New York City
Department of Environmental Protection

Watershed Water Quality Monitoring Plan

Revised May 2016

Emily Lloyd, Commissioner
Paul V. Rush, P.E., Deputy Commissioner
Bureau of Water Supply

Table of Contents

List of Figures

List of Tables

Acknowledgements

This Watershed Water Quality Monitoring Plan (WWQMP) represents a description of the current (2015) water quality monitoring programs conducted by the Water Quality Directorate (WQD). These programs are continually evolving to meet changing regulatory, operational, and modeling needs. Therefore, this revision was undertaken to bring the plan up to date by incorporating all changes that have been made since 2009. The original WWQMP was one of the requirements of the 2007 Filtration Avoidance Determination (FAD) for the NYC Water Supply. In this 2015 version of the WWQMP, the chapters are similarly organized according to overarching categories of objectives. The overarching objectives include: regulatory compliance, NYC's 2007 FAD requirements, modeling, and surveillance to guide operations. As in the previous version, these objectives are arranged in order of priority for the Bureau of Water Supply.

Mr. Paul Rush, P.E., Deputy Commissioner of the Bureau of Water Supply, and Mr. Steven Schindler, Director of Water Quality, provide oversight of the Water Quality Directorate, a group of over 200 water quality professionals. The staff of the Water Quality Science and Research (WQSR) Division, in conjunction with the Watershed Water Quality Operations (WWQO) Division, were responsible for production and review of this revised plan, respectively. Individuals were involved as follows. As Chief of WQSR, Dr. Lorraine Janus was responsible for assignments, scheduling, and overall organization of this report, as well as revising Chapter 1 (Introduction). Ms. Kerri Alderisio, Section Chief of Watershed Impacts and Pathogen Assessment, provided the revision of Chapter 2 on Regulatory Compliance, as well as objectives in other chapters that require pathogen monitoring. Mr. Jim Mayfield, Section Chief of Program Evaluation and Planning, provided oversight of revisions in Chapters 3 and 5. Mr. Emmet Owens of the Modeling Section updated Chapter 4, which includes monitoring support of the modeling work needed to fulfill the FAD requirements (such as evaluation of watershed protection and remediation programs) and guide the operational activities of the Bureau. Mr. Rich Van Dreason revised Chapter 5, which defines the monitoring needed for ongoing surveillance of the water supply, in terms of both routine and special investigations needed to guide operational changes. Mr. Jordan Gass, GIS Specialist, was responsible for production of the attractive maps throughout this report, which truly enhance communication of the plan's content. Mr. Donald Kent reviewed and incorporated all of the edits from each section and was also responsible for desktop publishing work which brought the plan into its final form.

The WWQO Division, directed by Ms. Lori Emery, is acknowledged for providing a thorough review of the plan to ensure that it reflects current activities. Ultimately, WWQO is the division responsible for implementation of the plan, so their review is essential. Implementation

of this extensive and complex plan is accomplished through the managerial expertise of Mr. Andrew Bader (Deputy Chief, WOH WWQO), Mr. Charles Olson (Deputy Chief, EOH WWQO), Mr. James Broderick (Deputy Chief, WWQO Systems Support), and Mr. Chris Nadareski (Section Chief, Wildlife Studies). The operational Section Chiefs of WWQO (Ms. Kirsten Askildsen at Kingston, Mr. Tracy Lawrence at Grahamsville, Mr. Dale Borchert at Hawthorne and Ms. Jennifer Sampson at Hawthorne) provide on-site management of the regional components of the monitoring plan with assistance from their Laboratory and Field Directors. WWQO is comprised of a Systems Support Unit, a Wildlife Studies Section, a Pathogen Laboratory (approved for the LT2 and NELAC-accredited through the State of New Hampshire), three Field Operations Units, and three Water Quality Laboratories (accredited by ELAP). The implementation of this plan would not be possible without the extensive laboratory, field, and overall technical expertise of these WWQO staff.

Mr. David Warne, Director of Watershed Protection and Planning, and his staff are acknowledged for transmitting ideas and objectives communicated to the Department through the meetings with USEPA, NYSDEC, and NYSDOH staff to ensure that the programs serve the needs of the Department.

It is the collective efforts and thinking of all the staff involved that has resulted in the "fine tuning" of DEP's field programs in support of the BWS mission to reliably deliver safe, clean drinking water to ten million consumers.

1. Introduction

1.1 Background and Organization of this Report

The purpose of this document is to produce a formalized description of the long-term, routine water quality monitoring conducted by the DEP within the watershed. This monitoring plan has been designed to meet the broad range of DEP's many regulatory and informational requirements. These requirements include: compliance with all federal, state, and local regulations to ensure safety of the water supply for public health; watershed protection and improvement to meet the terms of the Revised 2007 Filtration Avoidance Determination (FAD) (NYSDOH 2014); the need for current and future predictions of watershed conditions and reservoir water quality to ensure that operational decisions and policies are fully supported over the long term; and the need for ongoing surveillance to ensure delivery of the best water quality to consumers.

The chapters of the plan are presented here in approximate order of priority for the Bureau of Water Supply, but it is more appropriate to say that priorities form a pyramid rather than a linear sequence. Regulatory Compliance (Chapter 2) is detailed first and can be thought of as the pinnacle of the Bureau's priorities. This chapter includes all monitoring required by federal and state regulations, court consent decrees, administrative orders, and State Pollutant Discharge Elimination System (SPDES) permits. There is very little flexibility in the monitoring required for compliance programs. The data from these monitoring programs are typically submitted as regulatory compliance reports, but may also be developed into information for other purposes. From there on, the other categories of monitoring form the base which provides the context for interpretation of the compliance information. Since monitoring described in some chapters works in conjunction with other chapters, it would be difficult to diminish the role of any of the supporting elements. Among the supporting elements is another high priority of the Bureau addressed by the objectives of Chapter 3, which is designed to fulfill the requirements of the FAD. Since the FAD is written in broad terms for some requirements, there is some flexibility in development of the monitoring described in this chapter. Here, the FAD requirements have been translated into specific monitoring plans to address the information needs of the milestones specified in the FAD. In addition to providing data to evaluate status and trends of the water supply, monitoring is prescribed to allow for evaluation of the effectiveness of DEP's watershed protection and remediation programs and to develop watershed protection policies. Chapter 4 describes the data requirements of the Modeling Program. The objectives of modeling include both the long-term interests and short-term operations of the Bureau. The modeling objectives include: the evaluation of watershed protection programs and policies as requirements set by the FAD, management of operations to minimize treatment, and predictions for planning purposes as specified in the City's Action Plan for Climate Change (DEP 2008). Finally, Chapter 5 (Surveillance) includes additional monitoring needed to guide and support operational decisions, and to remain constantly vigilant of water quality conditions throughout the system. These surveillance measures allow DEP's Directorate of Water Quality (WQD) to anticipate problems and take action to maintain reliable delivery of high quality water to the distribution system. All of the components of the monitoring program work together to provide a comprehensive view of water quality throughout the system.

This report essentially builds on the experience gained from previous monitoring plans. Other plans that are direct predecessors of this one are the 1997 Water Quality Surveillance Monitoring report (DEP 1997), Comprehensive Watershed Monitoring (ILSI 1998), the 2003 Integrated Monitoring Plan (DEP 2003) and the Watershed Water Quality Monitoring Plan (DEP 2009). As DEP's monitoring plan has evolved over the years since the first Filtration Avoidance Determination in 1993, the need to document the program in detail has intensified. Documentation of the monitoring program preserves the original intent of objectives, allows for transfer of knowledge to new generations of samplers, allows for coordination and planning of time and materials needed for implementation, and systematic adjustment of the program to suit new requirements. Monitoring programs typically last for five years before the next major review is needed. As time passes, new developments in methods, circumstances, regulations, and infrastructure all create a new situation and accumulate to finally warrant a thorough review and update of the plan. These are the reasons that the monitoring plan should be considered a basic tool for managing the programs, but it should be recognized that adjustments of the plan must be made to meet new conditions. As watershed protection programs develop and analytical techniques for key parameters change, it is necessary to reassess the monitoring program to ensure that it continues to support watershed management. The monitoring program must retain its ability to evaluate the effectiveness of programs established under the FAD and MOA, as well as stand up to the scrutiny of reviews by outside organizations such as the National Research Council (NRC 2000). Small adjustments to the plan to accommodate changing conditions are documented as addenda, which are submitted according to the form in Appendix VIII and approved by management prior to implementation. This allows for an organized and systematic tracking of adjustments to the plan over time.

1.2 Objective-based Approach to Network Design for Water Quality Monitoring

Historically, water quality monitoring networks have been designed almost exclusively by determining "what" and "how" to monitor and rarely examining the question of "why" (Sanders et al. 1983). Typically, such designs produce large amounts of data which are difficult to analyze and often more difficult to interpret. This phenomenon is described by Ward et al. (1986) as "data rich and information poor" and is prevalent in many, if not most, routine water quality monitoring programs. The problem is associated with not defining the informational goals of the program specifically prior to the design of the monitoring network. The result is an accumulation of data that contributes little or no information to the understanding of the system. Data collection can become an end in itself and this pitfall should be avoided. In addition, individual studies and investigations traditionally have not been conducted in concert with existing "fixed" long-term monitoring programs. This often results in disjointed, inconsistent information and, at times, a duplication of effort resulting in limited applicability. In order to avoid these difficulties, the starting point is the definition of objectives as we have done for this plan.

Considerable effort has been made over the years to define the logic and science to be used in designing water quality monitoring networks. Ward (1996) describes a detailed summary of these efforts and further argues that water quality monitoring programs must be thought of, and designed as, water quality information systems.

Similarly, Smith et al. (1990) describe an approach used in designing the national water quality network for New Zealand. Careful consideration was given to a comprehensive list of tasks before the network was implemented. These included the following steps:

1) define goals and objectives,
2) confirm statistical design criteria,
3) produce a list of analytes,
4) recommend data analysis procedures, and
5) recommend reporting procedures.

Accordingly, to update DEP's water quality monitoring plan, the information required by each of these steps was compiled for each objective. A template was developed to systematically consolidate the information pertaining to each objective as follows:

Template for each objective:

Title of Objective
Background
Sites

Table X

Site Code	Site Description	Reason for Site Selection

Analytes and Frequencies

Table XX

Analyte	Sampling Frequency	Rationale for Analyte

Data Analysis and Reporting Goals

The objectives of this plan were defined as a consequence of the requirements of the information "end-users" as defined by the objectives, i.e., DEP management, regulators, and other external agencies. More specifically, the monitoring requirements were derived from legally binding mandates, agreements, operations, and watershed management information needs. The foremost regulatory requirements are specified in the Safe Drinking Water Act (SDWA) and its rules, the Clean Water Act (CWA), the New York State Water Quality Regulations (Title 6, Chapter X, Parts 700-705), the FAD, and the NYC Watershed Rules and Regulations (WR&R), as well as Administrative Consent Orders. Specific information on many of these underlying documents can be found by consulting the appendices of this report.

Once objectives were defined, several elements were considered in design including site selection, choice of analytes, methodology to be used, and sampling frequency. Statistical features of the historic database were used to guide the sampling design where possible. Analyses of past data revealed that some sites were not significantly different from others, indicating that they could be considered redundant. Similarly, sampling frequencies were approximately based on the rates of processes governing variability in water quality data, and therefore the sampling frequencies needed to track them. This type of statistical screening of differences between sites and collection times was used to streamline the monitoring site plans and to determine appropriate collection frequencies. DEP's watershed water quality laboratories are accredited by ELAP to NELAC standards. The watershed pathogen laboratory is accredited by New Hampshire ELAP. The data collected must be of known and documented quality to meet regulatory requirements, to evaluate and respond to the current challenges of watershed protection, and to support critical decisions related to the management of the New York City water supply.

In the interest of improved efficiency, data quality and access, a modern Laboratory Information Management System (LIMS) was purchased and configured for DEP use by all Watershed Quality Laboratory and Field programs. Additionally, Watershed Water Quality Operations (WWQO) began utilization of field data collection units. These new systems, phased in from 2010 to 2013, assist in planning and implementing WWQO's diverse collection and analysis protocols. The LIMS system (Abbott Informatics StarLIMS) is a web-based commercial off-the-shelf system designed for commercial and government laboratories. Water Quality staff, which includes managerial and laboratory staff, research scientists, modelers, and QA/QC staff and field personnel, all have the ability to interact directly or indirectly with the LIMS, reducing data access bottlenecks. Where possible, instrument data output from the laboratories and field programs are directly integrated with the LIMS, reducing the need for data transcription, and triggering additional QC calculations and validation prior to final database storage. The LIMS system also improves upon laboratory and managerial reporting capabilities through the use of Crystal Reports, permitting the creation of routine report templates, query-embedded live-linked Microsoft Excel sheets, and an in-house developed web-based Data Portal, all of which can be used by any WQ staff, improving data accessibility and efficiency. The data stored in the underlying SQL database are also available for connection with other Bureau of Water Supply (BWS) applications including the Operations Support Tool (OST) and a variety of water quality models. Non-laboratory Watershed Water Quality data are also stored in a select number of additional databases. The Hawthorne Field program maintains Kensico streamflow data using WISKI (Water Information System by Kisters). Also, Early Warning Remote Monitoring program continuous keypoint monitoring data are stored in two separate databases. These data are stored in a WISKI database, as data collected at one minute fixed frequency, and in a Wonderware Historian database, as data collected with delta triggered storage. The Wonderware Historian data is primarily used by Water Quality and Operations staff for treatment monitoring and production of the daily Systems Operation report.

Beyond the definition of individual objectives, this plan is integrated in that a significant overlap occurs in the data requirements that serve different objectives. Therefore the plan should be seen as superimposed networks that build on each other and provide multidimensional information, and multiple lines of evidence, to support operational and policy decisions. Water quality management often requires a network design that can address water quality issues which demand distinct spatial and temporal monitoring efforts. These efforts may, for example, require a combination of surveys that consist of fixed-frequency long-term and intensive short-term strategies. The design of water quality monitoring networks can be significantly enhanced by coordination and integration of such monitoring strategies. The integration of distinct water quality monitoring networks is essential in providing consistent and applicable water quality information (Ward et al. 1990, Payne and Ford 1988). In fact, further integration takes place when scientists provide analysis and interpretation of the data for scientific reports and publications. Only then does the importance of the interconnections of the monitoring networks and true value of the data materialize.

