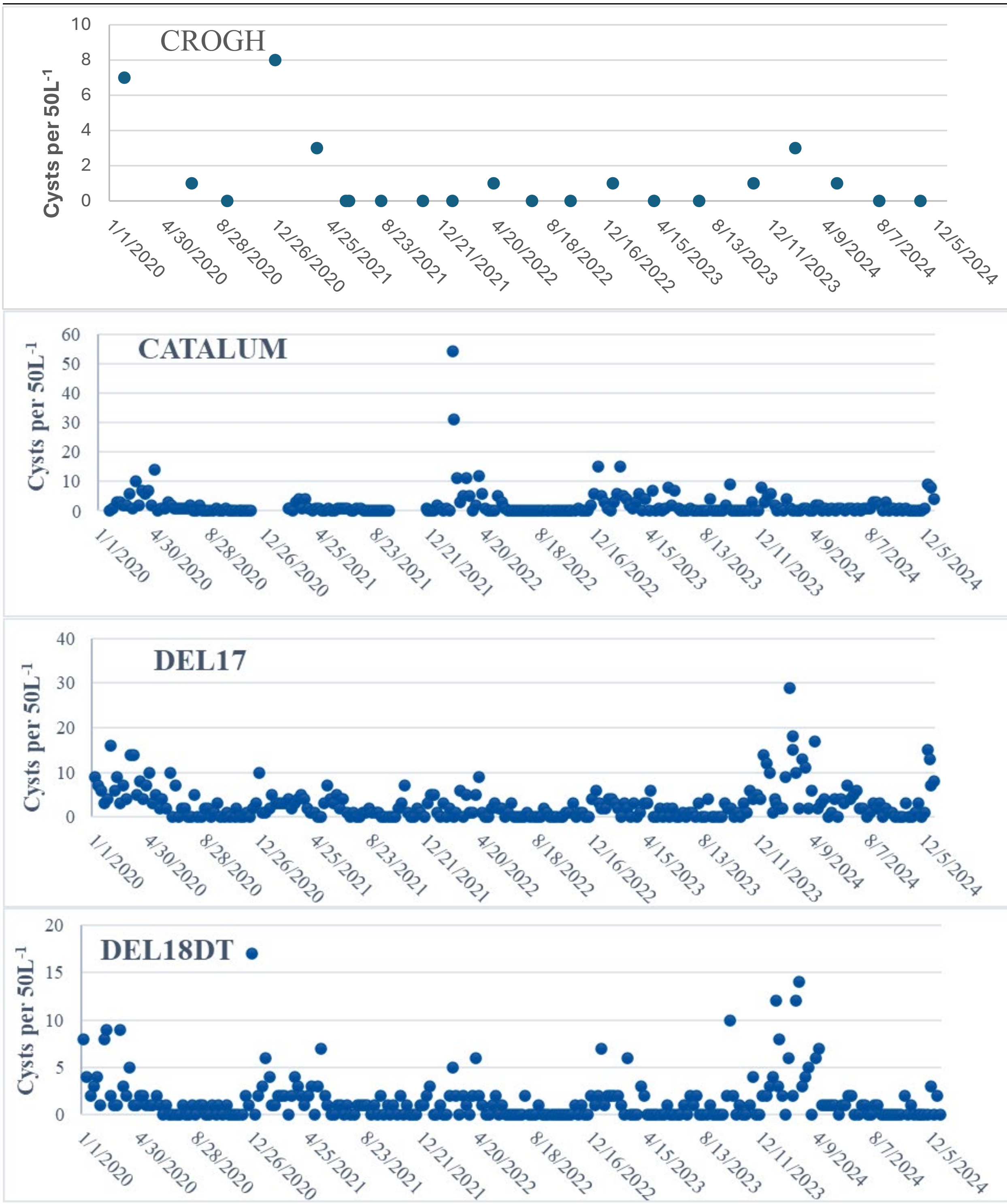

Figure 4.6 Kensico keypoint *Giardia* 2020-2024.

4.2.1 Source Water Quality Control Results

Quality control testing included ongoing precision and recovery samples and matrix spike samples. Weekly ongoing precision and recovery (OPR) testing involves spiking reagent-grade water with known amounts of oocysts and cysts. Acceptable OPR results of 45% to 100% for *Cryptosporidium* and 36% to 100% for *Giardia* were required before processing weekly samples. Ranges of recovery for protozoan OPR samples in 2024 were 32% to 92% for *Cryptosporidium* and 5% to 88% for *Giardia*, with re-testing conducted as necessary. To determine matrix spike recoveries, sample matrices are spiked with known amounts of oocysts and cysts and analyzed according to the same method used for routine samples. In 2024, matrix spike recoveries ranged from 22% to 72% for *Cryptosporidium* and 34% to 71% for *Giardia*, with complete results provided in Table 4.5.

Table 4.5 Keypoint matrix spike results - 2024.

Date	Site	***Cryptosporidium* % Recovery**	***Giardia* % Recovery**
4/29/2024	CATALUM	72	71
9/9/2024	CATALUM	24	50
2/12/2024	DEL17	22	48
11/4/2024	DEL17	55	59
3/18/2024	DEL18DT	66	42
7/29/2024	DEL18DT	38	34
12/9/2024	DEL18DT	38	66

4.3 Kensico Watershed Monitoring and Turbidity Curtain Inspections

4.3.1 Kensico Watershed Monitoring

DEP continued fixed-frequency monitoring at stream and reservoir sites in the Kensico watershed with turbidity, fecal coliform and pathogens being the primary analytes of interest. Routine samples were collected from eight perennial streams and seven profiled locations within Kensico Reservoir. Additional sites were monitored to evaluate potential impacts within the watershed and reservoirFigure 4.1. In 2024, monthly analyte collection was increased at the tributary sites E9 and E10 to include the following: anions, total phosphorus, TSS, alkalinity, nitrate and nitrite (NO_x), ammonia, DOC and total nitrogen (TN).

Kensico perennial streams have continuous flow measurement structures at each location except for E10, which is offline, and WHIP (Whippoorwill Creek) which has ongoing problems with equipment stabilization due to constant erosion of its streambeds and banks. WHIP and BG9 (Bear Gutter) flows are determined via a rating curve. E11 (Stream E11), E10 (Stream E10), MB-1 (Malcolm Brook), and N5-1 (Stream N5-1) flows are determined via a V-notch weir. N12 (Stream N12) and E9 (Stream E9) flows are determined via an H-flume that accommodates a wider range of

flows. With each watershed having a different drainage area and Best Management Practice (BMP) type, the hydrograph can be shaped differently, and same-day monitoring can occur at a different position on the hydrograph. The nearby USGS flow gage CROSS2 near Cross River provides an estimate of flow conditions within the Kensico watershed (Figure 2.3). Turbidity and fecal coliform 2024 routine monitoring results for these streams were typically near or below the previous 10-year monthly median concentrations except when monitoring was influenced by storm event flow (Figure 4.7).

For all Kensico Reservoir 2024 routine monitoring turbidity grab samples, the annual median turbidity concentration was 0.73 NTU (Figure 3.1) with individual results ranging from 0.2 to 3.1 NTU (Figure 4.8). Figure 4.8 shows interpolated concentrations, where shading and contour lines are an estimate of turbidity concentrations and may not fully represent actual concentrations in those portions of the reservoir. Profile location 5BRK had the highest mean turbidity concentration (1.4 NTU) since it is heavily influenced by incoming Catskill System water (CATIC). Fecal coliform results were also generally low; the 75th percentile in 2024 was 1 fecal coliform 100mL^{-1} (Figure 3.3) with approximately 52% of the monthly reservoir grab samples resulting in no detectable fecal coliforms and five results greater than 20 fecal coliform 100mL^{-1}. All fecal coliform results greater than 20 fecal coliform 100mL^{-1} were associated with precipitation events: two from June, one from July and two from an August storm event within the Kensico watershed. Fecal coliform results cannot be plotted as a contour plot because of the number of censored values.

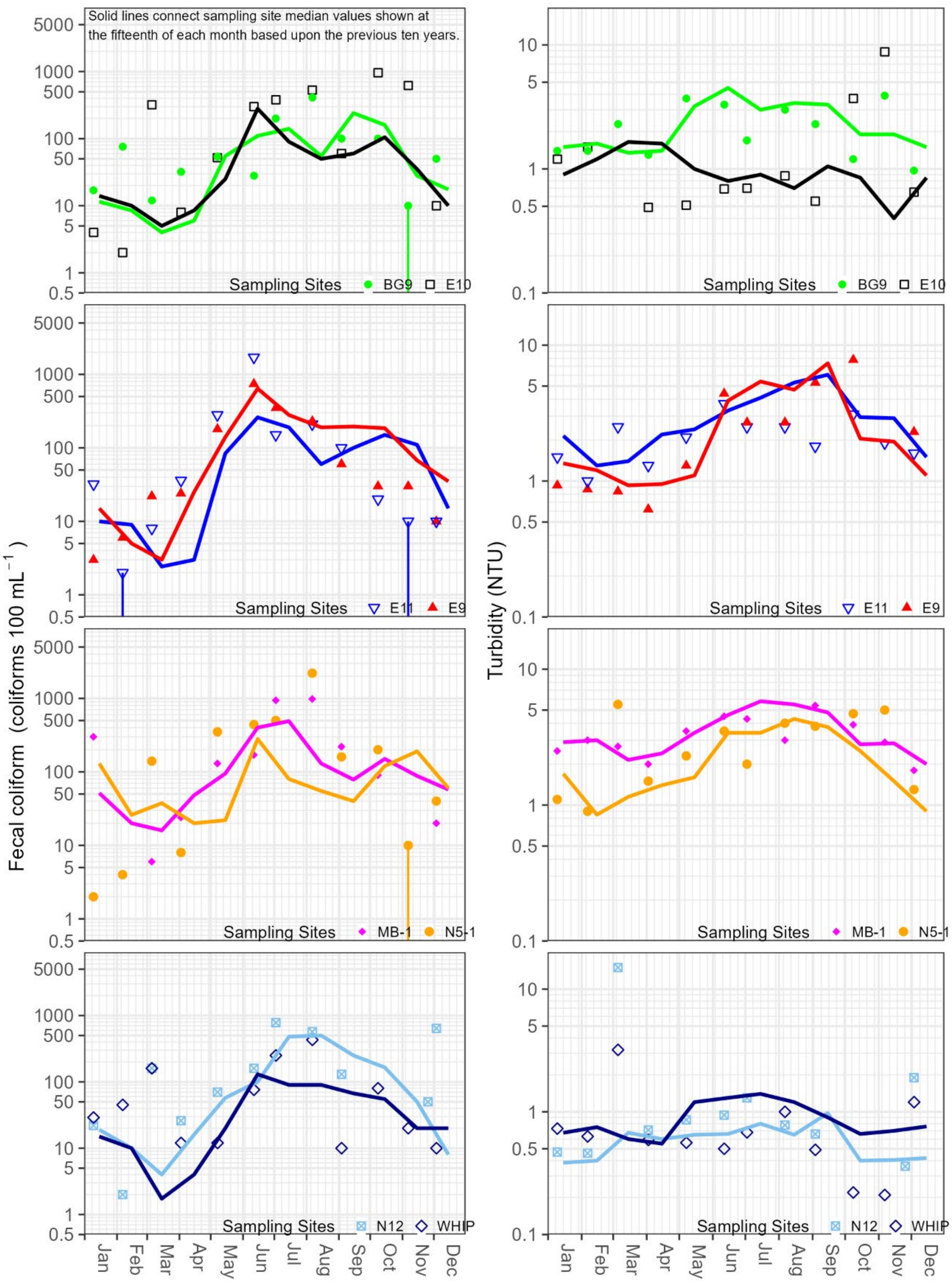

Figure 4.7 Routine Kensico stream monthly monitoring fecal coliform and turbidity results compared to previous ten-year median.

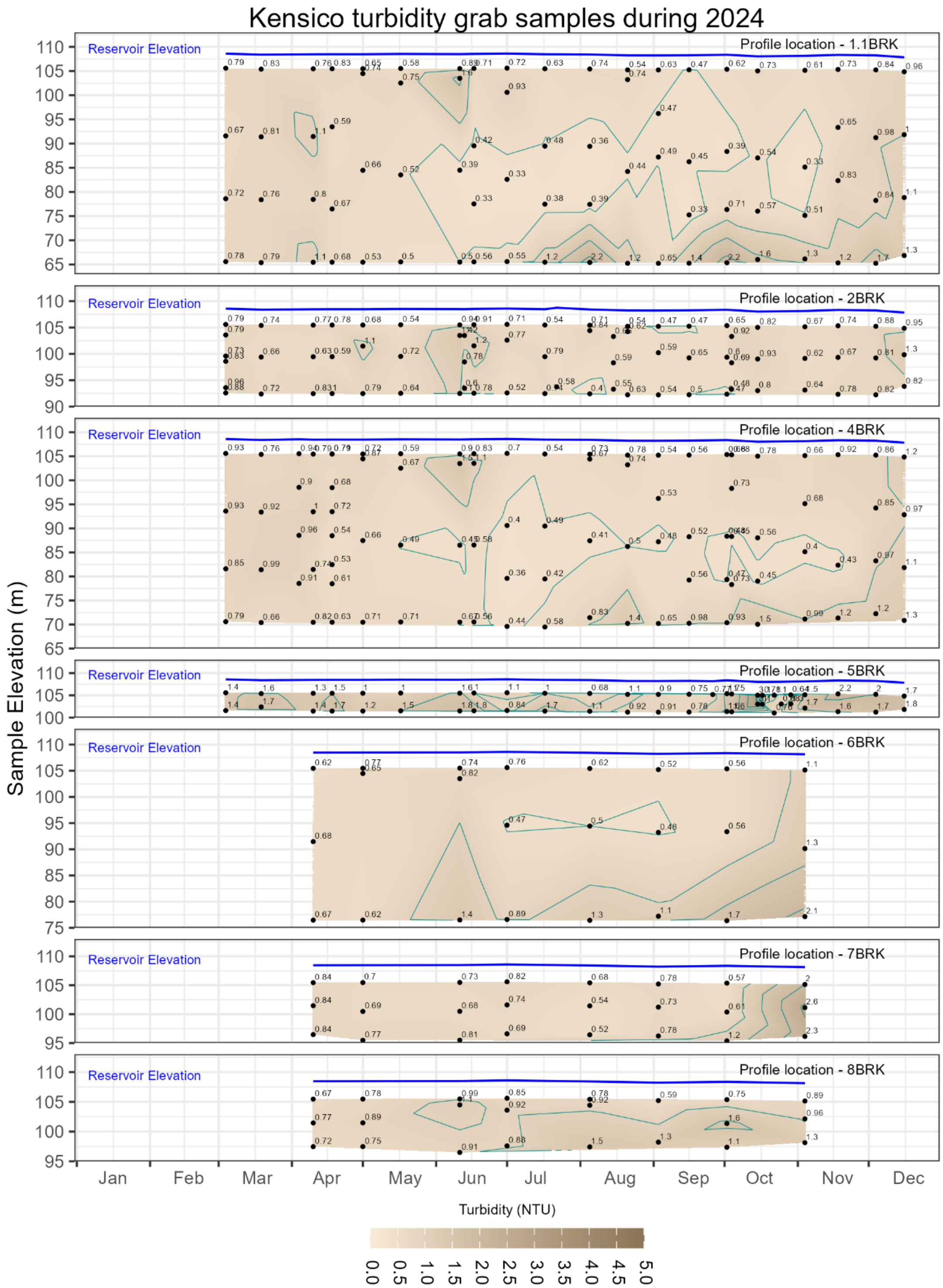

Figure 4.8 Kensico Reservoir turbidity grab sample results for 2024 with analytical measurements marked as points overlaying an interpolated concentration map.

4.3.2 Kensico Stream Pathogen Data

The Kensico perennial streams were monitored for protozoans monthly from January to December 2024. Percent detects and maximum counts for each site are summarized in Table 4.6, and individual results are displayed in Figure 4.9, Figure 4.10, Figure 4.11 and Figure 4.12. Overall, *Cryptosporidium* oocysts were detected in 45 out of 102 (44.1%) stream samples in 2024 and *Giardia* cysts were detected in 89 out of 102 samples (87.3%).

- BG-9 was resampled on 3/12/2024 due to *Giardia* counts exceeding 95% on 3/5/2024.
- E9 was resampled on 12/9/2024 due to *Giardia* counts exceeding 95% on 12/3/2024.
- MB-1 was resampled 10/15/2024 due to the loss of the MS sample from 10/8/2024.
- N12 was resampled on 3/12/2024 due to *Giardia* counts exceeding 95% on 3/5/2024.
- N12 was resampled on 12/9/2024 due to *Giardia* counts exceeding 95% on 12/3/2024.
- N5-1 was resampled on 3/12/2024 due to *Giardia* counts exceeding 95% on 3/5/2024.
- WHIP was resampled on 3/12/2024 due to *Giardia* counts exceeding 95% on 3/5/2024.

Table 4.6 *Cryptosporidium* and *Giardia* - Kensico streams – 2024.

Site	N	***Cryptosporidium***			***Giardia***		
		% Detects	**Max ($50L^{-1}$)**	**95%[1]**	**% Detects**	**Max ($50L^{-1}$)**	**95%[1]**
BG9	13	30.7%	2	2.00	76.9%	50	19.60
E10	12	25%	6	3.40	83.3%	61	13.20
E11	12	33.3%	1	6.00	91.6%	55	21.60
E9	13	46.1%	6	4.00	92.3%	197	94.0
MB-1	13	30.7%	3	10.50	76.9%	12	40.60
N12	13	76.9%	30	22.25	100%	765	19.35
N5-1	13	30.7%	8	8.25	92.3%	80	28.25
WHIP	13	76.9%	4	3.00	84.6%	165	11.00

[1]95% are based on the previous 10 years.

[2]Sample volumes not exactly equal to 50L are calculated to per L concentrations and then normalized to 50L.

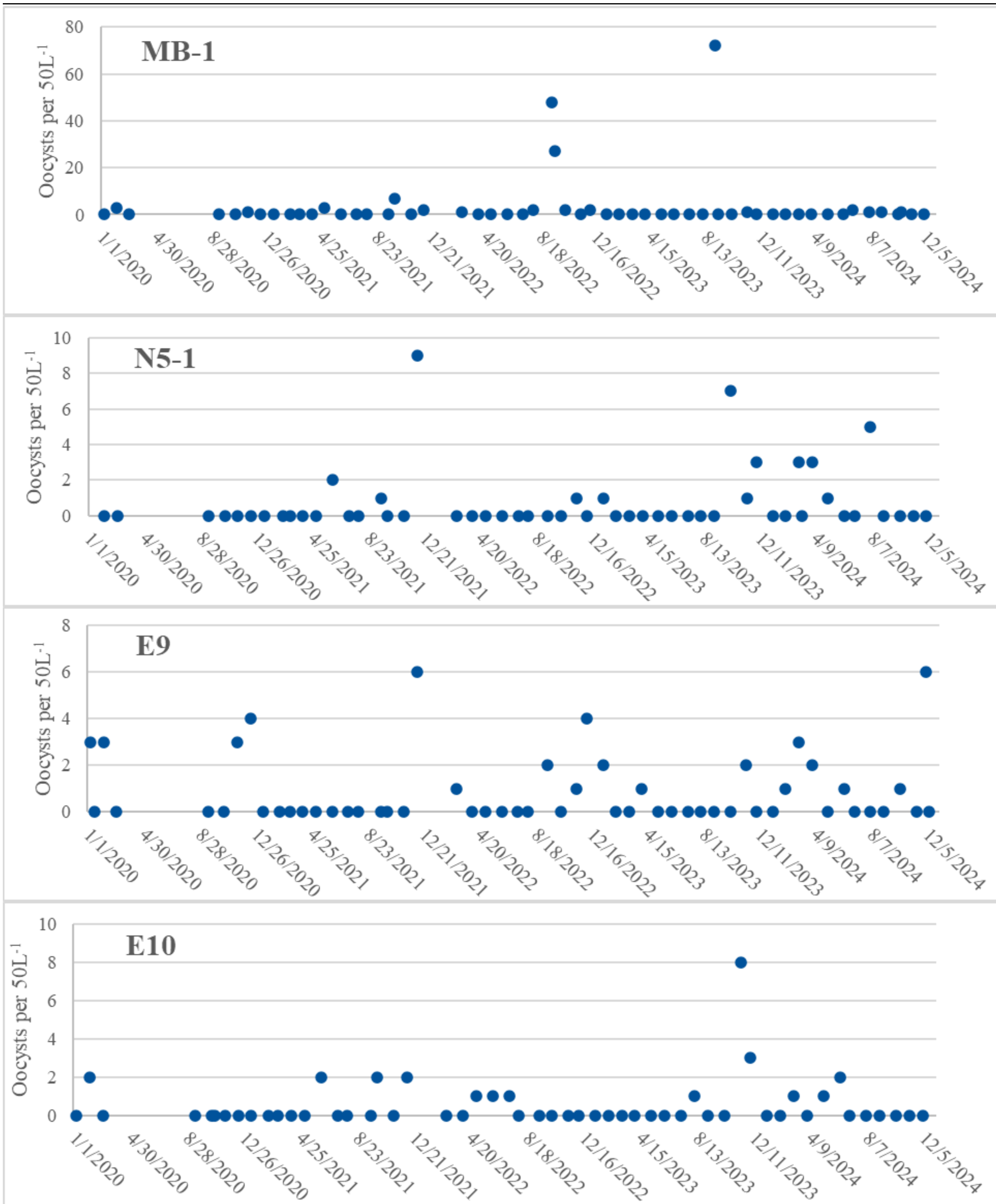

Figure 4.9 Kensico streams *Cryptosporidium* 2020-2024 (MB-1, N5-1, E9, E10).

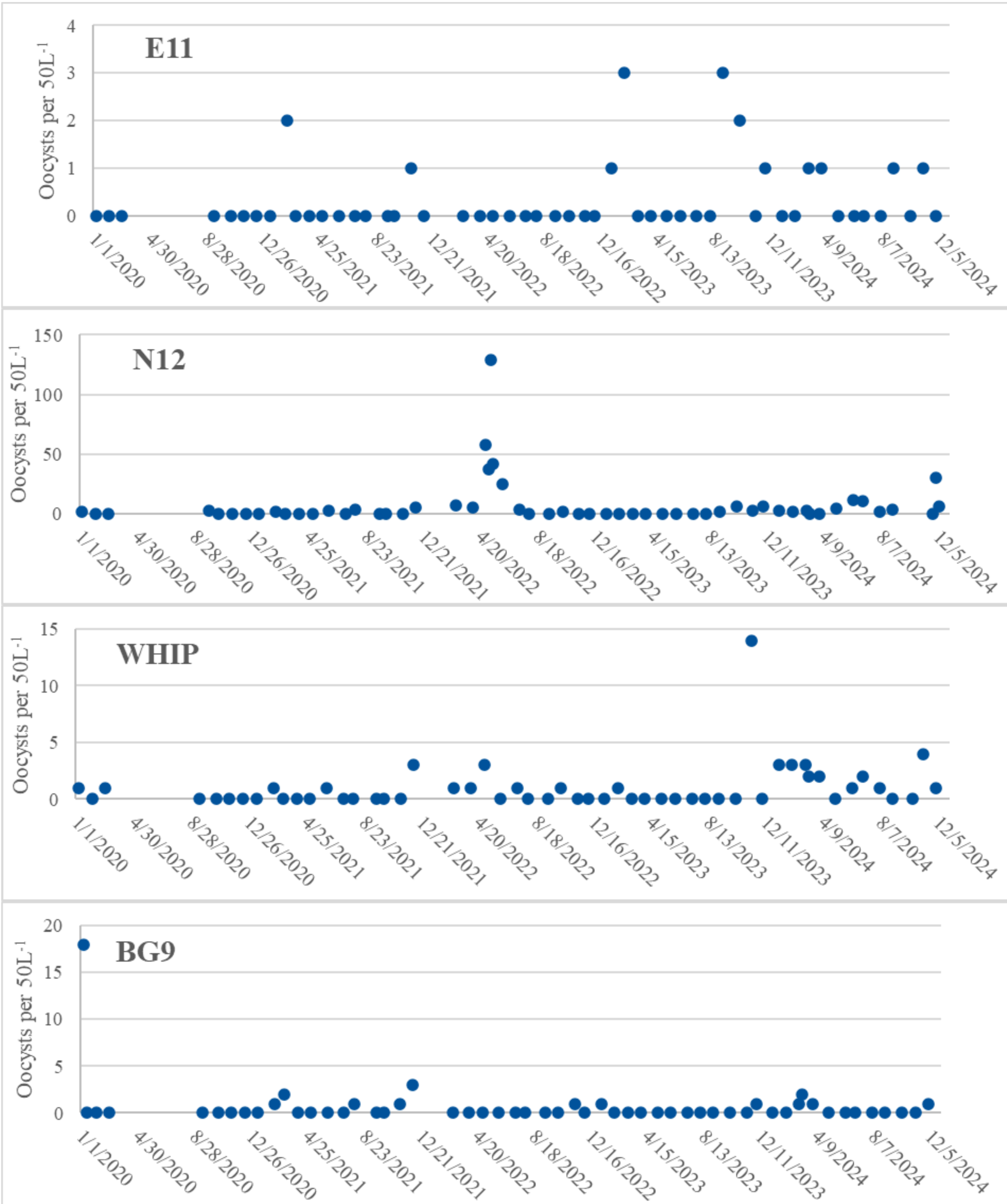

Figure 4.10 Kensico streams *Cryptosporidium* 2020-2024 (E11, N12, WHIP, BG9).

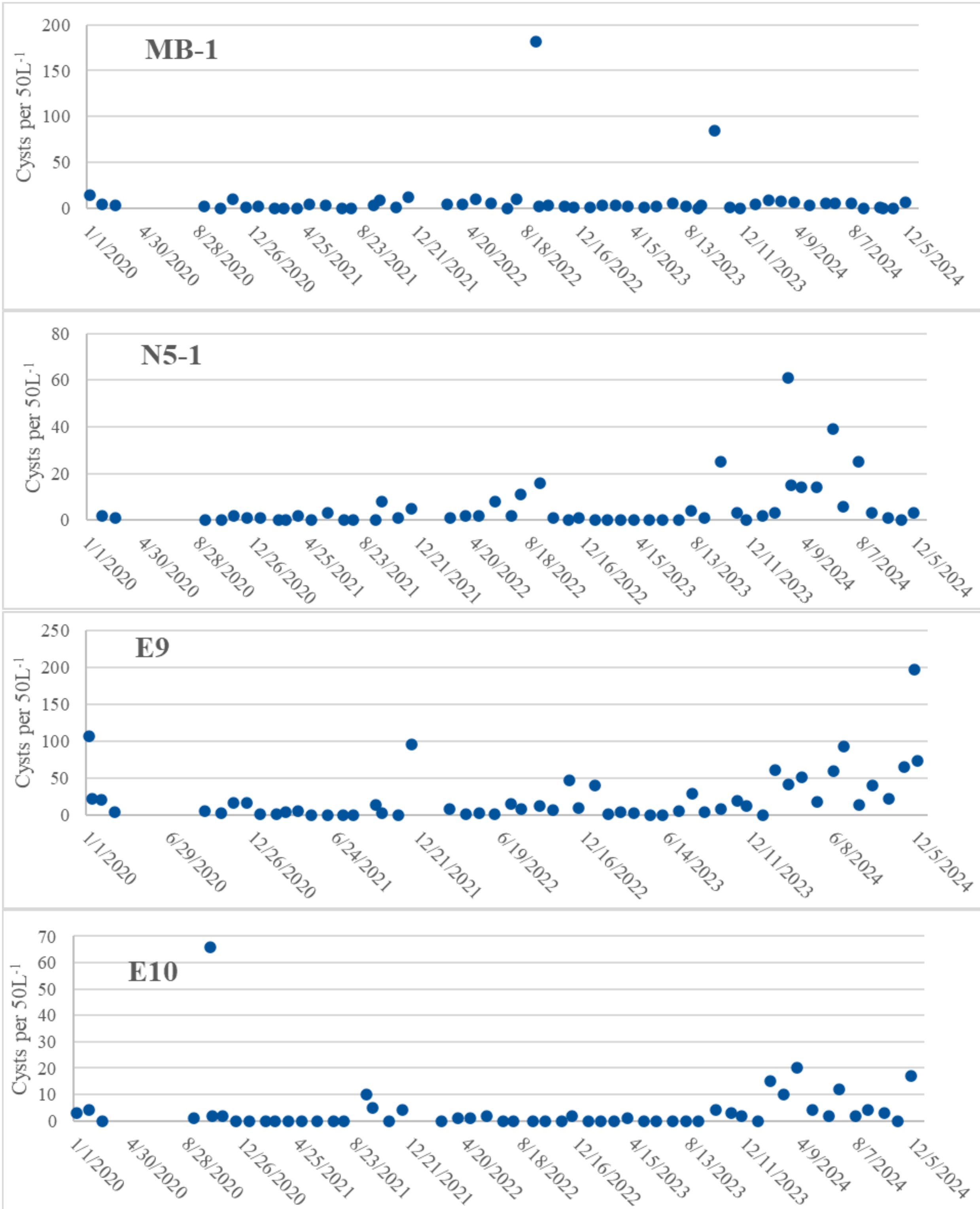

Figure 4.11 Kensico streams *Giardia* 2020-2024 (MB-1, N5-1, E9, E10).

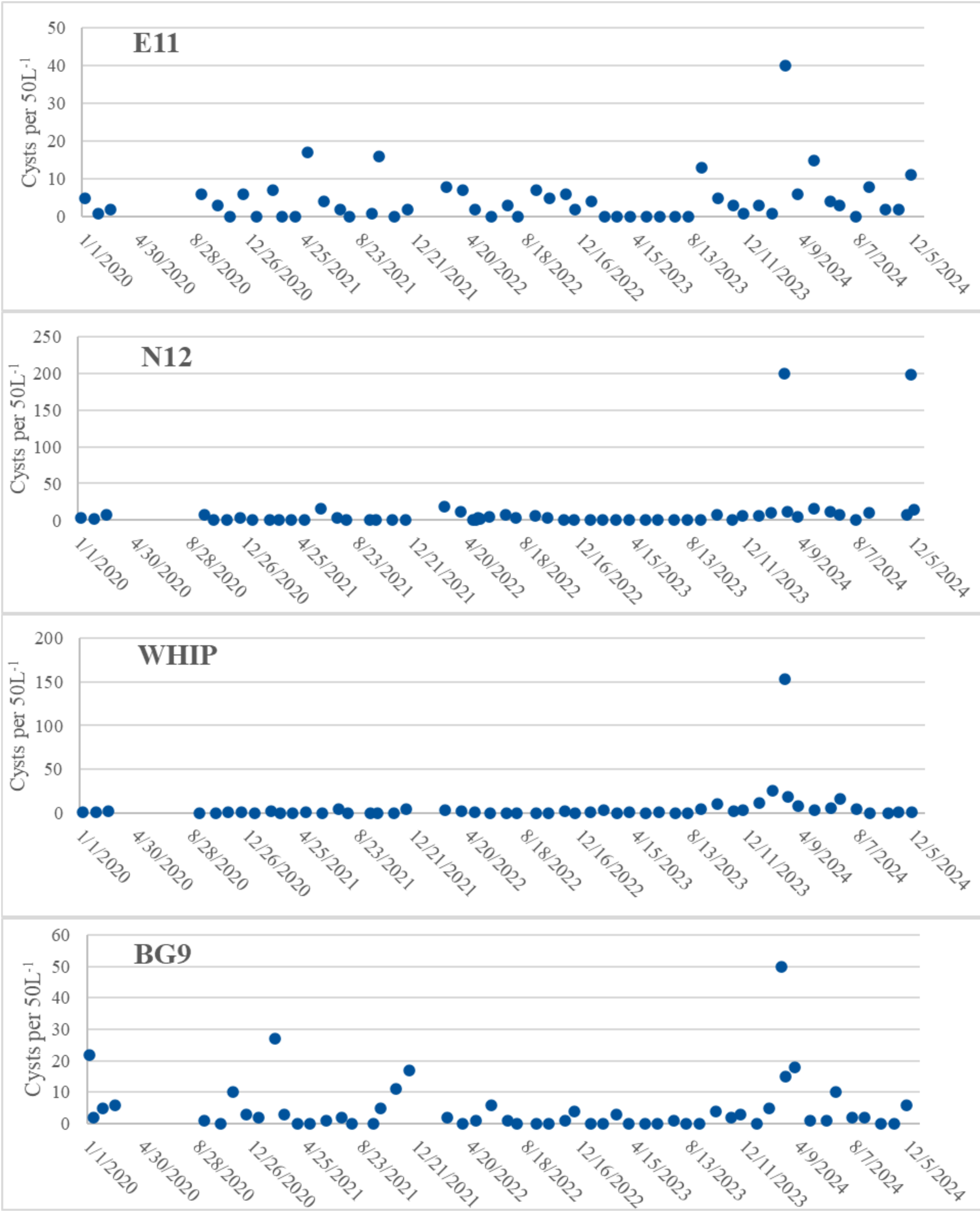

Figure 4.12 Kensico streams *Giardia* 2020-2024 (E11, N12, WHIP, BG9).

4.3.4 Storm Event: August 2024

Tropical Storm Debby was predicted to deliver at least 4 inches of rain in the region, however the final total rainfall measured at Westchester County Airport was 2.1 inches. Even though this was eventually not categorized as a “storm event” due to the less than 3 inches of rain, monitoring was undertaken due to the initial predicted severity of the storm and the prior period of dryness. Monitoring began on the afternoon of August 6, 2024 at sites MB-1 and N5-1. At MB-1, fecal coliform counts peaked at 48,000 CFU $100mL^{-1}$, with a turbidity of 27 NTU and UV_{254} at 0.344 abs cm^{-1}. At N5-1, fecal coliform counts peaked at 72,000 CFU $100mL^{-1}$, with a turbidity of 28 NTU and UV_{254} at 0.209 abs cm^{-1}. Fecal coliform counts, turbidity and UV_{254} readings started to decrease in the early hours of August 7, 2024.

4.3.5 Turbidity Curtain Inspection

The three turbidity curtains in the Catskill Upper Effluent Chamber (CATUEC) cove are designed to redirect water from the CATUEC cove into the main waterbody of Kensico Reservoir to minimize impacts of storm events from Malcolm Brook (MB-1). Since September 2012, when the Catskill/Delaware Ultraviolet Light Disinfection Facility came online, CATUEC has been off-line. DEP BWS Water Treatment Operations staff visually inspect the turbidity curtains at least monthly from fixed shore locations around the cove as part of the ongoing maintenance program. Water Quality staff receive the inspection reports and provide input on the condition, positioning, and maintenance of the curtains where appropriate. Operations staff perform the appropriate repairs or adjustments.

4.4 Wildlife Management

4.4.1 Waterfowl Management

The Waterfowl Management Program (WMP) was designed to study the relationship between trends in seasonal bird populations and fecal coliform concentrations both within the reservoirs and at the keypoint water sampling locations. The objectives of the program are to minimize fecal coliform loading to the reservoirs from roosting birds during the migratory season and curtail reproductive success of waterfowl during the breeding season.

Migratory populations of waterbirds utilize NYC reservoirs as temporary staging areas and wintering grounds and can contribute to increases in fecal coliform loadings during the autumn and winter, primarily from direct fecal deposition in the reservoirs. These waterbirds generally roost nocturnally and occasionally forage and loaf diurnally on the reservoirs, although most foraging activity occurs away from the reservoirs. In the past, avian fecal samples collected from both Canada geese (*Branta canadensis*) and ring-billed gulls (*Larus delawarensis*) revealed that fecal coliform concentrations are relatively high per gram of feces (Alderisio and DeLuca 1999). This is consistent with data from water samples collected over multiple years near waterbird roosting and

loafing locations, demonstrating that fecal coliform levels correspond to waterbird populations at several NYC reservoirs (DEP 2002). Increases in fecal coliform bacteria levels have been associated with increases in seasonal waterbird populations during the avian migratory and wintering periods. Continued implementation of avian dispersal measures has led to reduced waterbird counts and fecal coliform levels, allowing DEP to maintain compliance with the federal SWTR.

Historical water quality monitoring data collected at the two main water influent and effluent facilities at Kensico, demonstrated that higher levels of fecal coliform bacteria were leaving the reservoir than were entering through aqueducts from the upstate reservoirs (DEP 1992). It was apparent then that a local source of fecal coliform bacteria was impacting Kensico.

One of DEP's Watershed Protection Program objectives was to identify and mitigate all potential sources of fecal coliform bacteria at Kensico Reservoir. Implementation of waterbird dispersal actions began in the autumn of 1993 and resulted in an immediate and marked decline in bacteria. Based on these data, DEP determined that waterbirds were the most important contributor to seasonal fecal coliform bacteria loads to Kensico.

The WMP includes standard bird management techniques at several NYC reservoirs that were approved by the U.S. Department of Agriculture's (USDA) Animal and Plant Health Inspection Service's Wildlife Services, and in part under Resident Canada Goose Registration and Depredation Permit by the U.S. Fish and Wildlife Service (USFWS), and a License to Collect and Possess with NYSDEC.

Avian management techniques include non-lethal dispersal actions by use of pyrotechnics, motorboats, airboats, propane cannons, remote-control boats, and physical chasing. Bird deterrence measures include waterbird reproductive management, nest removals of terrestrial avian species, shoreline fencing, bird netting, overhead bird deterrent wires, and meadow management.

The Surface Water Treatment Rule (40 CFR 141.71(a)(1)) states that no more than 10 percent of source water samples can exceed 20 fecal coliforms $100mL^{-1}$ over the previous six-month period. Since the inception of the WMP, no such violation has occurred at Kensico Reservoir. The success of the WMP is demonstrated by comparing source water fecal coliform levels before and after the implementation of the WMP (Figure 4.13). DEP will continue implementation of the WMP to help ensure delivery of high-quality water to City consumers.

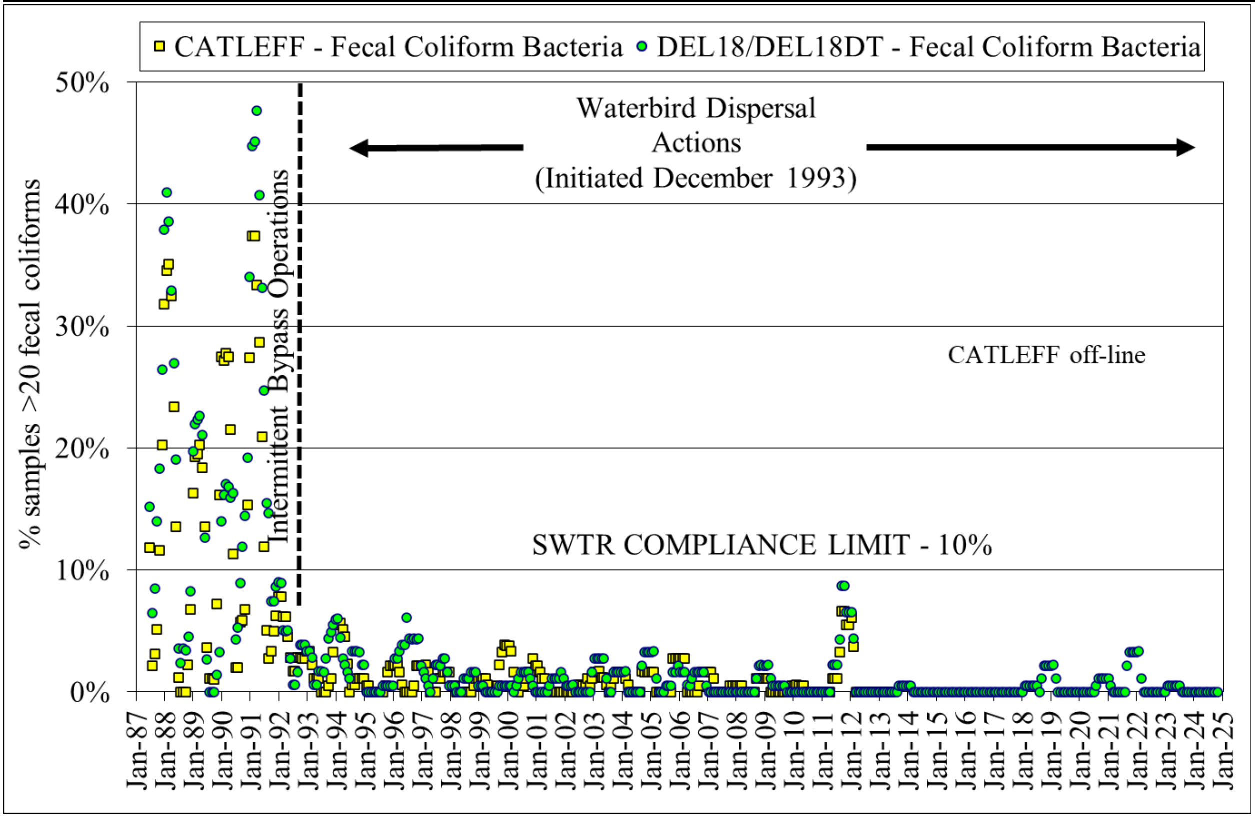

Figure 4.13 Percent of keypoint fecal coliform samples at Kensico Reservoir greater than 20 fecal coliforms 100mL-1 for the previous six-month period, 1987-2024. The first vertical dashed line indicates the year in which the WMP was implemented.

4.4.2 Terrestrial Wildlife Management

In advance of storm events that are expected to yield substantial precipitation levels and on a weekly schedule, wildlife excrement sanitary surveys are conducted adjacent to the Delaware effluent facility (Shaft 18) at Kensico Reservoir in the vicinity of the source water intake. Fecal excrement from birds and mammals is collected during these surveys, identified to species, and disposed of in advance of precipitation events to prevent the feces from being washed into the reservoir.

In calendar year 2024, DEP's contractor conducted 52 wildlife sanitary surveys at Kensico Reservoir (Table 4.7). Of the 2,666 fecal samples collected, 99.2% were confirmed to species level and 73% were attributed to passerine birds, 14% Canada geese, 6% to white-tailed deer (*Odocoileus virginianus*), 6% rabbits (*Sylvilagus spp.*) and the remaining to raccoons (*Procyon lotor*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), and unknown mammals. All samples were removed from the property following collections.

Table 4.7 Wildlife sanitary surveys conducted adjacent to Delaware Aqueduct Shaft 18.

Date of Survey	**Surveys per Month**	**White-tail Deer**	**Raccoon**	**Rabbit**	**Coyote**	**Bobcat**	**Canada Goose**	**Passerine (birds)**	**Other/ Unknown Mammal (Mink)**	**Total (all species)**
Jan-24	3	1	0	7	0	0	0	1	0	9
Feb-24	5	55	1	7	6	0	0	0	0	**69**
Mar-24	5	17	0	14	1	0	2	3	6	**43**
Apr-24	4	3	0	3	2	0	56	21	0	**85**
May-24	5	2	0	0	0	1	295	67	6	**371**
Jun-24	4	2	0	0	0	0	13	96	1	**112**
Jul-24	4	5	0	1	3	0	0	385	0	**394**
Aug-24	5	0	0	0	0	0	0	464	0	**464**
Sep-24	4	21	0	5	5	0	0	207	3	**241**
Oct-24	5	0	0	0	2	0	0	689	1	**692**
Nov-24	4	36	0	66	1	0	0	9	4	**116**
Dec-24	4	5	0	63	1	0	0	0	1	**70**
Total by species	**52**	**147**	**1**	**166**	**21**	**1**	**366**	**1,942**	**22**	**2,666**
Percent by species		**6%**	**<1%**	**6%**	**<1%**	**<1%**	**14%**	**73%**	**<1%**	

5. Modeling and Analysis

5.1 Overview

DEP's Water Quality Modeling Program uses models to quantify the impact of climate change, changes in land use, individual and grouped components of the watershed protection program, operation of the water supply system, and water demand on the quantity and quality of water delivered to the City.

In 2024, DEP continued to assess the degree of extreme climate conditions in the watershed using an aggregated index. The index combines several extreme climate indicators and compares to a reference period. DEP completed and refined the analyses of decadal scale variability in future extreme precipitation using four multi-model sets of downscaled climate products for WOH watershed. In 2024, DEP also began developing a method to analyze drought in the City's water supply. To that end, DEP extended gridded estimates of climatic parameters like precipitation and temperature across the WOH watershed region. The gridded climate dataset PRISM (Parameter-elevation Regressions on Independent Slopes Model) is available only from 1981 to the present; however, through DEP efforts in 2024, DEP extended the data back to 1893. In 2024, DEP initiated a research project to assess the impact of climate variability on deciduous forest phenology in the WOH watershed region. Preliminary results indicated that the annual green-up and mid-green-up stages exhibit a slight upward trend (delays) across the watershed, while the annual peak stage shows a downward or advancing trend.

In 2024, DEP integrated the Daily CENTURY (DAYCENT) based forest growth algorithm into SWAT-Carbon (Soil and Water Assessment Tool-Carbon) model and renamed the integrated model as Terrestrial Aquatic Sciences Convergence-Forest (TASC-Forest) model. The TASC-Forest model can now simulate key forest processes, such as biomass and nutrient allocation, litterfall, death, and the transformation of various tree components into litter and soil carbon pools. DEP also conducted a study to assess the effects of land use, climate, and atmospheric nitrogen deposition on stream nutrient dynamics in the urbanized Amawalk and forested Boyd Corners watersheds. In 2024, DEP explored the potential of using the Hydrologic and Water Quality System (HAWQS) for simulating inflows from the lower Delaware watersheds. HAWQS is a web-based, interactive modeling tool based on the SWAT framework, which eliminates the need for user-provided computational resources.

DEP tested a ML model employing the XGBoost algorithm for assessing the vulnerability of septic systems in the WOH watersheds. The model was trained using hydroclimatic, soil, and topographic data, supplemented by parcel data information as predictor variables. The model effectively identified the relative importance of predictors and predicted the likelihood of septic system failure with an average accuracy of 80% when validated against an independent testing dataset.

DEP is continuing to work on a multi-year project to develop DBP formation potential models for source water streams, fate and transport models for DBP precursors in reservoirs, and DBP model for the City's distribution system. In 2024, DEP began testing of two-dimensional hydrothermal and water quality model CE-QUAL-W2 (W2) for predicting UV_{254} in Ashokan Reservoir. The modeling analysis continues to support DEP's earlier finding that the nature of organic matter exported from the watershed and into the water supply is nearly refractory, i.e., resistant to biodegradation.