During the development of this plan, the information needs and goals of management and other stakeholders were used to define the monitoring network design. Once the information needs were clearly defined, consideration was given to determining priorities in view of the available resources. By addressing the many considerations and issues mentioned above during the planning process, a statistically-based, goal-oriented monitoring network was designed to provide the necessary information for managers to adequately manage the resource. Finally, information needs are reviewed periodically to ensure that the data collection is appropriate. As information needs change, the objectives of the plan and the sampling program should change accordingly. Ultimately, plans such as this one must undergo thorough review and revision to address new conditions.

1.3 Spatial Coverage by Monitoring Networks

DEP's watershed monitoring networks cover the entire watershed. They are depicted on the maps in this section according to sample "types," including: meteorological stations, snow surveys, stream sample sites, limnological sample sites, aqueducts, and wastewater treatment plants. Robotic monitoring of both streams and reservoirs is used to collect high-frequency data that supplements routine grab samples. Each network provides data that are used to characterize "state variables" (quantities), as well as their transformation rates, which are important components of the water supply's hydrology and water quality. Hydrological flow is the essential underlying element of water quality phenomena and water quality models are based on the hydrodynamics of the system. The interplay of water flow rates and physical, chemical, and biological rates determine water quality outcomes. These can only be estimated through models. Therefore it is essential to know basic hydrology of the watershed in order to anticipate changes for proactive management of the water supply.

Meteorological stations are shown in Figure 1.1. There are 20 sites west of the Hudson River and 5 sites east of the Hudson. This network was designed to provide the best data characterization of the conditions throughout the watershed in order to allow extrapolation and estimation of total precipitation entering the system. Orographic effects (such as greater precipitation at higher elevation on the windward side of mountains) were considered during site selection so sites at different elevations were selected to proportionately represent the full range of conditions, i.e., from the mountain peaks in the Catskills to the lower elevations of the Croton System. Sites were also located on the reservoirs in order to characterize the temperature and wind conditions needed for model input.

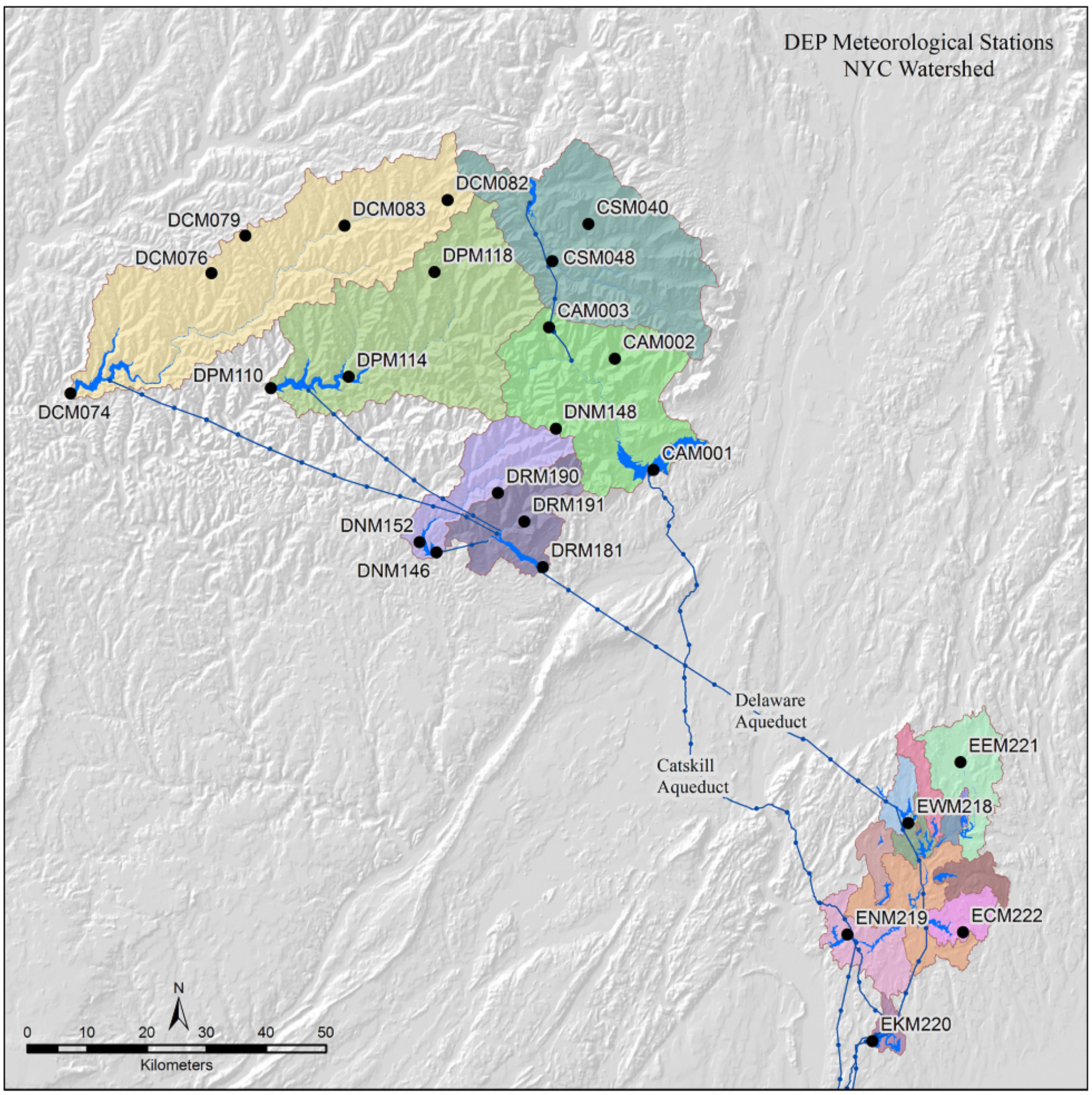


Figure 1.1 DEP meteorological stations in the NYC watershed.

A network for snow surveys is depicted in Figure 1.2. During the winter, snow surveys are periodically conducted to estimate how much water is stored on the watershed as snow and ice. These estimates are important in anticipating spring runoff and the impacts of rain-on-snow events, which may result in unusually large influxes of water to the reservoirs. Snow is an important part of the hydrological cycle and has an impact on stream and reservoir water temperatures throughout the spring.

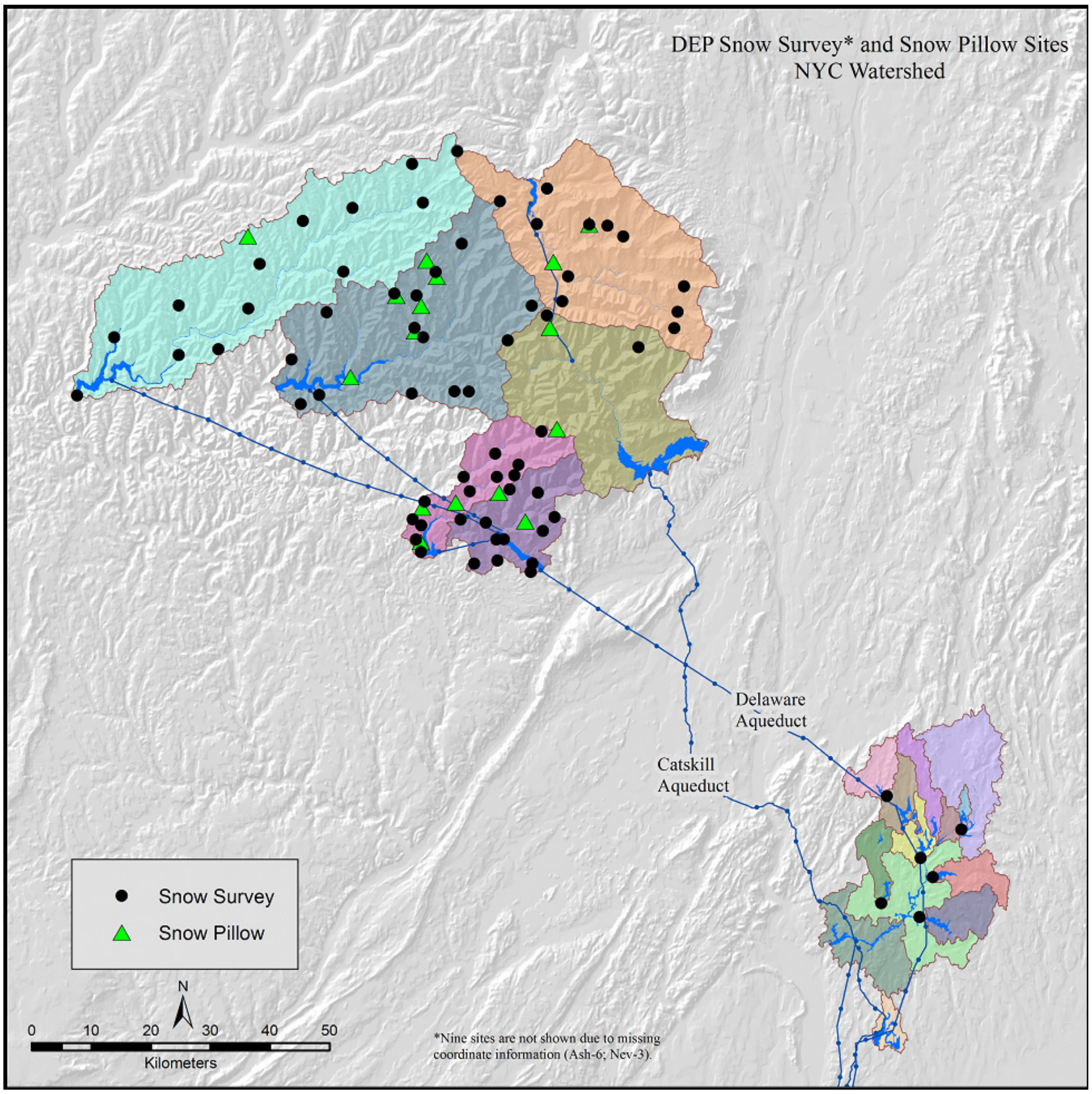


Figure 1.2 DEP snow survey sites in the NYC watershed.

Stream sampling sites are represented in Figures 1.3, 1.4, and 1.5. They were established as water quality monitoring sites in order to monitor and pinpoint various potential sources of pollution. They also allow quantification of pollutants entering the system so that appropriate measures can be taken to minimize impairment of the drinking water. Water quality of the streams and tributaries is essential input for models that guide management of the NYC reservoirs. A companion network to DEP's water quality stream sites is the network of US Geological Survey (USGS) stream gages shown in Figures 1.6 and 1.7. Most of these sites are operated and maintained by the USGS on behalf of DEP and provide important flow data. These data are available on the internet and are used widely by a variety of agencies. They are used by DEP to track the current condition of the system's stream flows, guide operational decisions, including meeting mandated flow targets, and also during droughts and floods. Streamflow data are particularly important to modeling. They can provide key inputs to reservoir models that are used to evaluate the consequences of different operating strategies and they provide data to calibrate and verify watershed models, which can estimate loads of water and nutrients to the reservoirs.

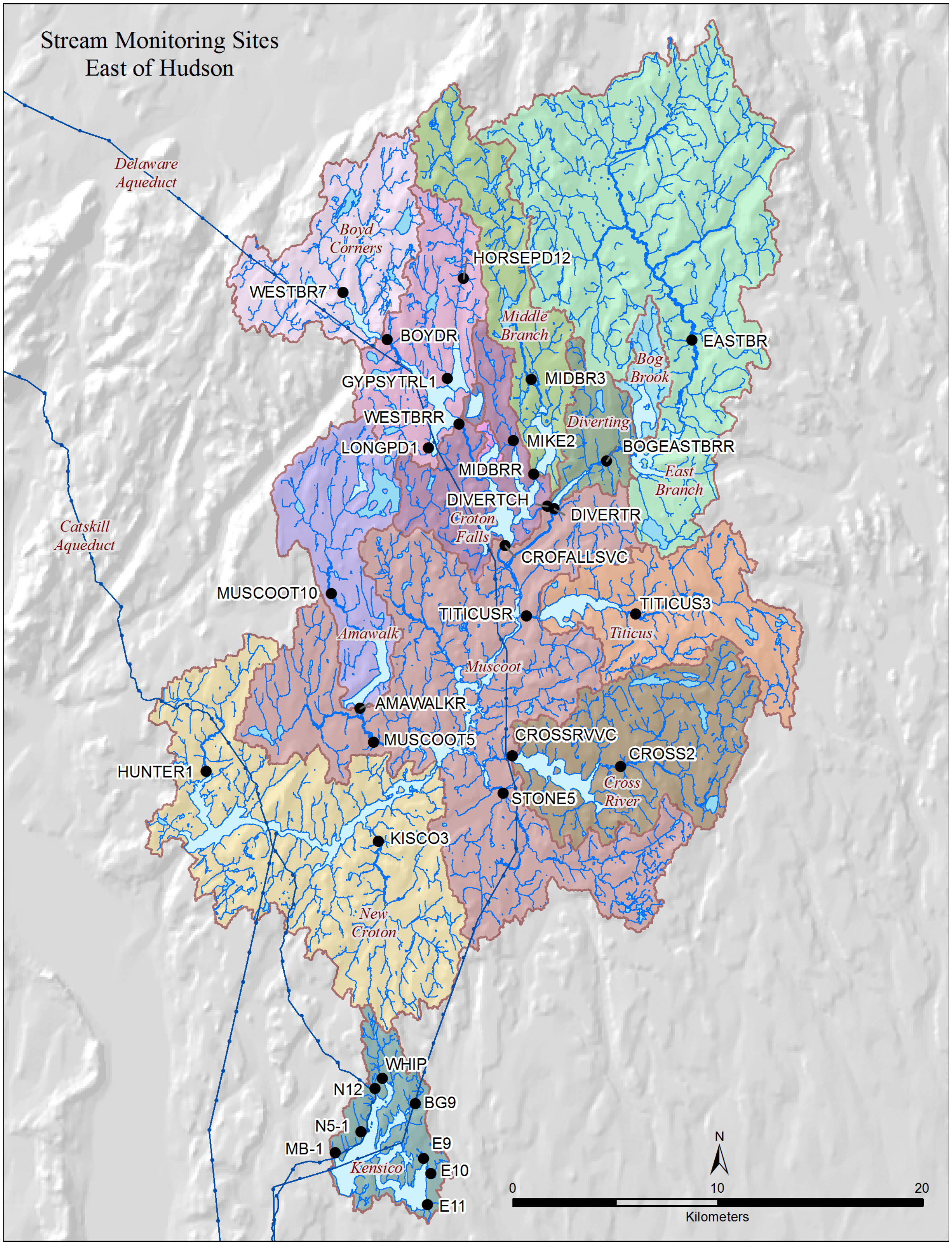


Figure 1.3 Stream sampling sites east of the Hudson River.

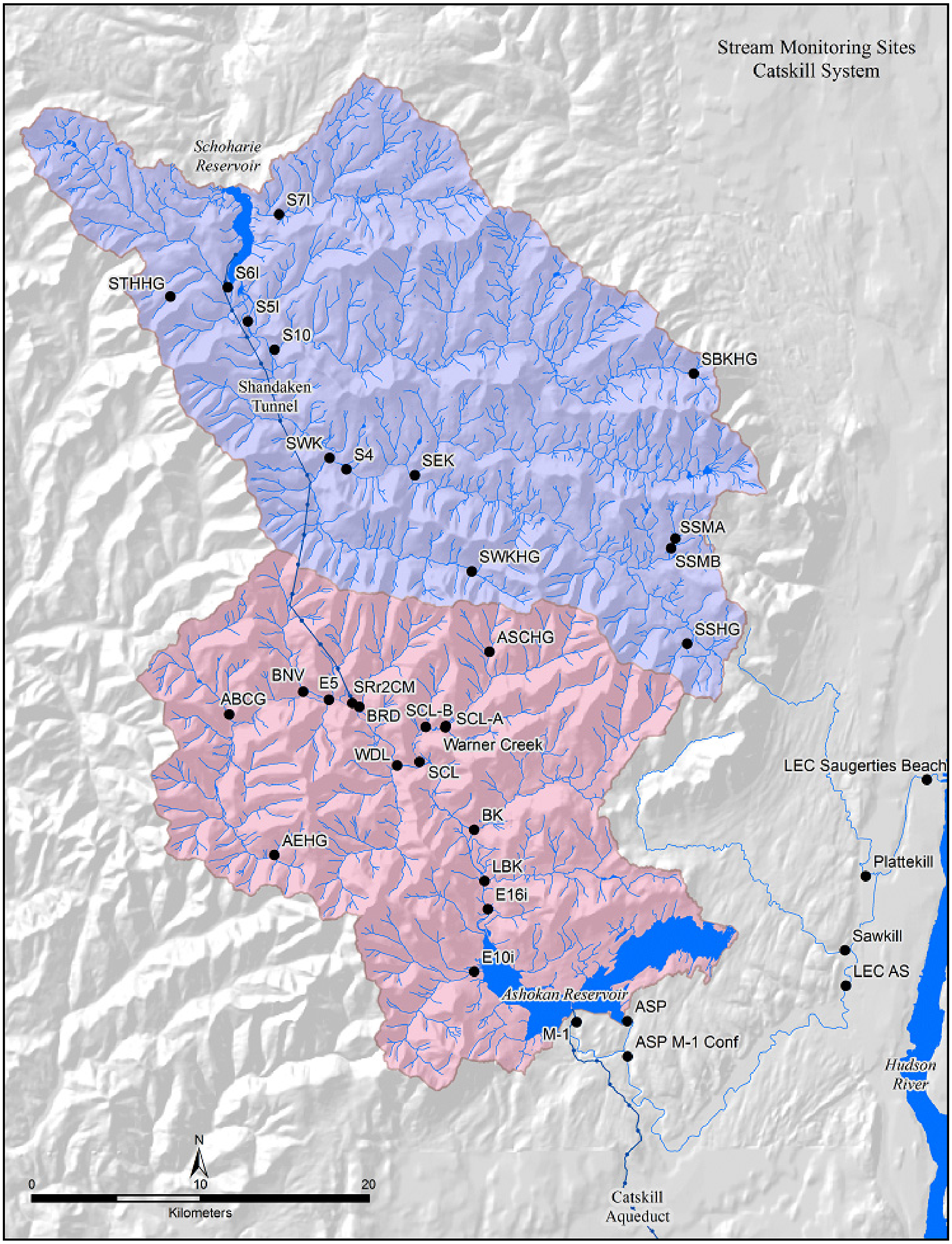


Figure 1.4 Stream sampling sites within the Catskill System drainage basins.

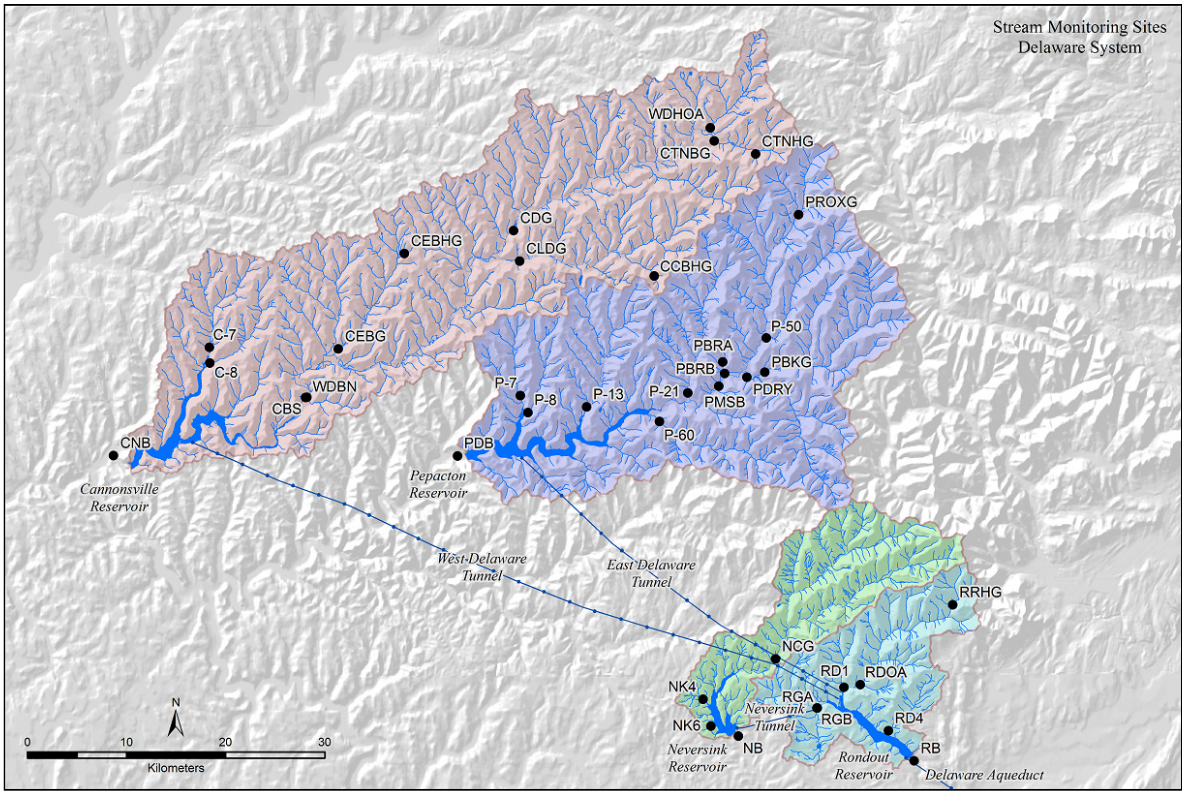


Figure 1.5 Stream sampling sites within the Delaware System drainage basins.

Upper Rondout watershed stream.

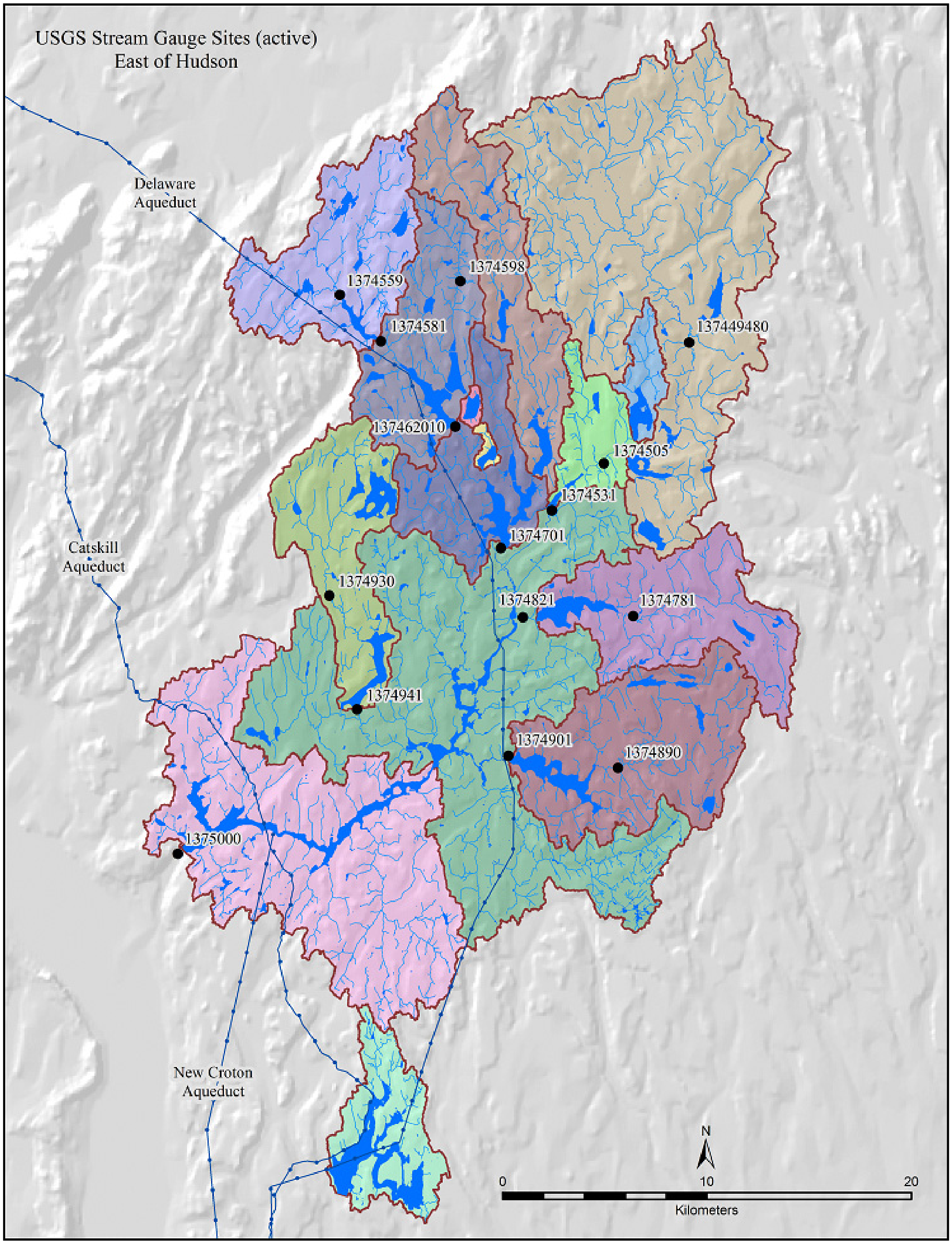


Figure 1.6 USGS stream gage sites east of the Hudson River.

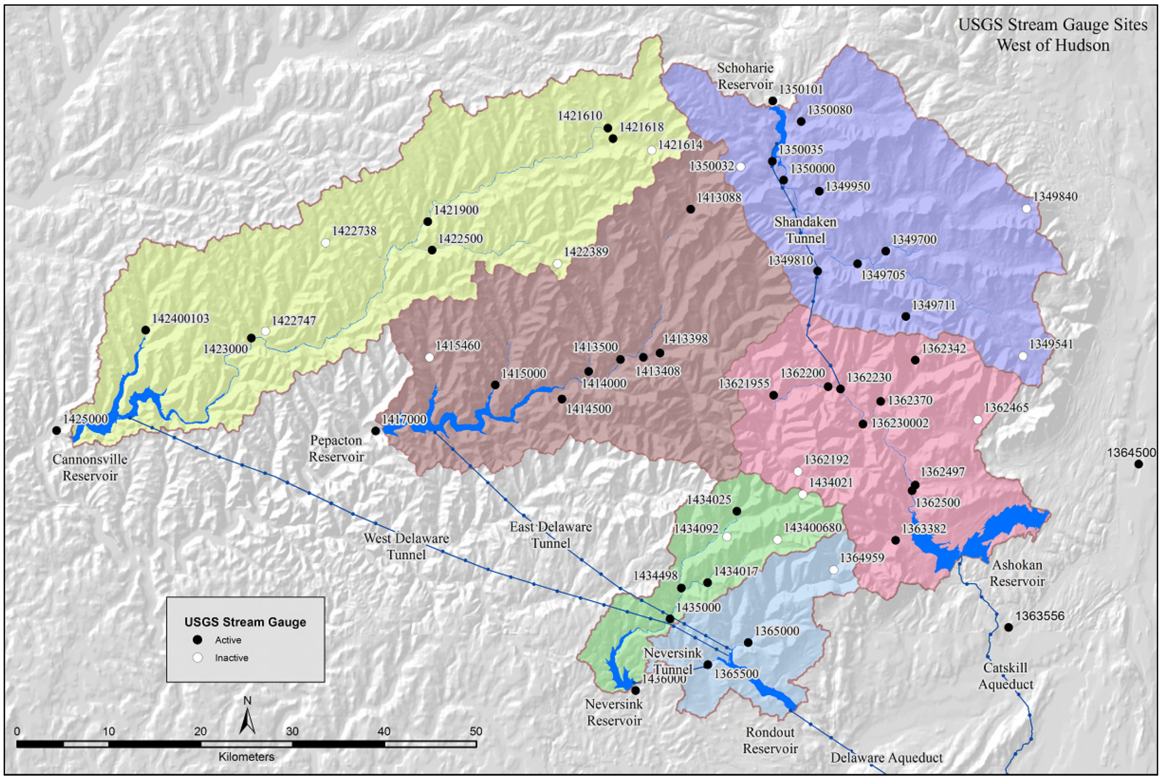


Figure 1.7 USGS stream gage sites west of the Hudson River.