DEP conducted several OST runs to guide operations of the Catskill Aqueduct and manage water quality in the aftermath of storms during December 2023-January 2024, and August 9-10, 2024. Furthermore, DEP conducted several runs to support the RWBT shutdown (pre-, during, and post-shutdown) work.

5.2 Climate Change Indicators for the Watershed

In 2024, DEP continued assessing climate change indicators and associated extreme meteorology and hydrology indices. The purpose of these indices is to describe the degree of extreme conditions for a given year relative to the reference period of 1970-2000. This reference period is used to calculate the 10^{th} and the 90^{th} percentiles for each indicator, with any indicator outside these values tagged as 'extreme'. Counts of these extreme values are summed for each year to generate the indices timeseries. Table 5.1 lists the indicators used in the calculation of extreme indices (Richter et al. 1996) (Sillmann et al. 2013)

Meteorology Index: The meteorology extreme index plot (Figure 5.1) shows that while the index for the baseline period (1970-1999) does not show a significant trend, the analysis period does show a clear and significant increase. Further, the meteorology index continues to show high variability in the underlying meteorological indicators relative to the reference period, with 47% of the indicators outside the 10^{th} – 90^{th} percentile range in 2024 (as compared to 20% during the reference period). While the trend is clear when aggregated across all airports, an individual airport may not show as clear of a trend. Table 5.2 describes the trends calculated for the extreme index. While all sites have a positive value for change, Binghamton, Burlington, Hartford, Newark, and Scranton have a significant trend with p-value less than 0.05.

Table 5.1 Lists the indicators used in the calculation of extreme climate indices.

Extreme Hydrology Indicators	Extreme Meteorology Indicators
Annual one-day minima - mean daily flow	End of Growing Season
Annual three-day minima - mean daily flow	Frost Days
Annual seven-day minima - mean daily flow	Growing Season Length
Annual 30-day minima - mean daily flow	Icing Days
Annual 90-day minima - mean daily flow	Max Annual Dry Spell Length
Annual one-day maxima - mean daily flow	Max Annual Wet Spell Length

Annual three-day maxima - mean daily flow	Maximum Consecutive Cool Days
Annual seven-day maxima - mean daily flow	Maximum Consecutive Warm Days
Annual 30-day maxima - mean daily flow	95th percentile Precipitation
Annual 90-day maxima - mean daily flow	99th percentile Precipitation
Low Flow Pulse Duration - Maximum Days	Precipitation > 10mm
Low Flow Pulse Duration - Mean Days	Precipitation > 20mm
Low Flow Pulse Duration - Median Days	Start of Growing Season
High Flow Pulse Annual Count	Summer Days
High Flow Pulse Duration - Maximum Days	Total Annual Precipitation
High Flow Pulse Duration - Mean Days	Tropical Nights
High Flow Pulse Duration - Median Days	Wet Days
	Annual mean minimum daily temperature
	Annual mean maximum daily temperature
	Annual mean daily temperature

Table 5.2 Results of meteorology extreme index trends for all airport sites. Trend is only described for locations with a p-value < 0.05.

Analysis location	**Trend**	**p-value**	**Tau**	**Change per year**
All Airports	Increasing	0.003	0.43	0.009
Albany	no trend	0.412	0.12	0.004
Binghamton	Increasing	0.018	0.34	0.009
Burlington	Increasing	0.029	0.31	0.008
Hartford	Increasing	0.015	0.35	0.011
Newark	Increasing	0.023	0.33	0.010
Scranton	Increasing	0.009	0.37	0.010
White Plains	no trend	0.278	0.16	0.004

Hydrology Index: The hydrology extreme index does not show significant trends during the analysis period, either at an aggregated level or at individual stream gauges. Figure 5.2 summarizes the extreme index for the average of all stream gauges. The index does appear to stabilize at a higher overall level based on the absolute value index relative to the baseline period, with a peak value of 68% of indicators in extreme conditions, but it does not have a significant change trend during the period of 2000-present. Because hydrologic conditions are more sensitive to antecedent conditions and other factors, there are additional biases introduced that may confound interpretation of hydrologic variables as direct indicators of climate change.

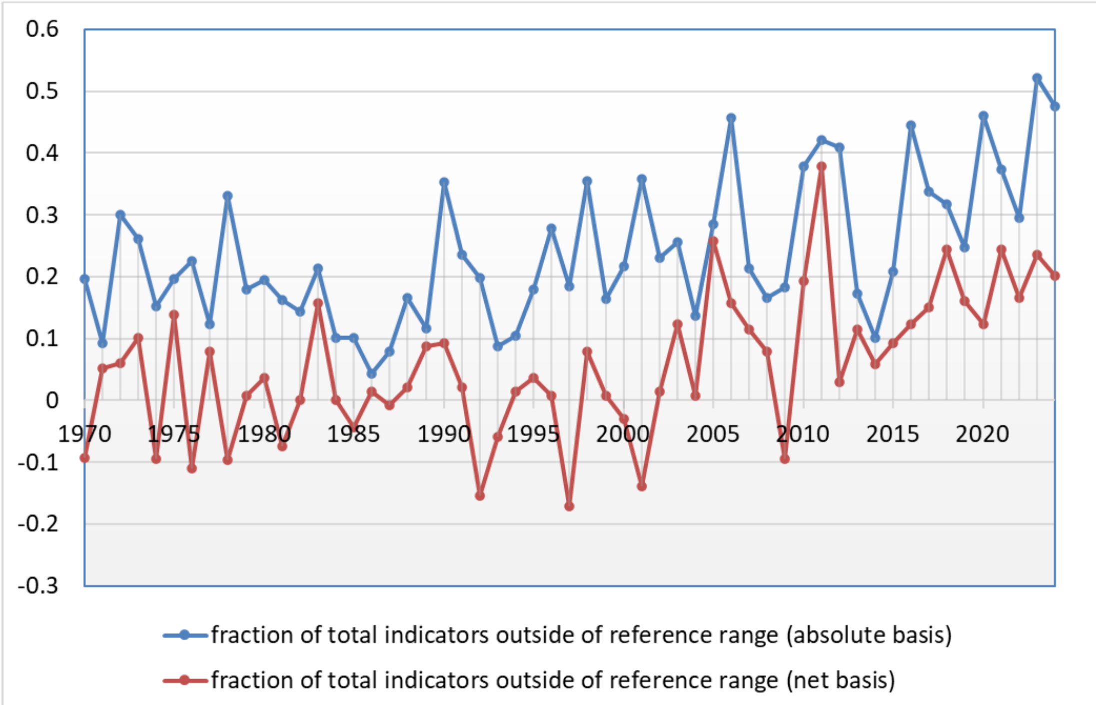

Figure 5.1 Meteorology extreme index results averaged across all airport locations for all indicators. When calculated on a net basis, a negative index value suggests that more indicators fell below the 10th percentile than exceeded the 90th percentile.

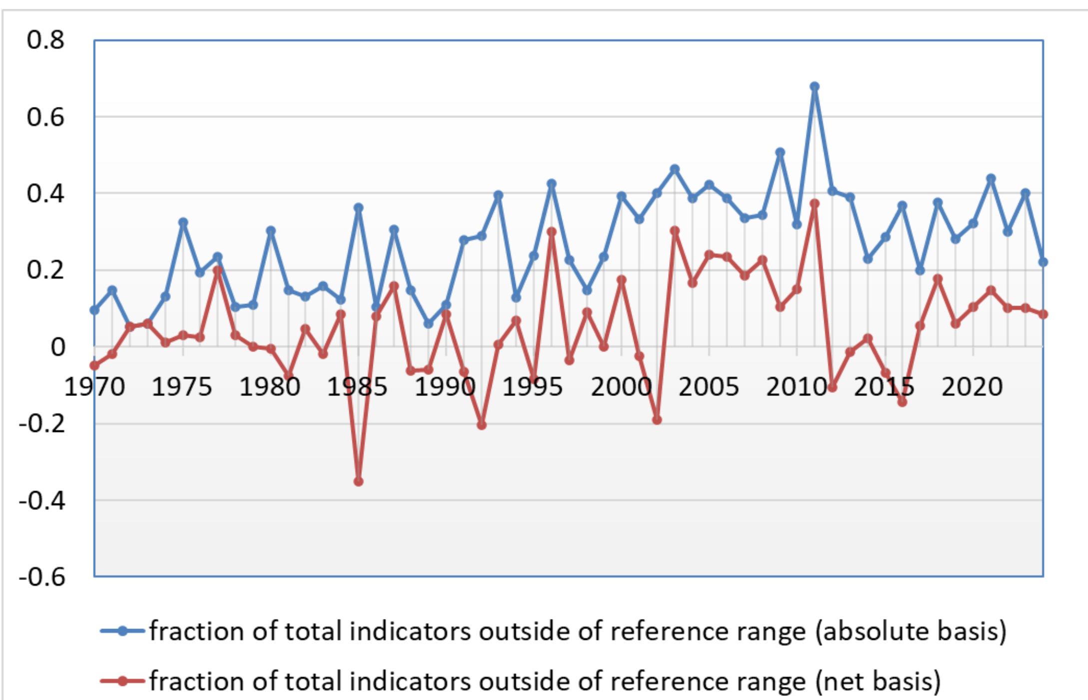

Figure 5.2 Hydrology extreme index results averaged across all stream gauges at reservoir inflows. When calculated on a net basis, a negative index value suggests that more indicators fell below the 10th percentile than exceeded the 90th percentile.

5.3 Extreme Precipitation Scenarios

In this portion of the project, DEP examined the likelihood and potential magnitudes of multi-year drought and pluvial precipitation events during the remainder of the twenty-first century. DEP uses Global Climate Models (GCMs) to provide a range of plausible precipitation scenarios for the WOH basins of the New York City Water Supply System. When using GCMs for relatively small-scale impact studies such as this it is common to encounter a complication referred to as “model bias”: while GCMs accurately capture most features of the climate system at large spatial scales, urban water supply systems are considered small scale in the context of a global model. For example, even a system as large as the WOH has a spatial extent that is less than or equal to the size of just one model grid point out of tens of thousands across the earth’s surface. Because GCMs are not meant to capture such fine scale features as accurately as larger scale features, impact studies often require corrections for small scale GCM biases. The most common of such “bias corrections” address temperature and precipitation simulations for mean and variance at time scales from daily to annual. However, these do not address biases at multiyear time scales.

Studies found in the literature have identified two tendencies that are common to GCM simulations across many regions of the globe, which DEP’s previous analyses have shown are true for the WOH region. The first is an underestimation by GCMs of historical multiyear precipitation variability compared to observations. The second is an increase in multiyear precipitation variability during the remainder of the 21st century compared to the historical period. The implication of these tendencies is that in some regions, including the WOH, GCMs do not capture the true magnitudes of multi-year drought or pluvial events, leading to a potential underestimation of the challenges in managing the water supply system for the remainder of the twenty-first century. Studies found in the literature have used a variety of metrics of precipitation “variability.” Here DEP uses the measure most relevant to DEP’s purpose, defining variability as the difference between the maximum (pluvial) and minimum (drought) values.

Prior to 2024 DEP developed a methodology to correct for GCM underestimation of multiyear precipitation variability over one basin (Frei et al. 2022); and, during 2023, DEP extended the methodology to include all six WOH basins, and four different downscaling techniques (Table 5.3). The inclusion of all these techniques allows DEP to compare GCMs to observations; to compare different downscaling techniques to each other; and, if possible, to identify particular GCMs or downscaling techniques that are most suitable for use in DEP’s region. During 2024 DEP refined the methodology and applied it to the full suite of GCMs described in Table 5.3, and prepared a manuscript which has now been submitted for publication (Frei et al. 2025, *in review*).

Table 5.3 Summary of downscaling groups.

Downscaling Group	N (No. of GCMs)	CMIP[1]	Scenario	Spatial resolution	Additional High Frequency Bias Correction period[3]	Reference
MACA	20	CMIP5	RCP 8.5	1/24°	1950-2005	(Abatzoglou and Brown 2012)
NASA	24	CMIP6	SSP5-8.5	¼ °	1985-2014	(Thrasher et al. 2022); Wood et al. (2002; 2004)
LOCA	30	CMIP6	SSP5-8.5	1/16°	1985-2014	(Pierce, Cayan, and Thrasher 2014; Pierce et al. 2015)
SPEAR-HI	10[2]	CMIP6	SSP5-8.5	¼°	1985-2014	(Delworth et al. 2020) (Jong et al. 2023)

[1] For information on CMIP5 and CMIP6, see https://wcrp-cmip.org/.

[2] SPEAR-HI includes ensemble members, not different GCMs. https://www.gfdl.noaa.gov/spear/ See text for explanation.

[3] High frequency bias correction method by (Gelda et al. 2019), using the method of (Li, Sheffield, and Wood 2010).

To demonstrate the motivation for this analysis, in this report DEP presents key features of one downscaled GCM precipitation time series in DEP's region for which DEP examined drought and pluvial events of 10-year duration (Figure 5.3). It is visually apparent in the figure that during the "calculation", or historical, period the station-based observed running mean (black) has a minimum value lower than, and a maximum value higher than, the GCM running mean (blue). Thus, in DEP's region GCMs underestimate multiyear variability and extremes. GCMs also predict that mean precipitation in DEP's region is likely to increase (red line); and that multiyear precipitation variability will increase, as indicated by visual comparison of the GCM running mean line (blue) during the historical and future periods.

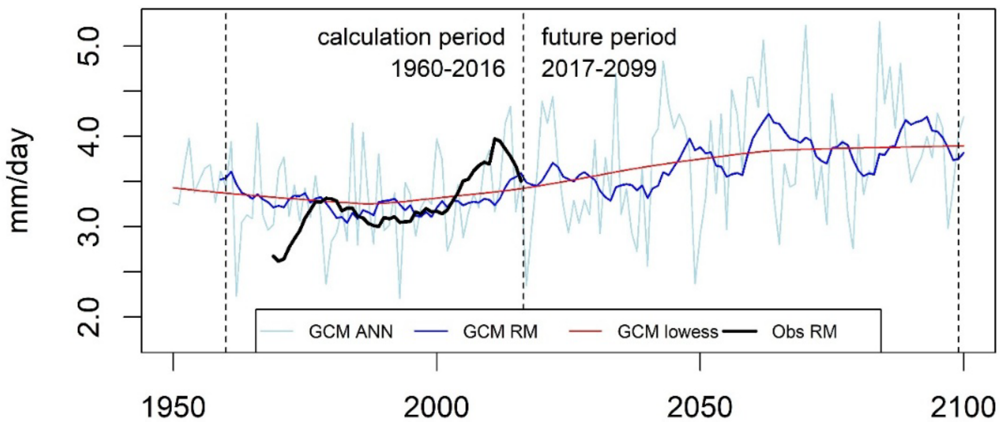

Figure 5.3 GCM and Observed Precipitation, 1950-2100. Shown in this figure are the example GCM annual (light blue) and 10-year running mean (blue) time series; example GCM Lowess smoother (red, smoothing parameter=2/3); observed 10-year running mean time series (black bold); and the calculation (i.e. historical) and future time periods (vertical dashed lines).

Figure 5.4 shows a demonstration of the application of the correction, which DEP calls Multiyear Precipitation Variability Bias Correction (MPVBC), during the historical period. The figure shows the running mean time series for uncorrected (blue solid) and corrected (blue dashed) GCM precipitation, and the observed running mean time series (black bold). The uncorrected GCM precipitation has less variability than the observations, and therefore underestimates extremes. The variability of the corrected GCM time series is greater than the uncorrected GCM time series, and in fact exactly matches the observed variability.

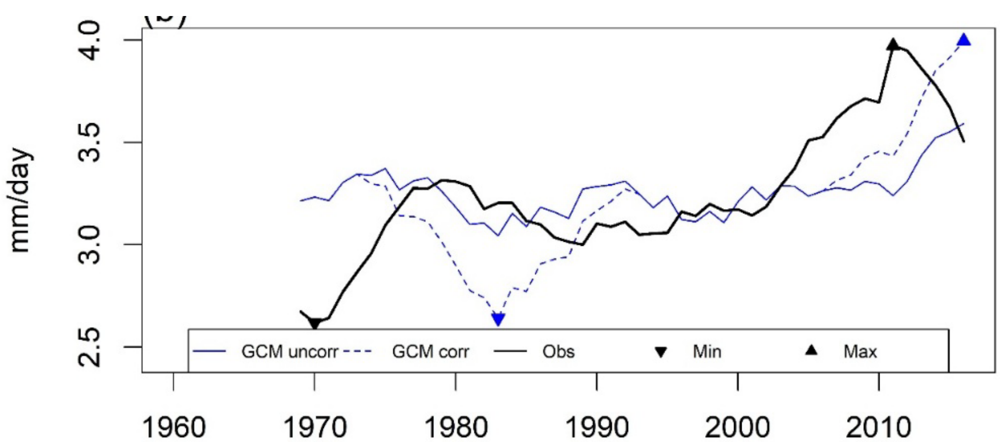

Figure 5.4 Application of MPVBC to the calculation time period (1960-2016). This figure shows 10-year running mean time series for uncorrected (blue) and corrected (dashed blue) GCM, and for observed (black), precipitation.

The factor by which the variability of the GCM time series was increased, which DEP calls the MPVBC Factor, or MPVBCF, is then applied to future simulations as well (Figure 5.5). In the future precipitation scenario presented in the figure, mean precipitation during the driest 10-year period dropped from 3.4 mm/day in the uncorrected GCM to 2.5 mm/day in the corrected GCM (from 1241 mm/year to 913 mm/year), a decrease of 26%. This means that, for this particular model and downscaling method, the application of DEP's correction results in a more realistic drought scenario, with 26% less precipitation than the uncorrected model, with which to employ DEP's hydrologic and operational models to test the resilience of the water supply system to potential future extremes. Without this correction the driest GCM 10-year scenario that would be considered vastly underestimates the magnitude of the potential drought that the City must prepare for.

Similarly, the wettest 10-year period in the future GCM scenario (Figure 5.5) has increased from an uncorrected value of 4.1 mm/day to a corrected value of 5 mm/day (from 1497 mm/year to 1825 mm/year), an increase of 18%. Managing a water supply system during pluvial extremes can be as challenging as during drought extremes, and in this example the magnitude of the potential challenge would be greatly underestimated without the correction.

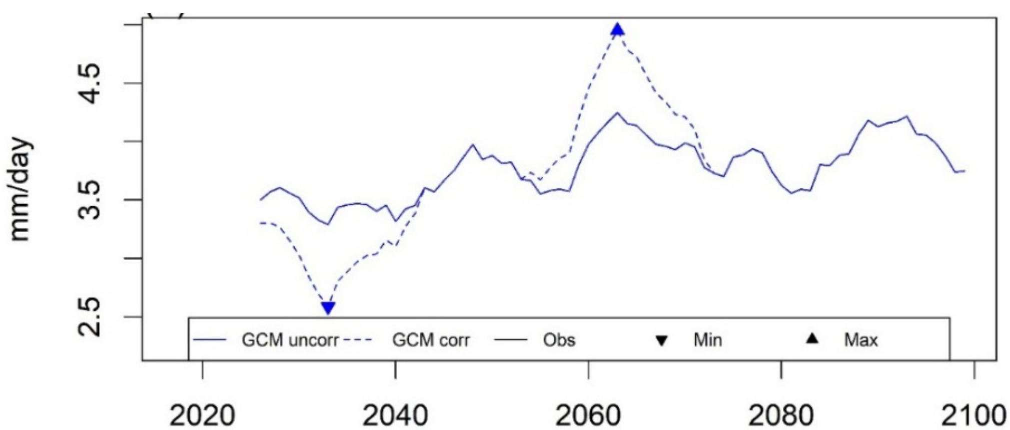

Figure 5.5 Application of MPVBC to the future period (2017-2099). As in Figure 5.4, except no observed values are included.

Figure 5.6 shows the impact of the correction on multiyear precipitation GCM extremes for future scenarios, for the full suite of models downscaled using the LOCA method, for durations from one to twenty years. DEP chose to show LOCA models here because, in DEP's region, model results downscaled using LOCA require *the smallest correction* of all four downscaling methods that DEP analyzed, and therefore may be the most applicable method for DEP's region (this may not be true in other regions). In this figure, each boxplot represents the range of results from all GCMs. For reference, the magnitudes of the extreme drought and pluvial events observed during the historical period are indicated on the figure with downward and upward triangles. Regarding drought, the open boxplots on the bottom half of the plot show the uncorrected GCM precipitation amounts for the extreme drought of each duration. Note that

the open boxplots are well above the downward triangles, meaning that the *uncorrected GCMs provide no drought scenarios comparable to the extreme that was experienced historically*. This is unrealistic. The corrected models (filled boxplots) provide a range of GCM drought scenarios at each duration which includes some drier, and some wetter, than the historical drought. This is realistic. Similarly, for future pluvial events of different durations, uncorrected GCMs (open boxplots on top half of the plot) include extreme wet scenarios only slightly wetter than the wettest historical period. With the corrections applied (filled box plots on top half of the figure), the models suggest much wetter extreme conditions.

These results suggest that uncorrected models do not provide extreme precipitation scenarios, either drought or pluvial, that are sufficiently extreme to adequately capture the full range of scenarios that the City's water supply system may experience in the coming decades. Corrected scenarios provide more realistic extreme precipitation scenarios, providing water managers with precipitation scenarios to adequately prepare for conditions that could plausibly be encountered during the remainder of the 21st century. During 2025 DEP's goal is to publish these results, and then use these precipitation scenarios to drive DEP's WOH water supply system hydrologic and operational models to evaluate the resilience of DEP's system to any plausible extreme scenario.

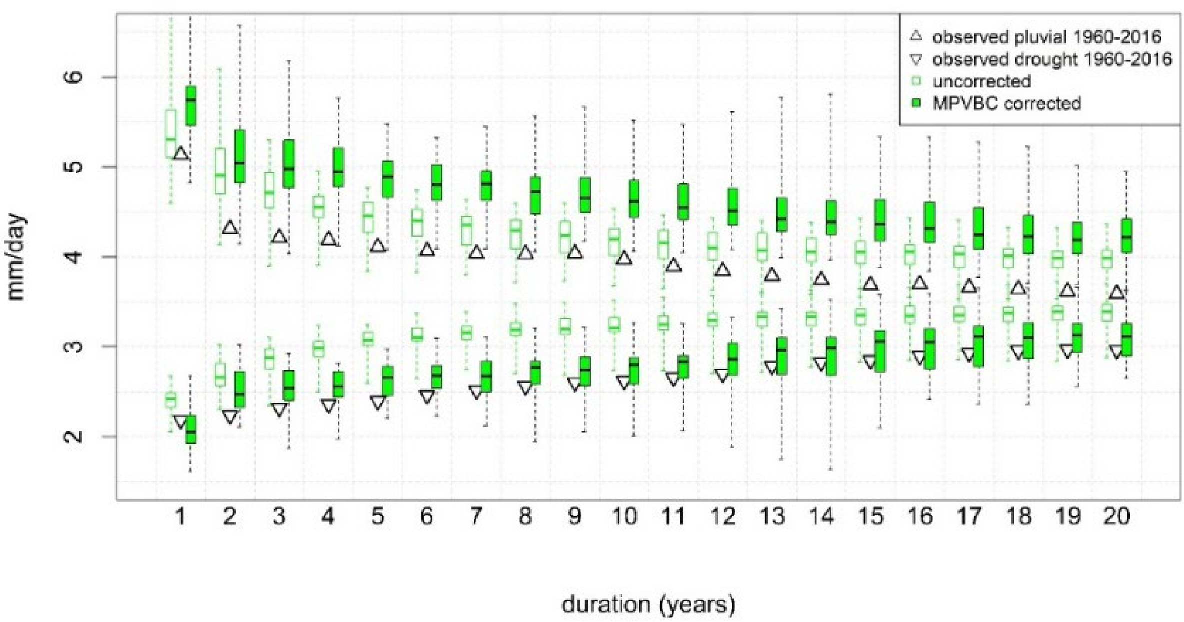

Figure 5.6 Future period mean (2017-2099) LOCA GCM precipitation during pluvial and drought events including uncorrected (open boxes) and corrected (filled boxes) values. Boxplots show the distribution of values for LOCA GCMs for each duration. Also shown are calculation period observed pluvial (upward pointing triangles) and drought (downward pointing triangles) extreme events.

5.4 Drought Modeling

Reliable drought modeling is essential for effective management of City's water supply, with direct implications for public health, ecosystem stability, and urban resilience. Accurate drought prediction depends on high-quality, long-term historical climate data. However, significant data gaps and limited historical coverage in existing datasets present major challenges to developing robust drought models. To address these limitations, this study aims to reconstruct continuous daily temperature and precipitation climate time series for the WOH and EOH watersheds of New York City. Existing gridded datasets, such as PRISM, offer valuable spatial coverage but are only available daily from 1981 onward. By leveraging long-term point-station observations dating back to the late 1800s, this study seeks to extend the temporal coverage of gridded climate data critical for drought analysis.

Initiated in 2024, this work focuses on two key tasks: (1) filling gaps in historical station records, and (2) using the gap-filled station data to reconstruct PRISM-like daily climate data back to 1893. To accomplish this, a range of methods—including statistical techniques, machine learning (ML), and deep learning (DL)—were applied to capture complex temporal patterns and improve the reliability of the reconstructed records.

This study integrates two core climate datasets to support improved drought modeling in later stages within the NYC watershed. First, long-term observational records from 12 temperature and 19 precipitation stations, sourced from NOAA's Global Historical Climatology Network (GHCN), provide data from 1890 to 2025. For the period 1948–2024, the 12 selected stations consistently exhibit median percentages of missing daily temperature data below 10%. Similarly, as illustrated in Figure 5.7, the 19 precipitation stations also show median missing-value percentages below 10% over the same period. Second, daily temperature and precipitation data from the PRISM Climate Group (1981–2024) are used, averaged over six WOH watersheds (Ashokan, Cannonsville, Neversink, Pepacton, Rondout, Schoharie) and one for the entire EOH watershed.

A variety of methods are available for gap-filling and reconstruction of historical climate data, ranging from traditional statistical approaches to advanced computational techniques. These include simple regression models, such as linear and multiple linear regression, as well as machine learning methods like Random Forest, Gradient Boosting Trees, and K-Nearest Neighbors. Additionally, deep learning approaches, such as Long Short-Term Memory (LSTM), Bidirectional LSTM, and transformer-based models, are increasingly utilized, alongside hybrid systems combining statistical and AI-driven techniques. The selection of method typically depends on the nature of the data gaps, the spatiotemporal characteristics of the dataset, and the intended modeling application.

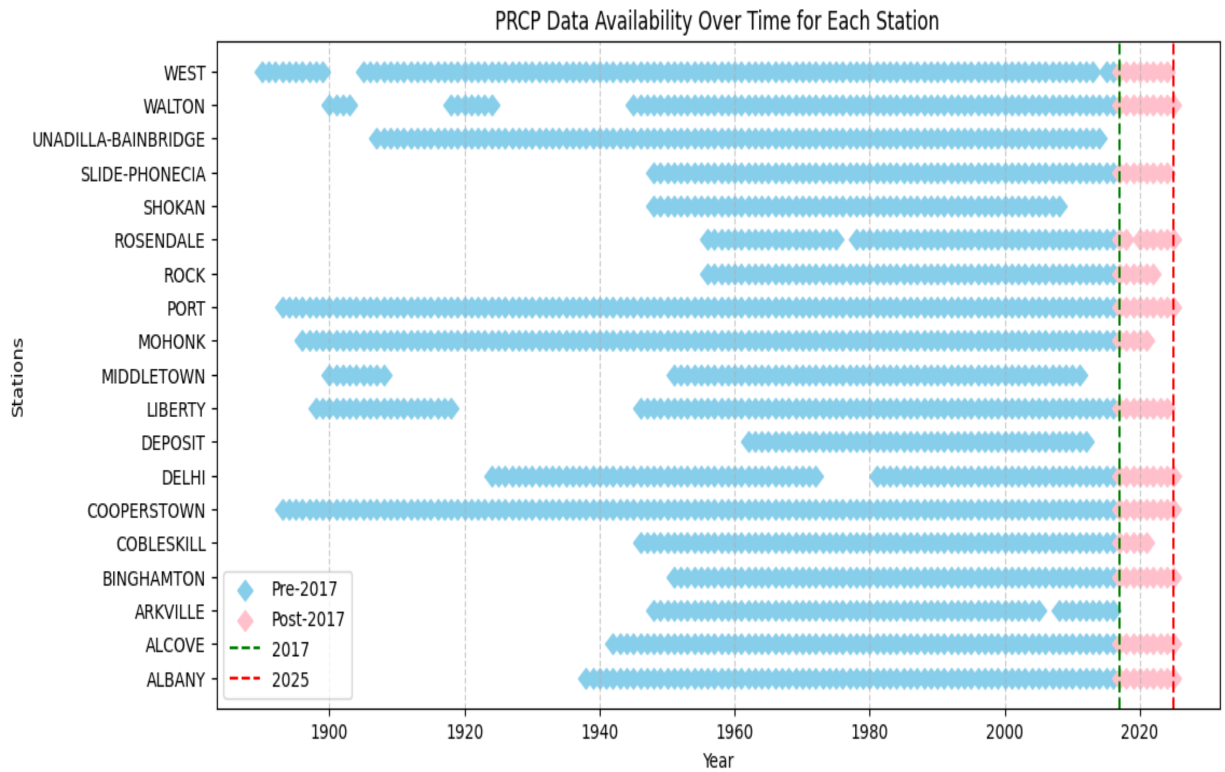

Figure 5.7 Precipitation data availability (1890–2025).

DEP's best-performing models for gap-filling historical climate data were a unified Long Short-Term Memory (LSTM) neural network for daily minimum (Tmin) and maximum (Tmax) temperature estimation and a two-tier LSTM framework for precipitation classification and prediction. For data reconstruction, a Bidirectional LSTM (Bi-LSTM) model exceled in reconstructing temperature, while Random Forest regression effectively reconstructed precipitation, yielding robust daily climatological records from 1893 to 2025. An example of the model performance for both gap-filling and reconstruction is shown in Table 5.4. Related timeseries of gap-filled and reconstructed datasets are shown in Figure 5.8 and Figure 5.9.

Table 5.4 Best performing models and evaluation metrics for gap-filling (Delhi) and reconstruction (Ashokan) of daily climate variables.

Gap filling of Delhi station data					Reconstruction of Ashokan watershed data			
Variable	Model	MAE	RSME	R2	Model	MAE	RSME	R2
Tmin	Unified LSTM	0.093 °C	0.129 °C	0.999	Bi LSTM	0.432 °C	0.637 °C	0.996
Tmax	Unified LSTM	0.092 °C	0.147 °C	0.999	Bi LSTM	0.466 °C	0.673 °C	0.996
Precip	Two-tier LSTM	0.012 cm	0.04 cm	0.997	RF	0.040 cm	0.1 cm	0.987

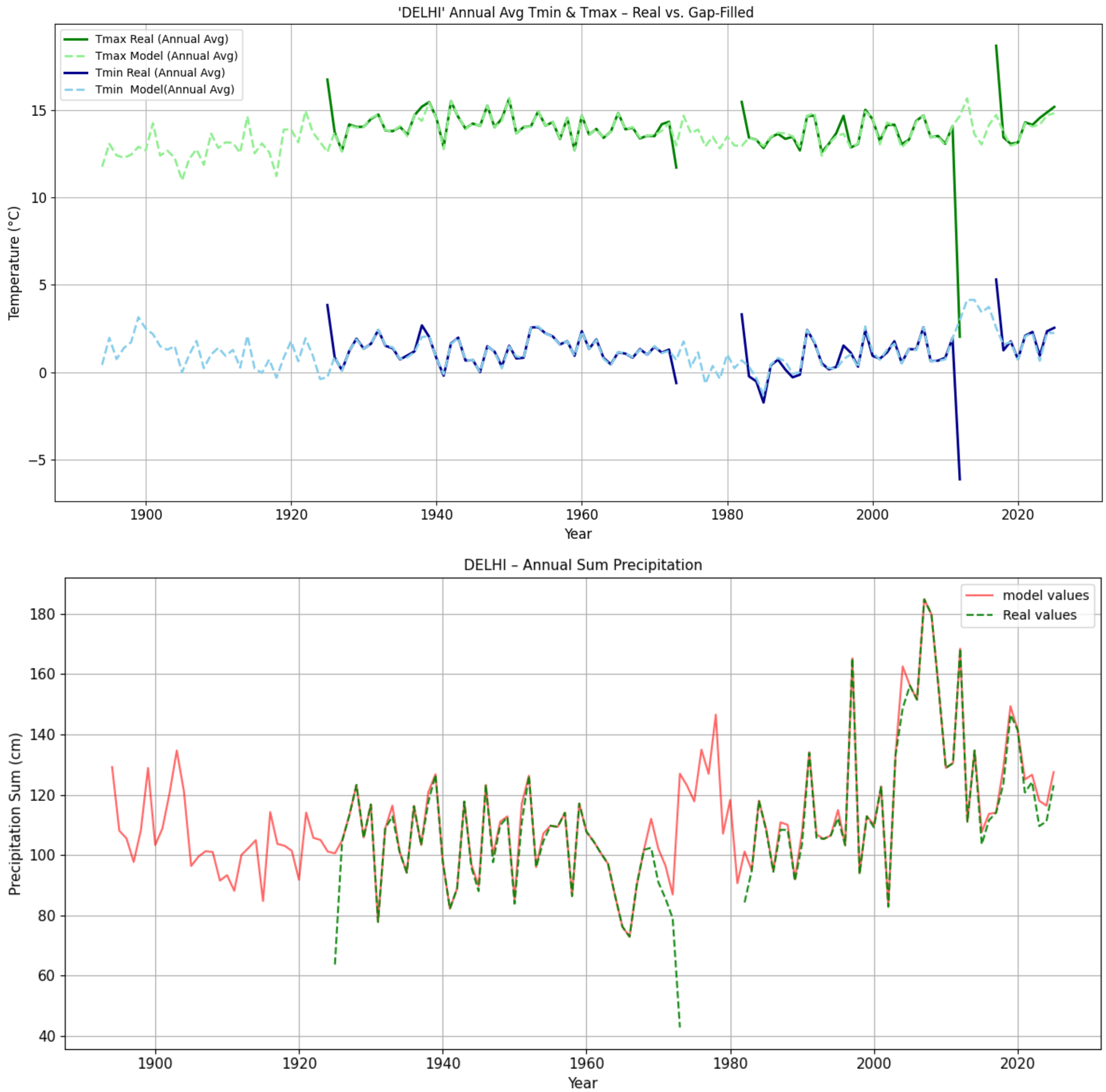

Figure 5.8 Timeseries of gap-filled maximum temperature, minimum temperature, and precipitation at Delhi station

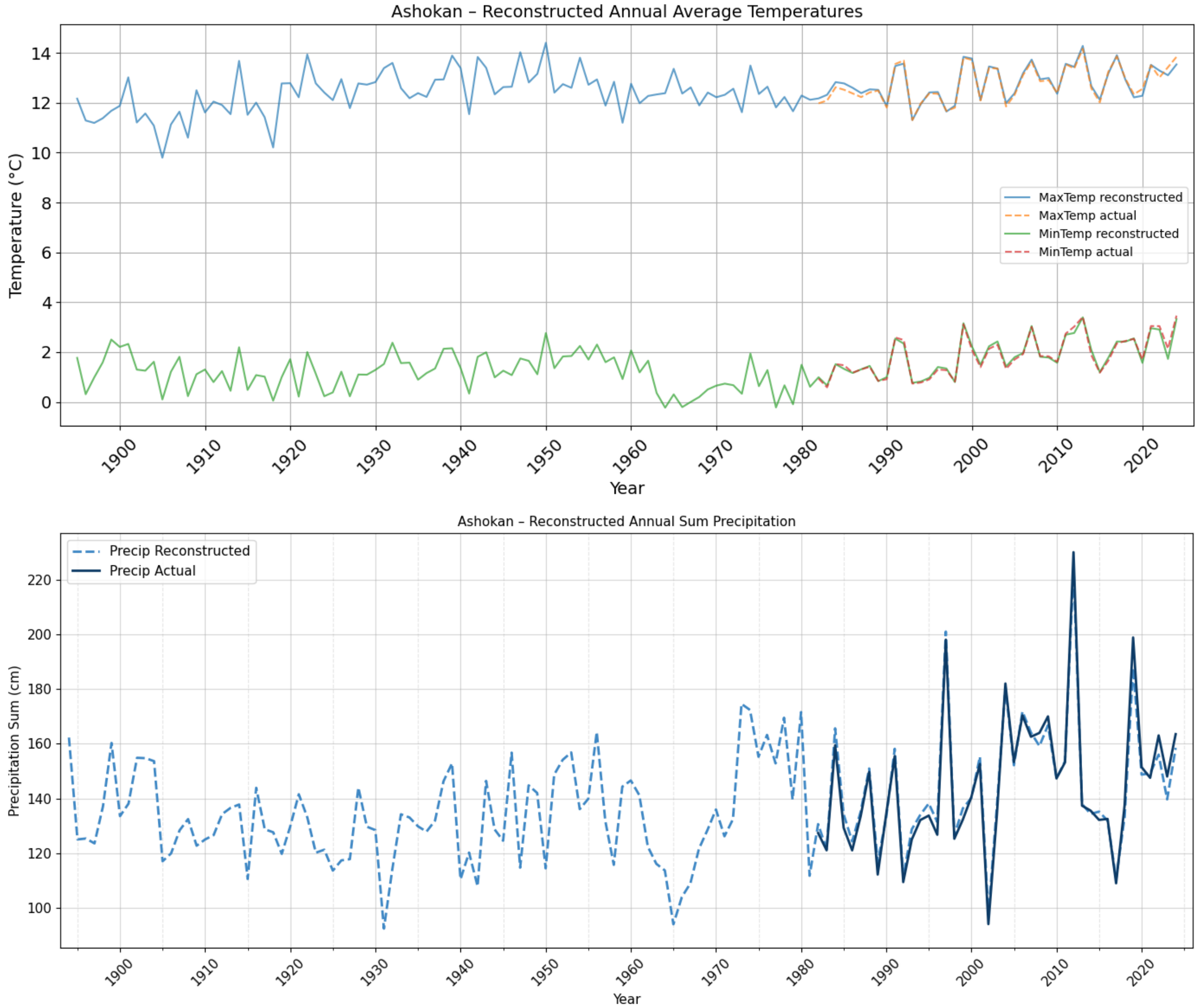

Figure 5.9 Timeseries of reconstructed maximum temperature, minimum temperature, and precipitation for Ashokan watershed

These results were consistently observed across other watersheds, indicating that the selected models are effective for generating reliable, long-term climatological datasets, thereby validating the use of ML-based approaches for gap-filling and reconstructing. Future research will consider evaluating reconstructions using models that incorporate Tmin, Tmax, and precipitation as multivariate inputs. Additionally, efforts will focus on utilizing supplementary regional data sources to enhance model validation and interpretability.

5.5 Climate Variability and Deciduous Forest Phenology

In 2024, DEP started a research project to assess the impact of climate variability on deciduous forest phenology in the WOH watershed region. The specific objectives were to identify the most suitable remote sensing product for monitoring forest phenology in the area and to investigate the influence of climate variability on forest phenology dynamics. After reviewing the literature, DEP selected Moderate Resolution Imaging Spectroradiometer (MODIS) products

for the study, rather than Landsat, Sentinel, Advanced Very-High-Resolution Radiometer (AVHRR), or Visible Infrared Imaging Radiometer Suite (VIIRS) products. This decision was based on MODIS's extensive historical data availability and high temporal resolution. Since the study focuses on detecting phenological changes, priority was given to temporal resolution over spatial resolution.

The MODIS Land Cover Dynamics Product (MCD12Q2) Collection 6.1 was used in this study. This phenology product maps global land surface phenology metrics (hereafter referred to as "phenometrics") at a 500-meter spatial resolution and at an annual time step. The phenometrics are derived from time series of MODIS-observed land surface greenness, calculated using a 2-band Enhanced Vegetation Index (EVI2), as described in Table 5.5 and illustrated in Figure 5.10.

Table 5.5 Description of phenometrics detected from MCD12Q2.

Phenology stage	Description
Greenup	Date when EVI2 first crossed 15% of the segment EVI2 amplitude
Mid Greenup	Date when EVI2 first crossed 50% of the segment EVI2 amplitude
Peak	Date when EVI2 reached the segment maximum
Maturity	Date when EVI2 first crossed 90% of the segment EVI2 amplitude
Senescence	Date when EVI2 last crossed 90% of the segment EVI2 amplitude
Mid Greendown	Date when EVI2 last crossed 50% of the segment EVI2 amplitude
Dormancy	Date when EVI2 last crossed 15% of the segment EVI2 amplitude

Multitemporal remote sensing imagery from the MODIS Land Cover Dynamics Product (MCD12Q2) Version 6.1 was used to extract phenology data for the period from 2001 to 2022. In these images, all pixel values represent the average date (Julian day) of the phenology stage across the watershed. Additionally, MODIS Enhanced Vegetation Index (EVI) data (MOD13A1), available at 16-day intervals, and Leaf Area Index (LAI) data (MCD15A3H Version 6.1), available at 4-day intervals, were used to supplement the analysis. EVI values typically range from -1 to +1, with values between 0.20 and 0.80 indicating healthy vegetation. Leaf Area Index is defined as the one-sided green leaf area per unit ground area in broadleaf canopies and as half the total needle surface area per unit ground area in coniferous canopies. Both the EVI and LAI datasets were available at a 500-meter spatial resolution.

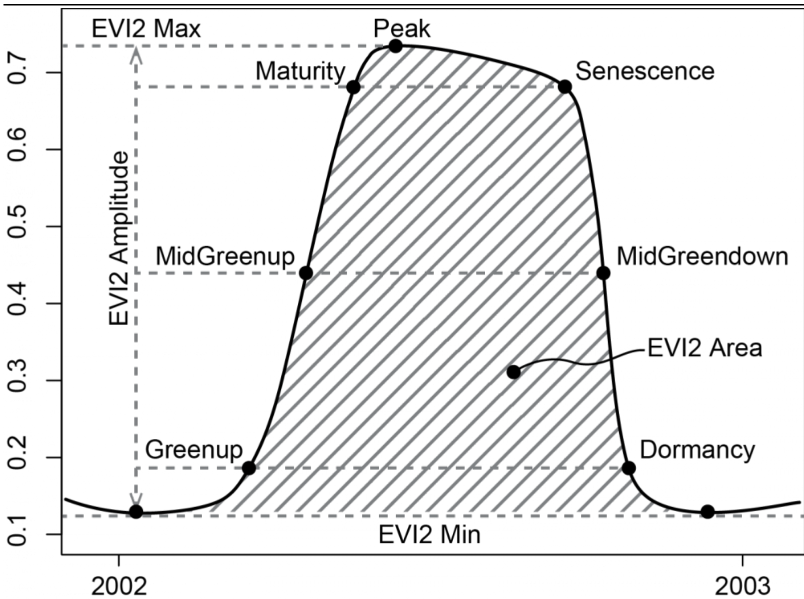

Figure 5.10 Diagram of phenometrics for a hypothetical vegetation cycle. (Source: https://www.usanpn.org/data/maps/land_surface_phenology).

Daily precipitation, along with minimum and maximum air temperature data, were obtained from the Parameter-elevation Relationships on Independent Slopes Model (PRISM, (Daly et al. 2008), available as 4-kilometer grids. These data were used to derive climate factors (Table 5.6) based on the criteria outlined by Xie et al. (2015a).

Table 5.6 Climate factors used as variables and their description.

Variables	Description
Hot Days (HD)	No. of days with Tmax ≥ 32 or 35 °C
Frost days (FD)	No. of days with Tmin ≤ 0 °C
Rainy days (RD)	No. of days with precipitation ≥ 2 mm
Heavy rainy days (ECA)	No. of days with precipitation ≥ 20 mm
Rainfall	Amount of rainfall per year.

*Tmax = Daily Maximum Temperature, Tmin = Daily Minimum Temperature

Based on the criteria mentioned above, temperature and rainfall data were categorized into HD, FD, RD, and ECA. For temperature data, only a limited number of days exceeded 32°C, so the threshold was reduced to 25°C, while other factors remained unchanged. In addition, Heat Units were calculated using the following formula:

Heat Units = [(Maximum Temp. + Minimum Temp.) / 2] - Threshold Temp.

A threshold temperature of 10°C was used to calculate the heat units (Xie et al. 2015b).

The Mann-Kendall trend test, widely used to detect and quantify trends in time series data, indicated that the annual greenup and midgreenup stages exhibit a weak upward trend

(delays) across the watershed, while the annual peak stage shows a weak downward or advancing trend. None of the observed trends were statistically significant (p-value > 0.05). (Figure 5.11).

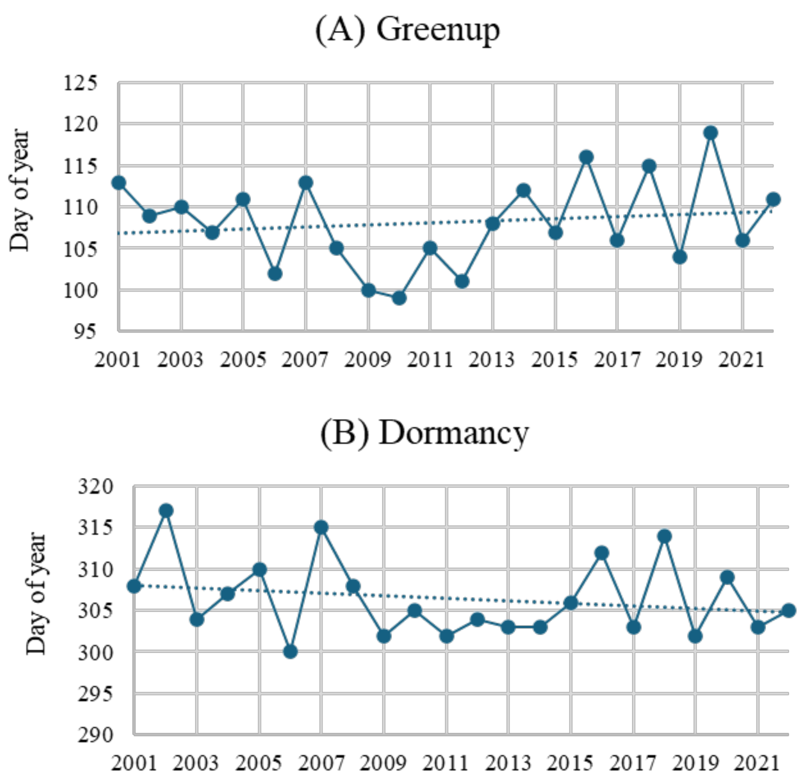

Figure 5.11 Trend in deciduous tree phenology in west-of-Hudson (WOH) watersheds; Greenup (A) and Dormancy (B).