Limnological sites throughout the 19 reservoirs and three controlled lakes of the water supply watershed are shown in Figures 1.8 and 1.9. The sites were selected to provide coverage of water quality and physical conditions throughout each reservoir. The details of site names for each reservoir are provided in Appendix I. The convention in use is that Site 1 of each reservoir is located at the dam. Site numbers generally increase in the upstream direction. Multiple depths are typically sampled at each site and these depths are determined according to the procedure in Appendix II. Limnological surveys provide information on the current status of basic physical, chemical, and biological conditions that determine water quality in the system, allow tracking of trends, provide data for models, and guide current operational decisions. Therefore, these surveys are important in serving many objectives.

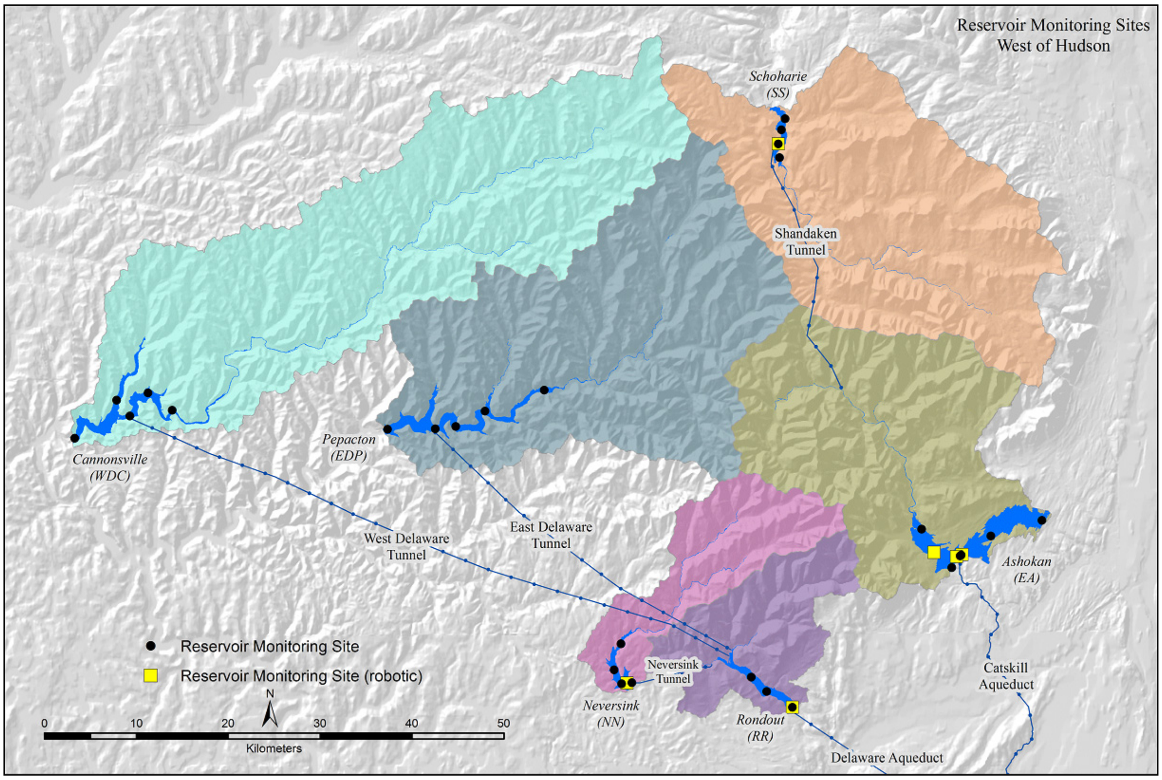


Figure 1.8 Limnological sampling sites for reservoirs west of the Hudson River.

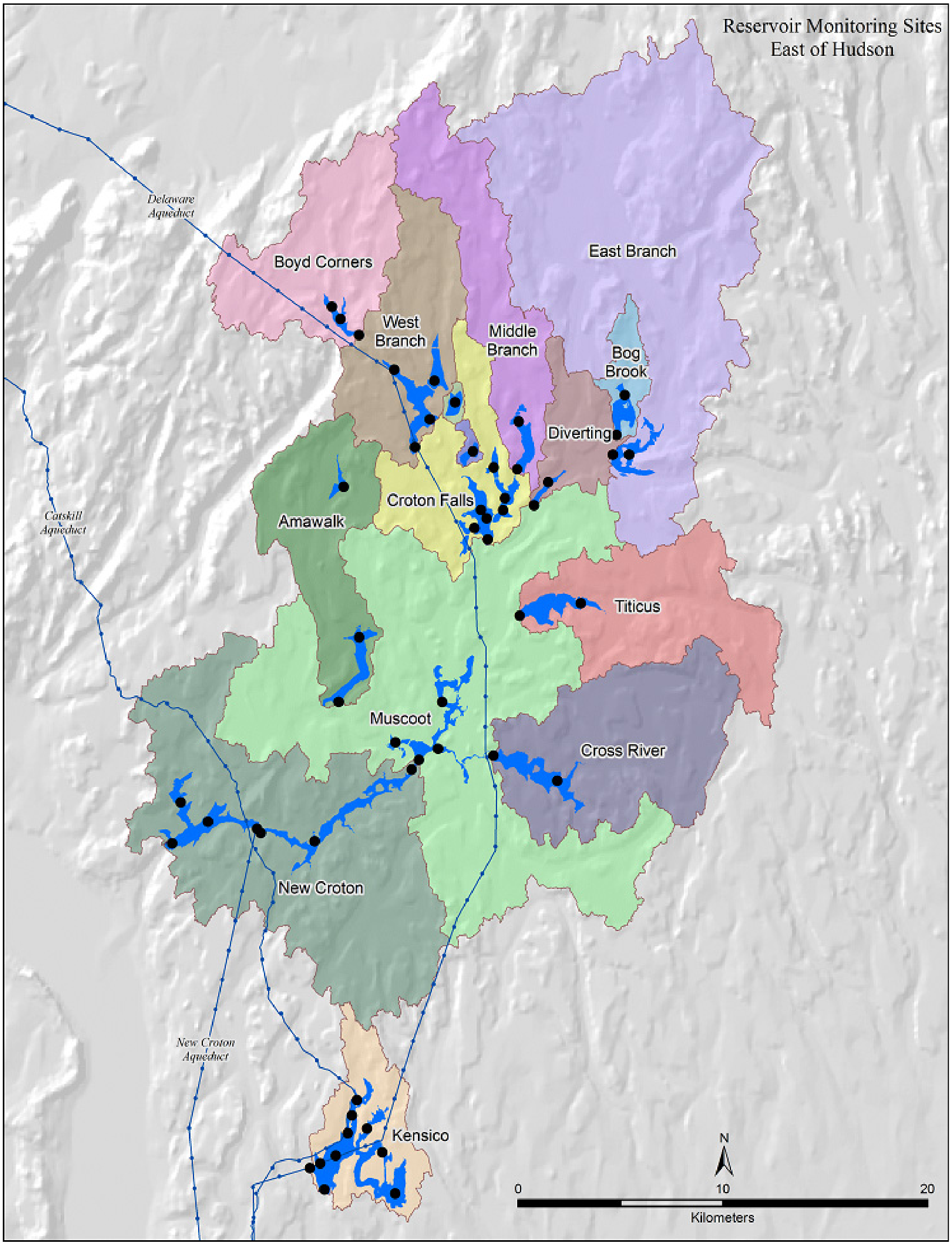


Figure 1.9 Limnological sampling sites for reservoirs east of the Hudson River.

The Robotic Monitoring Program (ROBOMON) was successfully insourced by Watershed Water Quality Operations (WWQO) in 2012 and has continued successfully since then. The project has fulfilled two basic requirements: (1) continuous representative measurements of current watershed conditions, and (2) timely communication of data to decision makers and to management tools (e.g., Operational Support Tool (OST) and watershed models). In 2015, the ROBOMON program generated nearly 1.9 million measurements.

There were two fixed-depth buoys deployed on Kensico Reservoir in 2014, one near the Delaware Aqueduct intake and the other approximately midway between the Delaware Aqueduct intake and the turbidity curtain which mitigates impacts from Malcolm Brook. Each buoy had three transmissometers which were suspended at 5, 10, and 15 meters in the water column to provide near-real-time estimates of turbidity. Data were recorded in 15-minute intervals and were used to determine trends in turbidity and assist with operational decisions at Delaware Shaft 18.

In 2014, four new reservoir water column profiling buoys were added to the existing buoy network. The existing four buoys were located on the West Basin of Ashokan Reservoir (Sites 1.4 and 3.1), the East Basin of Ashokan Reservoir (Site 4.2), and Kensico Reservoir (Site 4.1). Four new buoys were added at Rondout (Site 1), Neversink (Site 1.5), Schoharie (Site 3), and Kensico (Site 4) Reservoirs. These buoys performed full water column profiles every six hours with sensors measuring temperature, turbidity, and specific conductivity. Additionally, the Ashokan West Basin (Site 1.4) buoy and the Kensico (Site 4.1) buoy were outfitted with meteorological stations. See figures 1.10 and 1.11 for a map of sites. In 2015, the program was expanded with a RoboBuoy at Cannonsville (Site 4), enhancements to Neversink and Cannosnville buoys for Chla and fDOM, and a stormwater monitoring component at the Neversink RoboHut. We also replaced one of the fixed buoys at Kensico with a profiling buoy.

Watershed Water Quality Operations (WWQO) deployed two under-ice buoys specifically designed to monitor water quality during ice-over conditions at Ashokan Reservoir, thereby allowing access to water quality conditions that might otherwise remain invisible. These were fixed depth buoys located at two depths at approximate elevations of 555 feet and 515 feet at the gatehouse locations of each basin.

Six automated stream monitoring stations (RoboHuts) were maintained by WWQO staff throughout the year. RoboHuts, in the Catskill System at Esopus Creek near Coldbrook and in the Delaware System at Rondout Creek near Lowes Corners, continuously monitor water temperature, specific conductivity, and turbidity. Five additional stream monitoring stations—one on the Neversink River adjacent to the USGS gauge station, one on the West Branch Delaware River, and three in the Stony Clove/Warner Creek watershed—are monitored for turbidity and temperature only.

Each robotic monitoring location was powered by a battery which was charged by solar panels and contained data logging and communications equipment. At regular intervals, the most recent data were imported to a database at the Kingston Laboratory and made viewable on the DEP intranet through a custom Web application. In some cases near-real-time data were available within three minutes of the field measurement being Operating QUAL5000D describes data management procedures, and the web application includes the ability to display data comments as appropriate. The ROBOMON project yielded over 1,000,000 measurements in 2014 at 16 sites.

Table 1.1: Summary of ROBOMON Project for 2014.

System/Field section	Number of measurements[1]	Number of sites[2]
Catskill/Kingston	492,221	8
Delaware/Grahamsville	217,965	5
EOH/Kensico	320,261	4
Total	**1,030,447**	**16**

1. Includes turbidity, temperature, and specific conductivity.
2. Delaware Site 4WDC was not online in 2014.

Aqueduct “keypoint” monitoring is conducted as a means of keeping a “finger on the pulse” of the water supply with respect to the major water flowing through the system and into distribution. Monitoring at these sites is conducted through the use of continuous monitoring equipment, and daily or weekly grab sampling. These sites have some of the highest frequencies of sampling, the purpose of which is to maintain a high degree of reliability in the quality of water entering the distribution system. In addition to sites used for operational decisions, keypoint monitoring includes compliance sites for the Surface Water Treatment Rule (SWTR) and are of utmost importance for operation of the system to maintain the status of filtration avoidance.

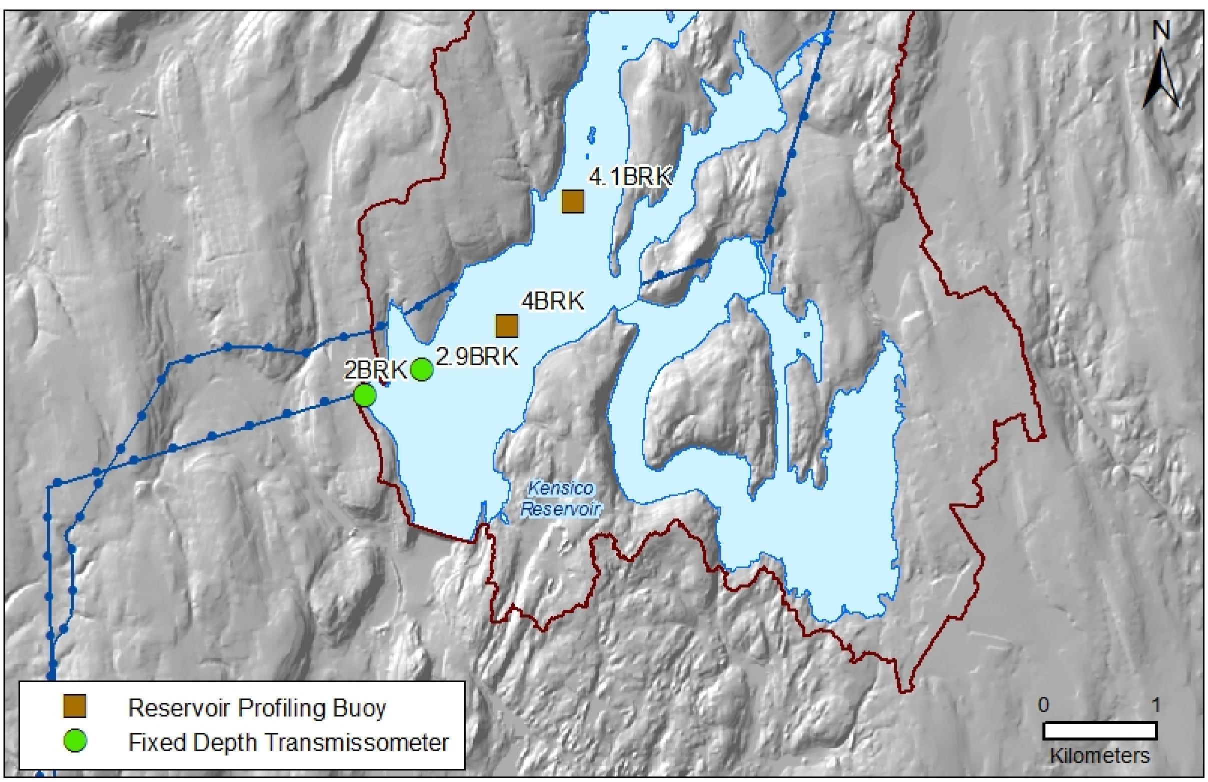


Figure 1.10 Kensico reservoir profiling buoys and fixed depth transmissometers.

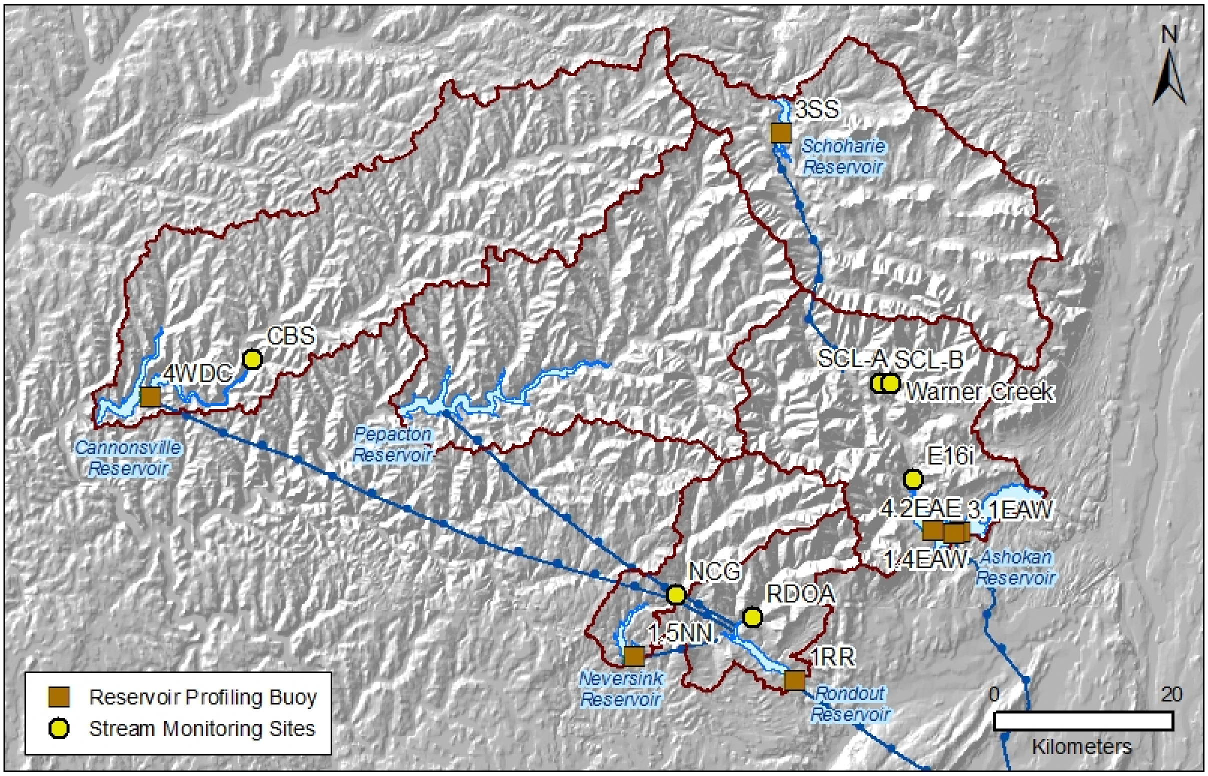


Figure 1.11 West of Hudson reservoir profiling buoys and stream monitoring sites.

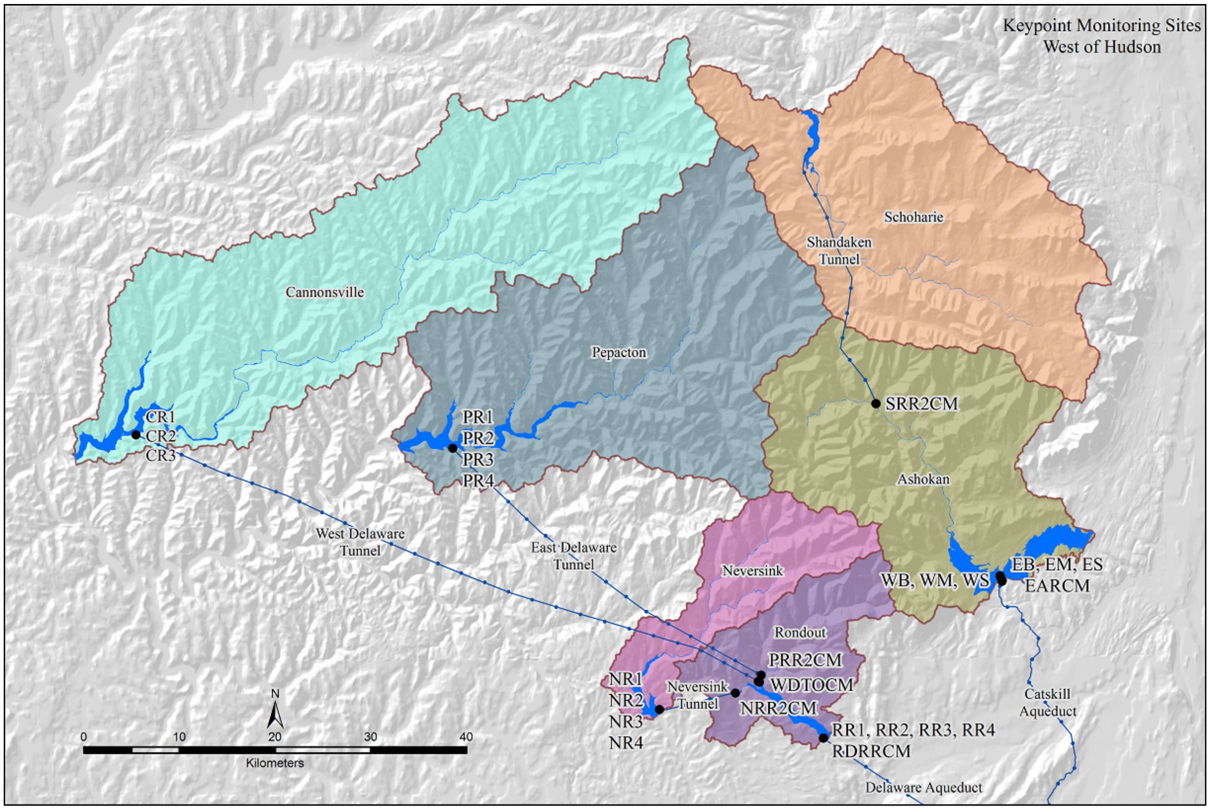


Figure 1.12 Aqueduct keypoint sampling sites west of the Hudson River.

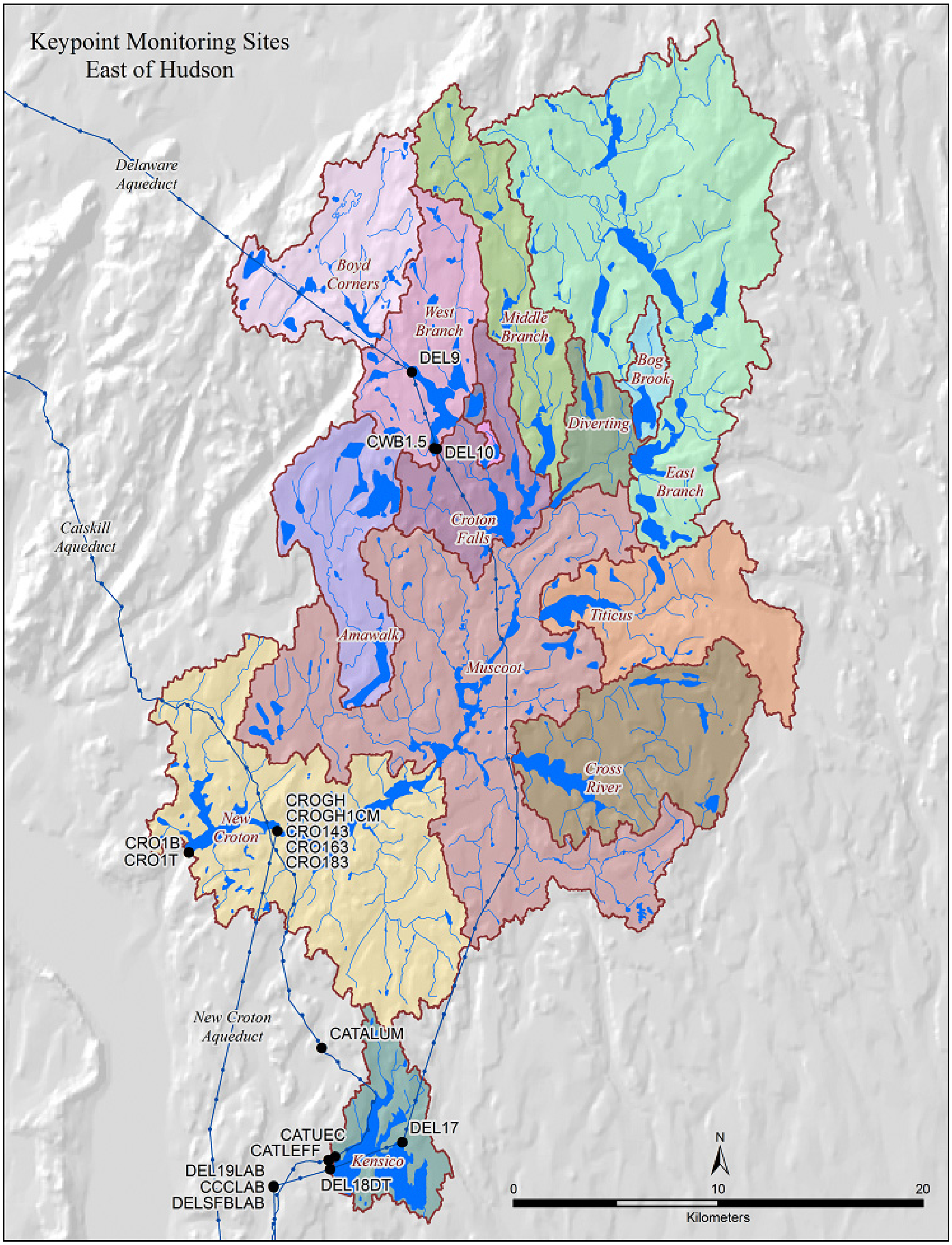
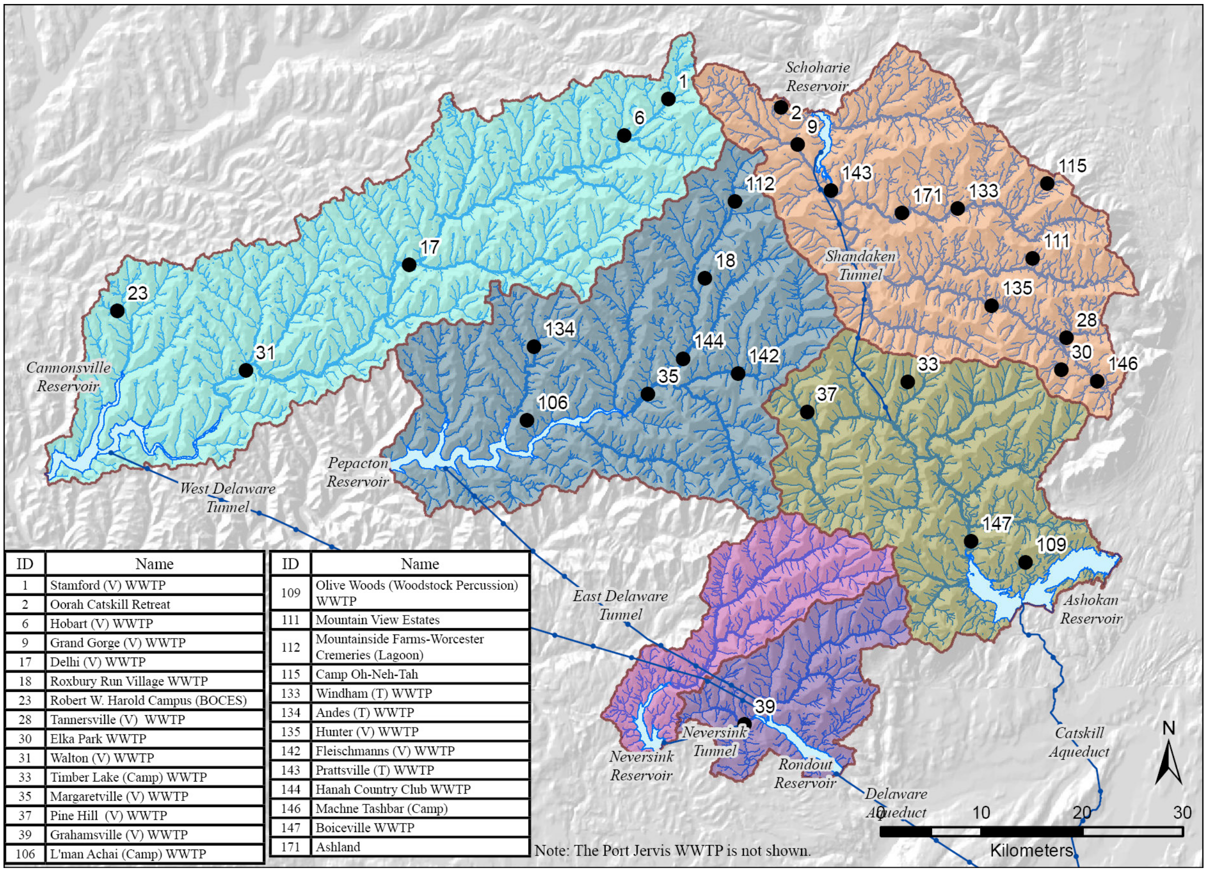


Figure 1.13 Aqueduct keypoint sampling sites east of the Hudson River.