Table 5.7 presents the correlation between climatic factors and phenological stages. This analysis revealed a weak negative correlation with rainfall, suggesting that increased rainfall advances phenological events. Conversely, a positive correlation was observed between the number of hot or frost days and phenological stages, indicating that phenological responses are delayed under these conditions.

Table 5.7 Correlation among climatic factors and phenological stages.

Stage	Rainfall	Frost days	Hot Days	Rainy Days	Heat Unit
Greenup	-0.154	**0.654**	0.290	-0.192	0.231
Mid Greenup	-0.068	**0.699**	0.276	-0.085	0.144
Peak	-0.093	0.410	0.253	-0.078	0.020
Maturity	-0.111	**0.555**	0.289	-0.108	0.083
Senescence	-0.273	**0.562**	**0.580**	-0.306	0.334
Midgreen down	-0.208	0.397	0.403	-0.185	0.083
Dormancy	-0.089	**0.578**	**0.588**	-0.145	**0.505**

*Values in bold are statistically significant with a significance level alpha=0.05

Based on the MODIS phenology product user guide, Midgreenup was considered the Start of Season (SOS), and Midgreendown was considered the End of Season (EOS). In the study area, day 134 was considered SOS, and day 223 was considered EOS, representing the median Midgreenup and Midgreendown dates. The corresponding EVI values were used to examine SOS and EOS variation over the past 23 years. Both SOS and EOS EVI show an upward trend over this period (Figure 5.12 A and B), indicating an increase in the length of the growing season. A comparison of yearly EVI data for 2001–2011 and 2012–2023 reveals a similar seasonal pattern for both decades, with peak EVI occurring around Julian days 145-193, which corresponds to the peak of the growing season (Figure 5.13). However, slight differences in EVI values were observed between the two periods, with the 2012–2023 series showing a marginally higher peak EVI compared to the 2001–2011 series. This suggests a potential increase in forest productivity in recent years.

This study is exploratory research on understanding how remote sensing products can be used to assess climate-phenology relationship in the Catskill region. Preliminary results from this analysis shows promise and the potential for MODIS remote sensing products to study the interaction between climate and forest growth dynamics in the region. Future work could explore how climate extremes, such as heatwaves, floods, droughts, and frost events, influence forest productivity and water quality in NYC watersheds.

5.6 TASC-Forest Model for Simulating Carbon in Forest Ecosystem

Process-based models have been widely used to understand the carbon and water cycling processes within forest ecosystems and to assess the impacts of natural disturbances and management practices under extreme weather events. Watershed models such as SWAT/SWAT-Carbon, which is part of the DEP's hydrologic models, often do not include state-of-the-art representation of forest ecosystem processes, therefore limiting their use in assessing environmental impacts of forest disturbance (e.g., land use change, forest management, and extreme weather events). Consequently, there is an urgent need to improve the current simplified forest growth algorithm by incorporating a process-based forest growth sub-model to enhance the simulation of forest growth dynamics.

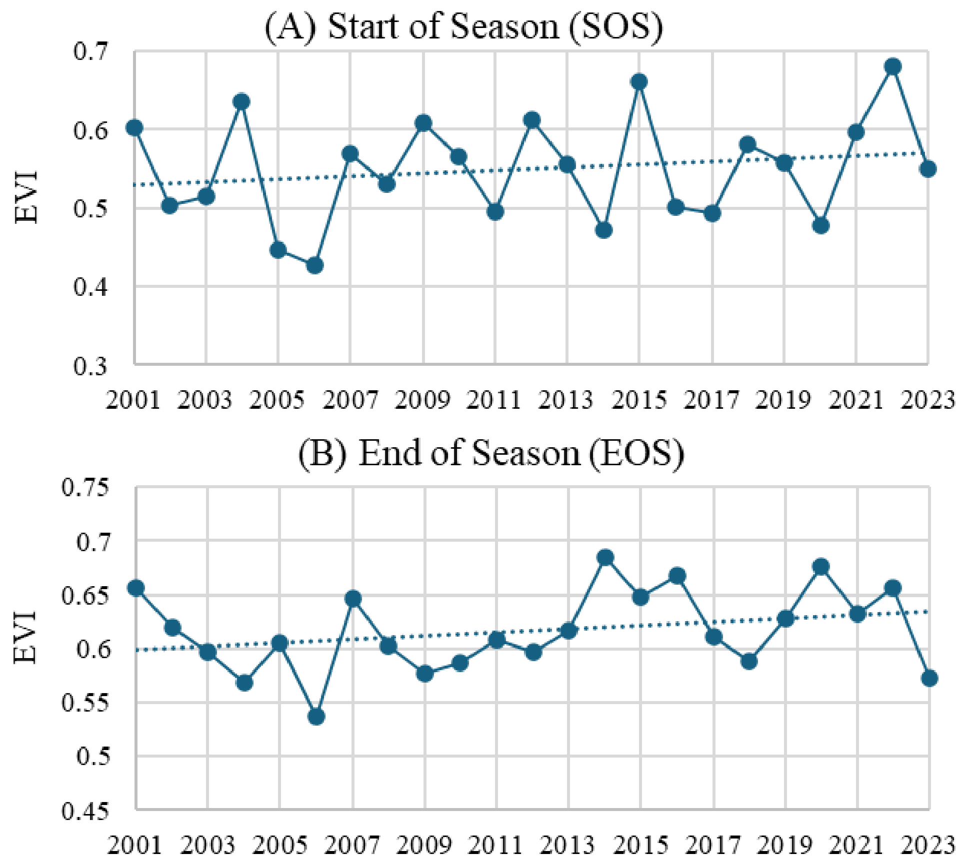

Figure 5.12 Trend in EVI during start of season (A) and end of season (B).

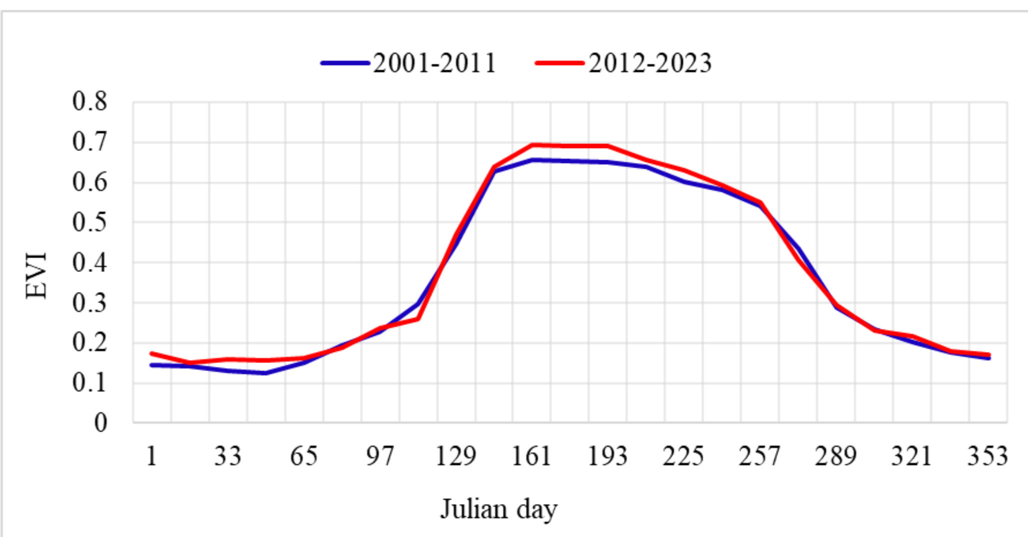

Figure 5.13 Difference in average annual EVI over two decades.

In this study, DEP integrated the Daily CENTURY (DAYCENT) based forest growth algorithm into SWAT-Carbon (Soil and Water Assessment Tool-Carbon) model and renamed the integrated model as Terrestrial Aquatic Sciences Convergence-Forest (TASC-Forest) model. Through this integration DEP aims to improve the representation of key forest processes, such as biomass and nutrient allocation, litterfall, death, and the transformation of various tree components into litter and soil carbon pools. DEP evaluated TASC-Forest's ability to simulate monthly carbon fluxes, i.e., net ecosystem exchange (NEE) and ecosystem respiration (R_{eco}), and evapotranspiration (ET) across multiple forest biomes: evergreen, mixed, and deciduous, using flux tower observations from seven AmeriFlux sites across the conterminous U.S.

5.6.1 Model setup, calibration, and validation

DEP used AmeriFlux eddy covariance-based monthly NEE and R_{eco} data. For NEE and Reco, DEP used NEE_VUT_REF and RECO_NT_VUT_REF, respectively, from the FLUXNET dataset. DEP calculated daily evapotranspiration from AmeriFlux observed late heat fluxes (LE_F_MDS), gap-filled with marginal distribution sampling approach, using algorithm suggested by the AmeriFlux data support system (Henderson-Sellers 1984) and aggregated it to monthly timescale. Using ArcSWAT, the model was set up for seven U.S. AmeriFlux sites (Figure 5.14). These sites, located at elevations ranging from 60 m to 3050 m, encompass forest biomes including evergreen, mixed, and deciduous forests. A detailed description of the model setup can be found in Yang and Zhang (2016).

DEP performed sensitivity analysis and calibration of model parameters using Sequential Uncertainty Fitting algorithm version 2 (SUFI-2) in R-SWAT (Nguyen et al. 2022). Using global sensitivity analysis in SUFI-2, DEP selected the most sensitive parameters (p-value ≤ 0.05) and iteratively calibrated the model parameters for each AmeriFlux site. DEP used monthly NEE, R_{eco}, and ET for model calibration and validation across various time periods (2006-2021; depending on the site). In addition, DEP used Taylor skill score (S) to summarize overall model performance for monthly NEE and to compare TASC-Forest performance with other ecosystem models tested at these sites (Schwalm et al. 2010). S ranges between zero and one, with one indicating perfect agreement.

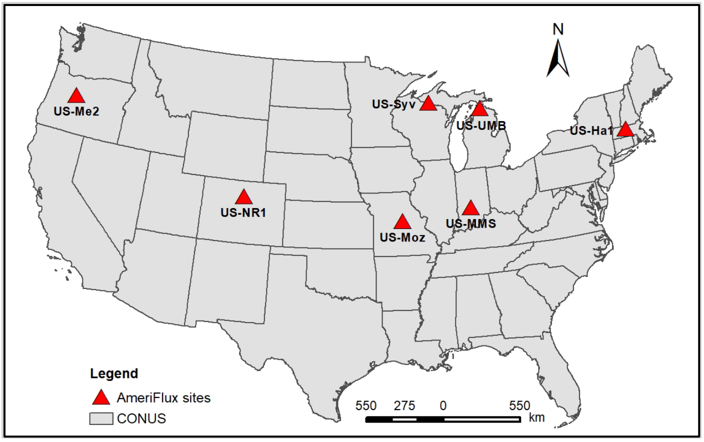

Figure 5.14 Location of seven U.S. AmeriFlux sites used for model evaluation.

5.6.2 Results

Net ecosystem exchange: Figure 5.15 compares the simulated and observed monthly NEE during calibration and validation periods across all sites. TASC-Forest reasonably simulates monthly NEE with $R^2 > 0.5$ and $KGE > 0.5$ during both calibration and validation periods but underestimates NEE by 15% during validation. High *KGE* values (≥ 0.5), particularly at deciduous sites, indicate good model performance in simulating NEE. However, the sites US-Syv and US-Me2 show poorer performance during the validation period, with *KGE* values less than 0. Despite this, both sites maintain moderate R^2 values greater than 0.3 and low *RMSE* during validation, suggesting that some aspects of model performance remain reliable even when *KGE* values are low.

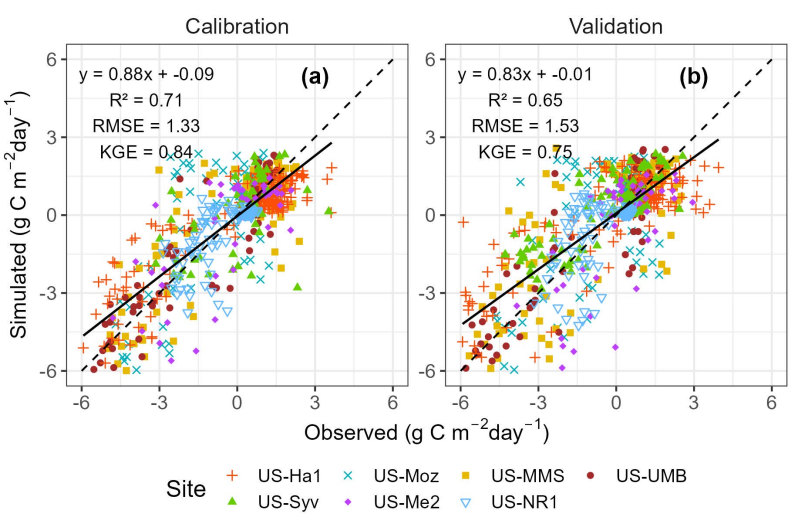

Figure 5.15 Comparison of simulated and observed monthly net ecosystem exchange during (a) calibration and (b) validation periods. Dashed line corresponds to 1:1 line.

Ecosystem respiration: Figure 5.16 shows the comparison between the simulated and observed monthly R_{eco} across all sites. TASC-Forest performs reasonably well in simulating R_{eco} with $R^2 > 0.5$ and $KGE > 0.4$ during calibration and validation periods, but underestimates R_{eco} by ca. 33% during both calibration and validation periods. The *RMSE* and *KGE* for simulated ecosystem respiration across the seven sites range from 1.04 to 4.09 and -0.17 to 0.66 during calibration, and from 1.03 to 3.52 and -0.03 to 0.71 during validation, respectively. Most sites exhibit moderate to good *KGE* values and low *RMSE* values, showing consistent performance during both calibration and validation periods. The model effectively simulates the seasonal variability of R_{eco} across most sites (R^2>0.5) during both calibration and validation periods, except for US-Me2 (R^2<0.3).

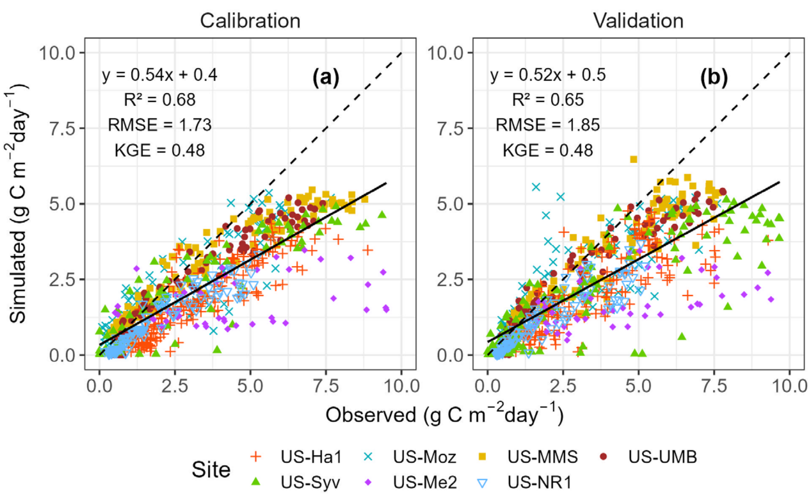

Figure 5.16 Comparison of simulated and observed monthly ecosystem respiration during (a) calibration and (b) validation periods. Dashed line corresponds to 1:1 line.

Evapotranspiration: TASC-Forest accurately simulated ET, achieving R^2>0.5 and *KGE*>0.8 (Figure 5.17). Additionally, TASC-Forest exhibited low bias of ca. -7%, during both the calibration and validation periods. Results from all seven sites indicate that the model accurately simulates the seasonal variability of ET at all sites (R^2>0.5) during both calibration and validation periods. The model performs well in terms of *KGE* for deciduous and mixed forest sites, with *KGE* > 0.5 during both calibration and validation periods. However, performance is notably poor at evergreen forest site US-NR1, where both R^2 and *KGE* are consistently low during both periods.

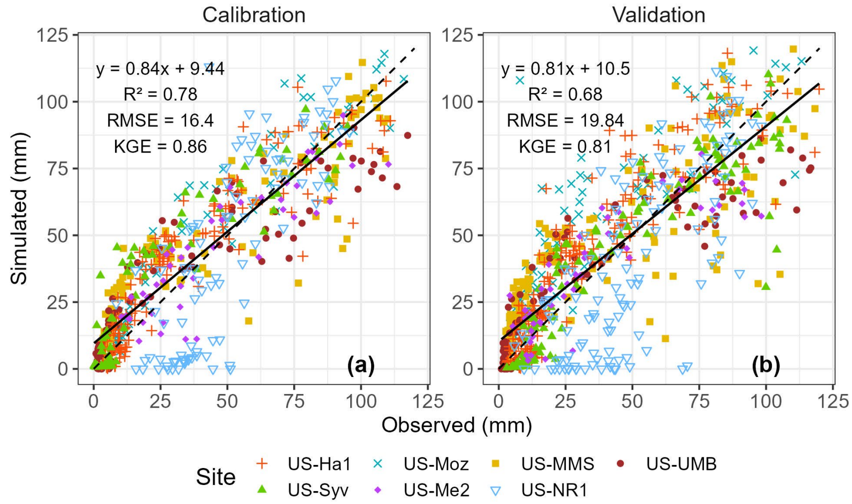

Figure 5.17 Comparison of simulated and observed monthly total evapotranspiration during (a) calibration and (b) validation periods. Dashed line corresponds to 1:1 line.

5.6.3 Discussion

Although the model generally performed well in simulating NEE and ET at most sites, it exhibited poor performance in simulating R_{eco}, consistently underestimating R_{eco} during the summer across all sites. A recent study by Huntzinger et al. (2020) found that other ecosystem models also exhibit difficulty in simulating R_{eco}, with most models underestimating R_{eco}. TASC-Forest performed poorly in simulating R_{eco} at US-Me2, located in the western U.S., which experiences warmer, wetter winters and drier summers compared to other sites. Soil respiration is influenced by soil organic matter content, temperature, and soil moisture (Huxman et al. 2003). DEP's results also show that soil moisture conditions have a significant impact on the simulation of carbon and ET fluxes. The dry summer conditions, which coincides with the model's overestimation of ET, slow the decomposition and transformation of carbon pools, resulting in the underestimation of R_{eco} at US-Me2 compared to other sites. Reynolds et al. (2015) similarly identified soil moisture as a limiting factor that constrains soil respiration, even under warmer conditions. These results indicate potential gaps in both the model and the data related to soil water simulation, where drier conditions lead to significant underestimation of R_{eco} during the summer months. Further investigation is needed in other regions with similar climatic conditions to address these issues.

DEP evaluated the performance of TASC-Forest model using results from seven forested sites, which included three forest types: deciduous, evergreen, and mixed. However, these sites do not encompass a broad range of forest types and ecoregions, which vary in tree carbon and nutrient uptake, allocation, storage, loss, and soil carbon dynamics. Therefore, future evaluations should consider tree species based on plant functional traits across different ecoregions to provide a more comprehensive assessment of TASC-Forest model's strengths and limitations.

TASC-Forest uses the same forest growth algorithm to simulate the growth of both deciduous and mixed forests. While this approach helps reduce model complexity, such generalization may have varying effects on forest ecosystem processes depending on the tree species composition in mixed forests. To more accurately simulate mixed forest growth, future research should expand the model's capabilities to allow for the simultaneous growth of multiple tree species, including both evergreen and deciduous trees. Changes in precipitation and temperature patterns directly impact tree species, and future scenarios may involve the replacement of current tree species with those more adaptive to new conditions (Anyomi et al. 2022; W. J. Wang et al. 2017). This necessitates the consideration of factors like mortality, shifts in forest composition, and succession in response to evolving climatic conditions.

The improved model is applicable to watershed-scale studies; however, further evaluation is essential to establish its reliability in simulating carbon and ET fluxes at that scale. Future research should focus on assessing the model's ability in simulating long-term spatiotemporal variations of forest ecosystem responses, particularly forest biomass, net ecosystem exchange, ecosystem respiration, evapotranspiration, and runoff in response to extreme weather events, natural and human disturbances, and forest management strategies.

5.6.4 Conclusion

In this study, DEP integrated a DAYCENT-based forest growth sub-model into the TASC vegetation growth sub-model to improve the representation of forest growth dynamics and carbon cycling. Overall, TASC-Forest demonstrated strong performance in simulating net ecosystem exchange (NEE), ecosystem respiration (R_{eco}), and ET across diverse forest biomes, including evergreen, mixed, and deciduous forests. TASC-Forest substantially improved the simulation of NEE and ET across seven AmeriFlux sites compared to TASC, but Reco was consistently underestimated during the summer months, likely due to the rapid decline in soil moisture during this period. When compared to other ecosystem models tested at DEP’s study sites, TASC-Forest’s performance for simulating NEE was on par with the top-performing models.

While further work is required to address discrepancies between simulated and observed photosynthesis and respiration arising from parameter uncertainties and an inadequate representation of carbon cycling processes, the findings from this study support the use of TASC-Forest in watersheds with extensive forest cover, offering a deeper understanding of the complex interactions between carbon and water cycling at the watershed scale. The modified model is expected to be a valuable tool for investigating hydrological and biogeochemical impacts of natural disturbances and management practices under future extreme weather scenarios.

Improving R-SWAT tool to streamline calibration of TASC-Forest model: TASC-Forest model requires estimates of biomass and nutrient content for each tree part (leaf, branch, wood, fine root, mature root, and coarse root) specific to each forest biome and stand age as initial conditions at the start of the simulation. To streamline this process, DEP added new capabilities

in R-SWAT, an open-source software tool based on R, to facilitate forest biomass initialization, as well as sensitivity analysis, and calibration of the TASC-Forest model. These enhancements include procedures for utilizing raster datasets of forest age and biomass, as well as tabular data from published literatures or field studies, as inputs for model initialization.

5.7 Land Use and Climate Impact on Water Quality in the Croton Watershed

The Croton watershed (Figure 5.18), covering approximately 971 km² and located east of the Hudson River, provides 10% of New York City's daily water supply. In 2024, DEP conducted a study to examine the impacts of land use, climate, and atmospheric nitrogen deposition on stream nutrient dynamics in the urbanized Amawalk and forested Boyd Corners watersheds. The Amawalk watershed, located upstream of the monitoring gauge, is characterized by 47% low-density urban land and 42% forested areas. In contrast, the Boyd Corners watershed above its monitoring station is predominantly forested, with 87% of the area covered by forests, and approximately 8% consisting of low-density urban areas. Both watersheds are primarily composed of deciduous forests.

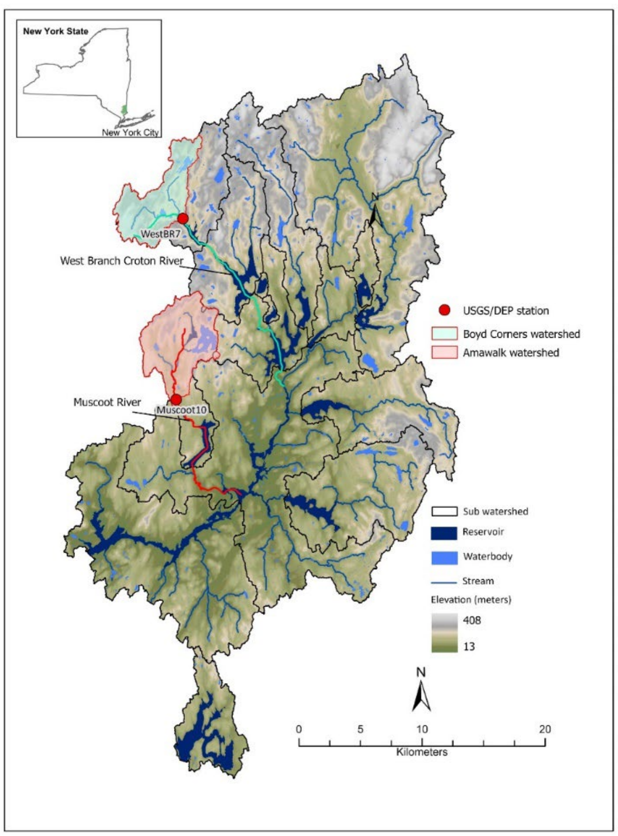

Figure 5.18 A map of the Croton watershed with study areas highlighted in the Amawalk and Boyd Corners sub-watersheds.

In previous reports, DEP presented the results of SWAT model calibration for streamflow and nutrients, as well as the contributions of land use and wastewater sources of nutrients in these watersheds. In this report, DEP focused on the observed trends in water quality across these watersheds and compared model performance under dry and wet conditions, highlighting the importance of long-term monitoring data. Detailed findings and the full study can be found in (Mukundan, Moknatian, and Gelda 2025).

The Seasonal Kendall nonparametric trend test (Hirsch, Slack, and Smith 1982) was applied to evaluate potential monotonic trends in seasonal streamflow and water quality from 2001 to 2020. This method utilizes monthly data from a specific site, with seasons (months) as the blocking variable, to assess trends using Kendall rank correlation. Trend slopes are estimated by comparing data within the same season, without cross-season comparisons. The overall trend slope is determined by the median of all within-season pairwise slopes. For this analysis, DEP used the *rkt* package in R statistical programming software.

Streamflow at both sites showed no significant trends during the study period (Figure 5.19 and Figure 5.20). The Seasonal Kendall trend test indicated a significant decreasing trend in NO_3-N concentrations at both the Amawalk and Boyd Corners stream sites from 2001 to 2020 (tau = -0.16, $p < 0.01$ for Amawalk; tau = -0.18, $p < 0.01$ for Boyd Corners). However, for Total Dissolved Phosphorus (TDP), only the Amawalk site exhibited a statistically significant decreasing trend (tau = -0.10, $p < 0.05$). The reduction in NO_3-N concentrations was attributed to a decline in atmospheric nitrogen deposition, while the decrease in TDP in the Amawalk watershed was linked to upgrades in wastewater treatment and restrictions on phosphorus-containing lawn fertilizers.

Atmospheric nitrogen deposition in the region has shown a decreasing trend since the early 2000s, as reported by Gilliam et al. (2019). At the Claryville, NY atmospheric deposition monitoring site, nitrogen deposition has declined from approximately 15 kg N ha^{-1} yr^{-1} in the early 2000s to around 8 kg N ha^{-1} yr^{-1} in recent years (CASTNET 2018). Figure 5.21 illustrates the relationship between atmospheric nitrogen deposition rates and the one-year lagged response in average annual NO_3-N concentrations in the Amawalk watershed from 2001 to 2020. Atmospheric nitrogen deposition explains about half of the variance in annual stream NO_3-N concentrations (p-value < 0.01). This suggests that further reductions in atmospheric nitrogen deposition could lead to decreased NO_3-N loading in the urbanized watershed.

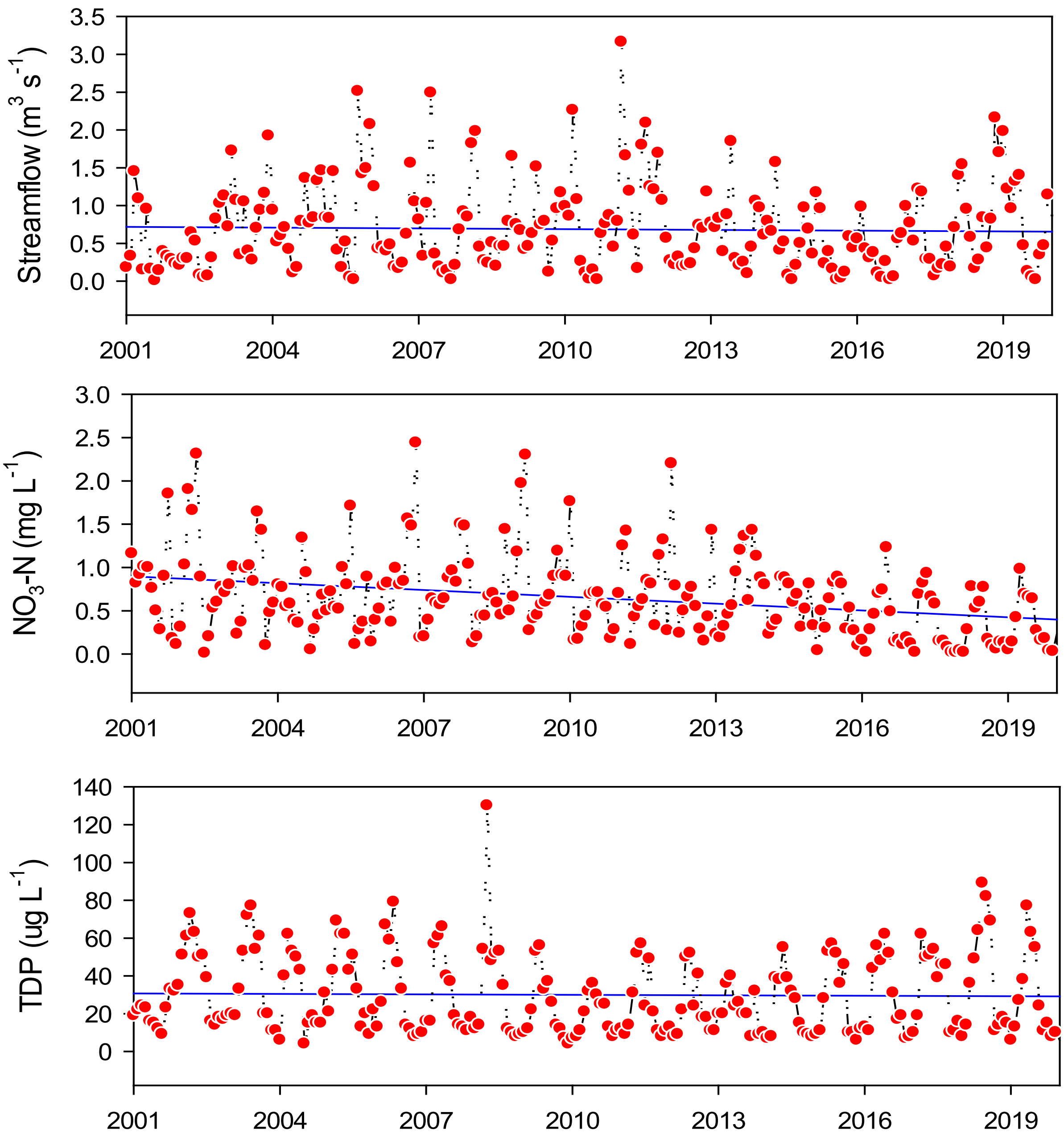

Figure 5.19 Monthly streamflow, NO3-N, and TDP data used for trend analysis (Amawalk). Linear trendline is shown in blue.

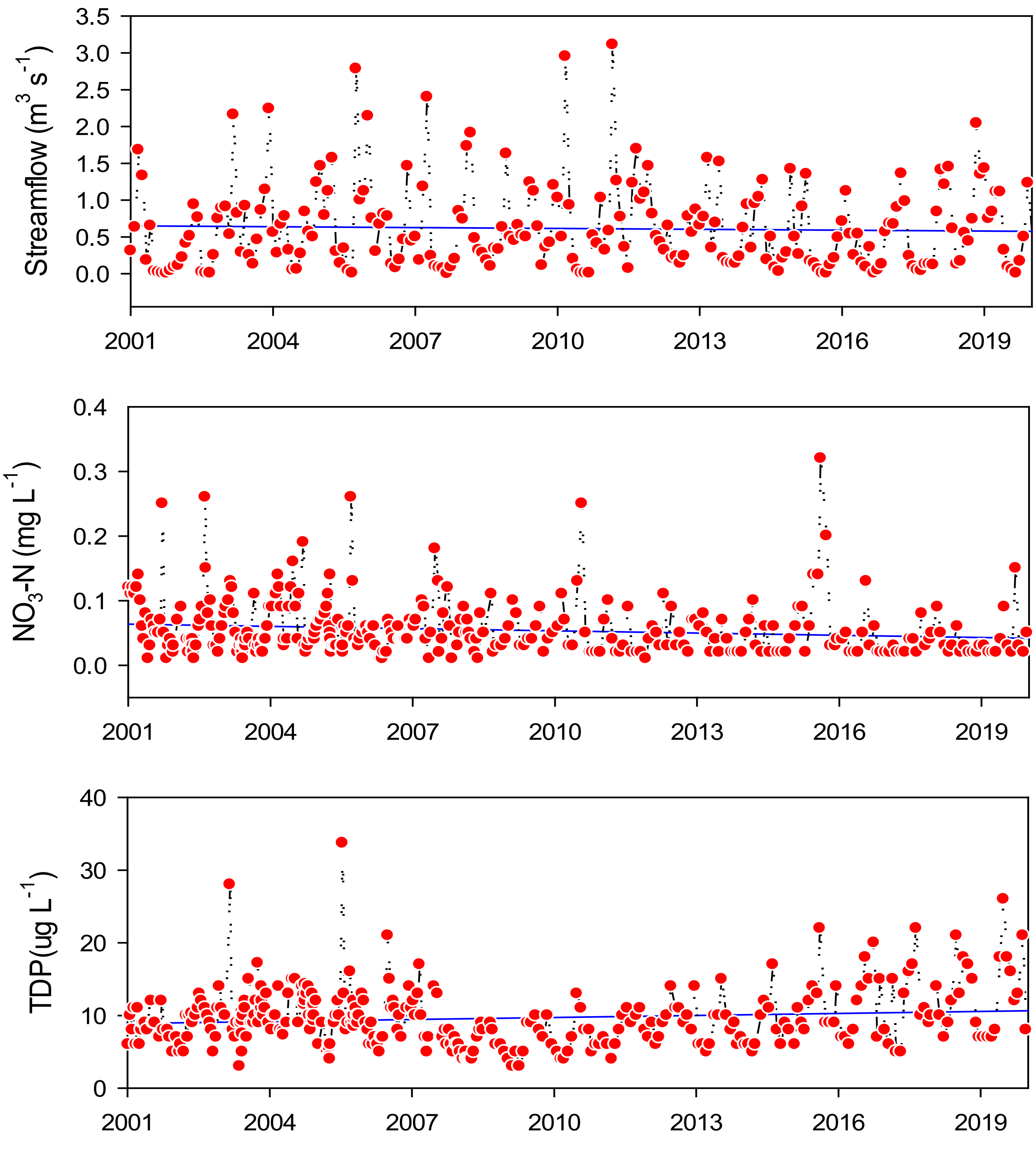

Figure 5.20 Monthly streamflow, NO3-N, and TDP data used for trend analysis (Boyd Corners). Linear trendline is shown in blue.

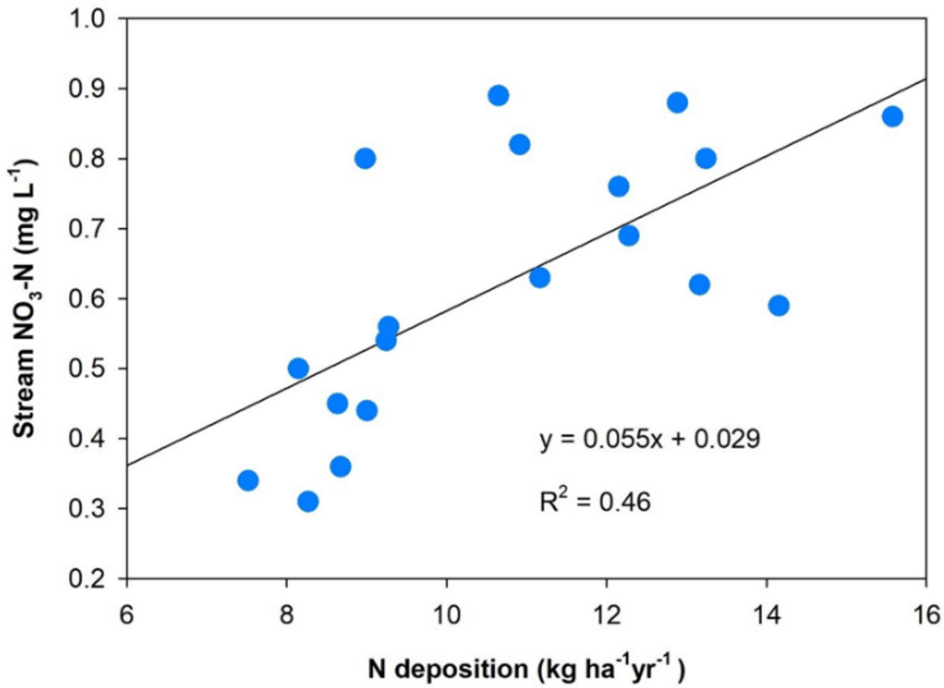

Figure 5.21 Relationship between regional atmospheric nitrogen deposition rate (from Claryville, NY site) and mean annual stream NO3-N concentration at Amawalk watershed at Muscoot10.

Using a threshold of approximately 1200 mm of annual precipitation, DEP categorized the simulation period into wet and dry years. This method identified 7 dry years and 3 wet years during the calibration period (2011–2020), and 3 dry years and 7 wet years during the validation period (2001–2010). Additionally, there was a six-year sequence of dry years from 2012 to 2017 and a five-year sequence of wet years from 2002 to 2006. Simulated streamflows were closer to observed flows in wet years than in dry years for both watersheds (Table 5.8). Water quality simulations, particularly for NO_3-N, performed better during dry years in the suburban watershed, while the opposite was observed in the forested watershed.

Table 5.8 Model performance at monthly timestep for streamflow, NO3-N and TDP during dry and wet periods for Amawalk and Boyd Corners watersheds at MUSCOOT10 and WESTBR7 respectively.

		Dry[1]		**Wet[2]**		**All years**	
Watershed	**Variable**	**R^2**	**NSE**	**R^2**	**NSE**	**R^2**	**NSE**
Amawalk	Flow	0.63	0.61	0.73	0.69	0.72	0.69
	NO_3-N	0.53	0.50	0.28	0.12	0.39	0.32
	TDP	0.43	-0.50	0.31	-0.16	0.38	-0.16
Boyd Corners	Flow	0.66	0.65	0.84	0.83	0.77	0.77
	NO_3-N	0.50	0.46	0.56	0.51	0.53	0.50
	TDP	0.32	0.09	0.50	0.47	0.45	0.38

1. Dry years are 2001, 2007, 2010, 2012, 2013, 2014, 2015, 2016, 2017, and 2020.
2. Wet years are 2002, 2003, 2004, 2005, 2006, 2008, 2009, 2011, 2018, and 2019.

It was not surprising that streamflow simulations performed better during wetter years, as model performance coefficients are typically influenced by higher flow values. The better simulation of NO_3-N during dry years, compared to wet years, in the suburban watershed may reflect the significant role of point sources, such as discharges from septic systems and groundwater contributions. The availability of long-term monitoring data covering a full range of hydrological conditions is crucial, as it eliminates the need to calibrate and validate models using data from periods dominated by either dry or wet conditions, which often have distinct statistical properties. As noted in this study, such periods can span 5–6 years. Long-term data also helps address the "divide and measure nonconformity" issue in hydrological modeling, as discussed by Klotz et al. (2024), and reduces uncertainty in model predictions.

5.8 Using HAWQS for Modeling Lower Delaware Watershed Inflows

Reliable projections of flows from the Lower Delaware Watershed (LDW) into the Delaware River are essential for evaluating how operational decisions affect New York City's water supply under future climate scenarios. These assessments must consider both overall water demand and seasonal variations. Typically, inflows are routed through the Operations Support Tool (OST) to estimate water supply reliability for different management strategies based on assumptions about climate, demand, and other influencing factors.

Historically, statistical methods have been used to estimate flows from this extensive watershed (>15,000 km²), which lies outside the Catskill-Delaware-Croton system (Groves et al. 2015). In 2024, DEP explored the use of the Hydrologic and Water Quality System (HAWQS 2.

0 2023) to simulate inflows from the LDW. HAWQS is a web-based, interactive modeling platform built on the Soil and Water Assessment Tool (SWAT) framework (Figure 5.22). It eliminates the need for user-provided computational resources and relies on standardized input data such as climate, land use, soil, and topography.

For this study, the LDW downstream of NYC's reservoirs was divided into 184 subbasins at the 12-digit Hydrologic Unit Code (HUC-12) scale. Within each subbasin, HAWQS defines Hydrologic Response Units (HRUs)—the smallest modeling units—based on unique combinations of land use, soil type, and slope. These HRUs are assumed to have similar hydrologic behavior.

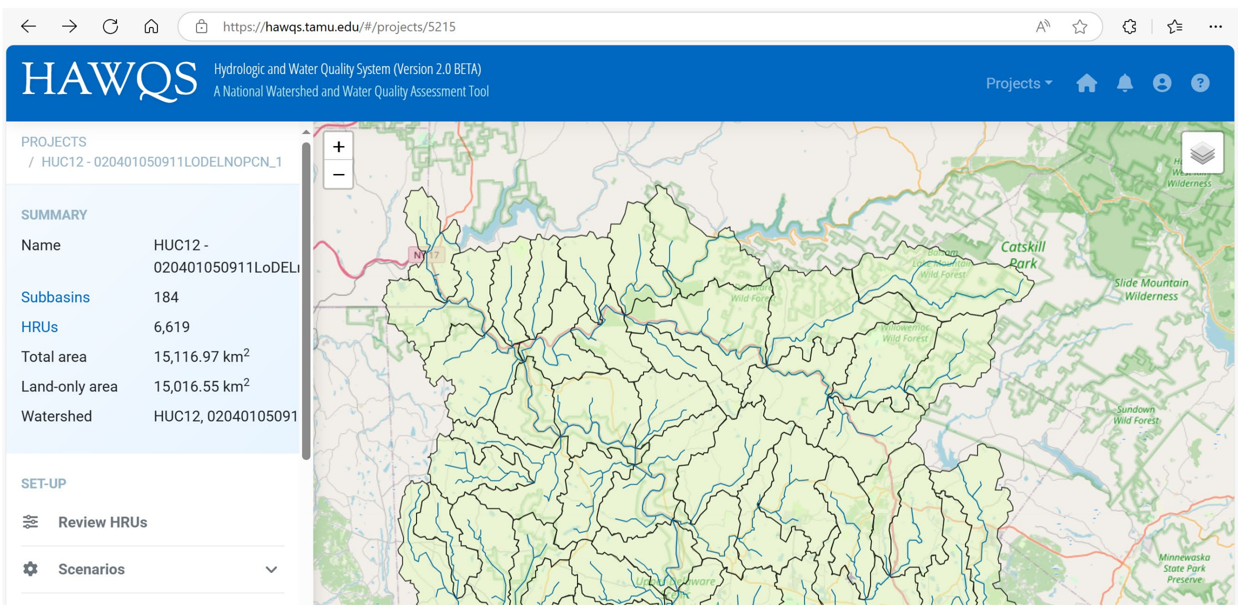

Figure 5.22 The HAWQS web interface. Subbasins shown on the map are portions of the lower Delaware watershed just downstream of NYC reservoirs.

The HAWQS-based SWAT model was set up for the LDW, focusing specifically on the region downstream of New York City's reservoirs—Cannonsville, Pepacton, and Neversink. Land use in the LDW (Figure 5.23) is predominantly forested, with forest types (FRSD, FRST, FRSE) and riparian forested wetlands (RIWF) covering approximately 75% of the drainage area. Agricultural lands (PAST, FESC, CORN, SOYB, COSY) account for about 14%, while urban areas (URLD, URMD) make up around 5%.

Initially, the model setup using the default land use distribution generated 61,451 HRUs. To reduce model complexity and improve computational efficiency, a minimum HRU size threshold of 0.5 km²—recommended by HAWQS for HUC-12 watersheds—was applied. This threshold led to the redistribution of HRUs associated with minor land uses. After aggregation,

the total number of HRUs was reduced to 6,619, allowing for faster model run times without compromising flow estimates.

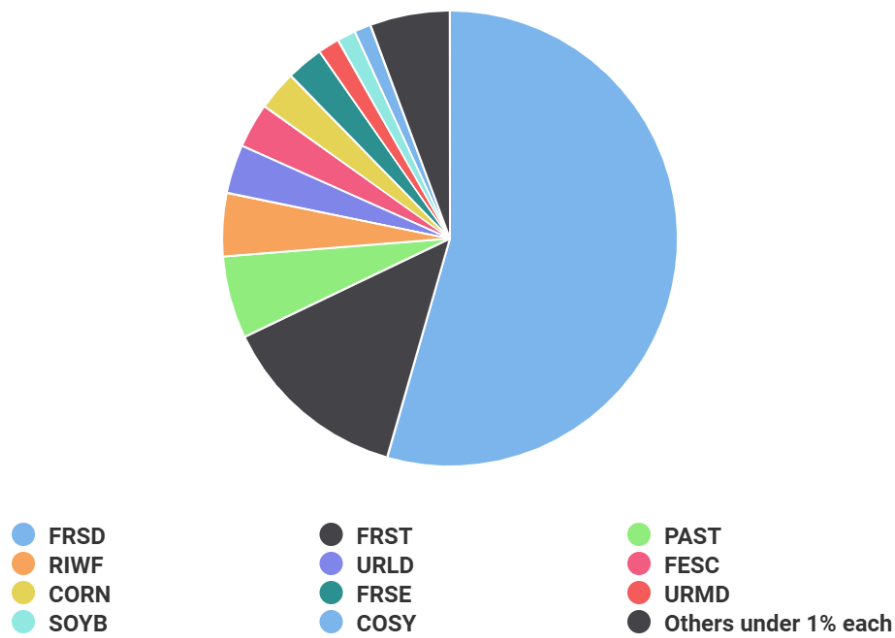

Figure 5.23 Land use distribution in the lower Delaware watershed.

Using climate data from PRISM (https://prism.oregonstate.edu/), streamflow was simulated with SWAT via HAWQS for the period from January 1, 1981, to December 31, 2020. The 40-year simulation had a model run time of 2 hours and 5 minutes. The default streamflow calibration site used by HAWQS for the LDW was the USGS gage #01463500 at Trenton, NJ. At the daily time step, reported model performance at this site was satisfactory, with a Nash-Sutcliffe Efficiency (NSE) of 0.74, Percent Bias of -7.1%, and Kling-Gupta Efficiency of 0.80 for the 1983–2001 period. Additional comparisons of simulated monthly streamflow with gauge measurements at the Trenton calibration site and two upstream locations for the period 1986–2020 also indicated satisfactory model performance, although model accuracy declined slightly at the upstream sites (Figure 5.24). Overall, the current HAWQS configuration demonstrates reliable performance and reasonable computational efficiency, making it a suitable tool for simulating flows in the Lower Delaware Watershed. These results support its application in climate change-related water supply management scenarios using the OST.

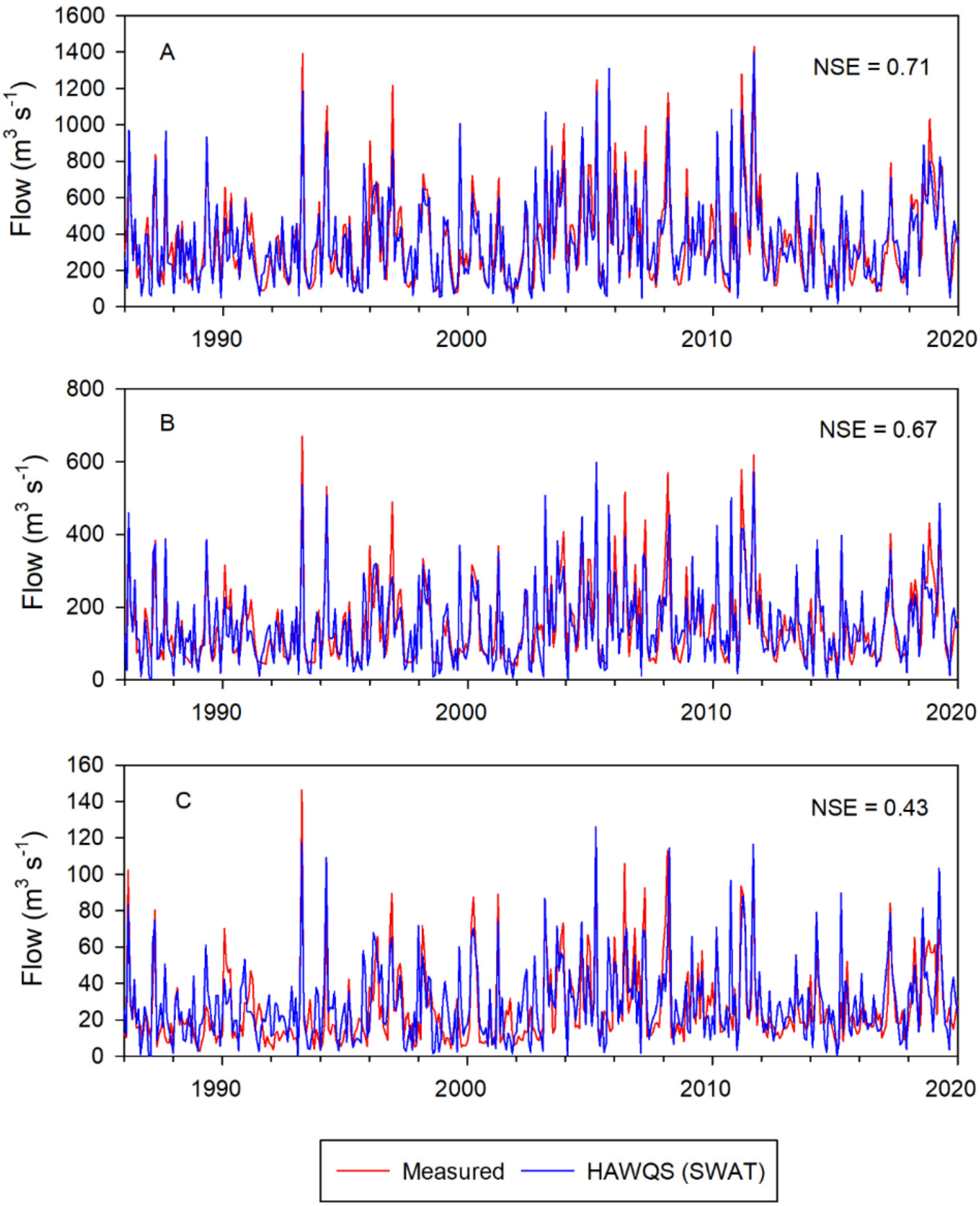

Figure 5.24 Comparison of simulated and measured flows at Delaware River at USGS gage#01463500, Trenton NJ (A), Delaware River at USGS gage#01434000, Port Jervis NY (B), and West Branch Delaware River at USGS gage#01426500, Hale Eddy NY (C).

5.9 Septic Systems Vulnerability Assessment in the West of Hudson Watersheds

In New York State, approximately 22% of homes rely on septic systems, which continue to serve as a long-term method of wastewater treatment for many residents (NYSDOH 2012). While properly designed, constructed, and maintained septic systems offer a safe and effective means of treating and disposing of wastewater, failures due to improper siting, design, or maintenance can lead to contamination of nearby waterbodies (Day 2004). Traditionally, identifying septic system failures has relied on field-based household inspections—a process that is both labor-intensive and logistically challenging. A more efficient approach involves conducting targeted inspections based on the likelihood of failure, which requires identifying predictive site characteristics and reliable methods for detecting them.

Few studies have examined the potential of machine learning methods to identify sites or conditions where septic systems are likely to fail or require replacement. Ravi and Johnson (2021) applied ML techniques to identify key factors contributing to septic system failures and to isolate high-risk locations, using data from multiple counties in Indiana. Similarly, Hoghooghi et al. (2021) utilized a modified soil topographic index and statistical models—including tree-based and logistic regression approaches—along with septic system specifications to predict replacement rates in Georgia's coastal plains. Building on these approaches, DEP developed and tested a desktop-based method to assess the vulnerability of septic systems in the West of Hudson (WOH) watersheds (Figure 5.25).

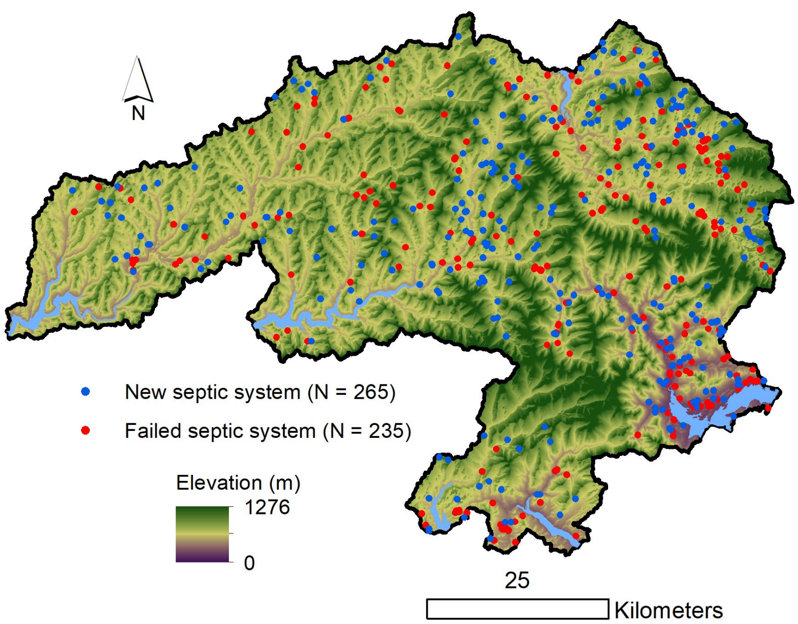

Figure 5.25 A map of the West of Hudson watershed showing locations of failed and new septic systems considered in the study.

The method utilized two septic inventory datasets: one representing “failed” septic systems (N = 235), identified through notices of violation, and another representing “new” and properly functioning systems (N = 265) installed since 2018. These two categories—failing and new systems—served as the dependent variables in the predictive modeling and analysis.

A machine learning model using the XGBoost algorithm was trained using climatic, soil, and topographic data, along with parcel information as predictor variables. XGBoost is an ensemble method that combines multiple weak models (learners) to create a powerful predictive model. This algorithm has been widely successful in real-world applications and is often noted for its superior predictive accuracy (Chen and Guestrin 2016). The model was trained using 13 predictor variables on 80% of the dataset (N = 400), with the remaining 20% (N = 100) used for testing. The training and testing process was repeated 100 times with random splits of the data. The model achieved a mean accuracy of 81% in predicting septic system status (failed vs. new) (Figure 5.26). To account for collinearity and reduce redundancy, a second model was trained using only five predictors. Despite the reduced feature set, the model’s performance remained strong, with a mean accuracy of 80% on the testing dataset. The relative importance of these five predictors is shown in Figure 5.27. These predictors include bath-to-bedroom ratio (bbr), building type (numerical indicator), elevation of the location, average annual precipitation, and topographic wetness index (*twi*) which indicates the likelihood of a location to saturate and generate runoff.

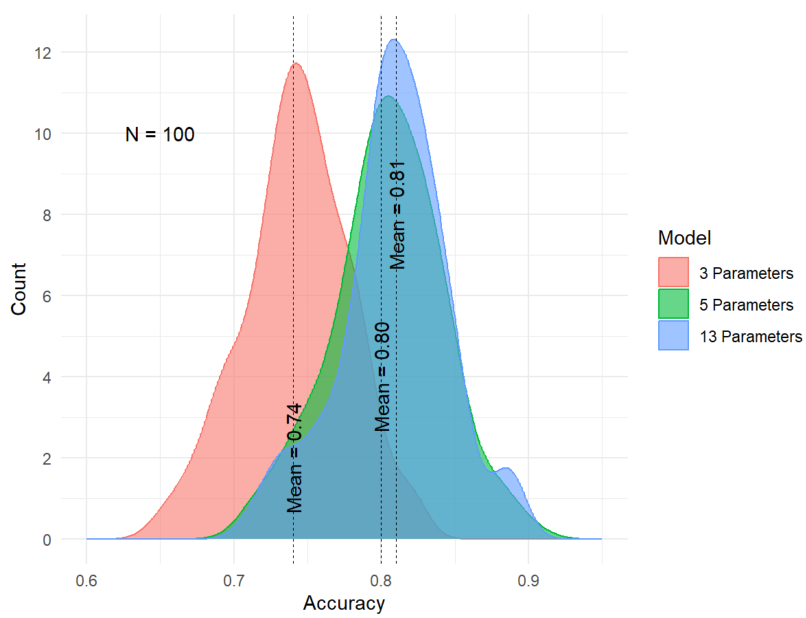

Figure 5.26 Comparison of prediction accuracy of ML models with 3, 5, and 13 parameters.

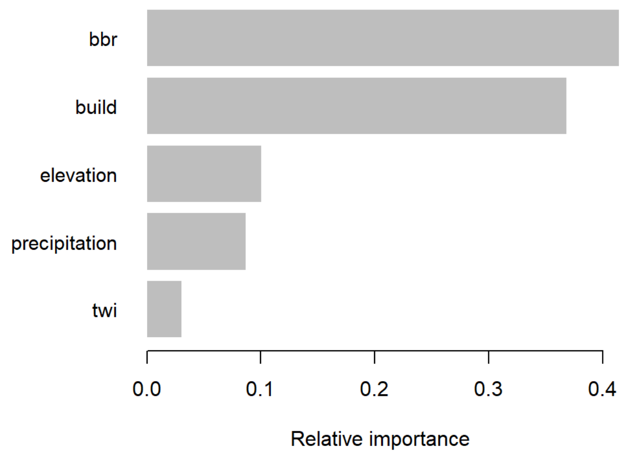

Figure 5.27 Relative importance of variables used to predict septic system vulnerability. Abbreviations used are *bbr* for bed-to-bath ratio, *build* for building type, and *twi* for topographic wetness index.

To further investigate the effects of statistically significant predictors, a conditional inference tree model was applied. This model uses binary partitioning of predictor variables and serves as an alternative to generalized linear models for categorical variables, offering unbiased results without the need for cross-validation. A p-value of 0.05 was set as the threshold for splitting nodes when comparing predictor variables to the response variables.

The conditional inference tree was built with septic system status (failed/new) as the dependent/response variable and all predictors as independent variables. Due to limited data availability, the entire dataset was used to construct the tree. The analysis revealed that only three predictors were statistically significant (p-value < 0.05) and were included in the final tree (Figure 5.28). These predictors—bed-to-bath ratio (≤ 0.4), elevation (≤ 517m), and topographic wetness index (*twi* > 11)—emerged as strong indicators of sites with a high likelihood of septic failures.

However, when the ML model was developed using only these three predictors, the mean accuracy was 74% (Figure 5.26). Figure 5.29 compares *twi* values for failed and new septic systems, showing that a relatively higher number of failing systems have *twi* values greater than 11.

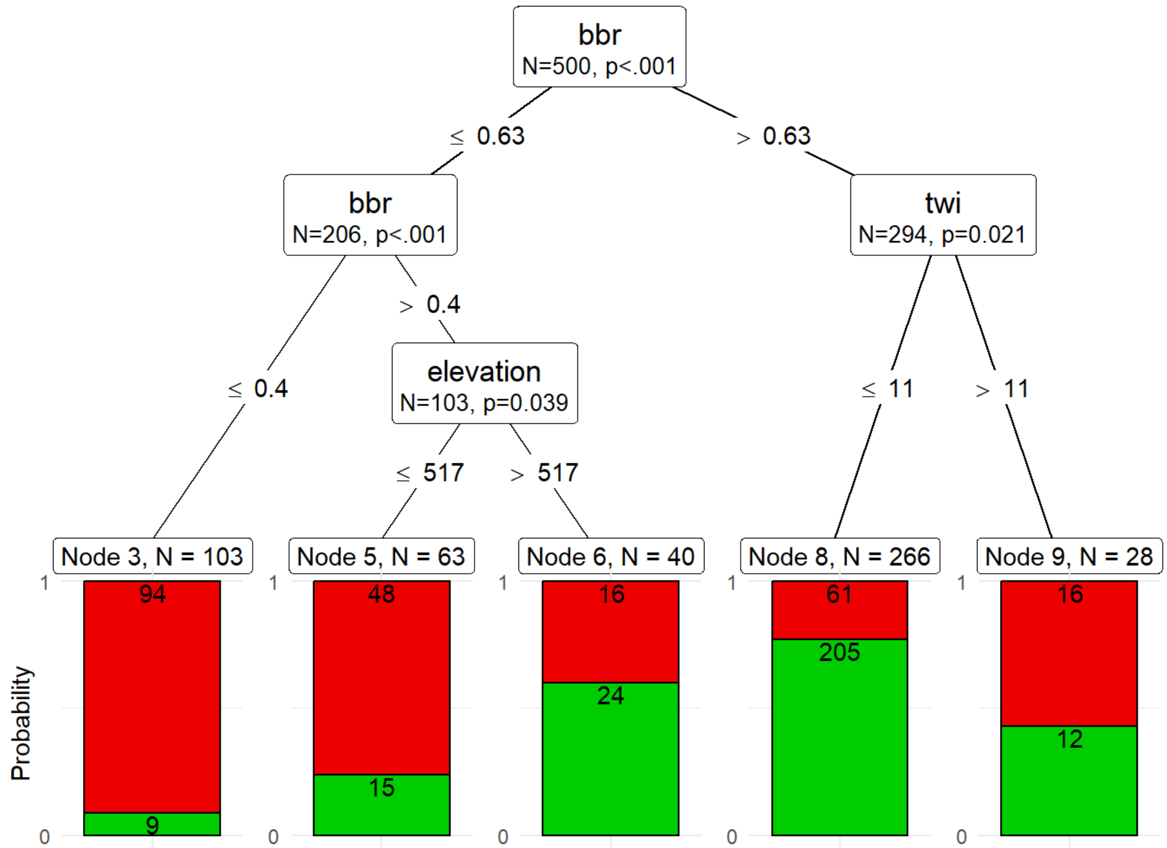

Figure 5.28 Conditional inference tree model based on binary recursive partitioning variables pertaining to septic system locations (n=500). The value of N next to the terminal node number represents the number of septic systems classified in that node. "p" is the p-value for splitting a node (p-value considered is <0.05). Each bar shows the proportion of septic systems classified as failed (red) or new (green).

A preliminary test of machine learning models shows promising results in their ability to identify key factors contributing to septic system failures and distinguish locations at high risk of failure from those with new, properly functioning systems. The models achieved an average accuracy of 80% when validated against an independent testing dataset. This approach has the potential to complement existing criteria for identifying areas less suitable for new septic system siting and to isolate locations where older systems are likely to fail in the NYC WOH watershed region.

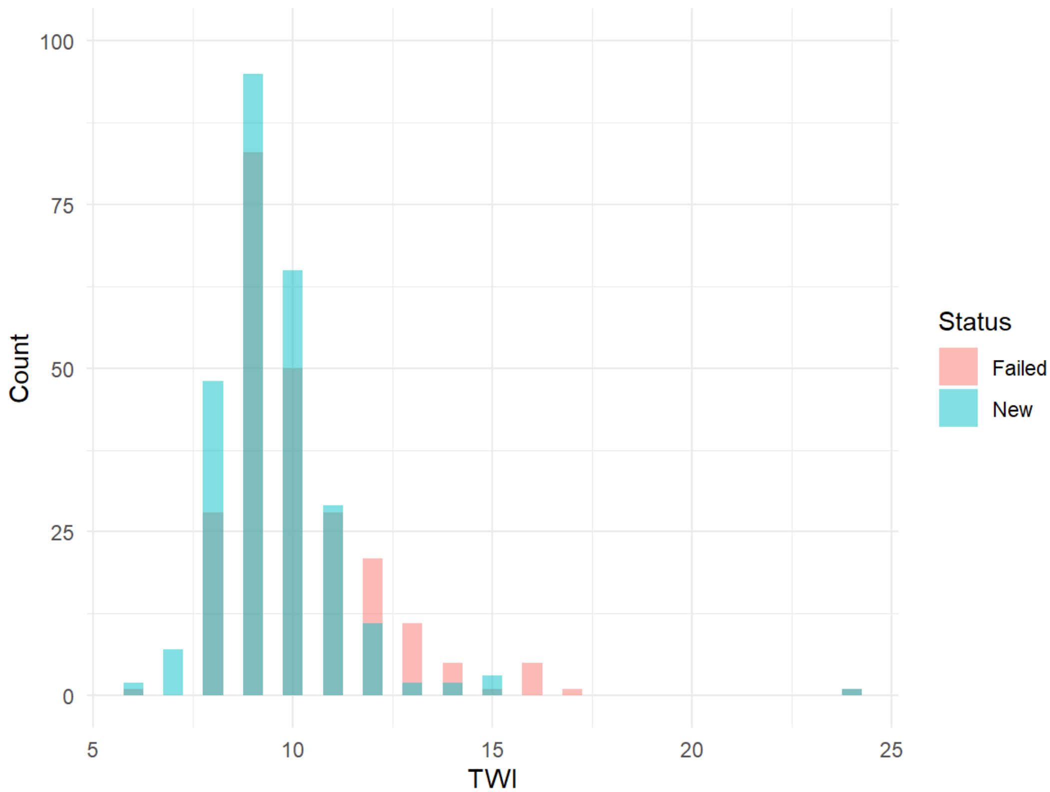

Figure 5.29 Topographic wetness index (TWI) values for failed and new septic systems.

5.10 Ashokan Reservoir UV_{254} Model

Based on measurements from 2016-2022 from selected inflow and outflow points in the NYC water supply system (NYCWSS), DEP established that UV_{254} measurement is a good proxy for DBPfp and DBPs (K. Wang, Mukundan, and Gelda 2024). UV_{254} is an inherent optical property of water; it measures absorption of ultraviolet light at 254 nm wavelength by water and DOM present in water. Using UV_{254} as a proxy, DEP presented an overall framework of modeling DBPs throughout the NYCWSS in DEP's earlier work (DEP 2023). DEP also presented development and testing of Cannonsville, Neversink and West Branch reservoirs models for simulating UV_{254} (DEP 2023; 2024b). Here DEP presents results of a similar model development and testing efforts for Ashokan Reservoir.

Model Setup: In 2024, DEP began testing of two-dimensional hydrothermal and water quality model CE-QUAL-W2 (W2) for predicting UV_{254} in Ashokan Reservoir. W2 setup for Ashokan Reservoir with model segments and locations of inflows, outflows, in-stream and in-reservoir routine water quality monitoring sites is depicted in Figure 5.30. The two basins were modeled separately. For DEP's earlier modeling work on Ashokan Reservoir, see Gelda et al. (2009), and Gannett Fleming & Hazen and Sawyer (2007). Model testing (calibration-validation) was performed for 2011-2022 (12 years), the longest period of available UV_{254} data in the diverted water. Input data required by the model included bathymetry, hourly meteorology (air temperature, dew point, wind, and solar radiation), inflows, outflows, water surface elevation,

inflow temperatures and inflow UV_{254}. Model testing data consisted of outflow temperatures and UV_{254}. Selected data used in the model development and testing are listed in Table 5.9. Effects of loading from Shandaken Tunnel into Esopus Creek and Ashokan Reservoir is considered explicitly.

Data Development: DEP started monitoring UV_{254} in the diversion at keypoint EARCM since 2011; however, currently no lacustrine site is monitored and monitoring at the inflow site E16i on Esopus Creek started in 2022 (1/month). The model requires that a value of UV_{254} for all inflows is specified for each day of simulation. To fill this need, DEP estimated long-term, continuous UV_{254} at E16i using a procedure outlined in Figure 5.31.

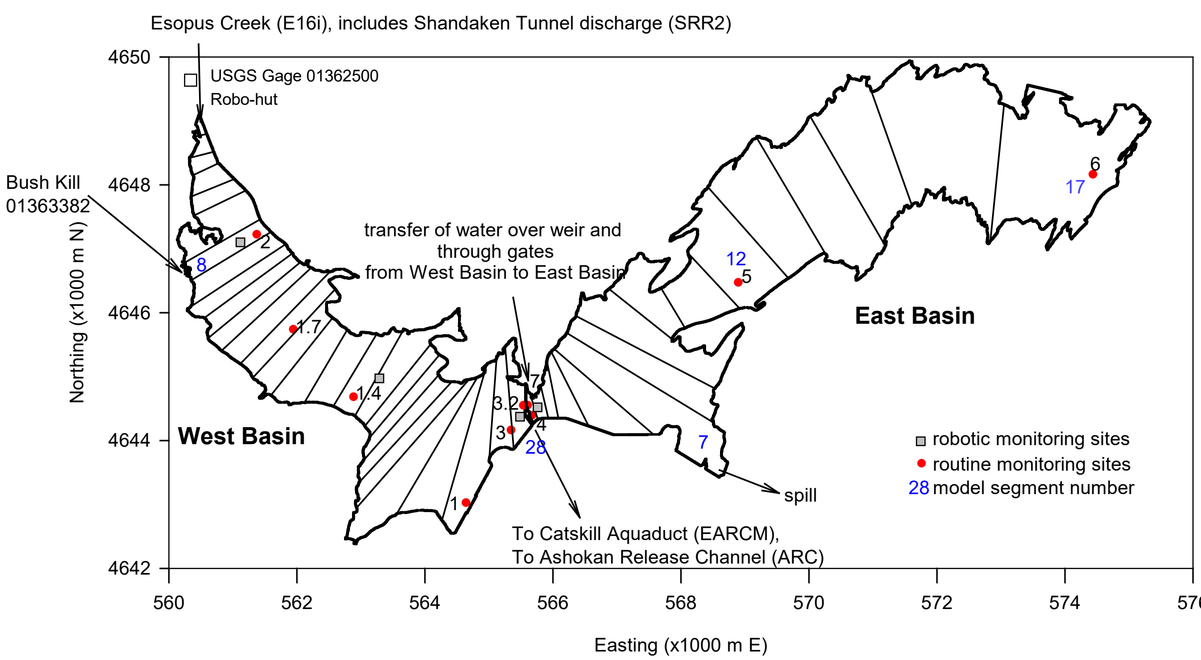

Figure 5.30 Ashokan Reservoir: Inflows, outflows, in-stream and in-reservoir routine water quality monitoring locations, and w2 model segments. Selected model segments are also numbered according to the numbering scheme of w2.

First, DEP adjusted the DOC (DOC_{e16i}) data (typically 1-2 per month and limited storm sampling; 1990-2022) to eliminate the influence of inter-basin transfer of water from Schoharie Reservoir. This was carried out by doing a mass balance calculation (Eq. 1) using flow (Q_{STP}) and DOC (DOC_{STP}) data from Shandaken Tunnel Portal (STP). It is assumed that DOC is conservative (in Esopus Creek) at the timescale of time of travel from STP to E16i, which is generally < 1 day.

$$Q_{esp}DOC_{esp} + Q_{STP}DOC_{STP} = Q_{E16i}DOC_{E16i} \quad (1a)$$

$$where,\ Q_{esp} = Q_{E16i} - Q_{STP} \quad (1b)$$

Second, a general additive model (GAM) was constructed to predict daily DOC using predictor variables that are available at higher frequency (see Wang et al., 2025 for details). The general form of GAM for E16i site was:

$$\ln(DOC_{esp}) = f_1(Q_{esp}) + f_2(Tn) + f_3(JD) + f_4(ADD) + \varepsilon \quad (2)$$

Where, Tn = Esopus Creek watershed turbidity, JD = Julian day, ADD = antecedent dry days metric, and ε = error term.

And third, the output from GAM (gap-filled daily DOC) was input into a regression relationship (Figure 5.32) between DOC and UV_{254}, and thus daily estimates of UV_{254} were generated. DEP adopted the regression relationship from another site in the NYC watershed (site NCG; Neversink River, inflow to Neversink Reservoir) which was well-monitored with substantially more data available (2016-2024, n = 468) encompassing a wide range of water quality conditions (maximum DOC ~ 8 mg/L). In comparison, at the site E16i, DEP had only 25 data points between 2022-2024. Even so, the congruence of the data between the two sites is notable (Figure 5.32) and use of DOC-UV_{254} relationship from NCG is justified.

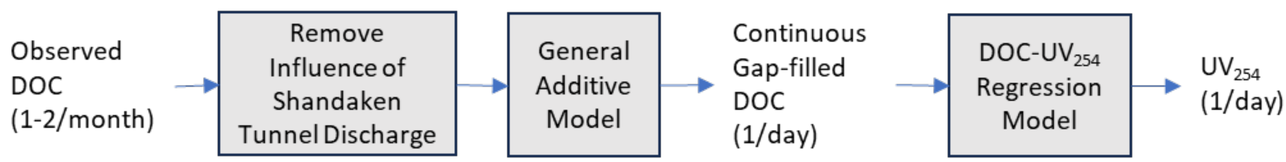

Figure 5.31 Procedure for estimating daily values of UV_{254} in Esopus Creek inflow at E16i, excluding the influence of Shandaken Tunnel discharge from Schoharie Reservoir.

UV_{254} at STP (site SRR2; representative of diversion from Schoharie Reservoir) was measured weekly during 2011-2024. To obtain daily values during this interval and hindcast prior to 2011, first, DEP used two linear regression relationships: (a) TOC-DOC, and (b) DOC-UV254 (Figure 5.33) to generate estimates for 1988-2010, and second, DEP used linear interpolation to fill gaps between weekly measurement and estimates. This was necessary because prior to 1997, only TOC was available, whereas in the later years, most of the data collected were DOC. In response to watershed events, reservoir water quality is modulated as compared to stream water quality, and therefore, linear interpolation of diversion water quality is a reasonable assumption. In future, however, if needed DEP will use W2 model-predicted UV_{254} for Schoharie diversion.

Table 5.9 Data sources for specifying boundary conditions[1] in W2 model for Ashokan Reservoir.

Tributary/Inflow	Flow (daily)	Temperature (hourly)	UV_{254} (daily)
Esopus Creek (E16i; Esp[2])	USGS	USGS (2008-2024) gap-filled with DEP (1998-2024) and model[+] (1987-1997)	Model (Figure 5.31 and Figure 5.32)
Bush Kill	USGS (2000-2024 and model[*]	Same as for E16i	Same as for Esp
Shandaken Tunnel Discharge	DEP and USGS	Same as for E16i	Linear interpolation of observations (since 2011) and model estimates (1988-2010) (Figure 5.33)
Distributed Transfer from West to East Basin: (a) over weir, (b) through gates	Flow balance Flow balance	Same as for E16i Predicted from W2 model for West Basin	Same as for Esp Predicted from W2 model for West Basin

[1]meteorological data corresponded to Albany Airport National Weather Service station data; [2]Esp is the same location as E16i but without the influence of Shandaken Tunnel;
[+]Hazen & Sawyer (2007); *Q_{Bush} ($m^3\ s^{-1}$) = 0.0934311 Q_{Esopus} ($m^3\ s^{-1}$);

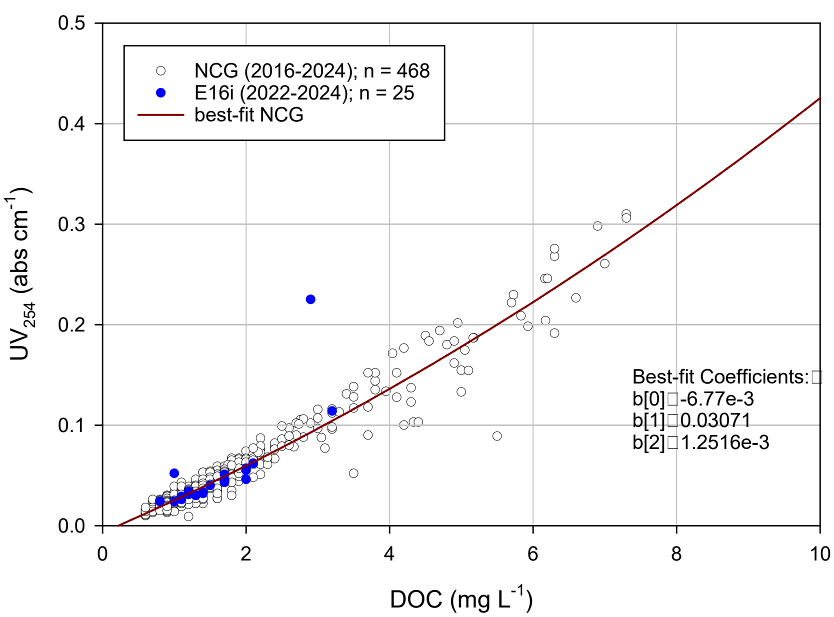

Figure 5.32 Nonlinear regression relationship between DOC and UV_{254}. The site NCG is located on Neversink River, and the best-fit line corresponds to data from NCG. Data from the site E16i show congruence with the data from NCG.

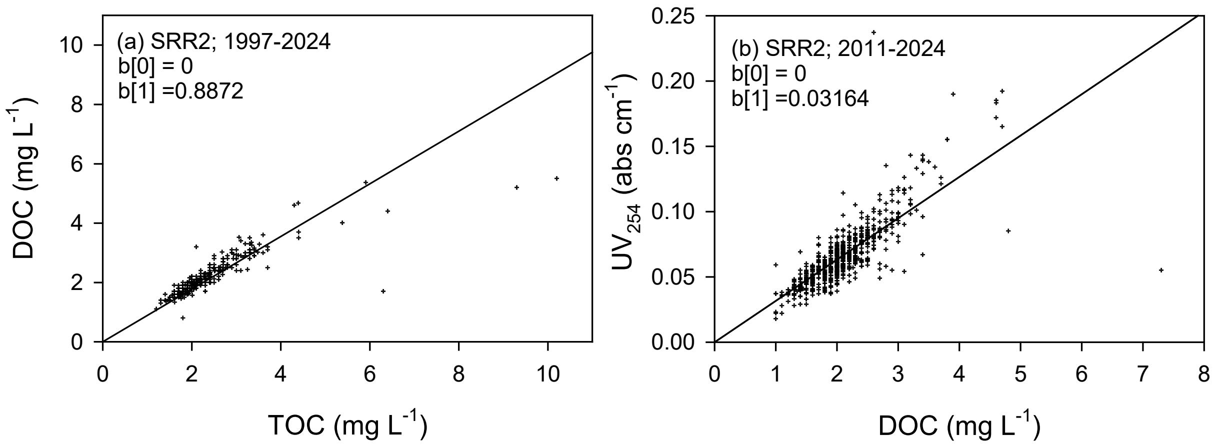

Figure 5.33 Linear regression relationships between (a) TOC and DOC, and (b) DOC and UV_{254}, for the site SRR2 (Shandaken Tunnel discharge into Esopus Creek). Best-fit regression lines are forced through origin.

Selected inflow-outflow observations and predictions of UV_{254} are presented in Figure 5.34 and Figure 5.35. Average UV_{254} from only Esopus Creek watershed was 0.035 abs cm^{-1} and it ranged from 0.014 abs cm^{-1} to 0.3 abs cm^{-1} during 2011-2022 (Figure 5.34b). In comparison, Shandaken Tunnel discharge on average contributed 0.066 abs cm^{-1} (range 0.02 – 0.3 abs cm^{-1}) during the same interval (Figure 5.35). Comparing the two sources in terms of mass equivalent units (i.e., flow m^3 s^{-1} × concentration abs cm^{-1}), Shandaken Tunnel contributed 1/3rd and the watershed 2/3rd of the total loading of UV_{254} causing organics. In the diversion from Ashokan Reservoir, UV_{254} was observed in a narrower range: 0.02 abs cm^{-1} – 0.07 abs cm^{-1} with average 0.036 abs cm^{-1} during 2011-2022 (Figure 5.34c).

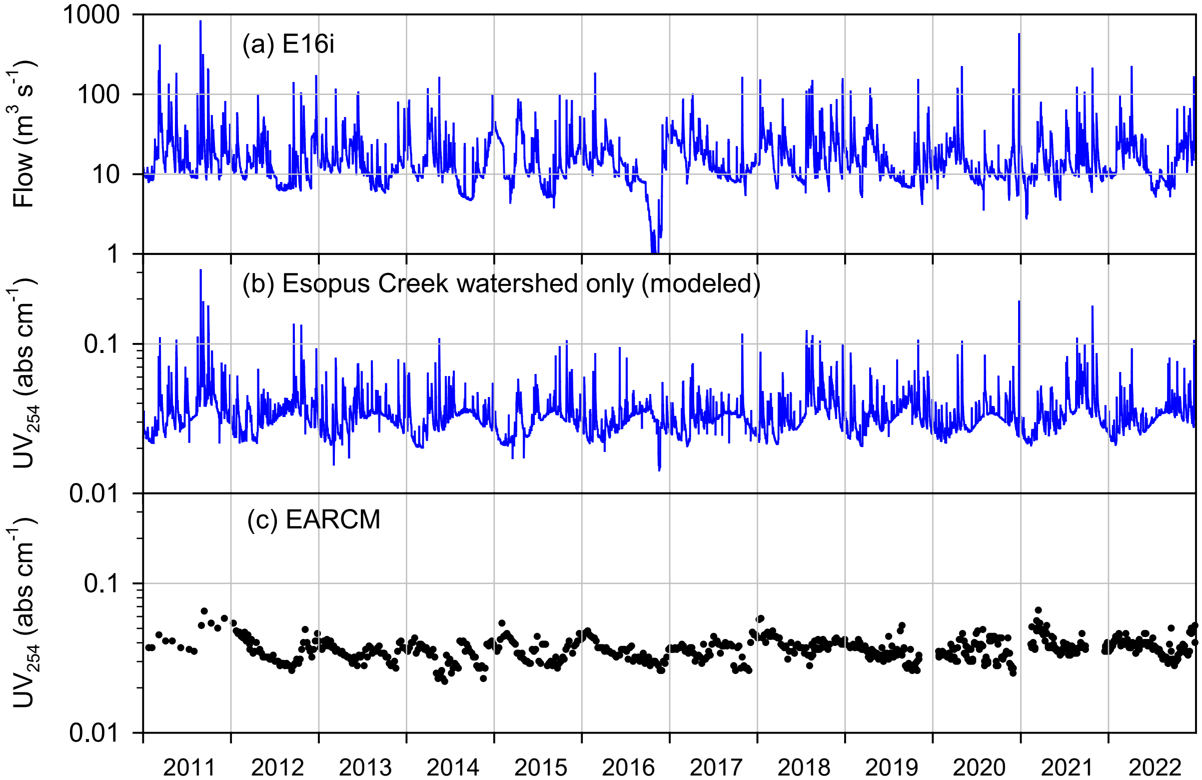

Figure 5.34 Time series of inflow and UV_{254} data for Ashokan Reservoir, 2011-2021: (a) inflow from Esopus Creek at E16i, including diverted water from Schoharie Reservoir, (b) modeled UV254 from Esopus Creek watershed, and (c) observed UV254 in diversion from Ashokan Reservoir.

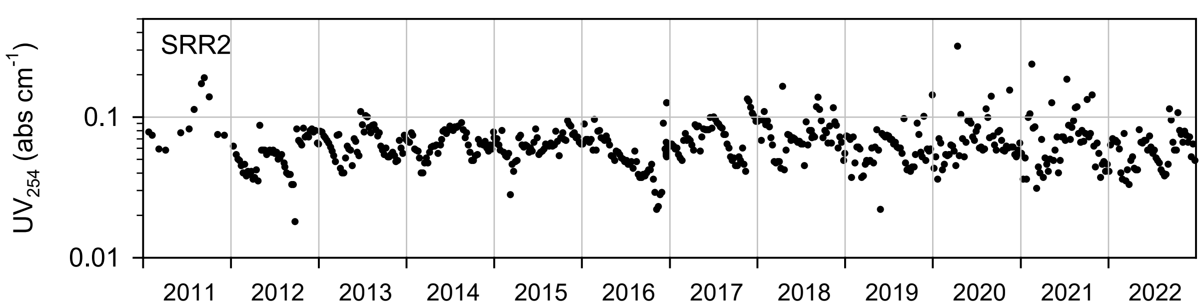

Figure 5.35 Time series of UV_{254} in Shandaken Tunnel discharge entering Esopus Creek, 2011-2022.

Model Description: UV_{254}, as a model state variable, is not explicitly available in W2, but it can be modeled as generic water quality constituent. DEP modeled it with first-order decay kinetics, where the net loss rate is temperature and concentration dependent:

$$\frac{dc}{dt} = -k\theta^{(T-20)}\frac{c}{c+k_s}c \quad (3)$$

where, c = UV_{254} concentration (abs cm^{-1}), t = time (sec), k = first-order net loss rate (sec^{-1}), θ = temperature correction multiplier (dimensionless), T = water temperature (°C), k_s = half-saturation constant (cm^{-1}). Photodegradation of UV_{254} is not included in the model at present, but DEP may consider it in the future work if DEP has necessary observations for calibrating the photolysis process and DEP finds that the simple model does not adequately explain the observed vertical gradients in UV_{254}. The first-order net loss rate coefficient, k was determined to be 0.002 d^{-1} for both basins of Ashokan Reservoir; θ was set to 1.024 – a typical value for biological processes used in water quality models (Chapra 2008), and k_s was set to a low (relative to typical in-reservoir levels) value of 0.001 abs cm^{-1}. In DEP's earlier work, optimal values of k were determined to be 0.0 d^{-1} for Neversink Reservoir (DEP 2023), 0.0025 d^{-1} for Cannonsville Reservoir (DEP 2023), and 0.002 d^{-1} for West Branch Reservoir models (DEP 2024b). All these values of k are indicative of nearly refractory, i.e., resistant to biodegradation, nature of organic matter exported from the watershed and into the water supply.

Model Performance: The ability of the model to reproduce observed behavior of temperature and UV_{254} was evaluated by comparing observations with the predictions in withdrawal from Ashokan Reservoir at EARCM for 2011–2022 (Figure 5.36). The model predicted well the seasonal dynamics in temperature, including fluctuations associated with reservoir operations (changing the withdrawal basin, blending from the two basins, and adjusting stop-shutters for optimal water quality), for example, in 2015 and 2022. Root mean square error was 1.27 °C (Figure 5.36a). The model also performed good in predicting withdrawal UV_{254} (RMSE = 0.006 abs cm^{-1}; Figure 5.36b), except during 2011-2012 due to uncertainty in estimates of loading of UV_{254} following Hurricane Irene in August 2011.

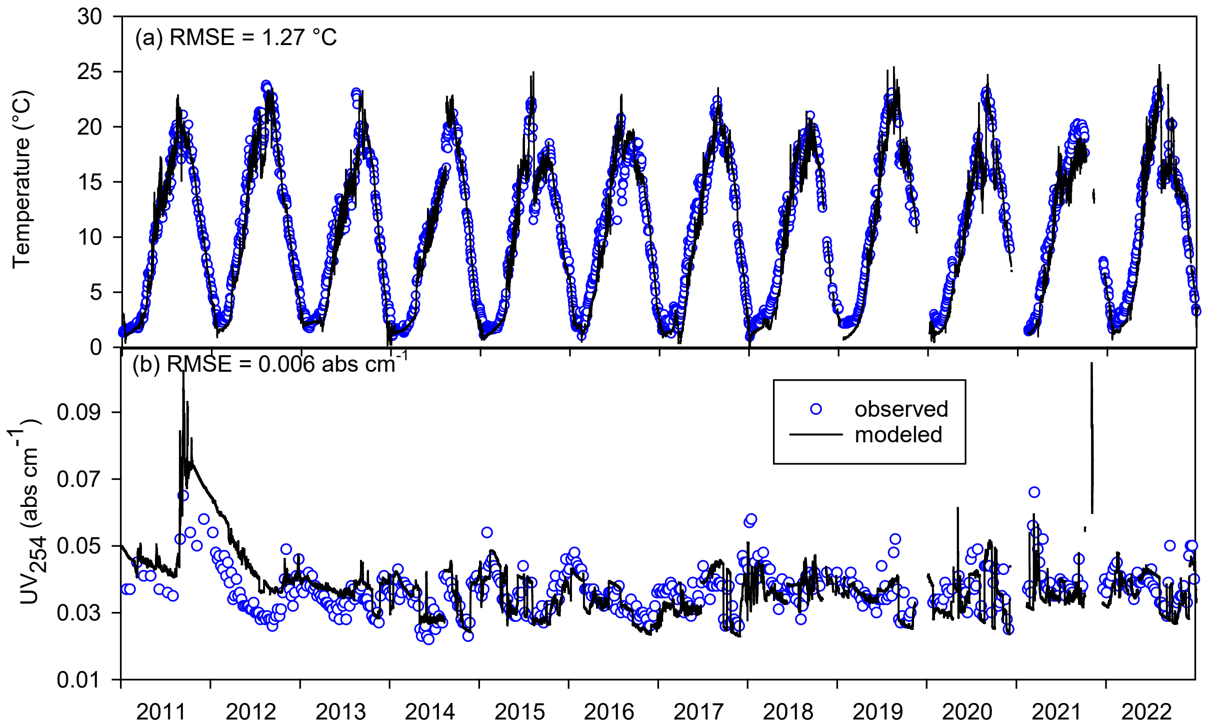

Figure 5.36 Performance of Ashokan Reservoir hydrothermal - water quality model, presented as comparison of observed and predicted withdrawal (site EARCM) (a) temperature, and (b) UV_{254}, for 2011-2022.

5.11 In-situ Absorption Spectra to Assess Dissolved Organic Matter Quality

As part of a pilot program, DEP has been exploring DBPfp monitoring within the Delaware district using in-situ measurements of absorbance (Figure 5.37).

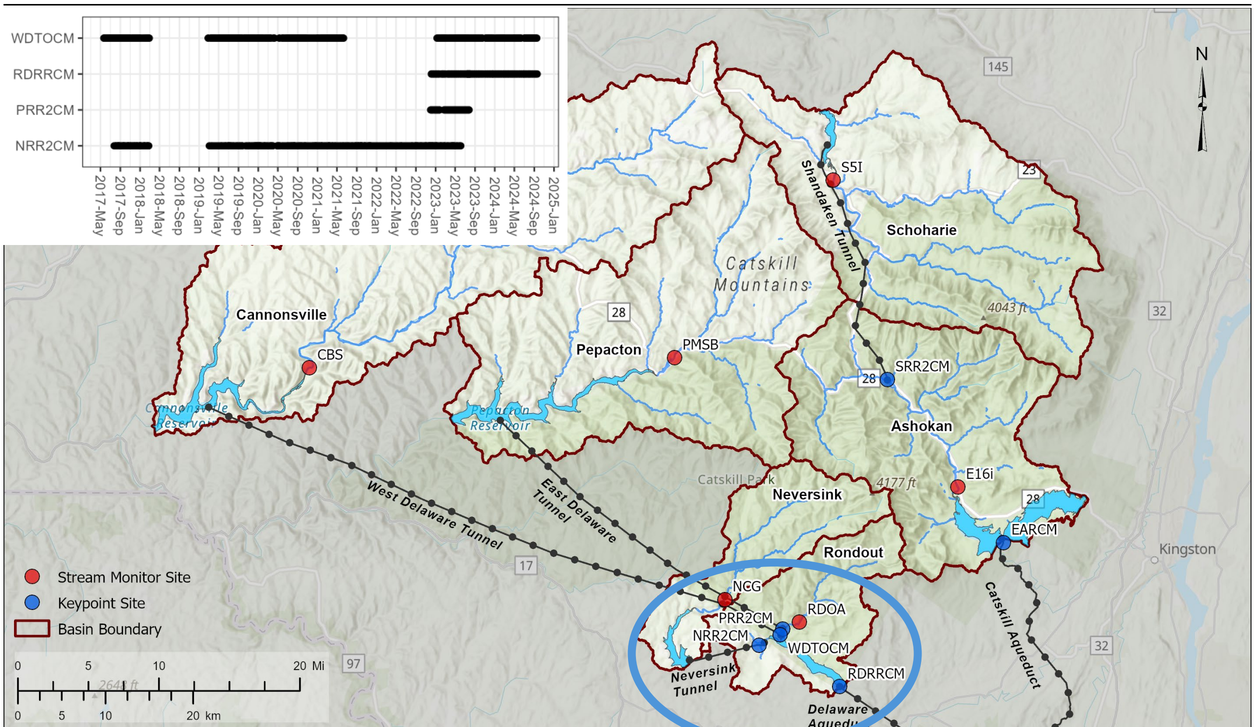

Figure 5.37 S::CAN UV-Vis Spectro::lyser deployment locations (circled keypoints) and period of deployment (inset).