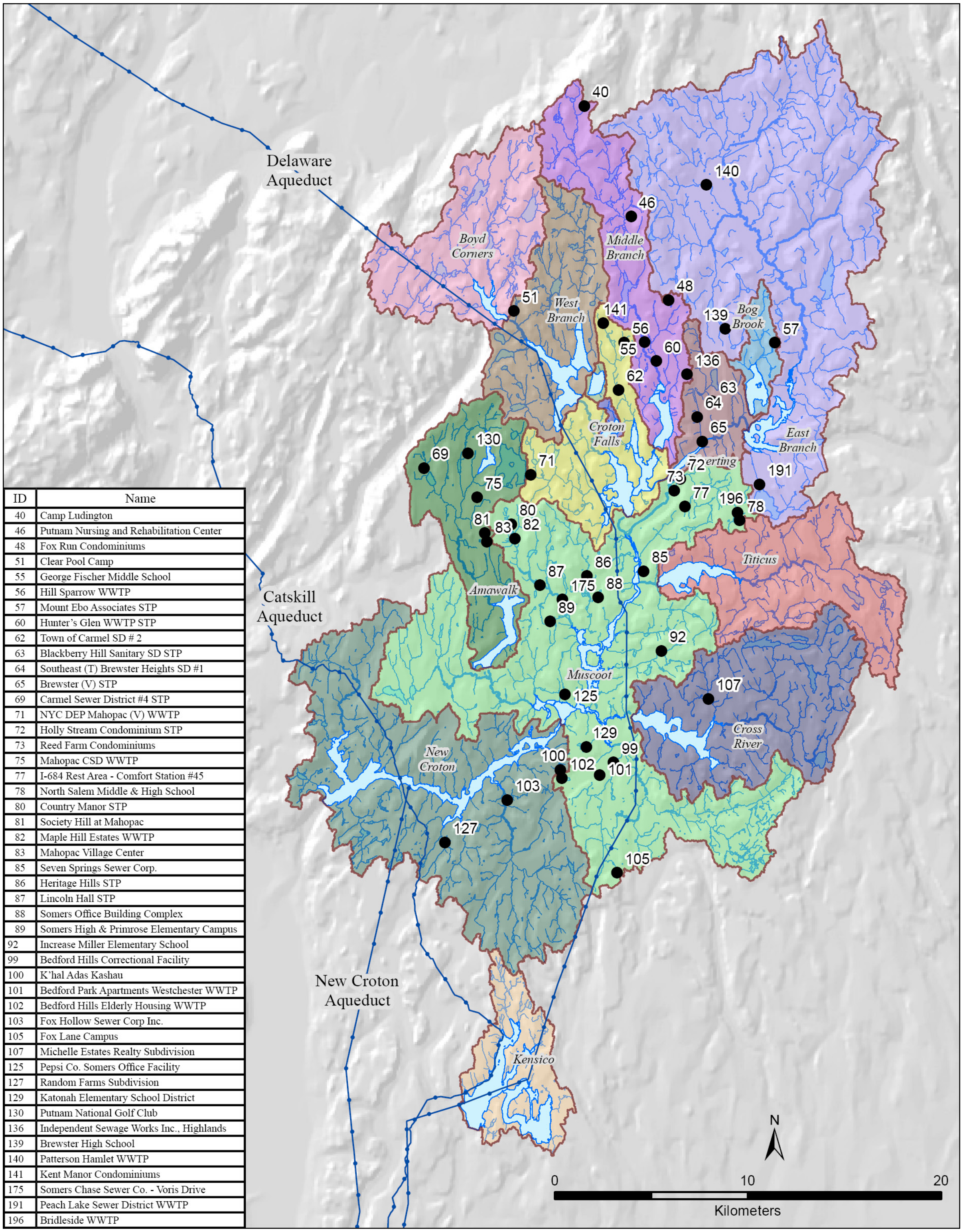
Finally, wastewater treatment plants (WWTPs) located throughout the watershed are shown in Figures 1.14 and 1.15. The locations of these treatment plants are potential sites of impairment, however, this risk has been greatly reduced in recent years because all treatment plants in the watershed have been upgraded to microfiltration (or equivalent) with tertiary treatment (nutrient removal). Plant upgrades have nearly eliminated the impacts that these plants formerly had in terms of nutrient and microbiological inputs. DEP previously monitored water quality above and below some of the larger plants, but the need for this has diminished. Stream water quality data has demonstrated that these plants are no longer showing heavy impacts. In this plan, WWTP monitoring relies on the surveillance monitoring to meet SPDES permits and there has been a reduction in the monitoring above and below WWTPs. Although DEP only owns six of the treatment plants and conducts monitoring according to their SPDES permits, additional monitoring of all plants is conducted.



ID	Name
1	Stamford (V) WWTP
2	Oorah Catskill Retreat
6	Hobart (V) WWTP
9	Grand Gorge (V) WWTP
17	Delhi (V) WWTP
18	Roxbury Run Village WWTP
23	Robert W. Harold Campus (BOCES)
28	Tannersville (V) WWTP
30	Elka Park WWTP
31	Walton (V) WWTP
33	Timber Lake (Camp) WWTP
35	Margaretville (V) WWTP
37	Pine Hill (V) WWTP
39	Grahamsville (V) WWTP
106	L'man Achai (Camp) WWTP

ID	Name
109	Olive Woods (Woodstock Percussion) WWTP
111	Mountain View Estates
112	Mountainside Farms-Worcester Cremeries (Lagoon)
115	Camp Oh-Neh-Tah
133	Windham (T) WWTP
134	Andes (T) WWTP
135	Hunter (V) WWTP
142	Fleischmanns (V) WWTP
143	Prattsville (T) WWTP
144	Hanah Country Club WWTP
146	Machne Tashbar (Camp)
147	Boiceville WWTP
171	Ashland

Figure 1.14 Wastewater Treatment Plants west of the Hudson River.



ID	Name
40	Camp Ludington
46	Putnam Nursing and Rehabilitation Center
48	Fox Run Condominiums
51	Clear Pool Camp
55	George Fischer Middle School
56	Hill Sparrow WWTP
57	Mount Ebo Associates STP
60	Hunter's Glen WWTP STP
62	Town of Carmel SD # 2
63	Blackberry Hill Sanitary SD STP
64	Southeast (T) Brewster Heights SD #1
65	Brewster (V) STP
69	Carmel Sewer District #4 STP
71	NYC DEP Mahopac (V) WWTP
72	Holly Stream Condominium STP
73	Reed Farm Condominiums
75	Mahopac CSD WWTP
77	I-684 Rest Area - Comfort Station #45
78	North Salem Middle & High School
80	Country Manor STP
81	Society Hill at Mahopac
82	Maple Hill Estates WWTP
83	Mahopac Village Center
85	Seven Springs Sewer Corp.
86	Heritage Hills STP
87	Lincoln Hall STP
88	Somers Office Building Complex
89	Somers High & Primrose Elementary Campus
92	Increase Miller Elementary School
99	Bedford Hills Correctional Facility
100	K'hal Adas Kashau
101	Bedford Park Apartments Westchester WWTP
102	Bedford Hills Elderly Housing WWTP
103	Fox Hollow Sewer Corp Inc.
105	Fox Lane Campus
107	Michelle Estates Realty Subdivision
125	Pepsi Co. Somers Office Facility
127	Random Farms Subdivision
129	Katonah Elementary School District
130	Putnam National Golf Club
136	Independent Sewage Works Inc., Highlands
139	Brewster High School
140	Patterson Hamlet WWTP
141	Kent Manor Condominiums
175	Somers Chase Sewer Co. - Voris Drive
191	Peach Lake Sewer District WWTP
196	Bridleside WWTP

Figure 1.15 Wastewater Treatment Plants east of the Hudson River.

1.4 Trend Detection

One theme for data collection to detect trends that must be acknowledged is the importance of retaining the same analytical method. When trends are sought, methodology should remain constant and sampling frequency must be chosen according to data variability and the statistical confidence and power required. Short-term intensive sampling can be redundant and possibly insufficient to define long-term trends because the effects of seasonality, extreme events, and non-uniform variance must be accounted for (Lettenmaier 1976, 1978; Loftis and Ward 1980). The practical consequence is that it is difficult to detect a trend on the order of a water quality variable's standard deviation for *n* smaller than 50-100 (Lettenmaier et al. 1982). Thus for a trend to be detected with reasonable confidence and power, *the network must stay fixed for at least five years to provide a sufficient sample size (n>60)*; this is the approximate time period that will be required to achieve several of the trend detection objectives described in this document. As new methods are introduced, side-by-side analyses must be conducted to allow mathematical translation of the results from samples analyzed by one method into terms comparable to another method.

Inherent in the design of any long-term program is data continuity. It is essential that any observed changes in data reflect changes in the environment and not be a consequence of methodological changes (e.g., Shapiro and Swain 1983, Smith et al. 1996, Smith 2000). This is important not only for trend analysis where step-trends (sudden increases or decreases in mean values (whether visually apparent or not)) can cause data trends, but also for other data where year-by-year comparisons are made, e.g., in P-restricted basin studies and modeling. Analytical methods must remain constant wherever possible because it has been shown that even very small changes in methods (even filters) can cause differences in results (Newell and Morrison 1993). Because analytical changes are sometimes unavoidable, DEP will endeavor to account for such method changes by running paired method comparisons wherever possible to allow appropriate data comparison (e.g., Newell et al. 1993).

Another aspect of laboratory data which can create problems for trend detection in particular is that of non-reporting data that falls below the "analytical detection limit". This is called "data censoring" and its effects, including trend masking and trend induction, have been reported in the literature (e.g., Gilliom et al. 1984, Bell 1990, Porter et al. 1988, Ellis and Gilbert 1980). DEP intends to take account of less-than-detection-limit data in its trend analysis.

References

Bell, H.F., 1990. IBM groundwater quality monitoring program at East Fishkill New York. In: Ward et al.(1990) op cit.

Ellis, J.C., and Gilbert C.F., 1980. How to handle "less-than" data when forming summaries. Water Research Centre Enquiry Report ER 764. Water Research Centre, Medmenham, England.

Executive Summary. Valhalla, NY. 14 pp.

DEP. 1997. 1997 Water Quality Surveillance Monitoring. New York City Department of Environmental Protection. Valhalla, NY. 146 pp.

DEP. 2003. Integrated Monitoring Report. New York City Department of Environmental Protection. Valhalla, NY. 154 pp.

DEP. 2008. Report 1. *Assessment and Action Plan - A Report Based on the Ongoing Work of the DEP Climate Change Task Force.* The NYCDEP Climate Change Program. DEP with contributions by Columbia University Center for Climate Systems Research and HydroQual Environmental Engineers and Scientists, P.C., New York, NY. 100 pp http://www.nyc.gov/dep

DEP. 2009. 2009 Watershed Water Quality Monitoring Plan. Valhalla, NY. 240 p.

Gilliom, R.J., Hirsch R.M., and Gilroy E.J., 1984. Effect of censoring trace-level water-quality data on trend-detection capability. Environmental Science & Technology 18: 530-535.

ILSI 1998. Comprehensive Watershed Monitoring: A Framework for the New York City Reservoirs. The ILSI Risk Science Institute, Washington, DC.

Lettenmaier, D.P. 1976. Detection of trends in water quality data from records with dependent observations. Water Resources Research 12: 1037-1046.

Lettenmaier, D.P. 1978. Design considerations for ambient stream water quality monitoring. Water Resources Bulletin 14: 884-892.

Lettenmaier, D.P., Conquest, L.L., and Hughes, J.P. 1982. Routine streams and rivers quality trend monitoring review. University of Washington, Department of Civil Engineering. Charles W. Harris Hydraulics Laboratory Report 75, Seattle, Washington, 233 pp.

Loftis, J.C. and Ward, R.C. 1980. Water quality monitoring—some practical sampling observations. Environmental Management 4: 521-526.

Newell, A.D., Blick D.J., and Hjort R.C., 1993. Testing for trends when there are changes in methods. Water, Air, and Soil Pollution 67: 457–468.

Newell, A.D., and Morrison M.L., 1993. Use of overlap studies to evaluate method changes in water chemistry protocols. Water, Air, and Soil Pollution 67: 433–456.

NRC 2000. Watershed Management for Potable Water Supply: Assessing the New York City Stategy. National Research Council. National Academy Press, Washington, DC. 549 pp.

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nycfad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

Payne, F.E., and Ford J., 1988. The Concept of Time – Temporally Integrated Monitoring of Eco-Systems - Supplement. Internal Report, U.S.E.P.A., Environmental Research Laboratory, Corvallis, Oregon.

Porter, P.S., Ward R.C., and Bell H.F., 1988. The detection limit. Environmental Science & Technology 22: 856-861.

Sanders, T. G., R. C. Ward, J. C. Loftis, T. D. Steele, D. D. Adrian, V. Yevjevich, 1983. Design of Networks for Monitoring Water Quality, Water Resources Publications, Littleton, Colorado, 328 pp.

Shapiro, J., and Swain E.B., 1983. Lessons from the silica “decline” in Lake Michigan. Science 221: 457–459.

Smith, D.G. and McBride, G.B., 1990. New Zealand’s national water quality monitoring network—design and first year’s operation. Water Resources Bulletin 26: 767–775.

Smith, D.G., McBride G.B., Bryers G.G., Wisse J., and Mink D.F.J., 1996. Trends in New Zealand's National River Water Quality Network. New Zealand Journal of Marine and Freshwater Research 30: 485–500.

Smith, D.G., 2000. Water quality trend detection in the presence of changes in analytical laboratory protocols. Proceedings of the National Water Quality Monitoring Council Conference 2000, Austin, TX, pp195-207.

Ward, R.C., 1996. Water Quality Monitoring: Where's The Beef? Water Resources Bulletin. 32: 673–680.

Ward, R.C., Loftis, J.C., and McBride, G.B., 1986. The "Data rich but Information Poor" Syndrome in Water Quality Monitoring. Environmental Management 10: 291–297. Van Nostrand Reinhold, New York, pp 231.

Ward, R.C., Loftis, J.C., and McBride, G.B., 1990. Design of Water Quality Monitoring Systems.

1.5 Site Changes

Table 1.2: Site Changes

Old site	New site	Date of change
1BRK	1.1BRK[1]	April 2005
1CCF	1.1CCF[2]	August 2006
1CBC	1.1CBC[2]	Sept. 2006
1CA	1.1CA[2]	April 2007
1CCR	1.1CCR[2]	April 2007
1CD	1.1CD[2]	April 2007
1CMB	1.1CMB[2]	April 2007
1CT	1.1CT[2]	April 2007
CATEV[3]		June 2012
CATLEFF[3]		June 2012
DEL18	DEL18DT[4]	August 2012
	DIVERTCH	Prior to 2013
DEL19	DEL19LAB	Jan. 2013
	CROFALLSVC[5]	Sept. 2013
	CROSSRVVC[5]	Sept. 2013
WDTO	WDTOCM[6]	Jan. 2014
	2.9BRK[7]	May 2014
3BRK[3]		May 2014
1CGD	1CGIL[8]	June 2014
1CGL	1CGLEN [8]	June 2014

[1]1.1BRK is located outside a protective boom placed along the Kensico dam in 2005. Water quality is assumed to be similar to 1BRK.