During 2017-2024, DEP deployed S::CAN UV-Vis Spectro::lyser V2 sensors (35 mm pathlength) at four keypoint locations within the Delaware district (NRR2CM, WDTOCM, PRR2CM, and RDRRCM) (Figure 5.37). The S::CAN sensors record absorption from 220 to 720 nm at an interval of 2.5 nm (Figure 5.38). The absorption spectral curve is typically an exponentially decaying curve, and the instrument can measure absorbance (abs cm^{-1}) at < 5 min frequency. The absorbance is defined as the negative log of the ratio of the light intensity transmitted through a path length divided by the initial intensity. Only the portion of the organic matter that interacts with UV-visible spectrum (Chromophoric Dissolved Organic Matter (CDOM)) is measured by the S::CAN sensors and the amount of CDOM affects the light intensity and spectral distribution. These CDOM measurements can be used as proxies for molecular weight and size, aromaticity, and source of NOM.

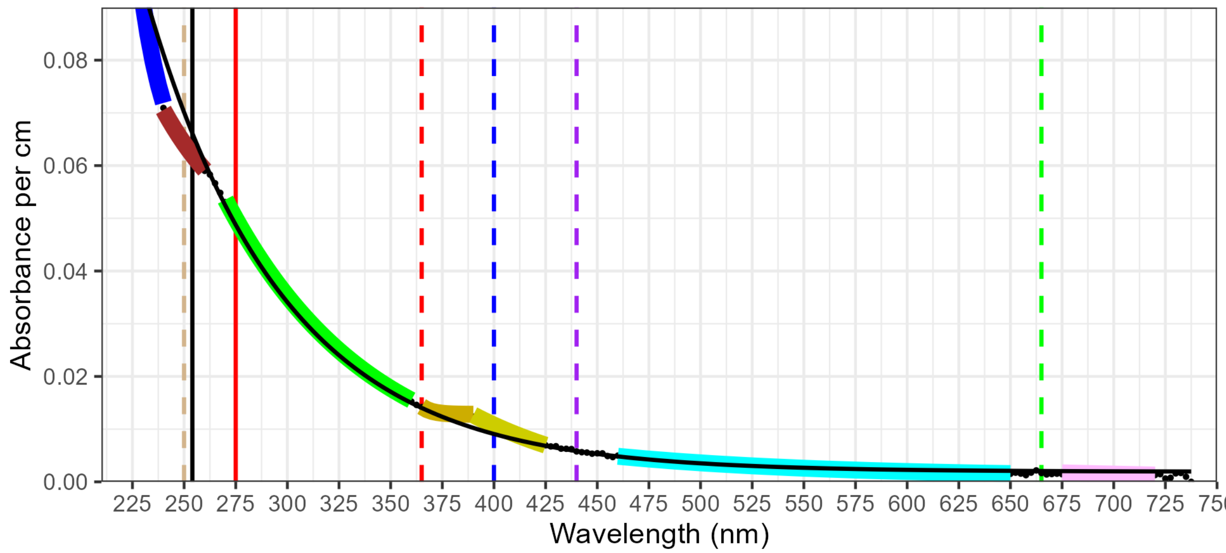

Figure 5.38 Typical absorption curve (black line). Commonly used wavelengths and slopes along the absorption curve to characteize NOM are also indicated.

In this study, DEP analyzed absorption spectra from NRR2CM. Between the literature (Korak and McKay 2024) and evaluation of NRR2CM spectral curves (Figure 5.38), there were four categories of spectral information to explore: 1) S::CAN measurements, 2) Absorbance ratio (ratio of two points on the spectral curve), 3) spectral slope (linear slope of a log curve), and 4) spectral slope ratio (ratio of two spectral slopes) (Table 5.10). The literature-based indices are absorbance ratios a_{250}/a_{365} (E2:E3), a_{250}/a_{400} (E2:E4), and a_{440}/a_{665} (E4:E6) and spectral slope $S_{275\text{-}295}$. SCAN275 is included in this list because a 1953 study suggested advocating for 275 nm, but 254 nm gained more popularity in the 1950 and 1960s because the wavelength 254 aligned better with the emission maxima of low-pressure mercury lamps. Literature reviews state a_{250}/a_{365} associated with DOM size, a_{250}/a_{400} associated with DOM source, a_{440}/a_{665} associated with aromaticity, and $S_{275\text{-}295}$ associated with molecular weight (Korak and McKay 2024).

Table 5.10 Spectral curve indices obtained from literature and analysis of NRR2CM data (literature values are in red)

S::CAN results	Absorbance Ratio	Spectral Slope		Spectral Slope Ratio
a_{255} (SCAN255)	a_{250}/a_{365} (E2:E3)	$S_{220\text{-}235}$	$S_{365\text{-}390}$	Sr $S_{220\text{-}235}/S_{240\text{-}260}$
a_{275} (SCAN275)	a_{250}/a_{400} (E2:E4)	$S_{220\text{-}240}$	$S_{390\text{-}425}$	Sr $S_{220\text{-}235}/S_{280\text{-}315}$
	a_{440}/a_{665} (E4:E6)	$S_{240\text{-}260}$	$S_{460\text{-}650}$	Sr $S_{220\text{-}240}/S_{270\text{-}360}$
		$S_{270\text{-}360}$	$S_{675\text{-}720}$	Sr $S_{220\text{-}240}/S_{450\text{-}650}$
		$S_{275\text{-}295}$		Sr $S_{275\text{-}295}/S_{350\text{-}370}$
		$S_{275\text{-}350}$		Sr $S_{275\text{-}350}/S_{415\text{-}600}$
		$S_{280\text{-}315}$		Sr $S_{275\text{-}350}/S_{675\text{-}720}$
		$S_{350\text{-}370}$		Sr $S_{365\text{-}390}/S_{390\text{-}425}$

5.11.1 Data preprocessing and analysis

Between 2017 and 2023, more than 200,000 discrete absorbance measurements were collected at NRR2CM, with sampling intervals ranging from 2 to 15 minutes. The dataset was initially screened to retain only those measurements closest to the quarter-hour marks and further filtered to include only spectral curves that corresponded with laboratory-analyzed water samples. Additionally, data collected between March 2018 and February 2019 were excluded from the working dataset, as the S::CAN turbidity correction feature was disabled during that period. All spectral curves were normalized to minimize the effect of sensor drift between maintenance events and improve comparability between each spectral curve (Figure 5.39). Normalization of each spectral curve required subtracting the minimum spectral curve value greater than 500 nm to each wavelength along the entire curve then add 0.001 abs/cm to ensure all normalized spectral values were greater than zero. Some data analysis involved log calculations.

Each normalized spectral curve was compared to a theoretical exponential decay curve (Figure 5.39) calculated using the cdom_fit_exponential function from the cdom R package. Initial assessment evaluated the residual differences between the normalized and theoretical spectral curve explored to determine if residual differences, over different wavelength ranges, could be used to exclude/qualify spectral curves for future data analysis. Preliminary residual difference calculations required significant trial and error to establish exclusion/qualifier thresholds and would probably require extensive customization for each monitoring site.

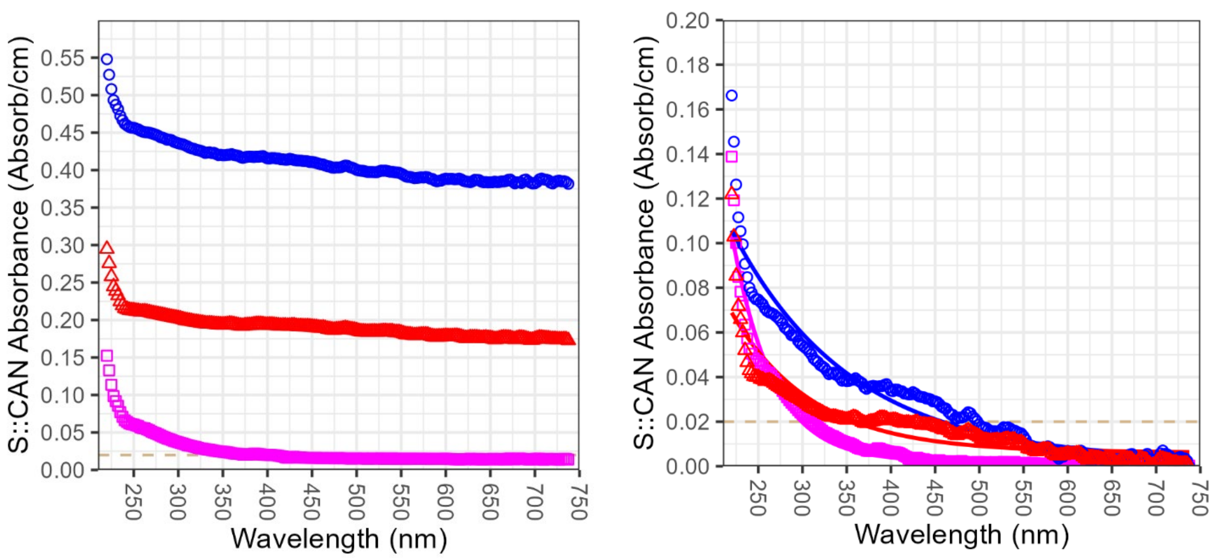

Figure 5.39 Comparison of raw spectral curve (left) to normalized spectral curve and theoretical exponential decay curve (right).

To determine the effectiveness of normalization procedure, spectral curve indices were evaluated as data-screens to determine the deviation between laboratory-measured UV_{254} and the closest S::CAN measured absorbance at 255 nm–SCAN255 (Figure 5.40). The data screening criteria established for the lab UV_{254}/SCAN255 relationship were also applied to the DOC-SCAN255 dataset. Three criteria were chosen: Sr_$S_{220\text{-}240}$ /$S_{280\text{-}315}$ >1.1, Sr_S365-390/S390-425> -1, and $S_{450\text{-}650}$>-0.009.

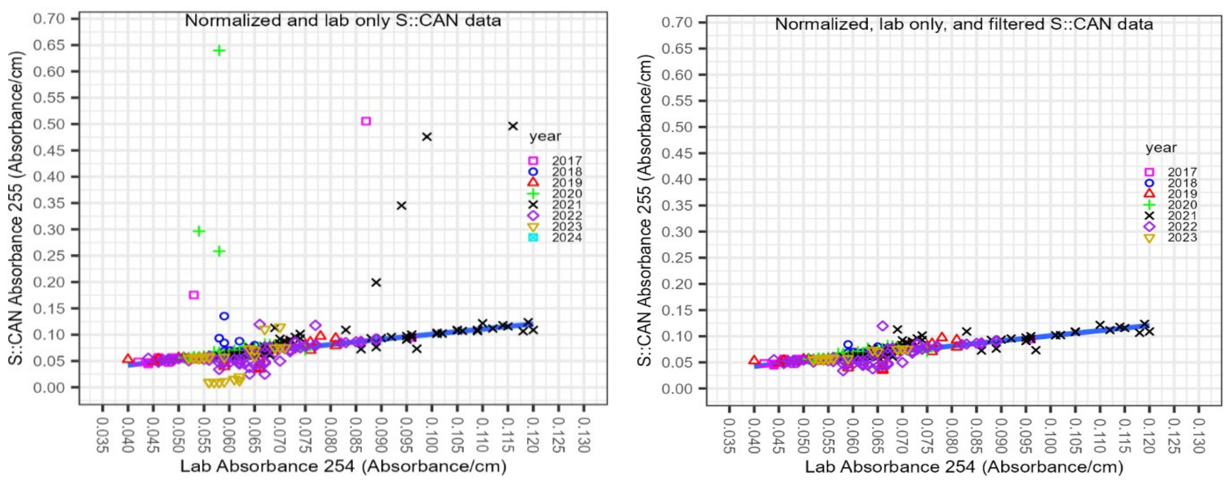

Figure 5.40 Linear regression of laboratory-measured UV_{254} and S::CAN measured a_{255} where spectral index Sr_$S_{220\text{-}240}$ /$S_{280\text{-}315}$ >1.1

With the normalized and screened data for analysis, correlations between laboratory and SCAN255 measurements were evaluated utilizing a correlation test to determine if SCAN255 can be predictive for other laboratory analytes (Figure 5.41). For the primary analytes of interest (DOC and UV_{254}) associated with this pilot project, applying a data-screen to the normalized data improved the linear correlation of UV_{254} from 0.39 to 0.83 and DOC from 0.39 to 0.70. To determine if there is a seasonal component to the linear correlations, correlation values were calculated for each month for the most routinely monitored analytes (Figure 5.42). Most correlations are positive when compared to SCAN255 except specific conductivity, temperature, and pH which were negative. Over the course of the year, the correlation values varied with May/June being a period when there is little to no correlation between lab analyte and SCAN255. Additionally, DOC and UV_{254} had similar patterns over the course of the year, but the SUVA relationship was inverted from February to June (Figure 5.42). This could be an indication that DOC is having a greater impact than UV_{254} during the spring snow-melt period.

To evaluate which spectral indices can predict the laboratory-measured analytes, the machine learning technique eXtreme Gradient Boosting (XGBoost; r package xgboost) was tested (https://deepai.org/machine-learning-glossary-and-terms/xgboost). The dataset was randomly split according to 75% for training and 25% for testing the model. To ensure that the

random split didn't accidentally introduce a bias, 30 iterations were completed and the composite importance factor was calculated to determine the important spectral indices (Table 5.11).

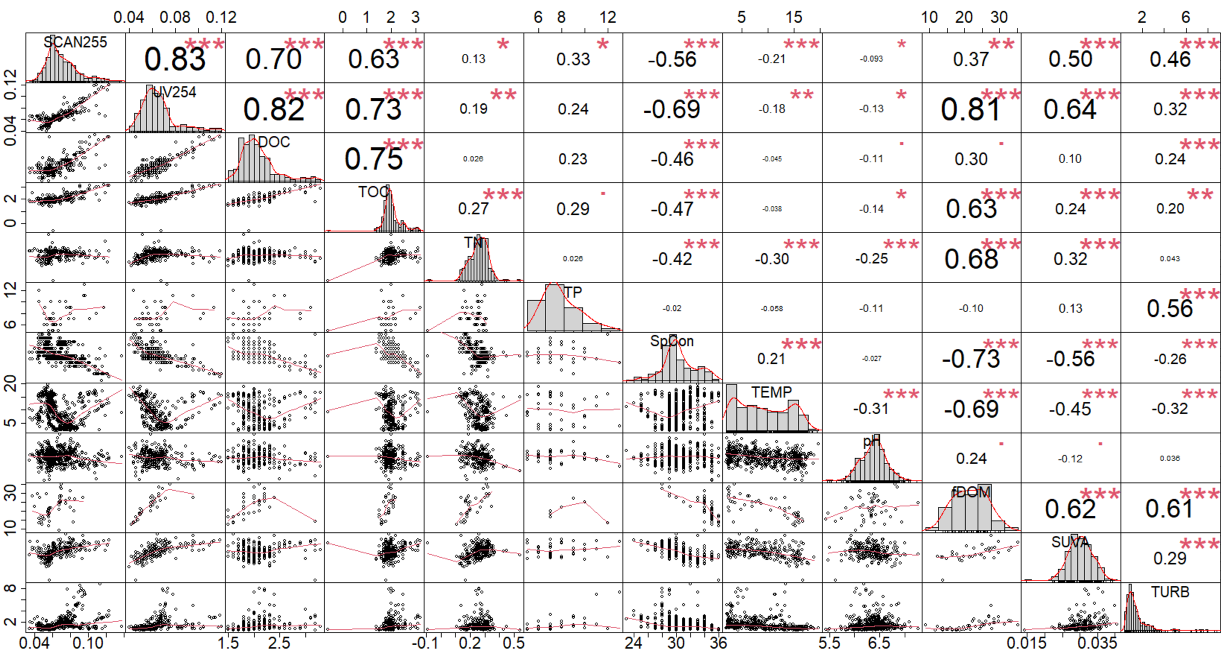

Figure 5.41 Normalized and screened NRR2CM dataset correlation matrix for the entire year. The red line for the scatter plots is a LOWESS line. In the upper right corner, statistical significance is represented by the *, *** represents p-value <0.001, ** represents p-value between 0.001 and 0.01, and * represents p-values between 0.01 and 0.05. In the upper right corner, the correlation values between two parameters which range between 1 and -1. A correlation of 1 represents perfect positive correlation, -1 represents perfect negative correlation, and 0 represents no correlation.

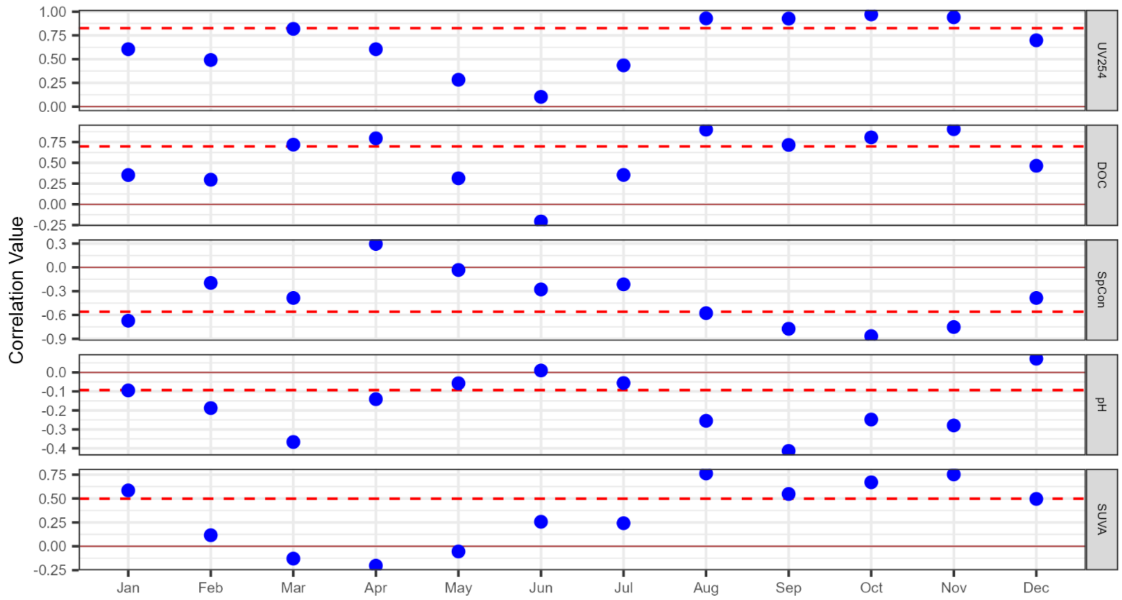

Figure 5.42 NRR2 Correlation of select laboratory analytes to S::CAN 255. Solid line represents zero correlation and dashed line represent the correlation for the entire year. Y-axes are different scales.

Table 5.11 Top eight composite spectral indices for normalized (with screening and no screening applied) for DOC/ UV_{254} at NRR2CM.

Screened DOC		Unscreened DOC		Screened UV_{254}		Unscreened UV_{254}	
Feature	Composite Importance	Feature	Composite Importance	Feature	Composite Importance	Feature	Composite Importance
$S_{365-390}$	6.74	**$S_{365-390}$**	6.25	**$S_{365-390}$**	6.52	**$S_{365-390}$**	6.1
SCAN255	3.48	**SCAN255**	3.38	**SCAN255**	5.88	**SCAN255**	5.13
SCAN275	3.00	**SCAN275**	2.62	**SCAN275**	2.27	**Sr_$S_{365-390}$/ $S_{390-425}$**	1.95
E4:E6	2.38	**E4:E6**	1.88	**Sr_$S_{365-390}$/ $S_{390-425}$**	1.45	**SCAN275**	1.92
E2:E4	2.25	**Sr_$S_{220-235}$/ $S_{240-260}$**	1.6	**Sr_$S_{220-240}$/ $S_{270-360}$**	1.13	**Sr_$S_{220-240}$/ $S_{270-360}$**	1.14
Sr_$S_{220-235}$/ $S_{240-260}$	1.9	**$S_{240-260}$**	1.3	**E4:E6**	1.08	**E4:E6**	1.13
$S_{675-720}$	1.7	**Sr_$S_{275-350}$/ $S_{415-600}$**	1.13	**Sr_$S_{220-235}$/ $S_{280-315}$**	0.9	**E2:E4**	1.07
Sr_$S_{275-350}$/ $S_{415-600}$	0.88	**E2:E4**	1.12	**E2:E4**	0.88	**$S_{280-315}$**	1.06

For DOC and UV_{254}, important spectral indices were $S_{365-390}$ followed by SCAN255 as the most predictive indices (Table 5.11). The spectral indices utilized for screening for the linear relationship (Sr_$S_{220-240}$ /$S_{280-315}$, Sr_$S_{365-390}$/$S_{390-425}$, and $S_{450-650}$) weren't the most predictive for DOC and only Sr_$S_{365-390}$/$S_{390-425}$ was in the top four for UV_{254}. To determine whether screened or unscreened data were important for the XGBoost model cumulative importance, four model runs were completed for screened and unscreened for DOC and UV_{254} with a total of 30 model runs for each combination. The rankings show that $S_{365-390}$ was clearly a better single predictor of DOC while $S_{365-390}$ was a better predictor than SCAN255 for UV_{254} but were more similar than for DOC.

This preliminary analysis explored residual difference, linear correlation, and XGBoost machine learning to determine which spectral curve properties are most predictive for laboratory-measured DOC and UV_{254}. In the future, DEP will expand this work to other locations in the watershed and link spectral curve properties to DBPfp.

5.12 Turbidity Loading

DEP continued evaluating relative contributions of turbidity loading from Shandaken Tunnel and Esopus Creek watershed into the West Basin of Ashokan Reservoir. In 2023, Shandaken Tunnel contributed 4.2% of the Esopus Creek watershed turbidity loading.

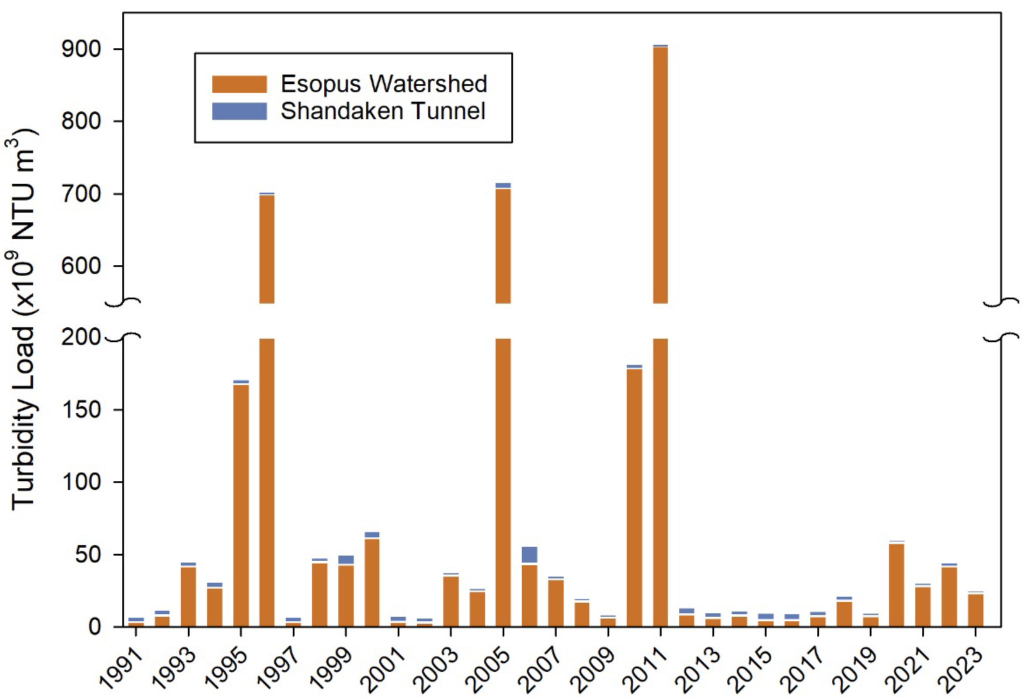

Figure 5.43 Turbidity loading from Shandaken Tunnel discharge and Esopus Creek Watershed to the West Basin of Ashokan Reservoir.

5.13 Model Applications

5.13.1 Evaluate Impact of Boyd Corners Reservoir on West Branch Reservoir Water Quality

West Branch Reservoir plays a crucial role as a terminal reservoir if the downstream Kensico Reservoir operates in bypass mode due to water quality issues. Consequently, ensuring the water quality of West Branch Reservoir becomes essential. In addition to the drainage from watershed (19.8 square miles), West Branch Reservoir receives water from three other basins: Boyd Corners Reservoir, Lake Gleneida, and Rondout Reservoir (via Delaware Aqueduct at site DEL9; ‘reservoir’ mode of operation of the aqueduct). Inflow from Boyd Corners and Rondout reservoirs are gauged. Inflow from Lake Gleneida is insignificant and is not gauged. Rondout and Boyd Corners reservoirs contribute 94.2% and 3.4% of the total inflow, respectively. When DEL9 is not in reservoir mode, Boyd Corners Reservoir becomes the largest source (58%) of water (DEP 2024b). The long-term average hydraulic residence time (HRT) is 15 days when Delaware Aqueduct is operated in the ‘reservoir’ mode, and 255 days in the ‘bypass’ mode.

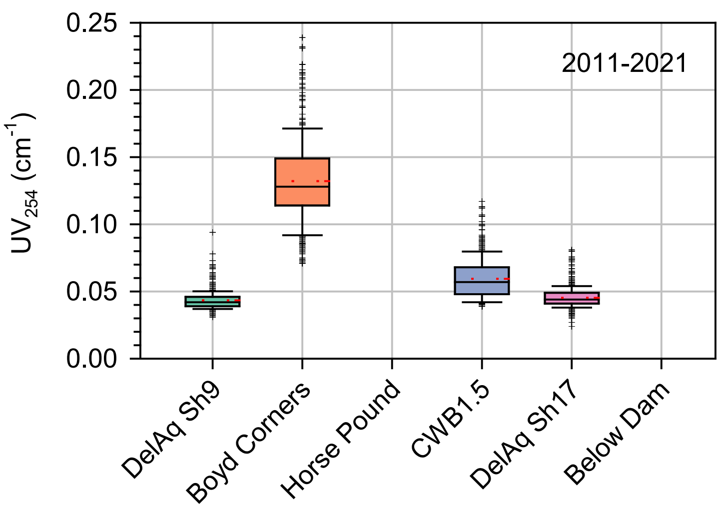

Figure 5.44 Boxplot of UV_{254} levels in inflows, in reservoir, and in outflows of West Branch Reservoir. Horse Pound Brook and below dam sites were not monitored for UV_{254} during the study period.

Hydrology: Median inflow from Boyd Corners Reservoir was 0.5 m^3 s^{-1} (12 MGD; 2001-2021). However, during Spring runoff periods, Boyd Corners Reservoir often spills and can contribute significantly to the total inflow and can impair water quality of West Branch Reservoir even when Delaware Aqueduct is in ‘reservoir’ mode. During 2001-2021, the inflow exceeded 173 MGD 1% of the time and a record 1-day maximum inflow of 38.2 m^3 s^{-1} was observed on April 16, 2007. Contribution from Horse Pound Brook, the only gauged tributary of the West Branch watershed, is relatively small (0.2 m^3 s^{-1} or 4.7 MGD; 1996-2021 average).

Water Quality: The water quality parameter of interest for this study is UV_{254}, a surrogate measure of dissolved organic matter. This organic matter includes substances that serve as precursors to disinfection byproducts when chlorination is carried out. Average UV_{254} in Boyd Corners outflow was 0.13 cm^{-1}, which was ~ 3 times that of DEL9 (0.045 cm^{-1}; Figure 5.44) during the study period. Seasonal dynamics in UV_{254} in the outflow from Boyd Corners and at site CWB1.5 in West Branch Reservoir for 2011-2023 are shown in Figure 5.45. UV_{254} levels in Boyd Corners outflow exhibited periodic increases and decreases that are perhaps associated with combined effects of runoff from its own watershed, in-reservoir kinetic processes, and operational control of the releases. These fluctuations directly impact UV_{254} levels in West Branch Reservoir often within a few hours to a few days following the input from Boyd Corners Reservoir. The impacts are more noticeable in the 'bypass' mode as no dilution from the lower UV_{254} waters from the Delaware System occurs. Furthermore, the duration, timing and magnitude of the impacts is governed by prevailing the stratification regime and related hydrodynamics of the reservoir. This can be illustrated by examining the observations for a couple of events as described next.

In Fall 2018, there was a runoff event when UV_{254} levels in the outflow from Boyd Corners peaked at 0.24 cm^{-1} on November 13th, with West Branch Reservoir operating in bypass mode. Following this, over the next two months, the outflow from Boyd Corners averaged 64 MGD, and UV_{254} gradually decreased to 0.13 cm^{-1}. However, at site CWB1.5 in West Branch Reservoir, UV_{254} levels increased from 0.07 cm^{-1} to 0.11 cm^{-1} during the same period (Figure 5.45). It took another six months for UV_{254} levels in West Branch Reservoir to return to normal. During and after another runoff event in late December 2020, spill from Boyd Corners caused an increase in UV_{254} at site CWB1.5 from 0.045 cm^{-1} to 0.07 cm^{-1}, while West Branch Reservoir was mostly operating in reservoir mode (Figure 5.45).

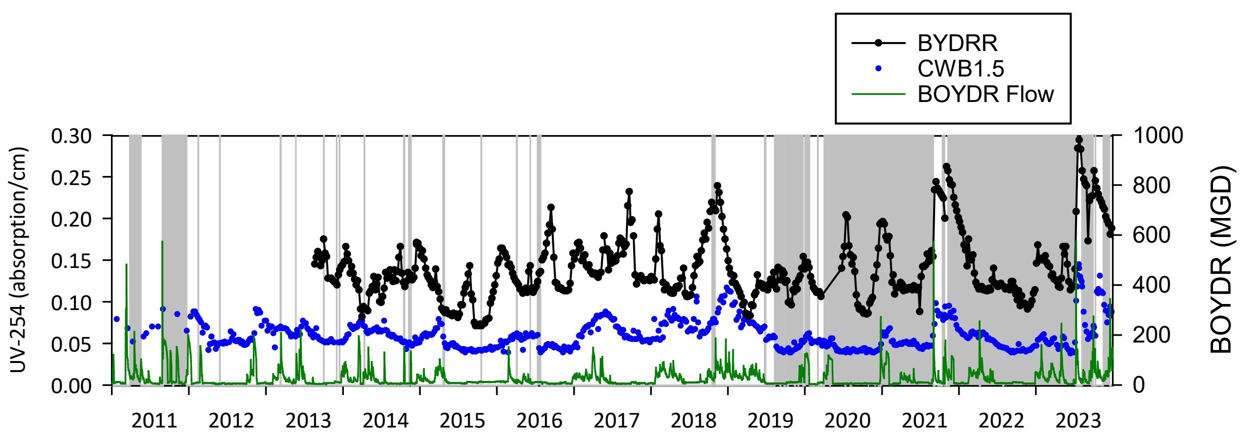

Figure 5.45 Observations of UV_{254} in outflow from Boyd Corners Reservoir (site BYDRR) and in West Branch Reservoir (site CWB1.5), and outflow (spill + release) rate from Boyd Corners Reservoir, 2011-2023. Shaded regions indicate periods of Delaware Aqueduct in 'reservoir' mode, otherwise it is in 'bypass' or 'float' mode.

Such patterns of increases in UV_{254} in the outflow from Boyd Corners followed by increase in West Branch Reservoir UV_{254} were observed throughout the study period. DEP hypothesized that if a portion of Boyd Corners outflow is bypassed during runoff events, then its impact on West Branch Reservoir could be lessened. To test this, DEP considered "what-if" scenarios of reducing the outflow by 30 MGD and evaluated the impacts with a stand-alone W2 model (i.e., not operating within OST) for West Branch Reservoir (Table 5.12). A combination of Boyd Corners outflow and Delaware Aqueduct mode of operation were considered (Table 5.12).

Table 5.12 Model scenarios to test bypass of Boyd Corners Reservoir outflow.

Run ID	Boyd Corners Outflow	Del. Aq. Shaft 9	Comment
0	No change	As operated	Baseline
4a	No change	Bypass	Worst for West Branch WQ
4b	Reduced by bypassing 30 MGD	As operated	Effect of reduced release/spill (potential improvement)
4c	Reduced by bypassing 30 MGD	Bypass	Effect of reduced release/spill (potential maximum improvement)

Results: Results of model runs are presented in the formats of (a) timeseries of UV_{254} at site CWB1.5 for 2018-2020, and (b) scatterplots of baseline and modeled UV_{254} for 2013-2021.

When no change is made to Boyd Corners outflow, but Delaware Aqueduct (DEL9) is operated in bypass mode (Run 4a, Table 5.12) for the entire duration of simulation (i.e., forcing bypass mode even when actually it was in reservoir mode), UV_{254} in West Branch Reservoir was simulated to be significantly higher during the intervals of reservoir mode (see shaded region of Figure 5.46, and the points above 1:1 line in Figure 5.49). This scenario represents a worst-case scenario for the water quality of West Branch Reservoir and underscores the importance of operating West Branch in reservoir mode as much as possible. It is an effective strategy to reduce the impact of elevated UV_{254} in the outflow of Boyd Corners.

In Run 4b (Table 5.12), Boyd Corners outflow entering West Branch Reservoir is reduced by 30 MGD and DEL9 is specified as operated (i.e., a mix of reservoir and bypass/float modes). The predictions from this run showed simulated UV_{254} were lower by ~ 0.01 cm^{-1}, especially when Boyd Corners was spilling, West Branch was in float/bypass mode, and West Branch UV_{254} > 0.075 cm^{-1}; otherwise, improvement was less than 0.01 cm^{-1} (Figure 5.47 and Figure 5.49). These results can be considered as representative of potential improvement in West Branch water quality if such a bypass of Boyd Corners water was carried out.

Results of Run 4c (Table 5.12) in which, Boyd Corners outflow entering West Branch Reservoir is reduced by 30 MGD, but DEL9 is always specified in bypass mode indicate modest improvement (similar to Run 4b) in West Branch UV_{254} during the periods of float/bypass mode (Figure 5.48 and Figure 5.49), but worsening UV_{254} when the original DEL9 mode was reservoir mode (Figure 5.48 and Figure 5.49).

Conclusions: Reducing Boyd Corners Reservoir flow entering West Branch Reservoir improves (i.e., reduces) UV_{254} absorbance modestly. Furthermore, When Boyd Corners is spilling, reservoir mode is effective in reducing the impact of elevated UV_{254} of Boyd Corners Reservoir. Future work may include exploring ways to manage Boyd Corners to minimize spill of elevated UV_{254} water, monitoring of Boyd Corners outflow more frequently, and investigating localized impacts of other tributaries (Long Pond, Horse Pound, Lake Gleneida) of West Branch Reservoir.

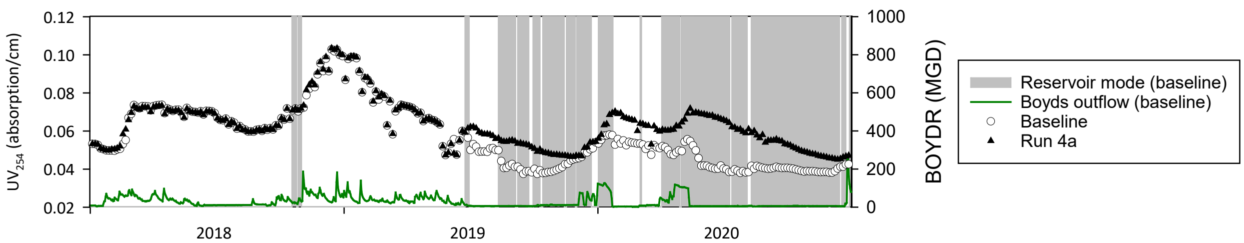

Figure 5.46 Comparison of simulated (Run 4a) and baseline UV_{254} in West Branch Reservoir at site CWB1.5 for 2018-2020. Simulations for a scenario of no change in Boyd Corners flow into West Branch Reservoir, while Delaware Aqueduct is in bypass mode. Baseline UV_{254} for the reservoir operating conditions as recorded.

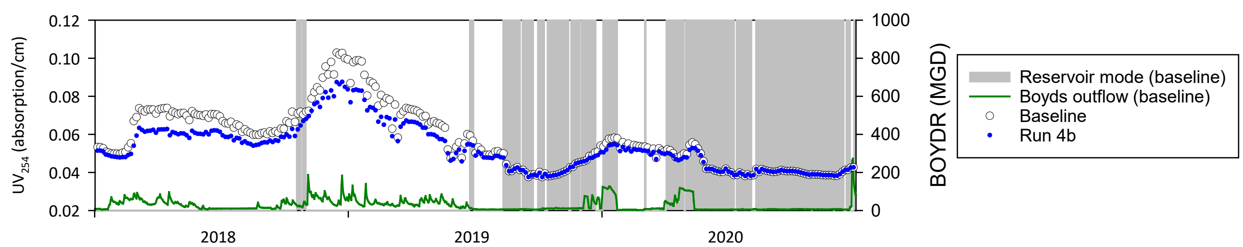

Figure 5.47 Comparison of simulated (Run 4b) and baseline UV_{254} in West Branch Reservoir at site CWB1.5 for 2018-2020. Simulations for a scenario of reduced Boyd Corners flow into West Branch Reservoir, while Delaware Aqueduct operation is as recorded. Baseline UV_{254} for the reservoir operating conditions as recorded.

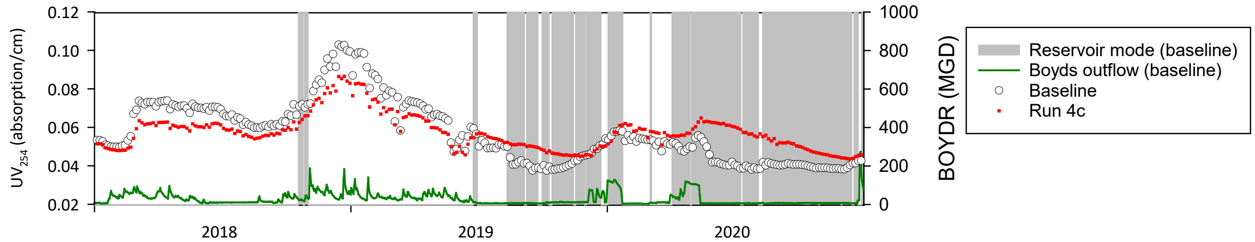

Figure 5.48 Comparison of simulated (Run 4c) and baseline UV_{254} in West Branch Reservoir at site CWB1.5 for 2018-2020. Simulations for a scenario of reduced Boyd Corners flow into West Branch Reservoir, while Delaware Aqueduct is in bypass mode. Baseline UV_{254} for the reservoir operating conditions as recorded.

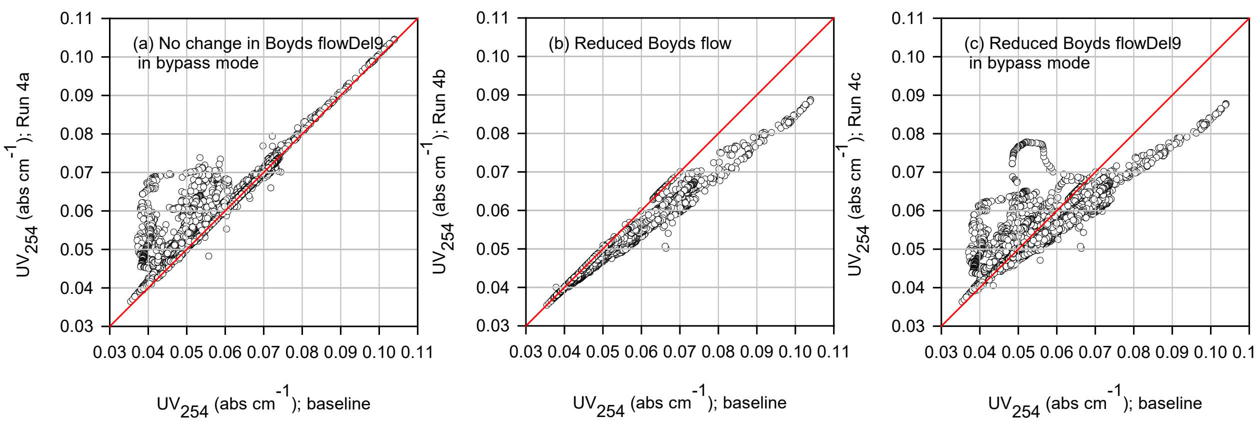

Figure 5.49 Comparison of simulated and baseline UV_{254} in West Branch Reservoir at site CWB1.5 for 2013-2021.

5.13.2 Support for Operational Decisions

OST-W2 runs: Three significant rainstorms during December 2023-January 2024 impacted water quality of Catskill System. During these events, peak instantaneous flows at E16i on Esopus Creek were 21,800 CFS (December 18, 2023), 6150 CFS (January 10, 2024) and 5770 CFS (January 13, 2024). Peak turbidity was > 1250 NTU in the inflow and ~ 30 NTU in the West Basin (Figure 5.50).

DEP conducted several OST runs to guide operations of the Catskill Aqueduct and manage water quality in the aftermath of these storms. After the first storm, three scenarios of Ashokan East Basin diversion flow rates of 450 MGD, 350 MGD, and 120 MGD + 240 MGD from Shaft-4 were considered. For each of the three flow scenarios, two turbidity scenarios (8 NTU and 15 NTU) were evaluated. OST-W2 simulations projected that Kensico diversion turbidity would not exceed ~ 1.5 NTU at 50^{th} percentile level in the scenarios with Delaware waters augmenting the Catskill waters via shaft-4 interconnection for three weeks after the storm. Thus, Ashokan diversion with shaft-4 was considered feasible without adversely affecting Kensico water quality, and diversion was planned and executed while following the interim release protocol for Ashokan Release Channel operation.

Additional OST (n = 36) runs were conducted during January 9-17, with a range of Ashokan East Basin diversion flow rates, with and without augmenting flow from the Delaware Aqueduct via Shaft-4 interconnection, to evaluate impact on Kensico effluent turbidity. All runs projected that in the near-term (1-2 weeks), Kensico effluent turbidity would remain < 5 NTU, and < 2 NTU if Shaft-4 was used. Results of three such runs are presented in Figure 5.51. No alum was added at inflow to Kensico Reservoir (CatAlum) during and after these storm events.

Another OST-W2 run was conducted to estimate time of recovery of West Basin. A run was setup with normal system operating conditions (i.e., 'OPEN' run). W2 models of Rondout, Schoharie, Ashokan, and Kensico were initialized with the best available observations of temperature and turbidity from special surveys conducted after the storm. It was projected that West Basin was unlikely to return to turbidity < 10 NTU by February 29, 2024 (Figure 5.52).

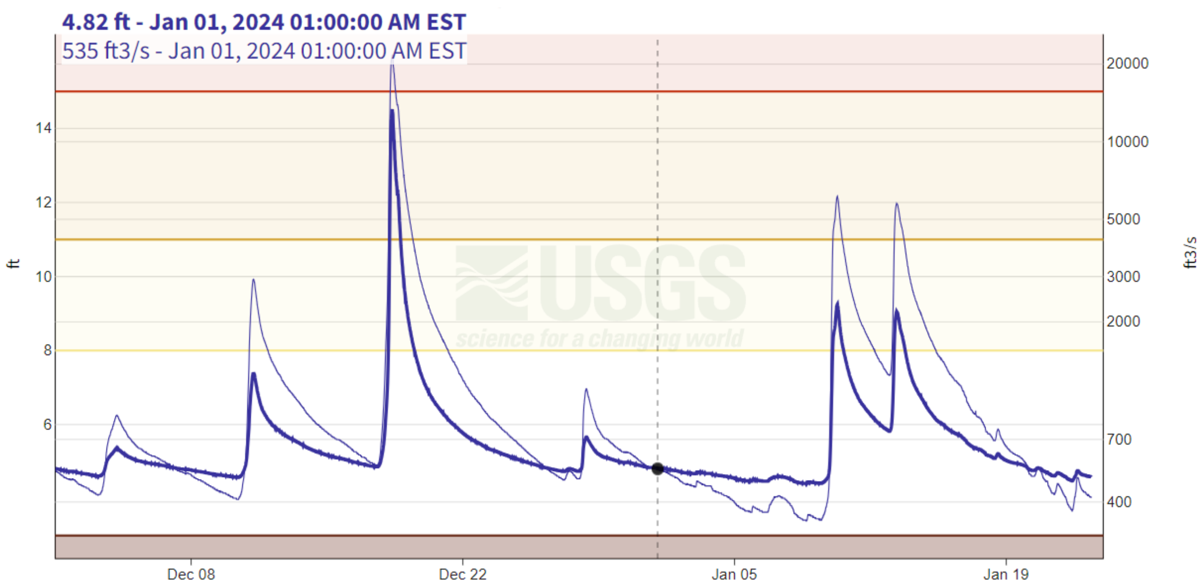

Figure 5.50 Stage height (darker line) and streamflow (lighter line) at Esopus Creek, December 1, 2023 – January 23, 2024.