[2]Site 1 moved to site 1.1 for safety reasons. Site 1 was deemed too close to Shaft buildings/spillways. In all cases site 1.1 is within 100 feet of site 1 and it is assumed that water quality is similar.

[3]Sites discontinued due to shutdown of Catskill Aqueduct.

[4] New site that provides more representative sample during all operational conditions. Site is located in the DEL18 downtake.

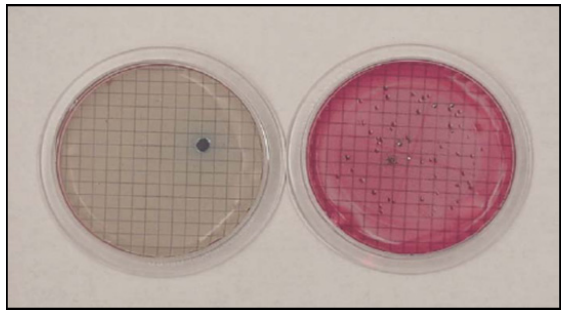
[5]New sample tap within Shaft building

[6]Side by side sample analysis indicated that WDTO and WDTOCM were not equivalent and suggested that WDTOCM was more representative of water entering Rondout from Cannonsville.

[7] New site designed to capture the mixture of upstream reservoir water and Malcolm Brook water.

[8] Site names changed because original names 1CGL and 1CGD were so similar that mislabeling of sample bottles occasionally occurred. Note that site names were changed to the new site names for the entire record.

2. Regulatory Compliance Monitoring



Fecal and total coliform bacteria cultures.

This chapter is a consolidation of regulatory compliance monitoring requirements for the New York City Watershed and source water monitoring points. The chapter covers requirements in the Surface Water Treatment Rule (SWTR), and its subsequent extensions, as well as the Watershed Rules and Regulations (WR&R), the Croton Consent Decree (CCD), Administrative Orders, and State Pollutant Discharge Elimination System (SPDES) permits. The sampling sites, analytes, and frequencies are defined in each objective according to a specific rule or regulation and are driven by the need of the water supply as a public utility to comply with all regulations. The monitoring in this chapter is not optional since it is necessary to maintain compliance with all USEPA, NYSDOH, NYSDEC, and DEP mandates.

2.1 Surface Water Treatment Rule (SWTR)

Objective

This objective addresses the requirement to monitor the appropriate sample locations and specified analytes to fulfill the SWTR.

Background

If a public water system uses surface water (e.g., lakes, ponds, rivers, streams) as its source, then it is regulated by the SWTR. The SWTR was published in the Federal Register June 19, 1989 as 40 CFR Parts 141 and 142. Filtration of water supplies was mandated; however, avoidance of filtration was an option if water supplies met certain water quality criteria. The NYC Catskill and Delaware water supplies met all the criteria and became an approved unfiltered water supply, while the New Croton system requires filtration.

Sites

The locations to be monitored include the raw source water effluents of the terminal reservoir and the primary chlorinated sites of the terminal reservoir. These sites include the raw and chlorinated effluent of Kensico Reservoir (DEL18DT and DEL19LAB, respectively) (Table 2.1). Site DELSFBLAB will be used as a backup location for DEL19LAB.

Analytes and Frequencies

Table 2.1: Sites, analytes, and frequencies for SWTR monitoring.

Site Code	Analyte	Sampling Frequency
DEL18DT	Total coliform (or)	5d/week
	Fecal coliform	5d/week[1]
	Turbidity	Every 4 hours/continuous[2]
DEL19LAB	Temperature	1/d minimum/continuous[3]
	pH	1/d minimum/continuous[3]
	Free chlorine residual	1/d at peak flow[3]
	Flow	Continuous
DELSFBLAB	Temperature	Continuous[4]
	pH	Continuous[4]
	Free chlorine residual	Continuous[4]

[1]Monitored seven days per week even though only five days are required as long as turbidity remains <=1 NTU. A coliform sample must be collected every day that turbidity exceeds 1 NTU.

[2]4-hour grab samples are primary data source. Continuous monitoring may be used as a backup.

[3]One measurement is required each day, but DEP uses continuous monitoring instrumentation as the primary data source and grab sample data for backup.

[4]Secondary data source when DEL19LAB data are not available.

Data Analysis and Reporting

Data are reported as per the SWTR regulations, including monthly filtration avoidance reports to USEPA and NYSDOH, annual Filtration Avoidance Determination (FAD) reports, and annual water quality reports.

References

40 CFR Part 141 and 142.

2.1.1 Interim Enhanced Surface Water Treatment Rule (IESWTR)

Objective

This objective addresses the requirement to monitor sites as specified in the IESWTR.

Background

The IESWTR was published in the Federal Register December 16, 1998 as Part V USEPA, 40 CFR Parts 9, 141, 142 National Primary Drinking Water Regulations. The primary purpose of the IESWTR was to: 1) improve control of microbial pathogens in drinking water, particularly for the protozoan *Cryptosporidium*, and 2) guard against significant increases in microbial risk that might otherwise occur when systems implement the Stage 1 Disinfectants and Disinfection By-Products (D/DBP) Rule.

The IESWTR amends the existing SWTR to strengthen microbial protection, including provisions specifically to address *Cryptosporidium,* and to address risk trade-offs with disinfection by-products. The final rule includes treatment requirements for waterborne pathogens, e.g., *Cryptosporidium*. In addition, systems must continue to meet existing requirements for *Giardia lamblia* and viruses. Specifically, the rule includes:

- A maximum contaminant level goal (MCLG) of zero for *Cryptosporidium*
- Strengthened combined filter effluent turbidity performance standards
- Individual filter turbidity monitoring provisions
- Disinfection profiling and benchmarking provisions
- Systems using groundwater under the direct influence of surface water now subject to the new rules dealing with *Cryptosporidium*
- Inclusion of *Cryptosporidium* in the watershed control requirements for unfiltered public water systems
- Requirements for covers on new finished water reservoirs
- Sanitary surveys, conducted by States, for all surface water systems regardless of size

The rule, with tightened turbidity performance criteria and individual filter monitoring requirements, is designed to optimize treatment reliability and to enhance physical removal efficiencies to minimize the *Cryptosporidium* levels in finished water. Turbidity requirements for combined filter effluent will remain at least every four hours, but continuous monitoring will be required for individual filters. In addition, the rule includes disinfection profiling and benchmarking provisions to assure continued levels of microbial protection while facilities take the necessary steps to comply with new DBP standards. Unfiltered supplies, like NYC's, are required to address this ruling within their Filtration Avoidance watershed control programs and include *Cryptosporidium* control requirements.

Sites, Analytes, and Frequencies

See FAD sampling program, Chapter 3, Sections 3.5.1, 3.5.2, 3.5.3.

2.1.2 Long-Term Enhanced SWTR (LT1)

Objective

This objective addresses the requirement to monitor sample locations to conform with the Long Term Enhanced SWTR (LT1). No sites are required for NYC under this rule, as the LT1 is merely an extension of the IESWTR to smaller systems serving less than 10,000 people. This subsection serves as a placeholder to document the existence of the LT1 and that NYC has no monitoring requirement.

Background

The LT1 was published in the Federal Register January 14, 2002, Vol. 67, No. 9. The purpose of the LT1 was to improve public health protection through the control of microbial contaminants, particularly *Cryptosporidium*, and prevent significant increases in microbial risk that might otherwise occur when systems implement the Stage 1 D/DBP Rule.

The LT1 rule builds upon the requirements of the SWTR and is the smaller system counterpart of the IESWTR. The utilities covered by this rule are public water systems that use surface water or Ground Water Under the Direct Influence [of surface water] (GWUDI) and serve fewer than 10,000 people.

Control of *Cryptosporidium*:

The maximum contaminant level goal (MCLG) is set at zero. Filtered systems must physically remove 99% (2-log) of *Cryptosporidium* oocysts. Unfiltered systems must update their watershed control programs to minimize the potential for contamination by *Cryptosporidium* oocysts. *Cryptosporidium* is included as an indicator of GWUDI.

2.1.3 Long-Term Enhanced SWTR (LT2)

Objective

This objective addresses the requirement to provide a second round of sample collection and analysis as specified in the LT2. DEP will monitor the appropriate sample locations and specified analytes to fulfill the requirements of the mandated LT2 (71 CFR 654, Vol. 71, No.3). This section is written with the assumption that the Catskill/ Delaware System will be operating as an unfiltered water supply, and the New Croton System is on-line and being operated as a filtered water supply.

Background

The LT2 rule was published in the Federal Register on January 5, 2006, Vol. 71, No. 3. The purpose of the LT2 rule is to reduce illness linked with the contaminant *Cryptosporidium* and other disease-causing microorganisms in drinking water. The rule supplements existing regulations by:

- Targeting additional *Cryptosporidium* treatment requirements to higher risk systems
- Requiring provisions to reduce risks from uncovered finished water storage facilities
- Providing provisions to ensure that systems maintain microbial protection as they take steps to reduce the formation of disinfection by-products.

This combination of steps, combined with the pre-existing regulations, is designed to provide protection from microbial pathogens while simultaneously minimizing health risks to the population from disinfection by-products. The second round of monitoring required under the LT2 began in April 2015 (Table 2.2).

Filtered and unfiltered systems must conduct a minimum of 24 months of source water monitoring for *Cryptosporidium*. Filtered systems must also record source water *E. coli* and turbidity levels. Unfiltered systems will calculate a mean *Cryptosporidium* level to determine treatment requirements. Filtered systems will calculate a mean *Cryptosporidium* level for bin placement, which results in the determination of treatment requirements. Systems may not use previously collected (grandfathered) data as was offered in the first round of monitoring.

Sites

Source water sites of both the Catskill/ Delaware and New Croton Systems are required to be monitored.

Table 2.2: Sites to be monitored for the second round of the LT2.

Site Code	Site Description	Reason for selection
DEL18DT	Outflow of Kensico Reservoir – intake to the Delaware Aqueduct, then UV	Source water site required for the LT2
1CR21	Jerome Reservoir outflow at Gatehouse 5 – prior to filter plant	Source water site required for the LT2

Note: CATLEFF is currently off-line and does not need to be monitored. It is not anticipated to come on-line during the LT2 monitoring period; however, if it comes back on –line (April 2015 – March 2017) it will need to be monitored under the LT2.

Analytes and Frequencies

Filtered and unfiltered systems must conduct a minimum of 24 months of source water monitoring for *Cryptosporidium* (once monthly for 2 years). Filtered systems must also record source water *E. coli* and turbidity levels. However, if a system samples more frequently than required, all data must be included in the LT2 data collection (Table 2.3). Sample collection forms must include pH and temperature as well. If enhanced monitoring (more frequent than weekly) is performed, data from that monitoring must be reported for the LT2 as well.

Table 2.3: Sites with analytes and frequencies of collection for the LT2.

Site Code	Analytes	Frequency
DEL18DT	*Cryptosporidium, Giardia*, turbidity, pH, temperature	Weekly
1CR21	*Cryptosporidium, Giardia*, *E. coli*, Turbidity, pH, temperature	Weekly

Data Analysis and Reporting

The Rule requires that the data be reported no later than 10 days after the end of the first month following the month that the sample was collected. The reporting will be done via monthly email from the Pathogen Laboratory Director to the NYS DOH.

References

LT2 (71 CFR 654, Vol. 71, No.3).

2.2 Potable Water Monitoring

2.2.1 USEPA and NYS Required Potable Water Monitoring

Objective

This objective addresses the requirement to sample for coliform bacteria and other analytes at upstate DEP facilities at which potable water is provided by DEP, as required by the Total Coliform Rule (TCR) and the Safe Drinking Water Information System (SDWIS).

Background

The Total Coliform Rule and the SDWIS apply to all public water systems (PWS), including "non-transient-non-community systems" which serve at least 25 individuals (Table 2.4). This includes a number of upstate DEP facilities at which potable water is regularly provided to at least 25 individuals. Analytes and sampling frequencies are listed in Table 2.5.

Sites

Table 2.4: Sample sites required by USEPA/NYS as PWS providing potable water.

Location	Site Code	Reason for Site	# Employees
Ashokan Headworks	Entry Point Alternate sites: BNL#14, City House #1, 3, 5, 6, Garage, Shokan Precinct	TCR, SDWIS	25+
Downsville Office	PSO1 (Entry Point) Alternate sites:[1] PSORAW, PSANX, PSGB, PSGK, PSO1RAW	TCR, SDWIS	25+
Downsville Police Barracks	DPB (Distribution) Alternate site:[1] DPBRAW	TCR, SDWIS	25+
Grahamsville Office Kitchen	DDOK (Distribution) Alternate sites:[1] DDRAW, DDSK[2], DDSWC[2], GL3WC[2], WSCCKS[2]	TCR, SDWIS	25+

[1]Alternate sites sampled if total coliform is positive.

[2]Alternate sites sampled for lead and copper every 9 years.

Analytes and Frequencies

Table 2.5: USEPA and NYS required potable water analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Total Coliform/*E. coli*[1]	Quarterly (Downsville Office and Police Barracks and Grahamsville)	TCR requirement
Total Coliform/*E. coli*[1]	Monthly (Ashokan)	TCR requirement
Physicals (pH, Temperature, Turbidity, Color, Scent, Specific Conductivity)	Quarterly (Downsville Office and Police Barracks and Grahamsville)	DEP EH&S Rules
Lead and Copper	5 per 3 years (Ashokan)	SDWIS
Lead and Copper	5 per 9 years (Grahamsville)	SDWIS
Primary Inorganic Chemicals[2]	Yearly (Ashokan and Grahamsville)	SDWIS
Nitrate-N	Yearly (Downsville Office and Police Barracks, Grahamsville, and Ashokan)	SDWIS
Secondary Inorganic Chemicals[2]	1 per 3 yrs (Grahamsville)	SDWIS
Disinfection By-products[2]	Yearly (Ashokan)	SDWIS
Principle Organic Chemicals	1 per 6 years (Ashokan and Grahamsville)	SDWIS
Synthetic Organic Chemicals[2]	1 per 3 yrs (Ashokan and Grahamsville)	SDWIS
Asbestos	1 per 9 years (Grahamsville)	SDWIS

[1]*E. coli* required only if total coliform is positive.
[2]Analyzed by contract lab or in some cases by the Distribution Water Quality Laboratory.