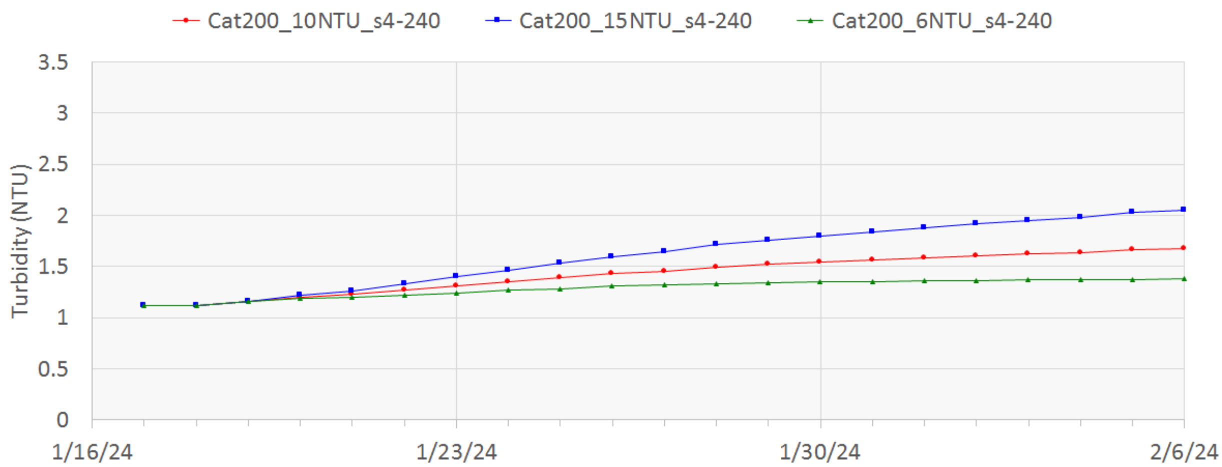

Figure 5.51 Projections (medians of ensembles of 62 traces) of Kensico diversion turbidity for a range of operating conditions of Catskill Aqueduct and Shaft-4.

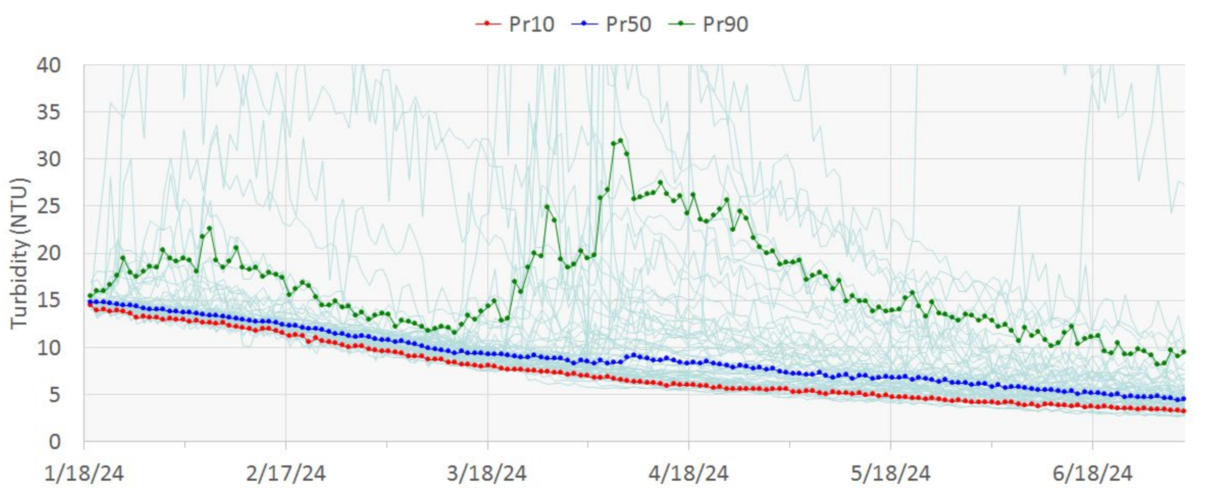

Figure 5.52 Ensemble of projections of Ashokan West Basin turbidity (Pr10, Pr50, and Pr90 indicate 10th, 50th, and 90th percentiles of the ensemble).

DEP also conducted OST-W2 runs to guide operations of the Delaware System reservoirs after receiving 8.5 cm of rain during August 9-10, 2024. Turbid waters from the West and East Branches of Delaware River entered Cannonsville and Pepacton reservoirs as interflow with peak impacts near the intake locations recorded at just above thermoclines (Figure 5.53). A combination of selective withdrawal location and diversion flow rate scenarios were evaluated (Figure 5.54). The median turbidity in Rondout diversion was projected to remain < 1 NTU for the two Cannonsville scenarios (300 MGD at 3 NTU and 10 NTU) until August 31st. Both scenarios used diversion from Pepacton as 450 MGD at 2.5 NTU and diversion from Neversink as 150 MGD at 1 NTU.

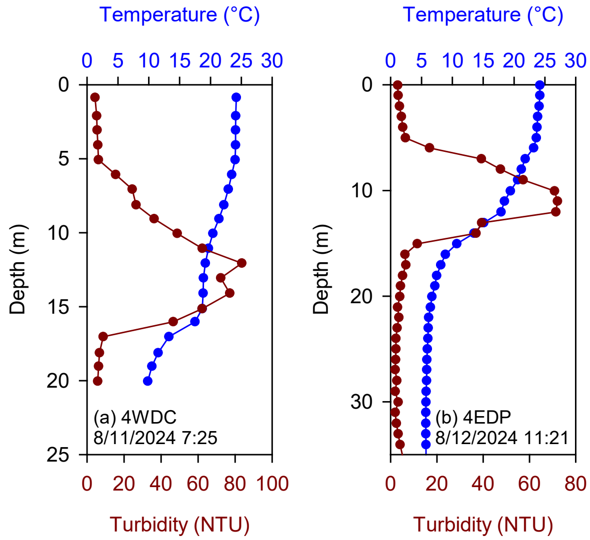

Figure 5.53 Profiles of temperature and turbidity: (a) Cannonsville Reservoir, and (b) Pepacton Reservoir.

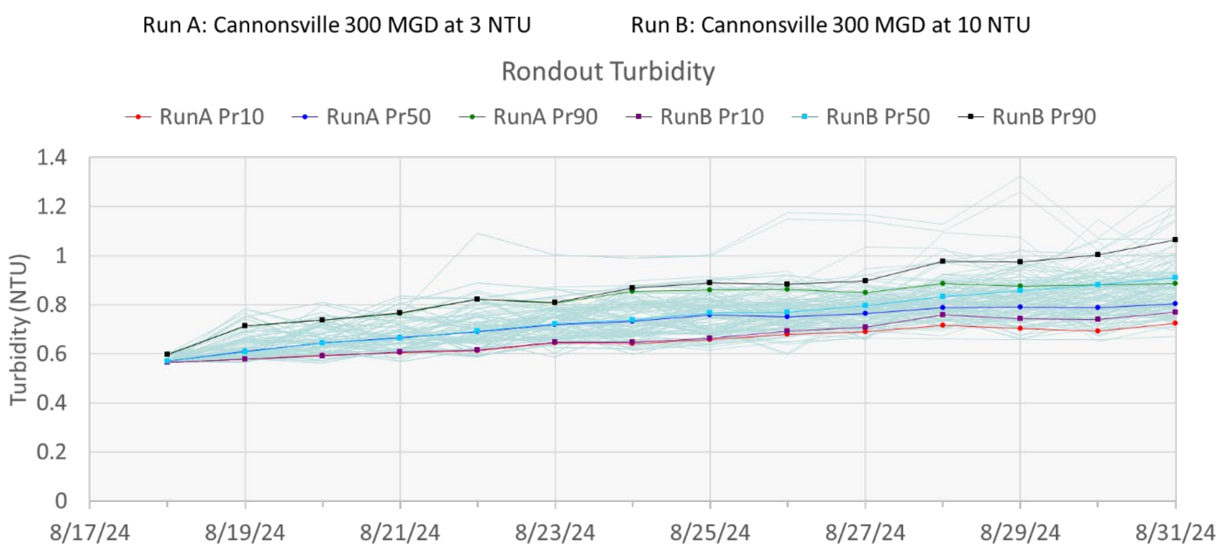

Figure 5.54 Projections of Rondout Reservoir diversion turbidity (Pr10, Pr50, and Pr90 indicate 10th, 50th, and 90th percentiles of the ensemble).

OST-W2 runs during Rondout West Branch Tunnel Shutdown Project: OST runs with W2=ON were routinely conducted during RWBT shutdown project in October 2024. These runs allowed DEP to evaluate and forecast turbidity in Kensico Reservoir frequently and ensured that DEP maintained a low baseline turbidity (< 1.5 NTU) in the reservoir. Results of a run with Catskill Aqueduct inflow turbidity of 5 NTU, and Delaware Aqueduct inflow turbidity of 4 NTU are shown in Figure 5.55. The model simulation projected that Kensico diversion turbidity would exceed 1.5 NTU (Figure 5.55a), but with the addition of alum at CatAlum, it would remain < 1.5 NTU (Figure 5.55b).

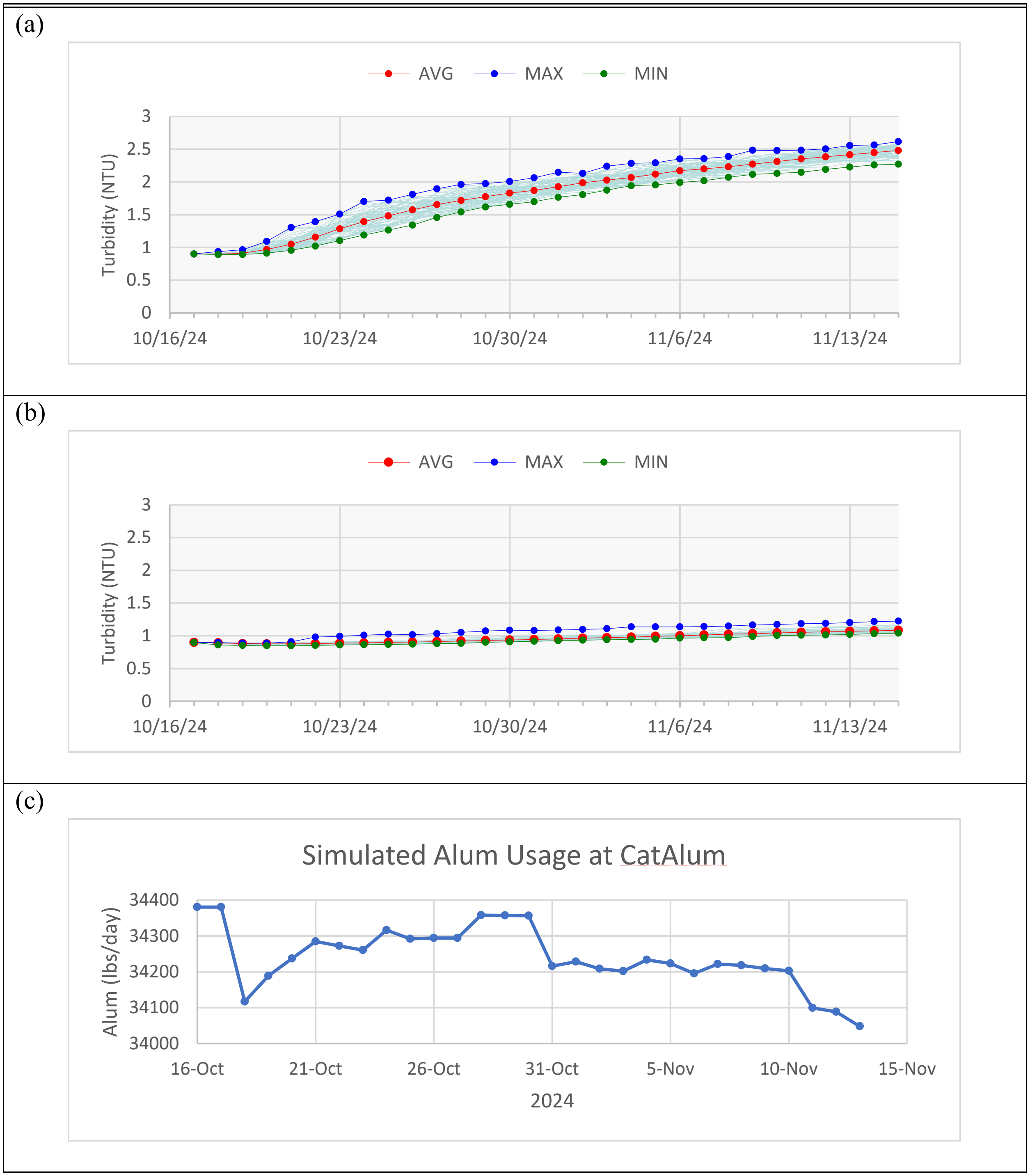

Figure 5.55 Projections of Kensico Reservoir diversion turbidity at Shaft-18: (a) without alum at Catskill Aqueduct inflow, (b) with alum, and (c) simulated alum usage.

5.15 Reservoir Operations Modeling and OST

During 2024, 950 OST simulations were performed. Hazen & Sawyer and RTI continued providing technical support, including enhancements and upgrades to OST and related tools to better align them with current operations rules, infrastructure status, the FAD program, and simulation of UV_{254} (a proxy for DBPs). 2024 OST infrastructure outage support included preparation, pre-outage and outage implementation phases of the Rondout West Branch Tunnel (RWBT) outage. Preparation activities included mock runs and pre-outage simulations. Pre- and outage OST runs outputs were used for informational briefings to DEP WSS outage management team and operators.

OST improvements in support of the FAD program included the addition of water quality models to simulate turbidity in Pepacton, Cannonsville and Neversink reservoirs. In addition, working with RTI and in collaboration with the NWS Middle Atlantic and Northeast River forecast Centers (MARFC and NERFC), and NOAA's Office for Water Prediction (OWP) DEP continued working on reducing the uncertainty associated with hydrological ensemble forecasts to improve inflow and turbidity loads specification in OST.

Some other tasks completed in 2024, or in-progress are:

a. Concluded automated initialization of EOH reservoirs elevations when starting OST Positional Analysis simulations to support daily operations.

b. Continued developing a new Climate Model to efficiently run climate change simulations involving traces/scenarios extending for 100s of years.

c. Developed an adjusted historical baseline inflow that includes 500 years of historical paleo-reconstructed streamflow estimations.

d. Implementing the final phase of OST transition to DEP Azure cloud tenant.

e. Developed an OST living documentation in web-based Confluent Atlassian platform. BWS DEP's Modeling team is now taking over maintenance and continued development of the platform.

f. Started building an enhanced Mixed Ensemble forecast Post-Processor (Mixed-EPP) that combines the existing DEP EPPv2, the NWS EnsPost, BWS Quantile-to-Quantile based (QQ-), Artificial Intelligence based (AI-) and a combined QQAI-based forecasts processors. In the Mixed-EPP each post-processor is selected for those OST forecast locations for which it shows the best performance among all post-processors.

g. Conducted training sessions and knowledge transfer activities. Some of the areas of the training were:

i. Overview of NYC Water Supply operations as implemented in OST: (a) OST Introduction and Operations Control Language (OCL) Flow Chart (b) Main OCL and utility code (c) Catskill Basin turbidity code (d) NYC_Alum and NYC_W2 OCL codes in OST (e) Delaware Basin and East of Hudson OST codes
ii. Reservoir balancing in OST
iii. Water quality W2 models in OST
iv. RWBT Shutdown modeling

h. Prepared two manuscripts for publication, which will be sent to journals for peer reviewed publication in 2025.

   i. "A monthly-to-daily k-nearest neighbor multisite streamflow disaggregation procedure to maintain daily flow continuity at month boundaries"

   ii. "Five centuries of variability of the Delaware River Basin streamflow"

6. Innovation and Research

The analytical, monitoring, and research activities of DEP are supported through a variety of contracts, staff participation in research projects conducted by The Water Research Foundation (WRF), and interactions with national groups such as The Cary Institute of Ecosystem Studies. Research engagement with external groups is a critical component of the Bureau of Water Supply's commitment to emerging research and technology in the water supply industry and provides opportunities to partner with subject matter experts. The ongoing internal research efforts, along with research partners and projects coordinated within Strategy, Policy & Innovation, are described in this chapter.

6.1 Research Inventory

BWS leads DEP's efforts to catalogue all research taking place across the agency. To achieve this, BWS developed an inventory of past, current, and proposed research to increase awareness of ongoing studies and to foster collaboration throughout the agency and with professional and academic peers. The inventory catalogues the agency's research utilizing an organizational framework that provides for a flexible and refined hierarchy. Broadly speaking, all research projects have been classified within four core subject areas that reflect the efforts underway and serve as a framework for research priorities moving forward:

- **Environment** is inclusive of all studies pertaining to the interface of the natural environment with the water supply and includes terrestrial, aquatic, climatological, air, and water resources such as streams, lakes (reservoirs) and wetlands.

- **Innovation** covers all new and emerging technologies, novel methods, and strategies to better manage and operate the City's water supply, as well as studies and research pertaining to emerging challenges.

- **Public Health** captures projects committed to ensuring safe, clean water is delivered to all users. It includes research related to water quality, treatment, and regulatory requirements.

- **Sustainability** includes opportunities for the water supply to be self-sustaining in the areas of energy, infrastructure, financing, and hydrology.

As of December 2024, BWS had 36 active or planned research projects. Across the core subjects, the Research Inventory includes 18 research areas (Figure 6.1).

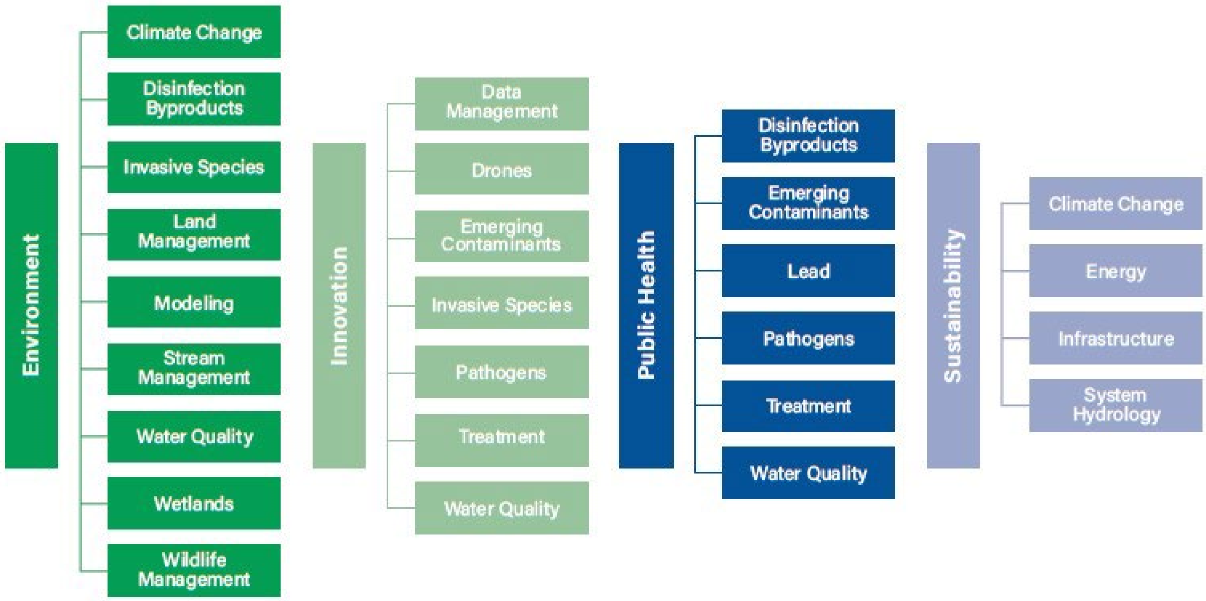

Figure 6.1 Research Inventory Research Areas.

6.2 Research Advisory Council

In 2020, BWS created the Research Advisory Council (RAC) to establish and manage a research process and act as a forum to communicate and support research initiatives. The RAC is a staff-level group with representation from all directorates: Core Services, Drinking Water Operations, Source Water Protection, and Strategic Operations & Research. The RAC is comprised of 17 appointed members and 4 at-large members, each serving for two-year terms.

In 2024, RAC members evaluated the RAC charge and proposed recommendations to optimize the Council's effectiveness. The RAC continues to coordinate participation in The Water Research Foundation projects identified in Table 6.4, below.

6.3 2024 BWS Conference

BWS held an internal conference, inviting staff to present on critical research underway within the bureau. The theme of the May 8, 2024, conference was *The Delaware Aqueduct Repair Project.* The project is the culmination of over a decade of planning and is a once-in-a-lifetime capital project. The half-day conference discussed the history of leaks along the Rondout-West Branch portion of the Delaware Aqueduct, along with numerous projects that supported the shutdown, and the required operational adjustments leading up to the shutdown. Presenters provided details on how the bypass tunnel was constructed, along with the challenges encountered along the way. In 2024, 387 staff attended the conference.

6.4 2024 BWS Webinars

In addition to the annual conference, BWS also highlights ongoing research or related activities with monthly "Thirsty Thursday" webinars. In 2024, 222 staff participated in four webinars (Table 6.1). Three webinars were unexpectedly cancelled and, therefore, participation is lower than usual.

Table 6.1 2024 Thirsty Thursday Webinars

Month	Topic
February	NYC Stormwater Resiliency
March	CAT/DEL UV Plant (CDUV) Lamp Life Extension Evaluation
October	BWS Drone Services Contract
December	USGS Groundwater Monitoring in Brooklyn and Queens

6.5 Working Groups

6.5.1 Drone Working Group

BWS continues to explore the use of unmanned aircraft systems (UAS), or drones, to collect data within water supply watersheds. A new (as of winter 2024) BWS drone services contract with Gedeon GRC Consulting (Syosset, NY) has enabled seven projects employing drones to date, and remains available for any BWS staff to implement project drone use. A recently acquired (as of spring 2024) underwater drone (Blueye X3, manufactured by Blueye Robotics of Trondheim, Norway) continues to be used in periodic zebra mussel inspections of Croton reservoir intake structures.

6.5.2 Salinity Task Force

The BWS Salinity Task Force (STF) completed the Salinity Management Assessment in 2024. This initiative provided an understanding of drivers of salinity increase in the City's watersheds and will provide recommendations towards a regional approach to salinity management. The final report was published in 2025.

The STF is comprised of staff appointed by the various directorates in BWS. The task force's goal is to examine, measure, and understand the trends of salinity for the NYC watersheds and water supply, and to develop a strategy to monitor and reduce salinity. While the STF found a sustained increase in chloride concentrations in all NYC reservoirs, the highest increases were in the EOH watersheds. These increases ranged in magnitude and the causes for observed increases are primarily connected to the use of road deicers in winter.

6.5.3 R Data Analysis Group

The overarching goal of the R Data Analysis Group (RDAG) is to develop DEP's data analysis and management skill sets for scientific reporting. This group serves to improve legacy knowledge transfer to the next generation of data analysts/scientists using the open-source R statistical software for statistical analysis and data visualization. During 2024, six meetings were held covering the topics of random forest and xgboost machine learning, creation of Word document tables, capturing data from internal and external data sources, utilizing the WRTDS package, and utilizing internally created R package (loweResopus) designed to capture, format, and plot data for external stakeholders.

6.6 Water Research Foundation

The Water Research Foundation (www.waterrf.org) is "the leading research organization advancing the science of all things water to meet the evolving needs of its subscribers and the water sector. WRF is a 501(c)(3) nonprofit, educational organization that funds, manages, and publishes research on the technology, operation, and management of drinking water, wastewater, reuse, and stormwater systems—all in pursuit of ensuring water quality and improving water services to the public." DEP has been a subscriber and participant in research conducted under the WRF since the early 1990s, both as project advisory committee (PAC) members and as a participating utility (PU), to remain current with cutting-edge research for the benefit of the City's drinking water.

The following sections describe DEP's engagement with WRF quantitatively through metrics and scholarships. In addition, WRF coordinated a workshop on filtration planning. Finally, BWS participated in 32 Water Research Foundation projects. These projects provide insight into pathogens, emerging contaminants, and corrosivity of source water that can interact with distribution system features and may have operational implications. The current projects in which BWS is involved are described in the following sections.

6.6.1 Metrics

BWS tracks involvement with The Water Research Foundation year-over-year to measure engagement and identify areas or opportunities for growth (Table 6.2). Webinar participation declined in 2022 for several reasons: the foundation held fewer webinars in and, of those webinars, most focused on wastewater resource recovery facility treatment of nutrients. In addition, staffing shortages have placed increased demands on staff time and many webinars are scheduled when staff are no longer in the office. In August of 2023, BWS made efforts to provide all bureau staff with access to WRF webinars and participation increased markedly, and in 2024 participation exceeds all previous years. Participation on planning and research bodies also continues to increase.

Table 6.2 Water Research Foundation Metrics 2019 – 2024.

Metric	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**
New Staff Accounts	18	32	1	15	1	13
External Organizations included in DEP's Subscription	5	5	5	5	5	5
DEP Staff Serving on WRF Planning/Research Bodies	17	24	32	45	59	64
Webinar Participation	65	215	287	24	112	326

6.6.2 WRF Workshop – Future Filtration: Lessons Learned

WRF organized a filtration workshop on behalf of BWS on July 10-11, 2024. The goals of the workshop were to:

- Develop a process to select a final treatment process for a CAT/DEL filter plant
- Identify challenges other utilities faced in maintaining a FAD
- Identify critical factors for planning a water treatment plant where the water supply may degrade due to climate change and increasingly more stringent regulatory requirements.

Utility experts from Vancouver, Seattle, Portland, Tacoma, San Francisco, and Boston shared their experiences developing advanced treatment and filtration for their surface water supplies (Table 6.3). The panel made numerous recommendations related to managing climate risk, shared their experiences navigating a shifting regulatory environment, and discussed the importance of supporting innovative thinking needed to safeguard a clean and sustainable water supply.

Table 6.3 Filtration Workshop: Subject Matter Experts.

Expert Panelists	
Yone Akagi Water Quality Manager, City of Portland Water Bureau	Kim Lebeau Water Quality Director, Massachusetts Water Resources Authority
Kim DeFolo Principal Engineer, Tacoma Water	Winsome Robinson Williams Drinking Water Quality Division Director, Seattle Public Utilities
Andrew DeGraca Water Quality Division Director, San Francisco Public Utilities Commission	Inder Singh Director of Interagency Projects & Quality Control, Metro Vancouver
Steve Estes-Smargiassi Director of Planning and Sustainability, Massachusetts Water Resources Authority	

6.6.3 WRF Project Participation

Table 6.4 summarizes all WRF project participation in 2024.

Table 6.4 2024 WRF Project Participation.

Title	Participation[1]
5344-Investigating the Effect of Operational Strategies and the Role of Microbial Biomass for Extending the Lifetime of Granular Activated Carbon	PAC
5339-Artificial Intelligence-Based Early-Warning & Mitigation System for Harmful Algal Blooms	PAC
5338-Microplastics in Drinking Water Distribution Systems	PAC
5318-Collaborative Forum on Microplastics Research	PU
5309-Developing a Protocol for Evaluating Pathogen Concentrations in Secondary Effluent	PAC
5308-Assessing Changing Salinity in Water Sources	PAC
5304-Optimizing Nature-based Solutions at the Watershed Scale with Real-time Sensing and Controls	PAC
5299-Assessment of Corrosion Control Treatment (CCT) Pipe Rig Study Data Compared to Distribution System Lead Levels	PAC
5295-Balancing Human and Natural Assets in a One-Water, Integrated Water Resource Management Framework	PAC
5294-Data Management Best Practices: Preparing and Integrating Data Sources for Treatment Optimization and Efficiency Projects	PU
5293-Comprehensive Corrosion Control Strategies for Various Water Infrastructure Materials	PAC
5287-Method Refinement and Standardization for Microplastics Sample Collection and Analysis	PAC
5285-Technology Readiness of Regeneration and Disposal Options for PFAS-Laden Drinking Water Treatment Residuals, Spent Media, and Associated Waste Streams	PAC
5257-Advancing Nature-Based Solutions by Assessing Long-Term Performance of Natural and Engineered Media	PAC
5254-Evaluation and Demonstration of Molecular Microbial Tools for Improved Operation and Optimization of Biofiltration	PAC
5246-Quantifying the Performance of Source Water Protection Measures to Improve Utilities' Decision Making	PU
5237-Ozone Nanobubble Technology for Water Treatment	PAC

Title	Participation[1]
5218-Inactivation of Amoeba-internalized Legionella pneumophila by UV-LED and Multi-Barrier Approaches	PAC
5174-Satellite and Drone Remote Sensing Models and Tools for Water Quality Monitoring and Ecological Assessment of Fresh Water Resources	PAC
5173-Feasibility of Full-Scale Implementation of LED UV Disinfection	PAC
5171-Cost-Effective Approaches for Control of Multiple Constituents of Emerging Concern	PAC
5156-Occurrence of Legionella in Drinking Water Distribution Systems	PAC PU
5125-Unregulated Organic Chemicals in Biosolids: Prioritization, Fate and Risk Evaluation for Land Applications	PAC
5122-Technologies and Approaches to Minimize Brominated and Iodinated Disinfection Byproducts in Distribution Systems	PU
5120-Utility Field Guide for Developing a Cyanobacteria and Cyanotoxin Monitoring Program	PAC
5119-Using Phosphate-Based Corrosion Inhibitors and Sequestrants to Meet Multiple Water Treatment Objectives	PAC
5088-Defining Exposures of Microplastics/Fibers (MPs) in Treated Waters and Wastewaters: Occurrence, Monitoring, and Management Strategies	PAC
5080-Assessment of Vulnerability of Source Waters to Toxic Cyanobacterial Outbreaks	PAC PU
4797-Designing Sensor Networks and Locations on an Urban Sewershed Scale with Big Data Management and Analytics	PAC

[1]PAC: Project Advisory Committee; PU: Participating Utility

6.7 American Water Works Association (AWWA)

The American Water Works Association is an international, nonprofit, scientific and educational society dedicated to providing total water solutions assuring the effective management of water. Founded in 1881, the association is the largest organization of water supply professionals in the world. The membership includes over 4,300 utilities that supply roughly 80% of the nation’s drinking water and treat almost half of the nation’s wastewater.

6.7.1 Technical Advisory Workgroups (TAWs)

Table 6.5 lists the technical advisory working groups with DEP participants.

Table 6.5 AWWA Technical Advisory Working Groups in 2024.

AWWA Committees	
Committee Name	**Participant**
Disinfection By-Products	Lori Emery, Director, Water Quality, Bureau of Water Supply
Microbial/Disinfection By-Products Rule	Salome Freud, First Deputy Director, Water Quality, Distribution Water Quality, Bureau of Water Supply
Lead and Copper Rule	Salome Freud, First Deputy Director, Water Quality, Distribution Water Quality, Bureau of Water Supply
Lead and Copper Rule Subcommittee	Julie Herzner, P.E., Chief, Water Quality Science and Planning, Water Quality, Bureau of Water Supply
Microbiological Contaminants Research	Kerri Alderisio, Senior Technical Advisor/WDRAP Coordinator, Distribution Water Quality, Water Quality, Bureau of Water Supply
Organisms in Water	Kerri Alderisio, Senior Technical Advisor/WDRAP Coordinator, Distribution Water Quality, Water Quality, Bureau of Water Supply
UV Disinfection for Wastewater	Matthew Burd, Advisor for Process, Wastewater Resource Recovery Operations, Drinking Water Operations, Bureau of Water Supply
Water Resources and Source Water Protection	Jeffrey Graff, Section Chief, City Land Stewardship, Source Water Protection, Bureau of Water Supply
NYSAWWA Water Utility Council	Salome Freud, First Deputy Director, Water Quality, Distribution Water Quality, Bureau of Water Supply
	Shilo Williams, Assistant Commissioner, Source Water Protection, Bureau of Water Supply

6.8 Town+Gown

Created in 2009-2010, Town+Gown is a city-wide university-community partnership program, resident at the New York City Department of Design and Construction (DDC), that brings academics and practitioners together to create actionable knowledge in the built environment. Under the terms of the consortium contract, BWS can issue requests for proposals (RFPs) for research initiatives.

6.8.1 Hemlock Woolly Adelgid

The hemlock woolly adelgid is an invasive, aphid-like insect that attacks North American hemlocks, and has been identified in much of the City’s watershed. BWS contracted with Cornell University in 2022 to determine how effective predatory insect species from the Pacific Northwest can be when used as biocontrol agents to control hemlock woolly adelgid populations. In 2024, DEP continued collaborating on the Cornell Hemlock Initiative to establish populations of *Laricobius nigrinus* (beetle) and *Leucotaraxis* spp. (silver fly) at several experimental release sites in both the East and West of Hudson watersheds. At the end of 2024 researchers at the

United States Forest Service completed a genetic analysis of specimens collected from foliage near release sites and confirmed establishment of the beetle. Monitoring for successful establishment of silver fly will continue.

6.8.2 A Regional-scale Assessment of Nutrient Loading for NYC Watersheds

In 2021 the RAC reviewed a study to account for patterns (e.g., seasonal, annual) and trends (i.e., change through time) in watershed nutrient export (i.e., nitrogen and phosphorus) to evaluate the influence and interaction of City watershed protection programs and climatological change over time. Additionally, this study will support the identification of high nutrient source areas and give insights into watershed protection program planning for the future.

The goal for this research is to apply a nutrient export approach using watershed models and anthropogenic nutrient input toolboxes coupled with results from trend analysis to describe the potential causes of observed nutrient trends in the NYC watershed. This was recommended by the National Academies of Sciences, Engineering, and Medicine in a consensus study report prepared as part of a review of the NYC Watershed Protection Programs (NASEM 2020). The desired outcome is to determine where the greatest sources (areas and types) of nutrients are located and how nutrient loads to reservoirs have changed over time to provide guidance for future watershed protection and other initiatives.

Cornell University's proposal was selected, and the contract is expected to register in 2025.

6.8.3 Croton Filtration Plant: Analysis of Biologically Activated Carbon Study

The Croton Filtration Plant (CFP) is capable of delivering up to 290 million gallons of water per day. CFP is a conventional water treatment plant that uses a dissolved air flotation (DAF) clarification process "stacked" over granular activated carbon (GAC)/sand dual media gravity filters. The DAF clarified water is conveyed to the gravity filters underneath where remaining particulates and contaminants (i.e., dissolved organic carbon (DOC) and emerging contaminants) are removed by the GAC media.

In 2018, customer complaints for taste and odor increased when the Croton system was online. It was determined that the likely cause was Geosmin and 2-methylIsoborneol. To combat this issue, the water treatment process at the Croton Water Filtration Plant was evaluated, and granular activated carbon (GAC) replaced anthracite in the filter beds. This update was successful, as the aesthetic issues of color, taste, and odor were reduced while maintaining treatment requirements. However, GAC is exhausted quickly, and additional testing is underway to determine if taste and odor removal through GAC filters can be improved.

An RFP was issued in 2024 to study whether the functionality of the granular activated carbon within the Croton Filtration Plant could be extended by converting to a biologically activated carbon media. Work is anticipated to begin in 2025.

6.9 Research Partners

6.9.1 Cary Institute of Ecosystem Studies

BWS continued a partnership with the Cary Institute of Ecosystem Studies in 2024. The Cary Institute administers the Catskill Science Collaborative, a program designed to promote scientific research and environmental monitoring in the Catskill region. Research conducted in 2024 included a literature review on watershed forest management, forest health and emerging threats to native forests in the northeastern United States. This review will evaluate factors including but not limited to invasive plants, insects, and pathogens, land use, and climate change. As part of this review, we will examine the connection between forest cover and water quality, as well as the current state of forest health monitoring and best practices, including the use of emerging technologies, to monitor the impacts of beech leaf disease in the Ashokan & Schoharie basins.

In addition, two requests for proposals were issued in 2024: 1) Enhancing riparian buffer effectiveness for improved water quality and ecosystem services in the Catskill watersheds and 2) Assessment of water quality variability in the West of Hudson watersheds influenced by forest phenological shifts under climate change. These research projects will commence in 2025 and are expected to be completed in 2026.

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Appendix A. 2024 Robotic Monitoring

Site	Location	System	Monitoring Type	Parameters[1]
3SS	Schoharie	Catskill	Reservoir Profiling Buoy	Temp, SpCon, Turb
S5i	Schoharie Creek	Catskill	Stream Hut	Temp, SpCon, Turb
S10-RF	Batavia Kill Creek	Catskill	Stream Hut	Temp, Turb
S10-LC	Batavia Kill Creek	Catskill	Stream Hut	Temp, Turb
1.4EAW	Ashokan West Basin	Catskill	Reservoir Profiling Buoy	Temp, SpCon, Turb
3.1EAW	Ashokan West Basin	Catskill	Reservoir Profiling Buoy	Temp, SpCon, Turb
4.2EAE	Ashokan East Basin	Catskill	Reservoir Profiling Buoy	Temp, SpCon, Turb
3.1iEAW	Ashokan	Catskill	Under Ice Buoy	Temp, SpCon, Turb,
3.2EAW	Ashokan	Catskill	Reservoir Fixed Depth Buoy	Temp, SpCon, Turb (2 depths)
4.2iEAE	Ashokan	Catskill	Under Ice Buoy	Temp, SpCon, Turb (2 depths)
E16i	Esopus Creek	Catskill	Stream Hut	Temp, SpCon, Turb
1.5NN	Neversink	Delaware	Reservoir Profiling Buoy	Temp, SpCon, Turb, BGA, DO, Chl *a*,
NCG	Neversink River	Delaware	Stream Hut	SpCon, Temp, Turb
4WDC	Cannonsville	Delaware	Reservoir Profiling Buoy	Temp, SpCon, Turb, BGA, DO, Chl *a*
CBS	West Branch Delaware	Delaware	Stream Hut	Temp, Turb
1RR	Rondout	Delaware	Reservoir Profiling Buoy	Temp, SpCon, Turb
RDOA	Rondout Creek	Delaware	Stream Hut	Temp, SpCon, Turb
1KWS	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Turb
1UEC	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Temp, SpCon, Turb
1WFC	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Turb
2KWS	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Turb
2WFC	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Turb
KWSFTS	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Temp, Turb
4BRK	Kensico	Catskill-Delaware	Reservoir Profiling Buoy	Temp, SpCon, Turb
4.1BRK	Kensico	Catskill-Delaware	Reservoir Profiling Buoy	Temp, SpCon, Turb

Site	Location	System	Monitoring Type	Parameters[1]
2BRK	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Temp, Turb
2.9BRK	Kensico	Catskill-Delaware	Reservoir Fixed Depth Buoy	Temp, Turb
1CNC	New Croton	Croton	Reservoir Profiling Buoy	Temp, SpCon, Turb, BGA, DO, Chl *a*, pH
4CNC	New Croton	Croton	Reservoir Profiling Buoy	Temp, SpCon, Turb, BGA, DO, Chl *a*, pH
2CWB	West Branch	Delaware	Reservoir Fixed Depth Buoy	Turb
3CWB	West Branch	Delaware	Reservoir Fixed Depth Buoy	Turb

[1]Parameter codes: Temp = temperature; SpCon = Specific conductivity; Turb = Turbidity; Chl *a* = chlorophyll *a* fluorescence; BGA = blue green algae fluorescence.

Appendix B. Watershed Water Quality Operations Early Warning Remote Monitoring (EWRM) Sites

Site	Location	System	Water Type	Parameters
SRR1CM	Schoharie Reservoir Gatehouse Continuous Monitoring	Catskill	Raw	Turbidity, pH, Temperature, Specific conductivity
SRR2CM	Shandaken Tunnel Outlet into Esopus Creek Continuous Monitoring	Catskill	Raw	Turbidity, pH, Temperature, Specific conductivity
EARCM	Ashokan Reservoir Raw Effluent	Catskill	Raw	Turbidity, pH, Temperature, Specific conductivity
EARATF	Ashokan Reservoir Effluent After Treatment	Catskill	Raw/Treated	Turbidity, pH, Temperature, Specific conductivity, Chlorine dioxide
M-1	Ashokan Reservoir Release Channel	Catskill	Raw	Turbidity
AEAP	Esopus Creek Above Shandaken Portal	Catskill	Raw	Turbidity
RDRRCM	Rondout Reservoir Effluent Chamber, Napanoch, NY	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, UV254
NRR2CM	Neversink Reservoir Outlet Continuous Monitoring	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, UV254

Site	Location	System	Water Type	Parameters
PRR2CM	East Delaware Tunnel Outlet Continuous Monitoring Tap	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, UV254
WDTOCM	West Delaware Tunnel Outlet Continuous Monitoring Tap	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity
RR1-RR4	Rondout Reservoir Elevation Taps (Tap1=730ft, Tap2=763ft, Tap3=795ft, Tap4=827ft)	Delaware	Raw	Turbidity
CDIS4-DEL	Delaware Aqueduct at Catskill Delaware Interconnect Shaft 4 (Delaware)	Delaware	Raw	Turbidity
CDIS4-CAT	Catskill Aqueduct at Catskill Delaware Interconnect Shaft 4	Catskill	Raw	Turbidity, pH, Temperature, Specific conductivity, Chlorine dioxide
CDIS4- Combined	Catskill Delaware Interconnect at Shaft 4	Catskill	Raw	Turbidity, Chlorine dioxide
DEL9	Delaware Aqueduct at Shaft 9	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, Total Chlorine Residual, Dechlorination analyzer, Dissolved oxygen
DEL10	Delaware Aqueduct at Shaft 10	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, Elevation

Site	Location	System	Water Type	Parameters
DEL17	Delaware Aqueduct at Shaft 17	Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, Total Chlorine Residual, Dechlorination analyzer, Dissolved oxygen
DEL18DT	Delaware Aqueduct at Shaft 18 Downtake	Catskill/ Delaware	Raw	Turbidity, pH, Temperature, Specific conductivity, Flow, Elevation, Fish biomonitoring system, UV254
DEL19LAB	Delaware Aqueduct Shaft 19 Uptake	Catskill/ Delaware	Pre-Treated	Turbidity, pH, Temperature, Specific conductivity, Free Chlorine Residual, Fluoride Residual
DELSFBLAB	Delaware South Forebay Laboratory	Catskill/ Delaware	Pre-Treated	Turbidity, pH, Temperature, Specific conductivity, Free Chlorine Residual, Fluoride Residual
CCCLAB	Catskill Connection Chamber Laboratory	Catskill/ Delaware	Pre-Treated	Turbidity, pH, Temperature, Specific conductivity, Free Chlorine Residual, Fluoride Residual
CROFALLSVC	Croton Falls Reservoir Valve Chamber	Croton	Raw	Turbidity
CROSSRVVC	Cross River Reservoir Valve Chamber	Croton	Raw	Turbidity
CATALUM	Catskill Alum Treatment Plant at Pleasantville, NY	Catskill	Raw	Turbidity, pH, Temperature, Chlorine dioxide, Dissolved oxygen

Site	Location	System	Water Type	Parameters
CATIC	Catskill Influent Chamber	Catskill	Raw	pH, Temperature, UV254
CROGH	New Croton Reservoir Effluent	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen, Fish biomonitoring system
CRO1T	New Croton Reservoir at Cornell Dam (150ft)	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen
CRO1B	New Croton Reservoir at Cornell Dam (100ft)	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen
CRO183	New Croton Reservoir Elevation Tap (183ft)	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen
CRO163	New Croton Reservoir Elevation Tap (163ft)	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen
CRO143	New Croton Reservoir Elevation Tap (143ft)	Croton	Raw	Turbidity, pH, Temperature, Specific conductivity, Dissolved oxygen

Appendix C. Key to Boxplots and Summary of Non-Detect Statistics Used in Data Analysis

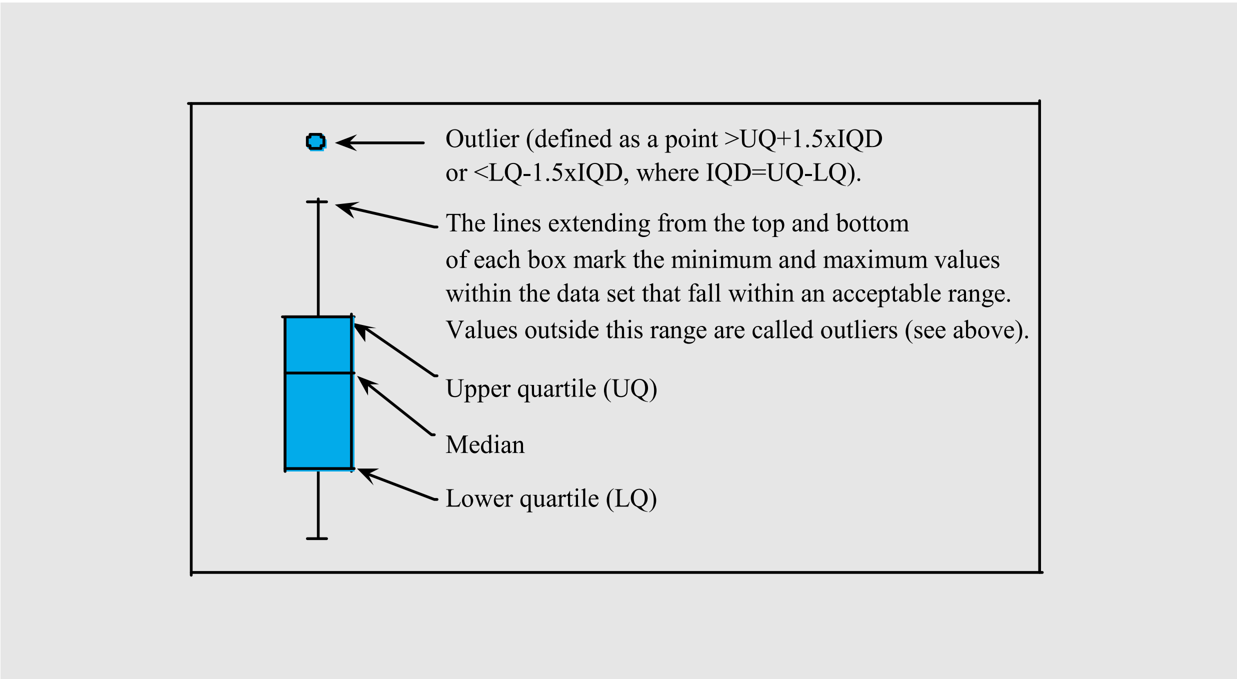

Figure C.1 Key to Boxplots and Summary of Non-Detect Statistics Used in Data Analysis

Water quality data are often left-censored in that many analytical results occur below the instrument's detection limit. Substituting some value for the detection limit results, and then using parametric measures such as means and standard deviations, will often produce erroneous estimates. In this report we used methods described in Helsel (2005), to estimate summary statistics for analytes where left censoring occurred (e.g., fecal and total coliforms, ammonia, nitrate, suspended solids). If a particular site had no censored values for a constituent, the summary statistics reported are the traditional mean and percentiles.

Appendix D. Sampling Locations

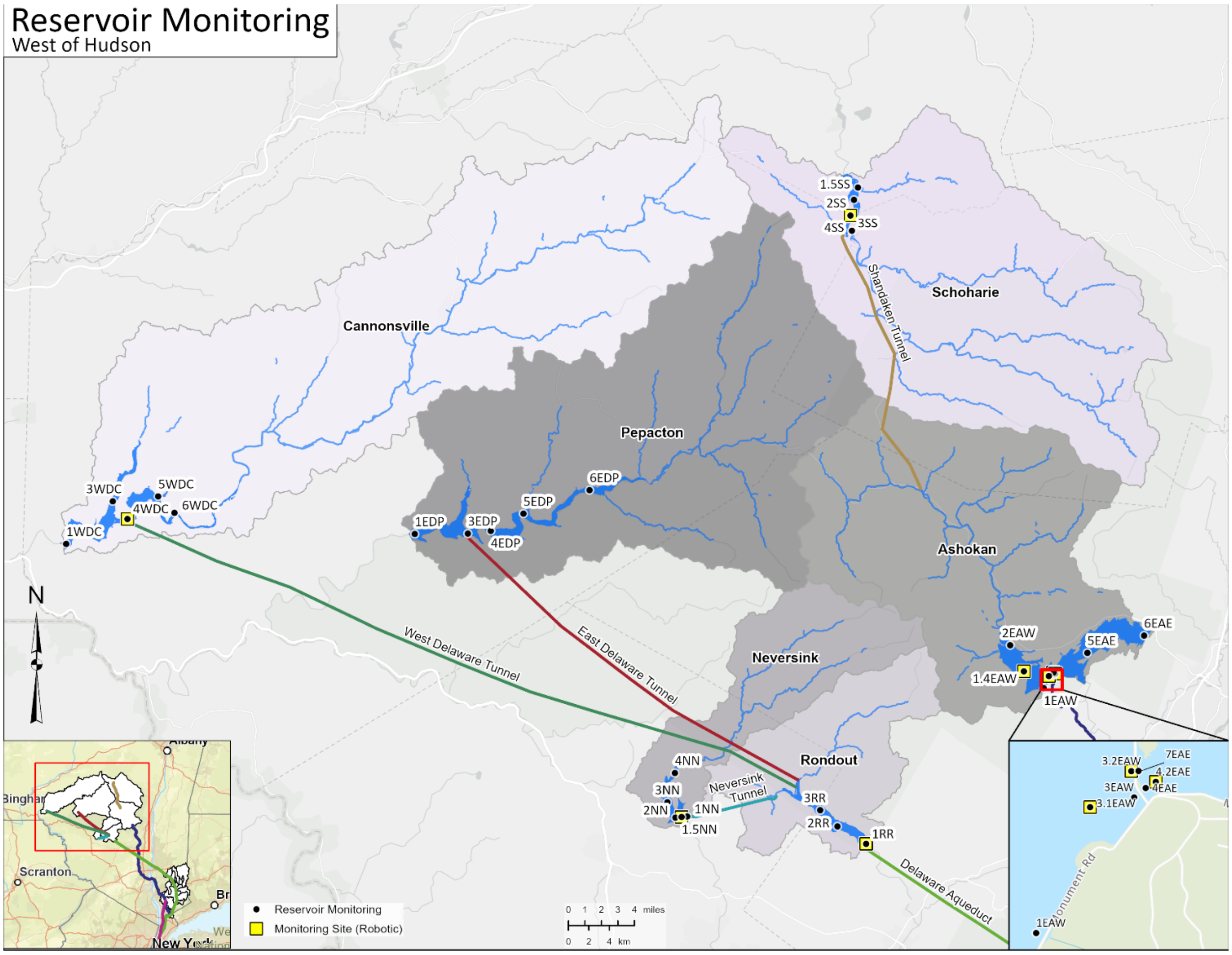

Figure D.1 WOH reservoir monitoring sites.

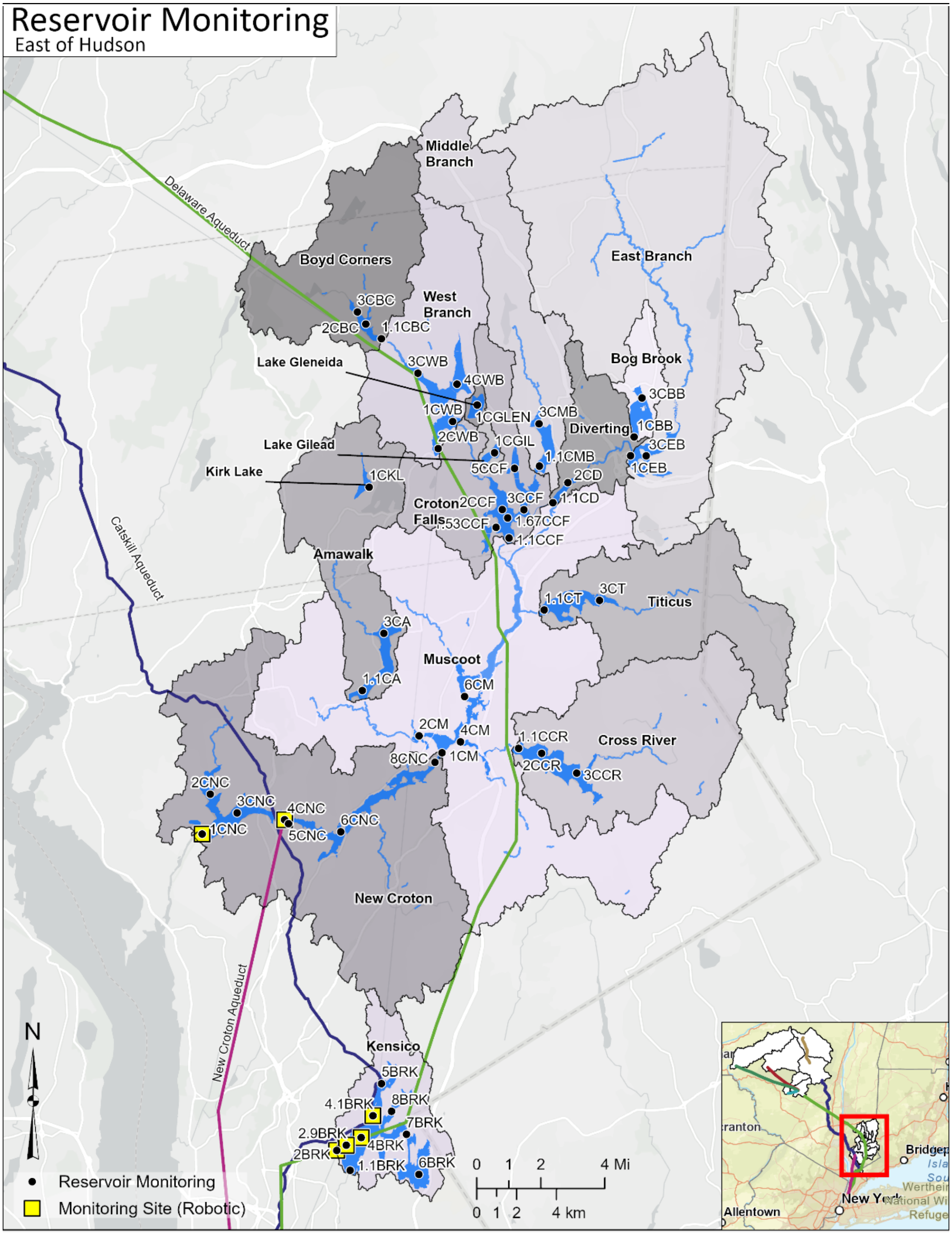

Figure D.2 EOH reservoir monitoring sites.

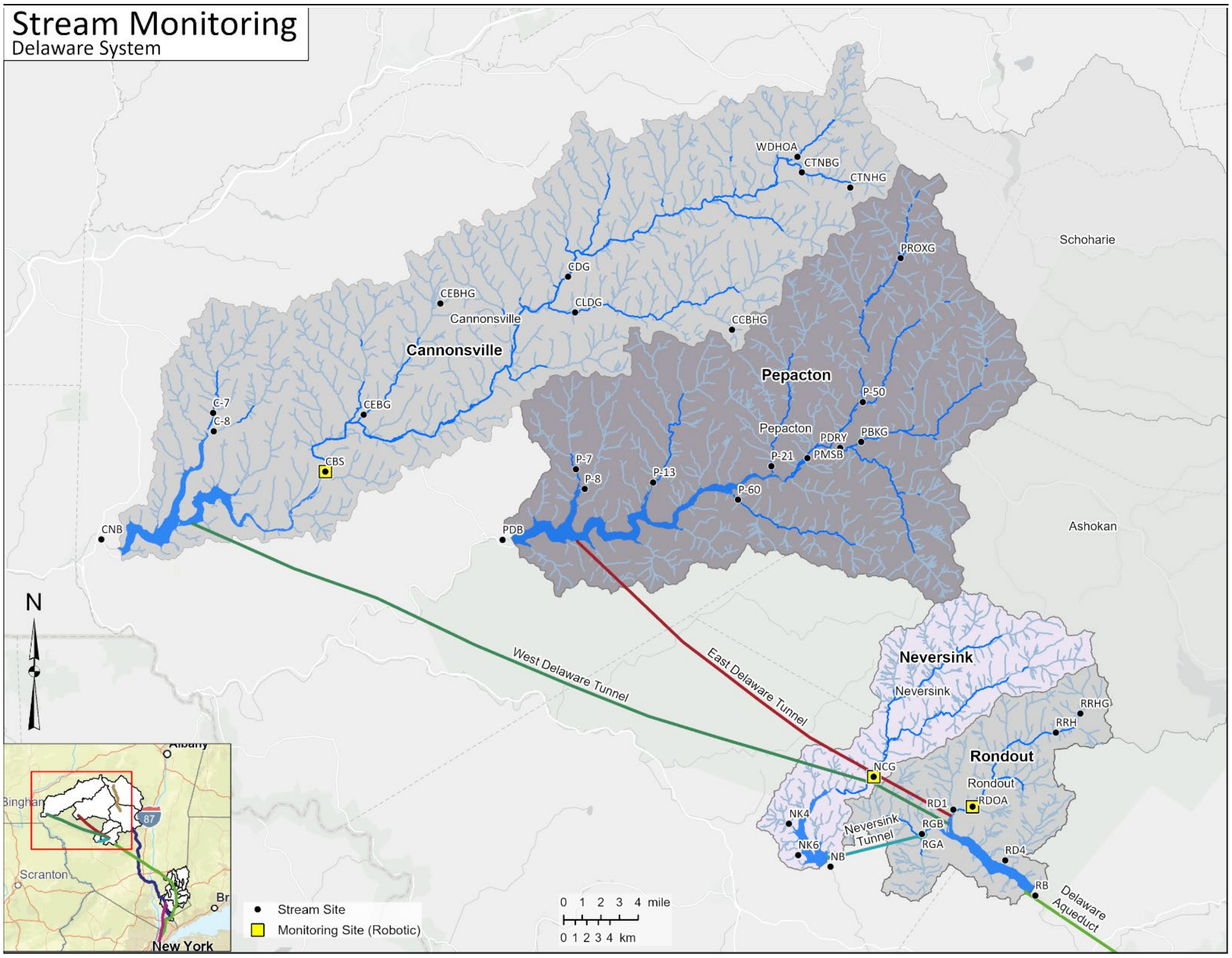

Figure D.3 Delaware System stream monitoring sites.

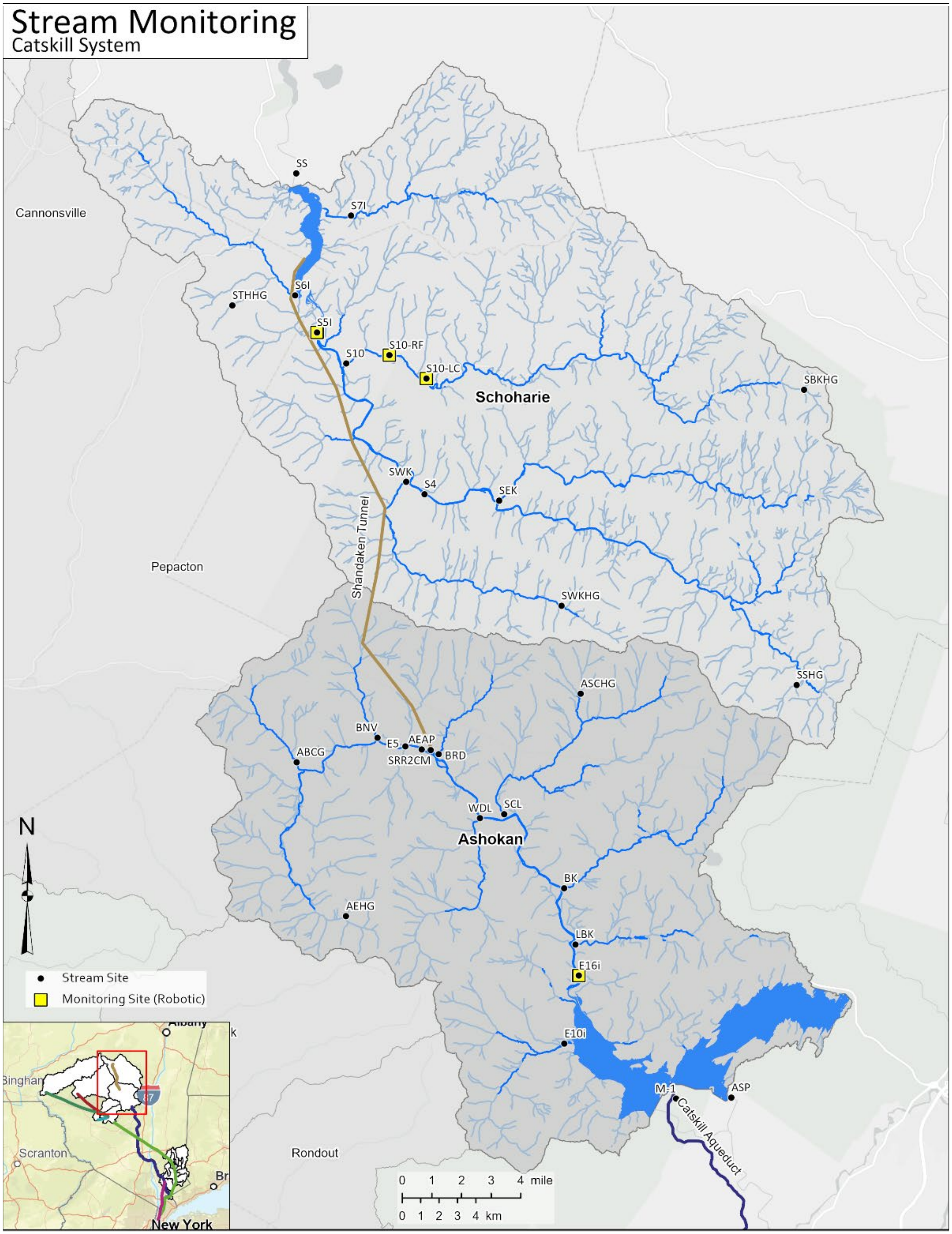

Figure D.4 Catskill System stream monitoring sites.

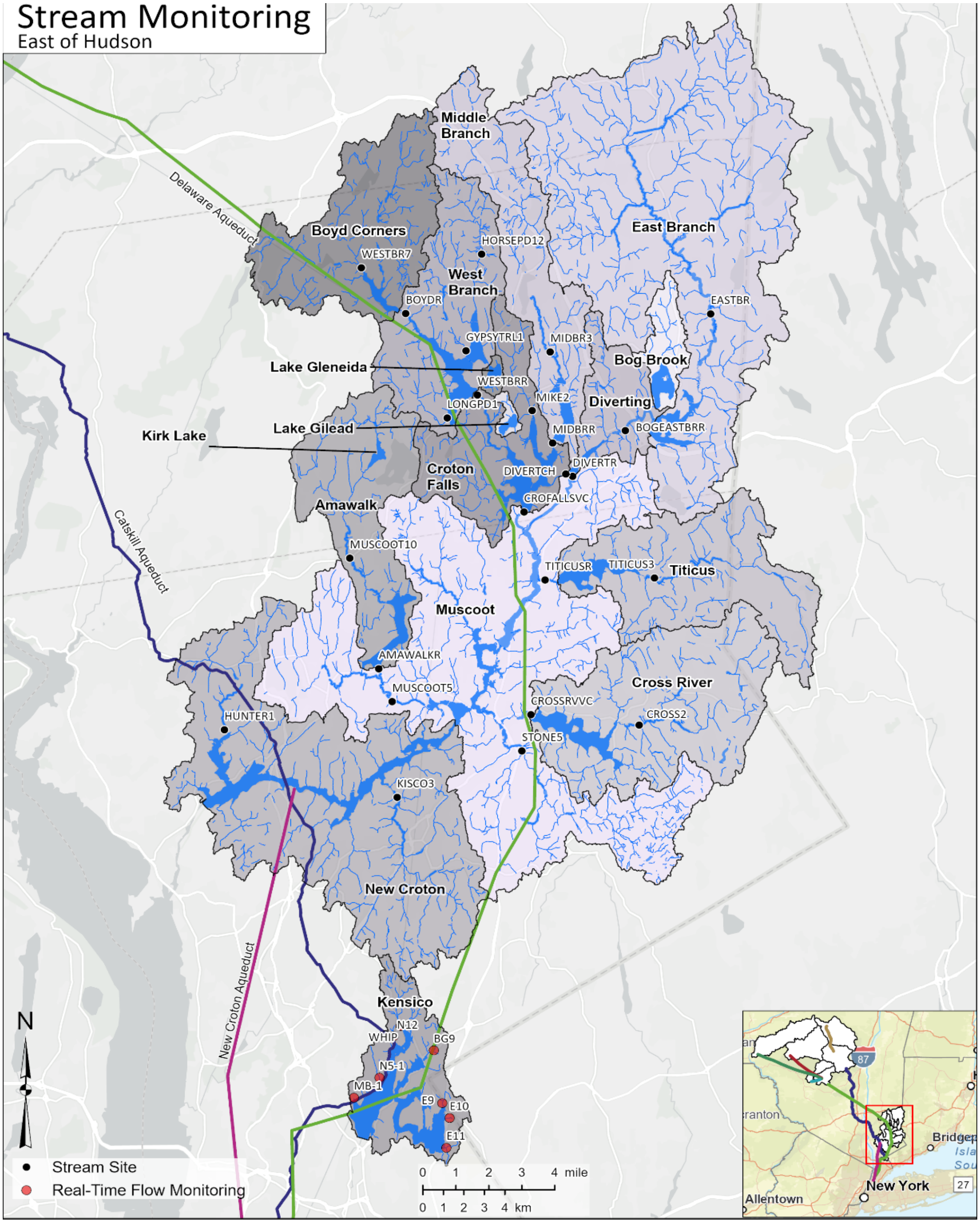

Figure D.5 EOH stream monitoring sites

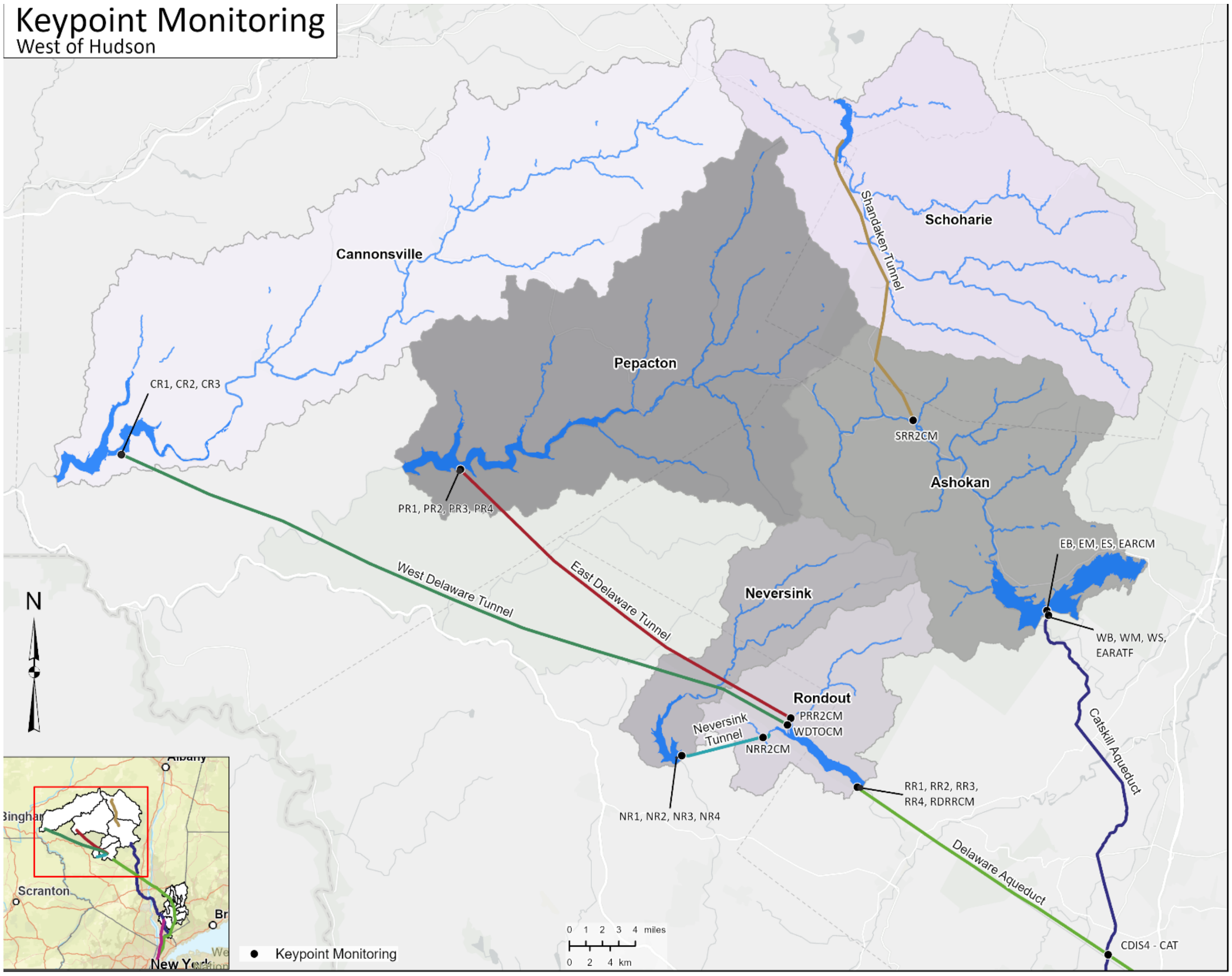

Figure D.6 WOH aqueduct keypoint monitoring sites.

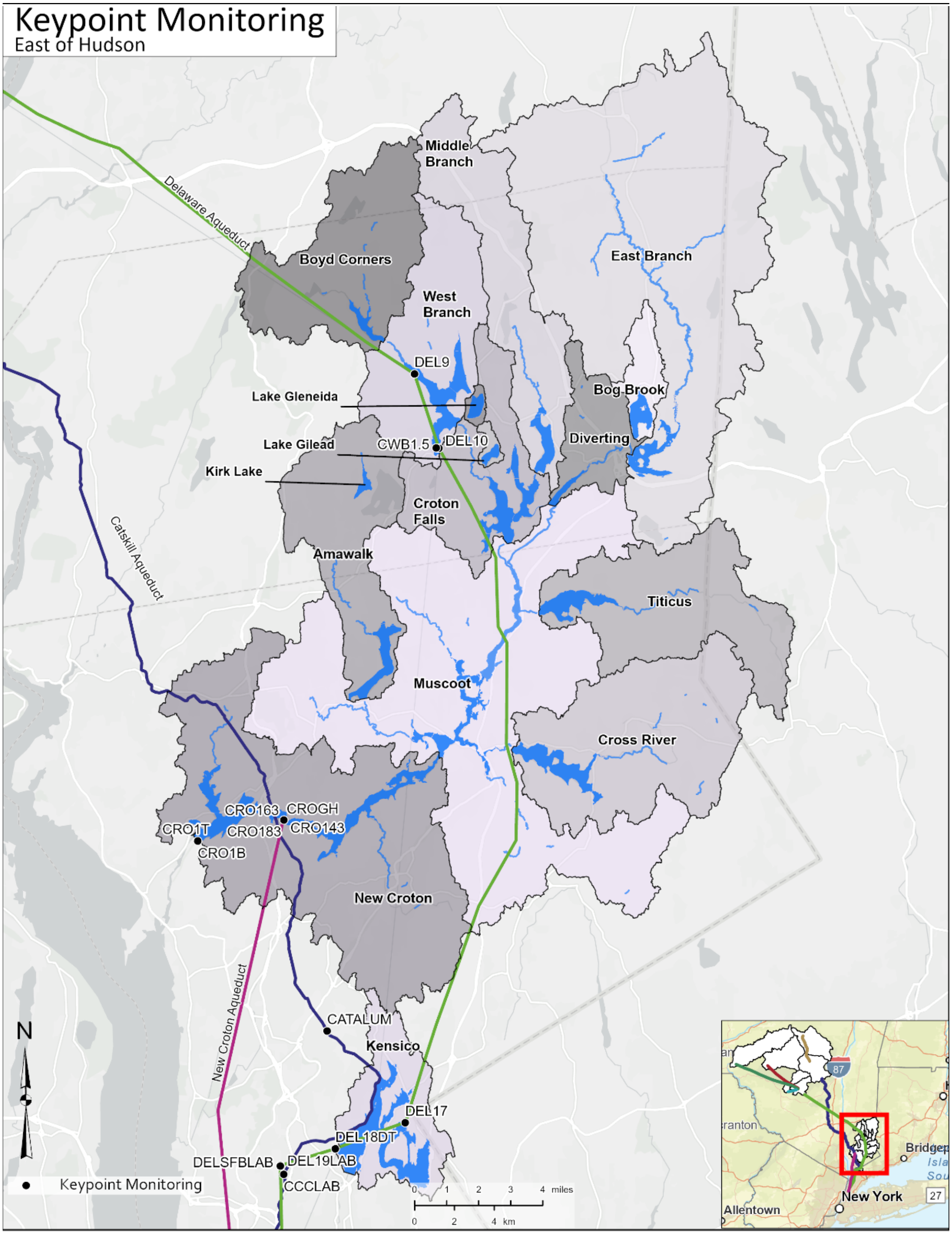

Figure D.7 EOH aqueduct keypoint monitoring sites.

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Appendix E. Monthly Coliform-Restricted Calculations used for Non-Terminal Reservoirs

Reservoir	Class & Standard (Median, Value not > 20% of sample)	Collection Date	N	CONF	Median Total Coliform (coliforms 100mL^{-1})	Percentage > Standard
Amawalk	A (2400, 5000)	Apr-24	5	0	E18	0
		May-24	5	0	70	0
		Jun-24	5	0	E44	0
		Jul-24	5	0	E28	0
		Aug-24	5	0	E4	0
		Sep-24	5	0	E36	0
		Oct-24	5	0	E12	0
		Nov-24	5	0	E4	0
Bog Brook	AA (50, 240).	Apr-24	5	0	E8	0
		May-24	6	0	E6	0
		Jun-24	5	0	≥E4	0
		Jul-24	5	0	E20	0
		Aug-24	5	0	E100	40
		Sep-24	5	0	E120	0
		Oct-24	5	0	E10	0
		Nov-24	0	0	No Samples	
Boyd Corners	AA (50, 240)	Apr-24	7	0	E40	0
		May-24	7	0	E10	0
		Jun-24	7	0	E55	0
		Jul-24	7	0	≥E20	0
		Aug-24	7	0	E150	29
		Sep-24	6	0	E60	0
		Oct-24	7	0	E180	14
		Nov-24	6	0	E50	0
Croton Falls	A/AA (50, 240).	Apr-24	8	0	E20	0
		May-24	8	0	E6	0
		Jun-24	8	0	E7	0
		Jul-24	8	0	≥46	12
		Aug-24	8	0	E60	12
		Sep-24	8	0	E95	38
		Oct-24	8	0	E20	0
		Nov-24	8	0	E32	0
Cross River	A/AA (50, 240)	Apr-24	6	0	E7	0
		May-24	6	0	E14	0
		Jun-24	6	0	E12	0
		Jul-24	6	0	E46	17

Reservoir	Class & Standard (Median, Value not > 20% of sample)	Collection Date	N	CONF	Median Total Coliform (coliforms 100mL^{-1})	Percentage > Standard
		Aug-24	6	0	90	17
		Sep-24	6	0	E60	0
		Oct-24	6	0	E20	0
		Nov-24	5	0	E5	0
Diverting	AA (50, 240)	Apr-24	5	0	E35	0
		May-24	5	0	260	60
		Jun-24	5	0	≥140	40
		Jul-24	5	0	580	100
		Aug-24	5	0	E160	20
		Sep-24	5	0	310	80
		Oct-24	0	0	No Samples	
		Nov-24	0	0	No Samples	
East Branch	AA (50, 240).	Apr-24	5	0	E6	0
		May-24	6	0	E18	0
		Jun-24	5	0	≥E8	0
		Jul-24	5	0	E20	0
		Aug-24	6	0	E45	0
		Sep-24	5	0	E20	0
		Oct-24	6	0	E10	0
		Nov-24	0	0	No Samples	
Lake Gilead	A (2400, 5000)	Apr-24	5	0	<5	0
		May-24	5	0	<2	0
		Jun-24	5	0	E2	0
		Jul-24	5	0	E24	0
		Aug-24	5	0	E8	0
		Sep-24	5	0	E4	0
		Oct-24	5	0	E4	0
		Nov-24	5	0	<4	0
Lake Gleneida	AA (50, 240)	Apr-24	5	0	E20	0
		May-24	5	0	E5	0
		Jun-24	5	0	≥<4	0
		Jul-24	5	0	<20	0
		Aug-24	5	0	<20	0
		Sep-24	5	0	<20	0
		Oct-24	5	0	E5	0
		Nov-24	5	0	E20	0
Kirk Lake	B (2400, 5000)	Apr-24	5	0	E20	0
		May-24	5	0	160	0
		Jun-24	5	0	E90	0
		Jul-24	5	0	E10	0

Reservoir	Class & Standard (Median, Value not > 20% of sample)	Collection Date	N	CONF	Median Total Coliform (coliforms 100mL^{-1})	Percentage > Standard
		Aug-24	5	0	E20	0
		Sep-24	5	0	E30	0
		Oct-24	5	0	E20	0
		Nov-24	0	0	No Samples	
Muscoot	A (2400, 5000).	Apr-24	7	0	E50	0
		May-24	7	0	320	0
		Jun-24	7	0	310	0
		Jul-24	7	0	≥270	0
		Aug-24	5	1	E350	0
		Sep-24	7	0	E160	0
		Oct-24	6	0	240	0
		Nov-24	0	0	No Samples	
Middle Branch	A (2400, 5000)	Apr-24	5	0	E10	0
		May-24	5	0	E85	0
		Jun-24	5	0	≥160	0
		Jul-24	5	0	100	0
		Aug-24	5	0	E40	0
		Sep-24	5	0	≥E20	0
		Oct-24	5	0	<20	0
		Nov-24	5	0	E30	0
Titicus	AA (50, 240)	Apr-24	5	0	E55	0
		May-24	5	0	E20	0
		Jun-24	5	0	E10	0
		Jul-24	5	0	E15	0
		Aug-24	5	0	E10	0
		Sep-24	5	0	170	40
		Oct-24	5	0	E35	0
		Nov-24	5	0	E10	0
Cannonsville	A/AA (50, 240)	Apr-24	15	0	E10	7
		May-24	15	0	E5	0
		Jun-24	15	0	E20	0
		Jul-24	14	0	<20	0
		Aug-24	14	0	E170	36
		Sep-24	14	0	<50	0
		Oct-24	12	0	<20	0
		Nov-24	12	0	E50	17
Pepacton	A/AA (50, 240).	Apr-24	16	0	E1	0
		May-24	16	0	E4	0
		Jun-24	16	0	E4	6
		Jul-24	16	0	≥<4	0

Reservoir	Class & Standard (Median, Value not > 20% of sample)	Collection Date	N	CONF	Median Total Coliform (coliforms $100mL^{-1}$)	Percentage > Standard
		Aug-24	16	0	<40	6
		Sep-24	14	0	E20	0
		Oct-24	13	0	<10	0
		Nov-24	13	0	E10	0
Neversink	AA (50, 240)	Apr-24	10	0	E13	0
		May-24	10	0	E4	0
		Jun-24	9	0	E8	0
		Jul-24	9	0	E10	0
		Aug-24	7	0	<20	0
		Sep-24	6	0	<20	0
Schoharie	AA (50, 240).	Apr-24	12	0	E5	0
		May-24	12	0	E16	0
		Jun-24	11	0	E35	0
		Jul-24	11	0	E40	0
		Aug-24	12	0	≥1150	100
		Sep-24	11	0	E150	18
		Oct-24	9	0	E50	0

Sampling Note: All other nonterminal reservoirs not listed were not sampled due to COVID-19 pandemic.

Analysis Note: The total of the N and CONF for each table row represents the total number samples analyzed.

Notes: The reservoir class is defined by 6 NYCRR Chapter X, Subchapter B. For those reservoirs that have dual designations, the higher standard was applied. 6NYCRR Part 703 requires a minimum of five samples per month. Both the median value and >20% of the total coliform counts for a given month need to exceed the stated value for a reservoir to exceed the standard. Codes associated with data reporting include the following: E: Estimated count based on non-ideal plate; ≥: plate count may be biased low based on heavy growth; >: observed count replaced with dilution-based value; <: below detection limit.

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Appendix F. Phosphorus Restricted Basin Assessment Methodology

A phosphorus restricted basin is defined in the New York City Watershed Rules & Regulations (DEP 2019), as "(i) the drainage basin of a source water reservoir in which the phosphorus load to the reservoir results in the phosphorus concentration in the reservoir exceeding 15 micrograms per liter, or (ii) the drainage basin of a reservoir other than a source water reservoir or of a controlled lake in which the phosphorus load to the reservoir or controlled lake results in the phosphorus concentration in the reservoir or controlled lake exceeding 20 micrograms per liter in both instances as determined by the department pursuant to its annual review conducted under §18-48 (e) of Subchapter D" (DEP 2019). The phosphorus restricted designation prohibits new or expanded wastewater treatment plants with surface discharges in the reservoir basin. The list of phosphorus restricted basins is updated annually in the Watershed Water Quality Annual Report.

A summary of the methodology used in the phosphorus restricted analysis will be given here; the complete description can be found in *A Methodology for Determining Phosphorus Restricted Basins* (DEP 1997). The data utilized in the analysis are from the routine limnological monitoring of the reservoirs during the growing season, which is defined as May 1 through October 31. Any recorded concentration below the analytical limit of detection is set equal to half the detection limit to conform to earlier analyses following the prescribed methodology. The detection limit for DEP measurements of total phosphorus is assessed each year by the DEP laboratories and typically ranges between 2-5 $\mu g\ L^{-1}$. The phosphorus concentration data for the reservoirs approaches a lognormal distribution; therefore, a geometric mean is used to characterize the annual phosphorus concentrations. Appendix F Table 1 provides the annual geometric mean for the past six years.

The five most recent annual geometric means are averaged arithmetically, and this average constitutes one assessment. This "running average" method weights each year equally, reducing the effects of unusual hydrological events or phosphorus loading, while maintaining an accurate assessment of the current conditions in the reservoir. Should any reservoir have less than three surveys during a growing season, the annual average may or may not be representative of the reservoir, and the data for the under-sampled year are removed from the analysis. In addition, each five-year assessment must incorporate at least three years of data.

To provide some statistical assurance that the five-year arithmetic mean is representative of a basin's phosphorus status, given the interannual variability, the five-year mean plus the standard error of the five-year mean is compared to the New York State guidance value of 20 $\mu g\ L^{-1}$ (15 $\mu g\ L^{-1}$ for potential source waters). A basin is considered **unrestricted** if the five-year mean plus standard error is below the guidance value of 20 $\mu g\ L^{-1}$ (15 $\mu g\ L^{-1}$ for potential source

waters). A basin is considered phosphorus **restricted** if the five-year mean plus standard error is equal to or greater than 20 μg L^{-1} (15 μg L^{-1} for potential source waters), unless the department, using its best professional judgment, determines that the phosphorus restricted designation is due to an unusual and unpredictable event unlikely to occur in the future. A reservoir basin designation, as phosphorus restricted or unrestricted, may change through time based on the outcome of this annual assessment. However, a basin must have two consecutive assessments (i.e., two years in a row) that result in the new designation to change the designation.

Table F.1 Geometric Mean Total Phosphorus Data used in the Phosphorus Restricted Assessments based on reservoir samples taken during the growing season (May 1 - Oct. 31).

Reservoir Basin	2019 (µg L^{-1})	2020 (µg L^{-1})	2021 (µg L^{-1})	2022 (µg L^{-1})	2023 (µg L^{-1})	2024 (µg L^{-1})
Non-Source Waters (Delaware System)						
Cannonsville Reservoir	15.6	14.3	15.3	17.3	15.7	16.0
Pepacton Reservoir	9.8	9.4	9.4	8.8	9.2	9.6
Neversink Reservoir	6.5	6.8	7.0	7.2	6.8	6.6
Non-Source Waters (Catskill System)						
Schoharie Reservoir	12.3	9.9	18.1	14.9	13.1	13.5
Non-Source Waters (Croton System)						
Amawalk Reservoir	17.3	NS	NS	26.5	23.4	18.8
Bog Brook Reservoir	14.1	NS	NS	20.7	36.6	22.5
Boyd Corners Reservoir	11.5	11.2	14.0	14.9	16.1	15.5
Diverting Reservoir	23.2	NS	43.3	35.2	35.3	32.2
East Branch Reservoir	21.6	NS	NS	25.3	27.4	33.3
Middle Branch Reservoir	18.3	NS	NS	29.3	37.8	31.6
Muscoot Reservoir	28.9	NS	40.2	34.6	37.5	40.5
Titicus Reservoir	23.1	NS	NS	28.4	29.1	30.5
Lake Gleneida	14.9	NS	NS	23.9	23.8	NS
Lake Gilead	20.5	NS	NS	45.8	22.9	42.7
Kirk Lake	18.4	NS	NS	26.9	31.6	27.0
Source Waters (all systems)						
Ashokan West Basin Reservoir	7.8	7.8	9.9	11.4	8.9	8.6
Ashokan East Basin Reservoir	7.2	7.0	7.0	9.1	8.7	7.9
Rondout Reservoir	7.8	7.3	8.1	8.6	9.4	8.0
West Branch Reservoir	9.5	10.0	11.3	11.8	13.4	11.4
Cross River Reservoir	16.8	19.7	20.9	23.6	21.9	26.9
Croton Falls Reservoir	15.3	21.5	20.5	24.4	22.7	23.4
Kensico Reservoir	6.8	7.7	8.4	8.5	9.0	9.6
New Croton Reservoir	19.5	NS	NS	24.2	24.0	24.4

NS: "Insufficient Data" - Total phosphorus sampling was missed, reduced, or eliminated, especially during 2020 and 2021 because of the COVID-19 pandemic; resulting in either no or a limited number of samples for the geometric mean calculations.

Appendix G. Comparison of Reservoir Water Quality Results to Benchmarks

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
Non-Source Waters (Delaware System)								
	Total Phosphorus (as P) (µg L^{-1})	15	111	61	55	NA	19	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	111	7	6	NA	7	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	111	0	0	NA	3	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	111	0	0	0.3	0.25	KM
	Ammonia (as N) (mg L^{-1})	0.1	111	3	3	0.05	0.02	ROS
	Fecal Coliform (coliforms 100mL^{-1})	20	111	6	5	NA	7	ROS
	Turbidity (NTU)	5	111	20	18	NA	3.6	
	Total suspended solids (mg L^{-1})	8	48	2	4	5	2.7	KM
Cannonsville Reservoir	Alkalinity (mg L^{-1})	NA	17	0	0	≥10	18.3	
	Dissolved Organic Carbon (mg L^{-1})	4	111	1	1	3	2.0	
	Sulfate (as SO4) (mg L^{-1})	15	17	0	0	10	3.6	
	pH (SU)	6.5-8.5	97	14	14	NA	7.12	
	Dissolved sodium (mg L^{-1})	16	12	0	0	3	7.0	
	Chloride (mg L^{-1})	12	17	0	0	8	10.2	
	Total dissolved solids (mg L^{-1})[3]		111	0	0		56	
	Chlorophyll a (µg L^{-1})	12	40	6	15	7	7.0	
	Total phytoplankton (ASU mL^{-1})	2000	53	1	2	NA	437	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	53	1	2	NA	182	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	53	0	0	NA	95	KM
	Total Phosphorus (as P) (µg L^{-1})	15	120	11	9	NA	11	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	120	0	0	NA	4	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	120	0	0	NA	2	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	120	0	0	0.3	0.13	KM
	Ammonia (as N) (mg L^{-1})	0.1	120	0	0	0.05	<0.02	>80%
	Fecal Coliform (coliforms 100mL^{-1})	20	120	0	0	NA	1	ROS
	Turbidity (NTU)	5	120	7	6	NA	2.0	
	Total suspended solids (mg L^{-1})	8	59	0	0	5	1.5	KM
	Alkalinity (mg L^{-1})	NA	20	0	0	≥10	14.5	
Pepacton Reservoir	Dissolved Organic Carbon (mg L^{-1})	4	120	0	0	3	1.7	
	Sulfate (as SO4) (mg L^{-1})	15	20	0	0	10	2.7	
	pH (SU)	6.5-8.5	120	23	19	NA	7.07	
	Dissolved sodium (mg L^{-1})	16	14	0	0	3	4.6	
	Chloride (mg L^{-1})	12	20	0	0	8	7.1	
	Total dissolved solids (mg L^{-1})[3]		120	0	0		41	
	Chlorophyll a (µg L^{-1})	12	37	1	3	7	5.0	
	Total phytoplankton (ASU mL^{-1})	2000	61	0	0	NA	214	KM
	Dominant phytoplankton genus (ASU mL^{-1})	1000	61	0	0	NA	93	KM
	Secondary phytoplankton genus (ASU mL^{-1})	1000	61	0	0	NA	48	KM
	Total Phosphorus (as P) (µg L^{-1})	15	51	1	2	NA	7	KM
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	51	0	0	NA	3	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	51	0	0	NA	2	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	51	0	0	0.3	0.15	KM
	Ammonia (as N) (mg L^{-1})	0.1	51	0	0	0.05	0.01	ROS
	Fecal Coliform (coliforms 100mL^{-1})	20	51	0	0	NA	1	ROS
	Turbidity (NTU)	5	51	0	0	NA	1.1	
	Total suspended solids (mg L^{-1})	8	18	2	11	5	3.8	KM
Neversink Reservoir	Alkalinity (mg L^{-1})	NA	7	0	0	≥10	3.6	
	Dissolved Organic Carbon (mg L^{-1})	4	51	0	0	3	2.0	
	Sulfate (as SO4) (mg L^{-1})	15	7	0	0	10	2.0	
	pH (SU)	6.5-8.5	51	41	80	NA	6.19	
	Dissolved sodium (mg L^{-1})	16	7	0	0	3	1.9	
	Chloride (mg L^{-1})	12	7	0	0	8	3.0	
	Total dissolved solids (mg L^{-1})[3]		51	0	0		17	
	Chlorophyll a (µg L^{-1})	12	17	0	0	7	2.1	
	Total phytoplankton (ASU mL^{-1})	2000	29	0	0	NA	282	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Dominant phytoplankton genus (ASU mL^{-1})	1000	29	0	0	NA	199	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	29	0	0	NA	48	KM
Non-Source Waters (Catskill System)								
Schoharie Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	78	18	23	NA	15	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	57	1	2	NA	6	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	57	0	0	NA	3	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	57	0	0	0.3	0.12	KM
	Ammonia (as N) (mg L^{-1})	0.1	57	2	4	0.05	0.02	ROS
	Fecal Coliform (coliforms 100mL^{-1})	20	77	13	17	NA	20	KM
	Turbidity (NTU)	5	78	36	46	NA	8.1	
	Total suspended solids (mg L^{-1})	8	78	14	18	5	5.3	KM
	Alkalinity (mg L^{-1})	NA	6	0	0	≥10	17.0	
	Dissolved Organic Carbon (mg L^{-1})	4	77	0	0	3	2.3	
	Sulfate (as SO4) (mg L^{-1})	15	6	0	0	10	2.6	
	pH (SU)	6.5-8.5	78	6	8	NA	7.04	
	Dissolved sodium (mg L^{-1})	16	6	0	0	3	6.4	
	Chloride (mg L^{-1})	12	6	0	0	8	9.4	
	Total dissolved solids (mg L^{-1})[3]		78	0	0		53	
	Chlorophyll a (µg L^{-1})	12	28	0	0	7	3.7	
	Total phytoplankton (ASU mL^{-1})	2000	40	0	0	NA	159	KM
	Dominant phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	114	KM
	Secondary phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	28	KM
Non-Source Waters (Croton System)								
Amawalk Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	40	25	62	NA	21	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	40	1	2	NA	2	ROS
	Turbidity (NTU)	5	0			NA		C19
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	40	2	5	NA	7.53	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]	175	0			150		C19
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
Bog Brook Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	17	14	82	NA	23	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	17	1	6	NA	8	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	17	0	0	NA	1	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	17	0	0	0.3	<0.02	>80%
	Ammonia (as N) (mg L^{-1})	0.1	17	1	6	0.05	<0.02	>80%
	Fecal Coliform (coliforms 100mL^{-1})	20	36	2	6	NA	4	ROS
	Turbidity (NTU)	5	17	0	0	NA	1.6	
	Total suspended solids (mg L^{-1})	8	5	0	0	5	1.9	
	Alkalinity (mg L^{-1})	NA	5	0	0	≥40	72.0	
	Dissolved Organic Carbon (mg L^{-1})	7	17	0	0	6	3.9	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	8.7	
	pH (SU)	6.5-8.5	26	4	15	NA	7.76	
	Dissolved sodium (mg L^{-1})	20	5	5	100	15	31.5	
	Chloride (mg L^{-1})	40	5	5	100	30	53.9	
	Total dissolved solids (mg L^{-1})[3]		17	0	0		220	
	Chlorophyll a (µg L^{-1})	15	8	0	0	10	5.2	
	Total phytoplankton (ASU mL^{-1})	2000	8	0	0	NA	715	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	8	0	0	NA	329	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	8	0	0	NA	207	
Boyd Corners Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	22	11	50	NA	16	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	22	0	0	NA	6	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	22	0	0	NA	2	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	22	0	0	0.3	0.02	ROS
	Ammonia (as N) (mg L^{-1})	0.1	22	1	5	0.05	0.02	ROS
	Fecal Coliform (coliforms 100mL^{-1})	20	54	1	2	NA	2	KM
	Turbidity (NTU)	5	22	2	9	NA	1.9	
	Total suspended solids (mg L^{-1})	8	8	0	0	5	1.5	KM
	Alkalinity (mg L^{-1})	NA	8	0	0	≥40	35.0	
	Dissolved Organic Carbon (mg L^{-1})	7	22	0	0	6	3.4	
	Sulfate (as SO4) (mg L^{-1})	25	8	0	0	15	4.8	
	pH (SU)	6.5-8.5	22	3	14	NA	7.00	
	Dissolved sodium (mg L^{-1})	20	6	0	0	15	16.3	
	Chloride (mg L^{-1})	40	8	0	0	30	22.9	
	Total dissolved solids (mg L^{-1})[3]		22	0	0		104	
	Chlorophyll a (µg L^{-1})	15	8	1	12	10	8.1	
	Total phytoplankton (ASU mL^{-1})	2000	8	0	0	NA	755	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	8	0	0	NA	441	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	8	0	0	NA	168	KM
Diverting Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	30	30	100	NA	31	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	30	7	23	NA	12	KM
	Turbidity (NTU)	5	0			NA		C19
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	30	1	3	NA	7.67	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]	175	0			150		C19
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
East Branch Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	21	20	95	NA	39	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	21	5	24	NA	22	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	21	2	10	NA	7	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	21	0	0	0.3	0.03	ROS
	Ammonia (as N) (mg L^{-1})	0.1	21	3	14	0.05	0.05	ROS
	Fecal Coliform (coliforms 100mL^{-1})	20	38	0	0	NA	2	KM
	Turbidity (NTU)	5	21	1	5	NA	2.1	
	Total suspended solids (mg L^{-1})	8	6	0	0	5	2.3	KM
	Alkalinity (mg L^{-1})	NA	6	0	0	≥40	85.0	
	Dissolved Organic Carbon (mg L^{-1})	7	21	0	0	6	4.2	
	Sulfate (as SO4) (mg L^{-1})	25	6	0	0	15	6.3	
	pH (SU)	6.5-8.5	31	2	6	NA	7.30	
	Dissolved sodium (mg L^{-1})	20	6	5	83	15	22.1	
	Chloride (mg L^{-1})	40	6	0	0	30	34.2	
	Total dissolved solids (mg L^{-1})[3]		21	0	0		196	
	Chlorophyll a (µg L^{-1})	15	7	2	29	10	11.0	
	Total phytoplankton (ASU mL^{-1})	2000	7	0	0	NA	821	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	7	0	0	NA	427	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	7	0	0	NA	132	
Middle Branch Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	40	40	100	NA	50	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	40	2	5	NA	3	KM
	Turbidity (NTU)	5	0			NA		C19
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19

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	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	40	6	15	NA	7.53	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]	175	0			150		C19
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Total Phosphorus (as P) (µg L^{-1})	15	47	47	100	NA	55	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	47	8	17	NA	31	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	47	3	6	NA	8	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	47	3	6	0.3	0.18	KM
	Ammonia (as N) (mg L^{-1})	0.1	47	9	19	0.05	0.19	KM
	Fecal Coliform (coliforms 100mL^{-1})	20	47	7	15	NA	9	KM
	Turbidity (NTU)	5	49	5	10	NA	2.8	
	Total suspended solids (mg L^{-1})	8	4	0	0	5	3.0	
	Alkalinity (mg L^{-1})	NA	4	0	0	≥40	80.9	
Muscoot Reservoir	Dissolved Organic Carbon (mg L^{-1})	7	47	3	6	6	4.1	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	6.4	
	pH (SU)	6.5-8.5	48	3	6	NA	7.41	
	Dissolved sodium (mg L^{-1})	20	4	4	100	15	32.9	
	Chloride (mg L^{-1})	40	4	4	100	30	56.0	
	Total dissolved solids (mg L^{-1})[3]		47	0	0		228	
	Chlorophyll a (µg L^{-1})	15	34	9	26	10	13.7	
	Total phytoplankton (ASU mL^{-1})	2000	30	10	33	NA	1540	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	30	9	30	NA	1080	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	30	0	0	NA	191	
	Total Phosphorus (as P) (µg L^{-1})	15	40	37	92	NA	39	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	40	0	0	NA	1	ROS
	Turbidity (NTU)	5	0			NA		C19
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
Titicus Reservoir	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	40	7	18	NA	7.72	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]	175	0			150		C19
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Total Phosphorus (as P) (µg L^{-1})	15	9	7	78	NA	50	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	40	0	0	NA	1	ROS
	Turbidity (NTU)	5	21	0	0	NA	1.2	
Lake Gleneida	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	40	3	8	NA	7.42	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]		21	0	0		268	
	Chlorophyll a (µg L^{-1})	15	0			10		C19

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	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
Lake Gilead	Total Phosphorus (as P) (µg L^{-1})	15	9	8	89	NA	77	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	40	0	0	NA	1	ROS
	Turbidity (NTU)	5	24	1	4	NA	1.4	
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	40	8	20	NA	7.49	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]		24	0	0		207	
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
Kirk Lake	Total Phosphorus (as P) (µg L^{-1})	15	8	8	100	NA	39	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	0			NA		C19
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	0			0.3		C19
	Ammonia (as N) (mg L^{-1})	0.1	0			0.05		C19
	Fecal Coliform (coliforms 100mL^{-1})	20	35	0	0	NA	2	KM
	Turbidity (NTU)	5	13	5	38	NA	5.3	
	Total suspended solids (mg L^{-1})	8	0			5		C19
	Alkalinity (mg L^{-1})	NA	0			≥40		C19
	Dissolved Organic Carbon (mg L^{-1})	7	0			6		C19
	Sulfate (as SO4) (mg L^{-1})	25	0			15		C19
	pH (SU)	6.5-8.5	30	2	7	NA	7.40	
	Dissolved sodium (mg L^{-1})	20	0			15		C19
	Chloride (mg L^{-1})	40	0			30		C19
	Total dissolved solids (mg L^{-1})[3]		11	0	0		215	
	Chlorophyll a (µg L^{-1})	15	0			10		C19
	Total phytoplankton (ASU mL^{-1})	2000	0			NA		C19
	Dominant phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
	Secondary phytoplankton genus (ASU mL^{-1})	1000	0			NA		C19
Source Waters (all system)								
Ashokan West Basin Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	73	1	1	NA	9	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	73	0	0	NA	4	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	73	0	0	NA	2	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	73	0	0	0.3	0.13	KM
	Ammonia (as N) (mg L^{-1})	0.1	73	0	0	0.05	<0.02	>80%
	Fecal Coliform (coliforms 100mL^{-1})	20	73	0	0	NA	1	ROS
	Turbidity (NTU)	5	73	9	12	NA	3.2	
	Total suspended solids (mg L^{-1})	8	73	1	1	5	2.8	KM
	Alkalinity (mg L^{-1})	NA	26	0	0	≥10	13.0	
	Dissolved Organic Carbon (mg L^{-1})	4	73	0	0	3	1.7	
	Sulfate (as SO4) (mg L^{-1})	15	11	0	0	10	2.4	
	pH (SU)	6.5-8.5	73	14	19	NA	6.86	
	Dissolved sodium (mg L^{-1})	16	8	0	0	3	3.9	
	Chloride (mg L^{-1})	12	11	0	0	8	6.1	
	Total dissolved solids (mg L^{-1})[3]		73	0	0		36	
	Chlorophyll a (µg L^{-1})	12	24	0	0	7	3.5	
	Total phytoplankton (ASU mL^{-1})	2000	40	0	0	NA	235	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	113	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	51	
Ashokan East Basin Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	64	0	0	NA	8	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	64	0	0	NA	3	KM

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	64	0	0	NA	2	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	64	0	0	0.3	<0.05	>80%
	Ammonia (as N) (mg L^{-1})	0.1	64	0	0	0.05	<0.02	>80%
	Fecal Coliform (coliforms $100mL^{-1}$)	20	64	0	0	NA	1	ROS
	Turbidity (NTU)	5	64	1	2	NA	1.3	
	Total suspended solids (mg L^{-1})	8	56	0	0	5	1.2	KM
	Alkalinity (mg L^{-1})	NA	15	0	0	≥10	12.3	
	Dissolved Organic Carbon (mg L^{-1})	4	64	0	0	3	1.8	
	Sulfate (as SO4) (mg L^{-1})	15	9	0	0	10	2.6	
	pH (SU)	6.5-8.5	64	14	22	NA	7.02	
	Dissolved sodium (mg L^{-1})	16	6	0	0	3	4.6	
	Chloride (mg L^{-1})	12	9	0	0	8	6.8	
	Total dissolved solids (mg L^{-1})[3]		64	0	0		37	
	Chlorophyll a (µg L^{-1})	12	24	0	0	7	2.7	
	Total phytoplankton (ASU mL^{-1})	2000	40	0	0	NA	209	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	87	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	40	0	0	NA	48	
Rondout Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	80	1	1	NA	8	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	56	0	0	NA	4	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	56	0	0	NA	2	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	56	0	0	0.3	0.12	KM
	Ammonia (as N) (mg L^{-1})	0.1	56	0	0	0.05	<0.02	>80%
	Fecal Coliform (coliforms $100mL^{-1}$)	20	80	0	0	NA	1	ROS
	Turbidity (NTU)	5	80	0	0	NA	1.0	
	Total suspended solids (mg L^{-1})	8	32	0	0	5	0.9	ROS
	Alkalinity (mg L^{-1})	NA	12	0	0	≥10	10.5	
	Dissolved Organic Carbon (mg L^{-1})	4	56	0	0	3	1.9	
	Sulfate (as SO4) (mg L^{-1})	15	12	0	0	10	2.7	
	pH (SU)	6.5-8.5	80	23	29	NA	6.83	
	Dissolved sodium (mg L^{-1})	16	8	0	0	3	4.4	
	Chloride (mg L^{-1})	12	12	0	0	8	6.6	
	Total dissolved solids (mg L^{-1})[3]		80	0	0		34	
	Chlorophyll a (µg L^{-1})	12	24	0	0	7	3.8	
	Total phytoplankton (ASU mL^{-1})	2000	46	0	0	NA	265	KM
	Dominant phytoplankton genus (ASU mL^{-1})	1000	46	0	0	NA	136	KM
	Secondary phytoplankton genus (ASU mL^{-1})	1000	46	0	0	NA	52	KM
West Branch Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	72	15	21	NA	13	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	72	0	0	NA	4	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	72	0	0	NA	<2	>80%
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	72	0	0	0.3	0.10	KM
	Ammonia (as N) (mg L^{-1})	0.1	72	0	0	0.05	0.02	ROS
	Fecal Coliform (coliforms $100mL^{-1}$)	20	72	0	0	NA	2	KM
	Turbidity (NTU)	5	72	0	0	NA	1.1	
	Total suspended solids (mg L^{-1})	8	9	0	0	5	1.2	KM
	Alkalinity (mg L^{-1})	NA	15	0	0	≥10	18.4	
	Dissolved Organic Carbon (mg L^{-1})	4	71	0	0	3	2.1	
	Sulfate (as SO4) (mg L^{-1})	15	15	0	0	10	3.5	
	pH (SU)	6.5-8.5	72	9	12	NA	6.81	
	Dissolved sodium (mg L^{-1})	16	10	2	20	3	9.2	
	Chloride (mg L^{-1})	12	15	6	40	8	12.5	
	Total dissolved solids (mg L^{-1})[3]		72	0	0		52	
	Chlorophyll a (µg L^{-1})	12	31	2	6	7	4.9	
	Total phytoplankton (ASU mL^{-1})	2000	43	3	7	NA	722	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	43	3	7	NA	365	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	43	0	0	NA	179	
Cross River Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	47	44	94	NA	43	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	24	4	17	NA	38	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	24	3	12	NA	7	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	24	0	0	0.3	0.03	ROS
	Ammonia (as N) (mg L^{-1})	0.1	24	8	33	0.05	0.22	KM
	Fecal Coliform (coliforms $100mL^{-1}$)	20	47	3	6	NA	6	KM
	Turbidity (NTU)	5	47	3	6	NA	2.0	
	Total suspended solids (mg L^{-1})	8	9	0	0	5	2.3	
	Alkalinity (mg L^{-1})	NA	9	0	0	≥40	48.6	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Dissolved Organic Carbon (mg L^{-1})	7	24	0	0	6	3.8	
	Sulfate (as SO4) (mg L^{-1})	25	9	0	0	15	7.0	
	pH (SU)	6.5-8.5	47	1	2	NA	7.21	
	Dissolved sodium (mg L^{-1})	20	6	0	0	15	15.4	
	Chloride (mg L^{-1})	40	9	0	0	30	26.0	
	Total dissolved solids (mg L^{-1})[3]		47	0	0		134	
	Chlorophyll a (µg L^{-1})	15	16	0	0	10	6.0	
	Total phytoplankton (ASU mL^{-1})	2000	16	2	12	NA	854	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	16	2	12	NA	539	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	16	0	0	NA	140	KM
Croton Falls Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	64	56	88	NA	25	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	64	2	3	NA	7	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	64	0	0	NA	2	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	64	14	22	0.3	0.28	KM
	Ammonia (as N) (mg L^{-1})	0.1	64	3	5	0.05	0.04	KM
	Fecal Coliform (coliforms $100mL^{-1}$)	20	64	0	0	NA	2	KM
	Turbidity (NTU)	5	64	2	3	NA	1.8	
	Total suspended solids (mg L^{-1})	8	9	0	0	5	2.0	
	Alkalinity (mg L^{-1})	NA	18	0	0	≥40	71.0	
	Dissolved Organic Carbon (mg L^{-1})	7	64	0	0	6	3.4	
	Sulfate (as SO4) (mg L^{-1})	25	18	0	0	15	7.9	
	pH (SU)	6.5-8.5	64	5	8	NA	7.55	
	Dissolved sodium (mg L^{-1})	20	12	12	100	15	28.5	
	Chloride (mg L^{-1})	40	18	15	83	30	45.3	
	Total dissolved solids (mg L^{-1})[3]		64	0	0		227	
	Chlorophyll a (µg L^{-1})	15	24	7	29	10	19.7	
	Total phytoplankton (ASU mL^{-1})	2000	24	1	4	NA	819	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	24	2	8	NA	470	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	24	0	0	NA	177	
Kensico Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	175	5	3	NA	10	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	175	0	0	NA	4	KM
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	175	0	0	NA	1	ROS
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	175	0	0	0.3	0.10	KM
	Ammonia (as N) (mg L^{-1})	0.1	175	1	1	0.05	0.02	ROS
	Fecal Coliform (coliforms $100mL^{-1}$)	20	175	3	2	NA	2	ROS
	Turbidity (NTU)	5	175	0	0	NA	0.9	
	Total suspended solids (mg L^{-1})	8	56	0	0	5	0.8	ROS
	Alkalinity (mg L^{-1})	NA	24	0	0	≥10	14.2	
	Dissolved Organic Carbon (mg L^{-1})	4	175	0	0	3	2.0	
	Sulfate (as SO4) (mg L^{-1})	15	24	0	0	10	3.7	
	pH (SU)	6.5-8.5	175	16	9	NA	6.92	
	Dissolved sodium (mg L^{-1})	16	16	0	0	3	6.4	
	Chloride (mg L^{-1})	12	24	0	0	8	9.8	
	Total dissolved solids (mg L^{-1})[3]		175	0	0		50	
	Chlorophyll a (µg L^{-1})	12	56	0	0	7	3.2	
	Total phytoplankton (ASU mL^{-1})	2000	72	0	0	NA	458	
	Dominant phytoplankton genus (ASU mL^{-1})	1000	72	1	1	NA	293	
	Secondary phytoplankton genus (ASU mL^{-1})	1000	72	0	0	NA	86	KM
New Croton Reservoir	Total Phosphorus (as P) (µg L^{-1})	15	167	151	90	NA	36	
	Total Dissolved Phosphorus (as P) (µg L^{-1})	15	167	19	11	NA	22	
	Soluble Reactive Phosphorus (as P) (µg L^{-1})	15	167	8	5	NA	7	KM
	Nitrate+Nitrite (as N) (mg L^{-1})	0.5	167	5	3	0.3	0.19	KM
	Ammonia (as N) (mg L^{-1})	0.1	167	24	14	0.05	0.09	KM
	Fecal Coliform (coliforms $100mL^{-1}$)	20	167	6	4	NA	3	KM
	Turbidity (NTU)	5	167	6	4	NA	1.9	
	Total suspended solids (mg L^{-1})	8	56	0	0	5	1.4	KM
	Alkalinity (mg L^{-1})	NA	40	0	0	≥40	70.5	
	Dissolved Organic Carbon (mg L^{-1})	7	167	0	0	6	3.4	
	Sulfate (as SO4) (mg L^{-1})	25	27	0	0	15	8.6	
	pH (SU)	6.5-8.5	167	2	1	NA	7.38	
	Dissolved sodium (mg L^{-1})	20	20	20	100	15	29.9	
	Chloride (mg L^{-1})	40	27	27	100	30	48.9	
	Total dissolved solids (mg L^{-1})[3]		167	0	0		206	
	Chlorophyll a (µg L^{-1})	15	56	5	9	10	8.4	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Total phytoplankton (ASU mL^{-1})	2000	77	1	1	NA	519	KM
	Dominant phytoplankton genus (ASU mL^{-1})	1000	77	1	1	NA	283	KM
	Secondary phytoplankton genus (ASU mL^{-1})	1000	77	0	0	NA	108	KM

[1] Means for data containing non-detects were estimated using techniques recommended in Helsel (2005) using an R program developed for U.S. Environmental Protection Agency (Bolks et al. 2014).
[2] Note indicates which analysis method was used to determine the statistics when there were left censored data. KM indicates Kaplan-Meier (used when >0% and <50% of the data is left censored), ROS indicates robust regression on order statistics (used when 50 to 80% of the data is left censored), and greater than 80% indicates that the mean could not be calculated for the following reasons: 1) the data contains greater than 80% censored data or 2) there are 5 or fewer samples with greater than 50% censored. In these cases, the detection limit, preceded by "<", is reported. A blank cell in the Note column indicates that the 2024 mean was calculated as the standard arithmetic average.
[3] Total dissolved solids is estimated from specific conductivity according to the USGS in van der Leeden et al. (1990) by multiplying specific conductivity by 0.65.

Appendix H. Comparison of Stream Water Quality Results to Benchmarks

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
Catskill System - Ashokan Basin								
E10I (Bushkill at West Shokan)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.12	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	6	50	NA	8.6	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	0.9	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	2.9	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	2.4	
	Chloride (mg L^{-1})	50	12	0	0	10	3.1	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	24	
E16I (Esopus Creek at Coldbrook)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.14	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	3	25	NA	19.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.7	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.0	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	5.6	
	Chloride (mg L^{-1})	50	12	0	0	10	9.2	
	Total dissolved solids (mg L^{-1})[3]	50	12	5	42	40	51	
E5 (Esopus Creek at Allaben)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.13	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	3	25	NA	15.4	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.1	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.0	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	6.5	
	Chloride (mg L^{-1})	50	12	0	0	10	9.6	
	Total dissolved solids (mg L^{-1})[3]	50	12	4	33	40	47	
Catskill System - Schoharie Basin								
S5I (Schoharie Creek at Prattsville)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.17	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	25.1	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.8	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.4	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	6.8	
	Chloride (mg L^{-1})	50	12	0	0	10	12.6	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	67	40	66	
S6I (Bear Kill at Hardenburgh Falls)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	2	17	0.4	0.67	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	34.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.6	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	5.3	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	8.9	
	Chloride (mg L^{-1})	50	12	0	0	10	20.5	
	Total dissolved solids (mg L^{-1})[3]	50	12	12	100	40	102	
S7I (Manor Kill)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.10	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	31.6	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.7	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.5	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	5.3	
	Chloride (mg L^{-1})	50	12	0	0	10	9.2	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	67	40	67	
	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.13	KM

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
SRR2CM (Schoharie Reservoir Diversion)	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	1	8	NA	19.9	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.1	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.1	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	6.7	
	Chloride (mg L^{-1})	50	4	0	0	10	9.3	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	67	40	51	
Delaware System - Cannonsville Basin								
C-7 (Trout Creek above Cannonsville Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.26	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	19.8	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.3	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	4.2	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	8.4	
	Chloride (mg L^{-1})	50	12	0	0	10	13.6	
	Total dissolved solids (mg L^{-1})[3]	50	12	11	92	40	64	
C-8 (Loomis Brook above Cannonsville Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.23	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	19.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.4	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	4.3	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	7.2	
	Chloride (mg L^{-1})	50	12	0	0	10	10.2	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	67	40	56	
CBS (formerly WDBN, West Branch Delaware River at Beerston Bridge)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.55	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	26.4	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.7	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	4.8	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	9.0	
	Chloride (mg L^{-1})	50	12	0	0	10	15.9	
	Total dissolved solids (mg L^{-1})[3]	50	12	12	100	40	79	
Delaware System - Neversink Basin								
NCG (Neversink River near Claryville)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.18	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	12	100	NA	4.3	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.5	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	2.3	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	1.7	
	Chloride (mg L^{-1})	50	12	0	0	10	2.7	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	17	
NK4 (Aden Brook above Neversink Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.19	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	8	67	NA	8.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.4	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	2.7	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	2.2	
	Chloride (mg L^{-1})	50	12	0	0	10	3.9	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	26	
NK6 (Kramer Brook above Neversink Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.14	ROS
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	0.02	ROS
	Alkalinity (mg L^{-1})	≥10.0	12	4	33	NA	13.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.4	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.5	
	Dissolved sodium (mg L^{-1})	10	3	3	100	5	16.5	
	Chloride (mg L^{-1})	50	12	0	0	10	29.8	
	Total dissolved solids (mg L^{-1})[3]	50	12	12	100	40	91	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
Delaware System - Pepacton Basin								
P-13 (Tremper Kill above Pepacton Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.19	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	21.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.5	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.4	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	6.3	
	Chloride (mg L^{-1})	50	12	0	0	10	10.8	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	67	40	56	
P-21 (Platte Kill at Dunraven)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.16	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	23.3	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.5	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.2	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	4.9	
	Chloride (mg L^{-1})	50	12	0	0	10	8.7	
	Total dissolved solids (mg L^{-1})[3]	50	11	6	55	40	57	
P-60 (Mill Brook near Dunraven)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.23	KM
	Ammonia (as N) (mg L^{-1})	0.25	11	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	5	42	NA	12.8	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.0	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	2.8	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	1.3	
	Chloride (mg L^{-1})	50	12	0	0	10	1.9	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	27	
P-7 (Terry Clove above Pepacton Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.30	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	3	25	NA	17.8	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.4	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.5	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	1.3	
	Chloride (mg L^{-1})	50	12	0	0	10	0.9	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	32	
P-8 (Fall Clove above Pepacton Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.29	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	3	25	NA	17.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.3	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.6	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	2.2	
	Chloride (mg L^{-1})	50	12	0	0	10	2.3	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	35	
PMSB (East Branch Delaware River near Margaretville)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.31	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	22.7	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.4	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.3	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	7.9	
	Chloride (mg L^{-1})	50	12	0	0	10	12.9	
	Total dissolved solids (mg L^{-1})[3]	50	12	8	73	40	65	
Delaware System - Rondout Basin								
RD1 (Sugarloaf Brook near Lowes Corners)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.16	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	12	100	NA	6.1	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.3	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.0	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	2.9	
	Chloride (mg L^{-1})	50	12	0	0	10	5.2	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	26	
RD4 (Sawkill Brook near Yagerville)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.09	KM
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	12	100	NA	6.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.0	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.8	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	2.9	
	Chloride (mg L^{-1})	50	12	0	0	10	4.5	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	26	
RDOA (Rondout Creek near Lowes Corners)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.19	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	11	92	NA	4.9	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	1.2	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	2.6	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	1.9	
	Chloride (mg L^{-1})	50	12	0	0	10	3.1	
	Total dissolved solids (mg L^{-1})[3]	50	12	0	0	40	19	
RGB (Chestnut Creek below Grahamsville STP)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.27	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	<0.02	>80%
	Alkalinity (mg L^{-1})	≥10.0	12	5	42	NA	9.8	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.3	
	Sulfate (as SO4) (mg L^{-1})	15	4	0	0	10	3.5	
	Dissolved sodium (mg L^{-1})	10	3	0	0	5	8.0	
	Chloride (mg L^{-1})	50	12	0	0	10	14.3	
	Total dissolved solids (mg L^{-1})[3]	50	12	6	50	40	53	
Croton System - Croton Basin								
AMAWALKR (Amawalk Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.33	KM
	Ammonia (as N) (mg L^{-1})	0.2	9	0	0	0.1	0.04	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	72.8	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	3.8	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	8.6	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	48.2	
	Chloride (mg L^{-1})	100	9	0	0	35	84.6	
	Total dissolved solids (mg L^{-1})[3]	175	9	9	100	150	292	
BOGEASTBRR (Combined release for Bog Brook and East Branch Reservoirs)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.11	KM
	Ammonia (as N) (mg L^{-1})	0.2	9	0	0	0.1	0.03	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	81.3	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	3.8	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	7.2	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	24.0	
	Chloride (mg L^{-1})	100	9	0	0	35	40.1	
	Total dissolved solids (mg L^{-1})[3]	175	9	8	89	150	204	
BOYDR (Boyd Corners Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.08	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	1	8	0.1	0.06	KM
	Alkalinity (mg L^{-1})	≥40.0	12	8	67	NA	35.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.3	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	4.8	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	16.3	
	Chloride (mg L^{-1})	100	12	0	0	35	21.9	
	Total dissolved solids (mg L^{-1})[3]	175	12	0	0	150	103	
CROFALLSVC (Croton Falls Reservoir Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.24	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.04	KM
	Alkalinity (mg L^{-1})	≥40.0	12	0	0	NA	61.4	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.0	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	7.9	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	28.2	
	Chloride (mg L^{-1})	100	12	0	0	35	44.4	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
	Total dissolved solids (mg L^{-1})[3]	175	12	10	83	150	188	
CROSS2 (Cross River above Cross River Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.12	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.02	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	1	8	NA	64.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	4.5	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	8.6	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	15.6	
	Chloride (mg L^{-1})	100	12	0	0	35	29.7	
	Total dissolved solids (mg L^{-1})[3]	175	12	3	25	150	160	
CROSSRVVC (Cross River Reservoir Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.07	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	1	8	0.1	0.06	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	0	0	NA	47.5	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.6	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	6.6	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	16.0	
	Chloride (mg L^{-1})	100	12	0	0	35	25.8	
	Total dissolved solids (mg L^{-1})[3]	175	12	0	0	150	131	
DIVERTR (Diverting Reservoir Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.16	
	Ammonia (as N) (mg L^{-1})	0.2	9	0	0	0.1	0.04	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	80.5	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	3.7	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	7.7	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	26.7	
	Chloride (mg L^{-1})	100	9	0	0	35	43.9	
	Total dissolved solids (mg L^{-1})[3]	175	9	9	100	150	211	
EASTBR (East Branch Croton River above East Branch River)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.06	KM
	Ammonia (as N) (mg L^{-1})	0.2	9	0	0	0.1	0.03	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	90.6	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	4.9	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	6.1	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	22.2	
	Chloride (mg L^{-1})	100	9	0	0	35	35.7	
	Total dissolved solids (mg L^{-1})[3]	175	9	6	67	150	202	
GYPSYTRL1 (Gypsy Trail Brook above West Branch Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.07	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.02	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	8	67	NA	35.0	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	4.2	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	6.1	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	14.1	
	Chloride (mg L^{-1})	100	12	0	0	35	26.4	
	Total dissolved solids (mg L^{-1})[3]	175	12	2	17	150	112	
HORSEPD12 (Horse Pound Brook above West Branch Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.26	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.02	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	5	42	NA	48.9	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.9	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	7.6	
	Dissolved sodium (mg L^{-1})	20	3	2	67	15	21.1	
	Chloride (mg L^{-1})	100	12	0	0	35	34.9	
	Total dissolved solids (mg L^{-1})[3]	175	12	2	17	150	150	
KISCO3 Kisco River above New Croton Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.56	
	Ammonia (as N) (mg L^{-1})	0.2	9	0	0	0.1	0.02	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	82.5	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	4.0	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	12.0	
	Dissolved sodium (mg L^{-1})	20	3	2	67	15	40.9	
	Chloride (mg L^{-1})	100	9	2	22	35	76.8	
	Total dissolved solids (mg L^{-1})[3]	175	9	8	89	150	290	
	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.21	

Site	Analyte	Single Sample Maximum (SSM)	Number samples	Number that exceeds SSM	Percent that exceed SSM	Annual Mean Standard	2024 Mean[1]	Note[2]
LONGPD1 (Long Pond outflow above West Branch Reservoir)	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.01	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	0	0	NA	63.2	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.9	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	9.4	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	32.0	
	Chloride (mg L^{-1})	100	12	2	17	35	62.9	
	Total dissolved solids (mg L^{-1})[3]	175	12	10	83	150	230	
MIKE2 (Michael Brook above Croton Falls Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	10	83	0.35	7.19	
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.02	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	0	0	NA	90.5	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	3.9	
	Sulfate (as SO4) (mg L^{-1})	25	5	2	40	15	49.2	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	93.4	
	Chloride (mg L^{-1})	100	12	10	83	35	154.5	
	Total dissolved solids (mg L^{-1})[3]	175	12	12	100	150	524	
MUSCOOT10 (Muscoot River above Amawalk Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	10	0	0	0.35	0.32	
	Ammonia (as N) (mg L^{-1})	0.2	10	0	0	0.1	0.05	KM
	Alkalinity (mg L^{-1})	≥40.0	10	0	0	NA	84.6	
	Dissolved Organic Carbon (mg L^{-1})	25	10	0	0	9	5.0	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	13.0	
	Dissolved sodium (mg L^{-1})	20	3	3	100	15	66.6	
	Chloride (mg L^{-1})	100	10	6	60	35	121.1	
	Total dissolved solids (mg L^{-1})[3]	175	10	10	100	150	387	
TITICUSR (Titicus Reservoir Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	9	0	0	0.35	0.17	KM
	Ammonia (as N) (mg L^{-1})	0.2	9	1	11	0.1	0.05	KM
	Alkalinity (mg L^{-1})	≥40.0	9	0	0	NA	70.0	
	Dissolved Organic Carbon (mg L^{-1})	25	9	0	0	9	3.6	
	Sulfate (as SO4) (mg L^{-1})	25	4	0	0	15	6.8	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	16.3	
	Chloride (mg L^{-1})	100	9	0	0	35	27.2	
	Total dissolved solids (mg L^{-1})[3]	175	9	1	11	150	161	
WESTBR7 (West Branch Croton River above Boyd Corners Reservoir)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.35	0.04	KM
	Ammonia (as N) (mg L^{-1})	0.2	12	0	0	0.1	0.02	ROS
	Alkalinity (mg L^{-1})	≥40.0	12	6	50	NA	41.1	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	5.3	
	Sulfate (as SO4) (mg L^{-1})	25	5	0	0	15	4.9	
	Dissolved sodium (mg L^{-1})	20	3	0	0	15	15.9	
	Chloride (mg L^{-1})	100	12	0	0	35	23.0	
	Total dissolved solids (mg L^{-1})[3]	175	12	0	0	150	110	
WESTBRR (West Branch Reservoir Release)	Nitrate+Nitrite (as N) (mg L^{-1})	1.5	12	0	0	0.4	0.11	
	Ammonia (as N) (mg L^{-1})	0.25	12	0	0	0.05	0.02	ROS
	Alkalinity (mg L^{-1})	≥10.0	12	0	0	NA	15.4	
	Dissolved Organic Carbon (mg L^{-1})	25	12	0	0	9	2.2	
	Sulfate (as SO4) (mg L^{-1})	15	5	0	0	10	3.8	
	Dissolved sodium (mg L^{-1})	10	3	1	33	5	7.5	
	Chloride (mg L^{-1})	50	12	0	0	10	10.0	
	Total dissolved solids (mg L^{-1})[3]	50	12	5	42	40	50	

Streams included in this analysis are required by WWQMP as per 3.2.1. Status of Stream Water Quality and 5.8. Croton System Streams – Water Quality Status

[1] Means for data containing non-detects were estimated using techniques recommended in Helsel (2005) using an R program developed for U.S. Environmental Protection Agency (Bolks et al. 2014).

[2] Note indicates which analysis method was used to determine the statistics when there were left censored data. KM indicates Kaplan-Meier (used when >0% and <50% of the data is left censored), ROS indicates robust regression on order statistics (used when 50 to 80% of the data is left censored), and greater than 80% indicates that the mean could not be calculated for the following reasons: 1) the data contains greater than 80% censored data or 2) there are 5 or fewer samples with greater than 50% censored. In these cases, the detection limit, preceded by "<", is reported. A blank cell in the Note column indicates that the 2024 mean was calculated as the standard arithmetic average.

[3] Total dissolved solids is estimated from specific conductivity according to the USGS in van der Leeden et al. (1990) by multiplying specific conductivity by 0.65.

Appendix I. Biomonitoring Sample Sites

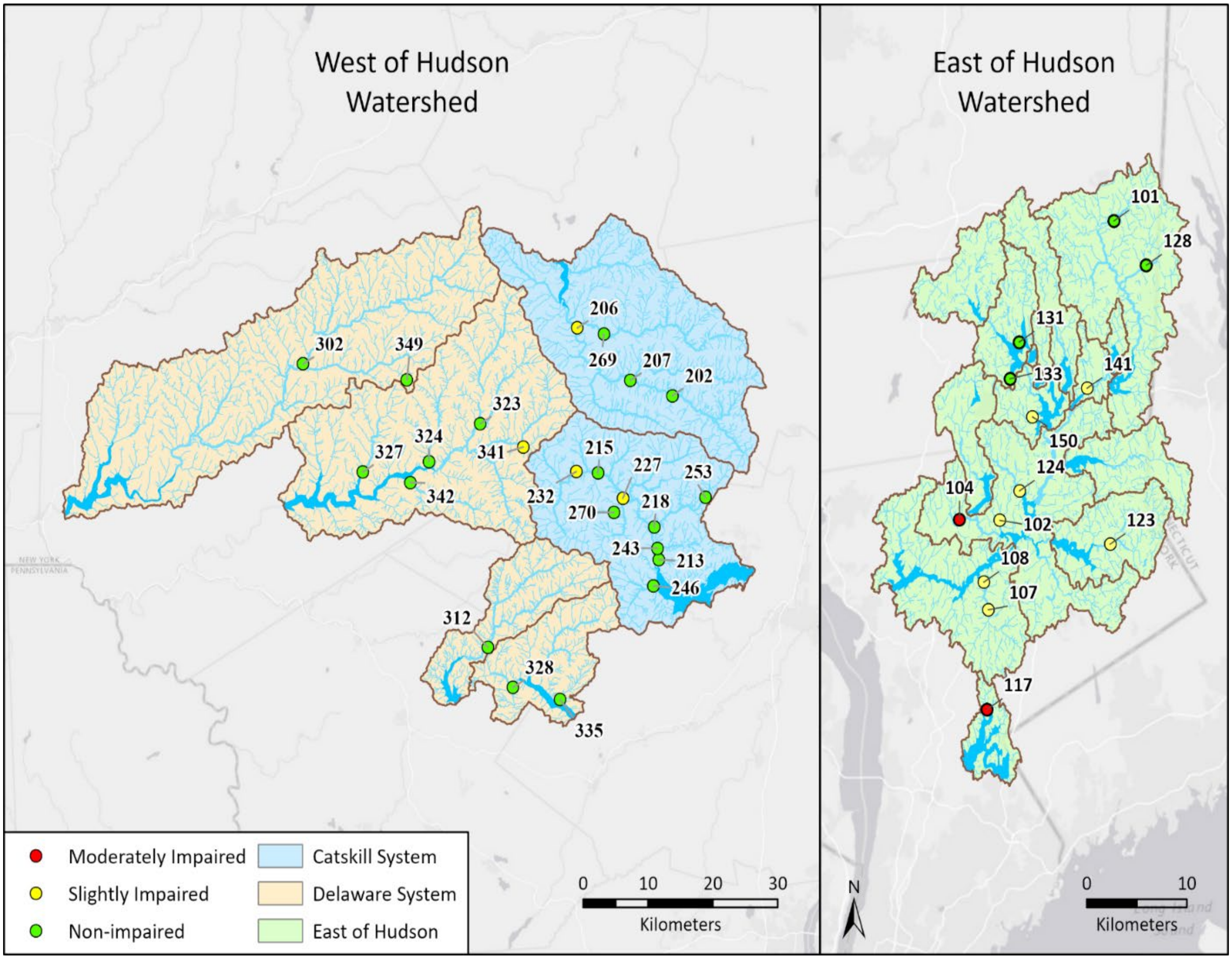

Figure I.1 2024 Biomonitoring Sample Sites

Table I.1 2024 Biomonitoring and Impairment Status

SYSTEM	SITE	WQ SITE	STREAM	IMPAIRMENT STATUS
EOH	101	BB5	Brady Brook	Non-impaired
	102	ANGLE5	Angle Fly Brook	Slight
	104	HMILL7	Hallocks Mill Brook	Moderate
	107	KISCO5	Kisco River	Slight
	108	KISCO3	Kisco River	Slight
	117	WHIP	Whippoorwill Creek	Moderate
	123	CROSS2	Cross River	Slight
	124	PLUM2	Plum Brook	Slight
	128	HH7	Haviland Hollow Brook	Non-impaired
	131	GYPSYTRL1	Gypsy Trail Brook	Non-impaired
	133	LONGPD1	Long Pond Stream	Non-impaired
	141	N/A	Tonetta Brook	Slight
	150	N/A	Trib. To Croton Falls Res.	Slight
Catskill	202	S3	Schoharie Creek	Non-impaired
	206	S10	Batavia Kill	Slight
	207	SEK	East Kill	Non-impaired
	213	E16i	Esopus Creek	Non-impaired
	215	E5	Esopus Creek	Non-impaired
	218	BK	Beaver Kill	Non-impaired
	227	AEAWDL	Esopus Creek	Slight
	232	N/A	Seneca Hollow	Slight
	243	LBK	Little Beaver Kill	Non-impaired
	246	E10i	Bush Kill	Non-impaired
	253	N/A	Beaver Kill (Mink Hollow)	Non-impaired
	269 (New)	S10-LC	Batavia Kill	Non-impaired
	270 (New)	N/A	Panther Kill	Non-impaired

SYSTEM	SITE	WQ SITE	STREAM	IMPAIRMENT STATUS
Delaware	302	DTPA	West Br. Delaware River	Non-impaired
	312	NCG	Neversink River	Non-impaired
	323	P-50	Batavia Kill	Non-impaired
	324	P-21	Platte Kill	Non-impaired
	327	P-13	Tremper Kill	Non-impaired
	328	RK	Red Brook	Non-impaired
	335	RD4	Sawkill Creek	Non-impaired
	341	N/A	Emory Brook	Slight
	342	P-60	Mill Brook	Non-impaired
	349	CCBHG	Coulter Brook	Non-impaired

Appendix J. Semivolatile and Volatile Organic Compounds and Herbicides

Table J.1 EPA 524.2 Volatile Organics

Analyte	CAS Number	Analyte	CAS Number
1-1-1-2-Tetrachloroethane	630-20-6	cis-1-2-Dichloroethylene	156-59-2
1-1-1-Trichloroethane	71-55-6	cis-1-3-Dichloropropene	10061-01-5
1-1-2-2-Tetrachloroethane	79-34-5	Dibromochloromethane (Chlorodibromomethane)	124-48-1
1-1-2-Trichloroethane	79-00-5	Dibromomethane	74-95-3
1-1-Dichloroethane	75-34-3	Dichlorofluormethane	75-71-8
1-1-Dichloroethylene	75-35-4	Dichloromethane	75-09-2
1-1-Dichloropropene	563-58-6	Ethylbenzene	100-41-4
1-2-3-Trichlorobenzene	87-61-6	Hexachlorobutadiene	87-68-3
1-2-3-Trichloropropane	96-18-4	Isopropyl ether (Di-isopropyl ether)	108-20-3
1-2-4-Trichlorobenzene	120-82-1	Isopropylbenzene	98-82-8
1-2-4-Trimethylbenzene	95-63-6	m-p-Xylenes	179601-23-1
1-2-Dichloroethane	107-06-2	m-Dichlorobenzene (1-3-DCB)	541-73-1
1-2-Dichloropropane	78-87-5	Methyl-tert-butyl ether (MTBE)	1634-04-4
1-3-5-Trimethylbenzene	108-67-8	n-Butylbenzene	104-51-8
1-3-Dichloropropane	142-28-9	N-Propylbenzene	103-65-1
1-3-Dichloropene Total	542-75-6	Naphthalene	91-20-3
2-2-Dichloropropane	594-20-7	o-Dichlorobenzene (1-2-DCB)	95-50-1
2-Butanone (MEK)	78-93-3	o-Xylene	95-47-6
2-Chlorotoluene (o-Chlorotoluene)	95-49-8	p-Dichlorobenzene (1-4-DCB)	106-46-7
4-Chlorotoluene (p-Chlorotoluene)	106-43-4	sec-Butylbenzene	135-98-8
4-Isopropyltoluene (p-Isopropyltoluene)	99-87-6	Styrene	100-42-5
4-Methyl-2-pentanone (MIBK)	108-10-1	Tert-amyl methyl ether	994-05-8
Benzene	71-43-2	Tert-butyl ethyl ether	637-92-3
Bromobenzene	108-86-1	tert-Butylbenzene	98-06-6
Bromochloromethane	74-97-5	Tetrachloroethene (PCE) (Tetrachloroethylene)	127-18-4
Bromodichloromethane	75-27-4	Toluene	108-88-3
Bromoethane	74-96-4	Total Xylenes	1330-20-7
Bromoform	75-25-2	trans-1-2-Dichloroethylene	156-60-5
Bromomethane (methyl bromide)	74-83-9	trans-1-3-Dichloropropene	10061-02-6
Carbon disulfide	75-15-0	Trichloroethylene (TCE)	79-01-6
Carbon tetrachloride	56-23-5	Trichlorofluoromethane (Freon 11)	75-69-4
Chlorobenzene	108-90-7	Trichlorofluorethane	76-13-1
Chloroethane	75-00-3	Trihalomethanes, Total	67-66-3

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Analyte	CAS Number	Analyte	CAS Number
Chloroform (Trichloromethane)	67-66-3	Vinyl chloride (VC)	75-01-4
Chloromethane (methyl chloride)	74-87-3		

Table J.2 EPA 525.2 Semivolatile Organics

Analyte	CAS Number	Analyte	CAS Number
2-4-DDD	53-19-0	Dimethhylphthalate	131-11-3
2-4-DDE	3424-82-6	Endosulfan I (Alpha)	959-98-8
2-4-DDT	789-02-6	Endosulfan II (Beta)	33213-65-9
2-4-Dinitrotoluene	121-14-2	Endosulfan sulfate	1031-07-8
2-6-Dinitrotoluene	606-20-2	Endrin aldehyde	7421-93-4
4-4-DDD	72-54-8	Endrin	72-20-8
4-4-DDE	72-55-9	EPTC	759-94-4
4-4-DDT	50-29-3	Fluoranthene	206-44-0
Acenaphthene	83-32-9	Fluorene	86-73-7
Acenaphthylene	208-96-8	gamma-Chlordane	5103-74-2
Acetochlor	34256-82-1	Heptachlor epoxide (isomer B)	10234-57-3
Alachlor (Alanex)	15972-60-8	Heptachlor	76-44-8
alpha-BHC	319-84-6	Hexachlorobenzene	118-74-1
Alpha-Chlordane	5103-71-9	Hexachlorocyclopentadiene	77-47-4
Anthracene	120-12-7	Indeno[1-2-3-c-d]pyrene	193-39-5
Atrazine	1912-24-9	Isophorone	78-59-1
Benz(a)anthracene	56-55-3	Lindane	58-89-9
Benzo[a]pyrene	50-32-8	Malathion	121-75-5
Benzo[b]fluoranthene	205-99-2	Methoxychlor	72-43-5
Benzo[g-h-i]perylene	191-24-2	Metolachlor	51218-45-2
Benzo[k]fluoranthene	207-08-9	Metribuzin	21087-64-9
beta-BHC	319-85-7	Molinate	2212-67-1
Di(2-ethylhexyl)phthalate	117-81-7	Naphthalene	91-20-3
Bromacil	314-40-9	Parathion	56-38-2
Butachlor	23184-66-9	Pendimethalin (Penoxaline)	40487-42-1
Butylbenzylphthalate	85-68-7	Phenanthrene	85-01-8
Caffeine (method 525 mod)	58-08-2	Propachlor	1918-16-7
Chlorobenzilate	510-15-6	Pyrene	129-00-0
Chloreneb	2675-77-6	Simazine	122-34-9
Chlorothalonil (Draconil, Bravo)	1897-45-6	Terbacil	5902-51-2
Chloropyrifos (Dursban)	2921-88-2	Terbuthylazine	5915-41-3
Chrysene	218-01-9	Thiobencarb (ELAP)	28249-77-6
delta-BHC	319-86-8	Total Permethrin (mixed isomers)	52645-53-1

Analyte	CAS Number	Analyte	CAS Number
Di-(2-ethylhexyl) adipate	102-23-1	trans-Nonachlor	39765-80-5
Di-n-butyl phthalate	84-74-2	Trifluralin	1582-09-8
Di-n-octyl phthalate	117-84-0	Aldrin	309-00-2
Diazinon (Qualitative)	333-41-5		
Dibenz(a-h)anthracene	53-70-3		
Diclorvos (DDVP)	62-73-7		
Dieldrin	60-57-1		
Diethylphthalate	84-66-2		
Dimethoate	60-51-5		

Table J.3 Herbicides – EPA Method 547

Analyte	CAS Number
Glyphosate	1071-83-6

Table J.4 Other organics – EPA Method 515.4

Analyte	CAS Number
Pentachlorophenol	87-86-5