Data Analysis and Reporting

DEP laboratories provide drinking water quality reports to water system operators within the Operations Directorate, which compiles a quarterly report to NYSDOH. Results of sampling are included in those reports.

References

WWQO Operational Guidance Plan for Monitoring Potable Water.
http://www.health.state.ny.us/environmental/water/drinking/part5/subpart5.htm

2.3 Watershed Rules & Regulations

2.3.1 Phosphorus-Restricted Basin Monitoring

The New York City Watershed Rules and Regulations (WR&R) (DEP 2010) specify that DEP conduct a review of the City's reservoirs on an annual basis to determine which reservoirs are phosphorus-restricted. A phosphorus-restricted basin is defined in the Regulations as "the drainage basin of a reservoir or controlled lake in which the phosphorus load to the reservoir or controlled lake results in the phosphorus water quality values established by the New York State

Department of Environmental Conservation and set forth in its Technical and Operational Guidance Series (TOGS) 1.1.1, Ambient Water Quality and Guidance Values (October 22, 1993).” If these values are exceeded as determined by the Department pursuant to its annual review, required under Section 18-48e of Subchapter D, then the basin will be designated as phosphorus restricted. The phosphorus-restricted designation prohibits new or expanded wastewater treatment plants with surface discharges in the reservoir basin.

Background

Assessments in the past few years have shown that Kensico, West Branch, Boyd Corners, Cross River and all of WOH reservoirs were typically not phosphorus-restricted. Cannonsville Reservoir was restricted and improved to non-restricted for the past several years. The remaining EOH reservoirs have been phosphorus-restricted.

Sites

To adequately characterize the total phosphorus concentrations in each reservoir, samples are collected from multiple depths and multiple sites. Site selection is determined by field staff on the day of collection and may comprise of any combination of sites listed in Table 2.6. Maps showing site locations are provided in Appendix I. The sample depth collection plan is provided in Appendix II. All sites are collected to determine the annual geometric mean.

Table 2.6: Potential sampling sites for assessment of phosphorus-restricted basins status.

Reservoir	Frequency[1]	Sites							
Catskill									
Ashokan-East	monthly	4EAE	5EAE	6EAE					
Ashokan-West	monthly	1EAW	2EAW	3EAW					
Schoharie	monthly	1.5SS	2SS	3SS	4SS				
Delaware									
Cannonsville	monthly	1WDC		3WDC	4WDC	5WDC	6WDC		
Pepacton	monthly	1EDP		3EDP	4EDP	5EDP	6EDP		
Neversink	monthly	1NN	2NN		4NN				
Rondout	monthly	1RR	2RR	3RR					
East of Hudson									
Kensico	monthly	1.1BRK	2BRK	2.9BRK	4BRK	5BRK	6BRK	7BRK	8BRK
New Croton	monthly	1CNC	2CNC	3CNC	4CNC	5CNC	6CNC		8CNC
Muscoot	monthly	1CM	2CM	4CM	6CM				
Amawalk	monthly	1.1CA	3CA						
Cross River	monthly	1.1CCR	3CCR						
Titicus	monthly	1.1CT	3CT						
Croton Falls	monthly	1.1CCF		3CCF		5CCF			
Diverting	monthly	1CD	2CD						
Middle Branch	monthly	1.1CMB	3CMB						
West Branch	monthly	1CWB	2CWB	3CWB	4CWB				
East Branch	monthly	1CEB							
Bog Brook	monthly	1CBB							

Table 2.6: (Cont.)Potential sampling sites for assessment of phosphorus-restricted basins status.

Reservoir	Frequency[1]	Sites
Boyd Corners	monthly	1.1CBC
Lake Gleneida	3 samples/quarter	1CGLEN[2]
Lake Gilead	3 samples/quarter	1CGIL[3]

1. Samples must be collected from each basin monthly (quarterly for controlled lakes) from May 1 to October 31.
2. Site 1CGL was renamed 1CGLEN in June 2014.
3. Site 1CGD was renamed 1CGIL in June 2014.

Analytes and Frequencies

Samples must be collected monthly from each basin, from May 1 through October 31, for the reservoir sites listed in Table 2.6. Samples on the controlled lakes are only collected on a quarterly basis during the same time period. This period represents the growing season, a time when phosphorus is utilized for primary production in the photic zone.

Data Analysis and Reporting

A summary of the methodology used in the phosphorus-restricted analysis is provided; the complete description can be found in A Methodology for Determining Phosphorus-Restricted Basins (DEP 1997b). The data utilized in the analysis are from the routine monitoring of the reservoirs. All reservoir samples taken during the growing season are used. Any recorded concentrations below the analytical limit of detection are set equal to half the detection limit. Phosphorus concentration data for the reservoirs approach a lognormal distribution; therefore, the geometric mean is used to characterize the annual phosphorus concentrations. The five most recent annual geometric means are averaged arithmetically, and this average constitutes one assessment. The “running average” method weights each year equally, thus reducing the effects of unusual hydrology or phosphorus loading for any given year, while maintaining an accurate assessment of the current conditions in the reservoir. If any reservoir has less than three surveys during a growing season, then that 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.

Given the inter-annual variability of phosphorus in the reservoirs, the five-year mean plus the standard error of the five-year mean is compared to the NYS guidance value of 20 µg L^{-1} for non-terminal reservoirs and 15 µg L^{-1} for terminal reservoirs. This provides some statistical assurance that the five-year arithmetic mean is representative of a basin’s phosphorus status. A basin is unrestricted if the five-year mean plus standard error is below the guidance value of 20 µg L^{-1} and phosphorus-restricted if it is equal to or greater than 20 µg L^{-1}, unless DEP, using its best professional judgment, determines that the phosphorus-restricted designation is due to an unusual and unpredictable event. 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 in order to officially change the designation.

The annual assessments are provided in the Watershed Water Quality Annual Reports (e.g., DEP 2014).

References

DEP. 1997b. Methodology for Determining Phosphorus-Restricted Basins. New York City Department of Environmental Protection. Valhalla, NY.

DEP. 2010. New York City Watershed Rules and Regulations. 1997, amended April 4, 2010. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf. (Accessed 12/10/14)

DEP. 2014. Watershed Water Quality Annual Report. Valhalla, NY.

2.3.2 Coliform-Restricted Basin Monitoring

Coliform bacteria are used by water suppliers as indicators of potential pathogen contamination. To protect its water supply, New York City has promulgated regulations (the "Watershed Rules & Regulations") that restrict potential sources of coliforms in threatened water bodies (DEP 2010). These regulations require the City to perform an annual review of its reservoir basins to decide which, if any, should receive coliform-restricted determinations. Once a watershed is determined to be restricted, no new sewage treatment plants can be built in the catchment.

Coliform bacteria cultures.

Background

Coliform-restricted determinations are governed by two sections of the regulations, "terminal basins" and "all reservoirs and controlled lakes." The section on terminal basins [Section 18-48(c) (1)] applies to those that serve, or potentially serve, as source water reservoirs (Kensico, West Branch, New Croton, Ashokan, and Rondout). The coliform-restricted assessments of these basins is based on compliance with federally-imposed limits on *fecal* coliforms collected from waters within 500 feet of the reservoir's aqueduct effluent chamber. To date, none of the terminal basins have been determined to be coliform-restricted. The section on all reservoirs and controlled lakes [Section 18-48(a) and Section 18-48(c)] applies to the remaining reservoirs and Lakes Gilead and Gleneida, and specifies that coliform-restricted assessments of these basins be based on compliance with 6 NYCRR Parts 701 and 703 limits on *total* coliform bacteria. Coliform bacteria are regulated in source waters by the Safe Drinking Water Act (SDWA) at levels of 20 FC 100 mL^{-1} for fecal coliforms and 100 TC 100 mL^{-1} for total coliforms. Both are used as indicators of potential pathogen contamination; however, fecal coliform bacteria are more specific in that their source is the gut of warm-blooded animals, while the total coliforms may be comprised of organisms from water, soil, and sediments.

Sites

Fecal coliform monitoring is required within 500 feet of the aqueduct effluent of a terminal reservoir at a frequency of five samples per week. The EOH terminal reservoirs are sampled a minimum of five days each week at the continuous monitoring site. To satisfy this requirement at the WOH terminal reservoirs, DEP samples four days each week at the continuous monitoring site with one additional sample taken each week from the elevation tap representative of the effluent.

Total coliform monitoring for other reservoir and controlled lake surveys has a minimum monitoring requirement of 5 samples per month and there are an adequate number of sites and depths to meet the requirement. Sampling sites are described in Table 2.7. Appendix II provides details on the sample depth collection. Additional depths must be included on any reservoir having two or less sampling locations such that five samples are collected for each reservoir.

Table 2.7: Potential sampling sites for assessment of coliform-restricted basins.

Reservoir and Keypoint Sites	Sample frequency	Samples typically collected per month
Terminal basins—require assessment of fecal coliform on a minimum of five samples per week, collected at keypoint and respective elevation tap (ET) sites.		
Ashokan (EARCM)	5 samples/week (4 EARCM + 1 ET)	20
Rondout (RDRRCM)	5 samples/week (4 RDRRCM + 1 ET)	20
West Branch (CWB 1.5)	5 samples/week	20
Kensico (DEL18DT)	5 samples/week[1]	30
New Croton (CROGH)	5 samples/week	20
Non-terminal basins—require assessment of total coliform on a minimum of five samples per month, collected at reservoir sites.[2]		
West of Hudson:		
Cannonsville (Sites 1, 3, 4, 5, 6)	1 survey/month	15
Neversink (Sites 1, 2, 4)	1 survey/month	10
Pepacton (Sites 1, 3, 4, 5, 6)	1 survey/month	17
Schoharie (Sites 1, 2, 3, 4)	1 survey/month	12
East of Hudson:		
Amawalk (Sites 1.1, 3)	1 survey/month	5
Bog Brook (Sites 1, 3)	1 survey/month	5

Table 2.7: (Cont.)Potential sampling sites for assessment of coliform-restricted basins.

Reservoir and Keypoint Sites	Sample frequency	Samples typically collected per month
Boyd Corners (Sites 1.1, 2, 3)	1 survey/month	6
Cross River (Sites 1.1, 3)	1 survey/month	6
Croton Falls (Sites 1.1, 3, 5)	1 survey/month	8
Diverting (Sites 1.1, 2)	1 survey/month	5
East Branch (Sites 1, 3)	1 survey/month	5
Lake Gilead (Site 1)	1 survey/month	5
Lake Gleneida (Site 1)	1 survey/month	5
Middle Branch (Sites 1.1, 3)	1 survey/month	5
Muscoot (Sites 1, 2, 4, 6)	1 survey/month	7
Titicus (Sites 1.1, 3)	1 survey/month	5

1. Despite 5 samples/week requirement the monitoring is done daily

2. Refer to Appendix I maps for locations of the sites.

Analytes and Frequencies

Fecal coliforms are required for the terminal basins (five samples per week) and total coliforms are required for the non-terminal reservoirs and controlled lakes (five samples per month). Table 2.7 provides a listing of reservoirs, keypoints and frequency of sampling for these analytes.

Data Analysis and Reporting

Currently, coliform-restriction assessments are made using fecal coliform data on the terminal reservoirs from a minimum of five samples each week over two consecutive six-month periods. The threshold for fecal coliform is 20 CFU $100mL^{-1}$. If 10% or more of the effluent samples measured ever have values ≥20 CFU $100mL^{-1}$, and the source of the coliforms is determined to be anthropogenic (man-made), the associated basin would be deemed coliform-restricted. This assessment is reported on an annual basis in the Watershed Water Quality Annual Report (e.g. DEP 2008). Until such time that a method for determining anthropogenic sources is accepted, the source of the coliforms will be noted as “undefined”.

References

DEP. 2010. New York City Watershed Rules and Regulations. 1997, amended April 4, 2010. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf. (Accessed 12/10/14)

DEP. 2014. Watershed Water Quality Annual Report. Valhalla, NY.

2.4 Croton Consent Decree

Croton Lake Gatehouse.

Objective

This objective addresses the requirement to monitor required sites outlined in the Croton Consent Decree (CCD) (1998) agreement and the more recent Third Supplement to the Consent Decree (2014).

Background

Since the Croton System did not meet the requirements for Filtration Avoidance under the SWTR, DEP has been required to perform mandated supplemental monitoring until filtration of the Croton water supply is in place. The Croton Consent Decree was issued to enforce the construction schedule for the Croton water supply filtration system. It requires that coliform and other samples be collected in streams, reservoirs, and controlled lakes of the Croton System. The Third Supplement to the Consent Decree, filed on October 1, 2014, solidified a reduction in sampling requirements specified in an earlier letter, dated July 24, 2012. The 2012 letter was based on an agreement which modified the CCD monitoring requirements with sample frequency and site reductions since the City was not utilizing the Croton System. As of May 2015, the Croton Filtration Plant (CFP) began sending filtered Croton water into the City's distribution system. The monitoring requirements of the Third Supplement, outlined in the specific sections below, will remain in effect for one year after the CFP has been certified for operation.

2.4.1 Hydrology: Croton Consent Decree Monitoring

Sites

In accordance with the Third Supplement to the Consent Decree (2014), DEP must conduct monthly monitoring for total and fecal coliform at Croton Watershed streams. DEP currently monitors 24 streams as listed in the following table (Table 2.8). Analytes and sampling frequencies are listed in Table 2.9.

Table 2.8: Stream sites for CCD monitoring .

Site Code	Site Description	Reason for Site Selection
HORSEPD12	Horse Pound Brook site 12, Town of Carmel. Collect sample adjacent to USGS gaging station. Park near 492 Horse Pound Road near the DEP gate on the west side of the road. Hike (about 20-30 minutes) down footpath until you reach the stream and look for the USGS hut	To meet requirements of CCD

Table 2.8: (Cont.) Stream sites for CCD monitoring .

Site Code	Site Description	Reason for Site Selection
GYPSYTRL1	Gypsy Trail Brook site 1, Town of Kent. Collect sample downstream of bridge/culvert crossing on Gypsy Trail Road. DEP staff gage site mounted to upstream side of bridge at REW	To meet requirements of CCD
LONGPD1	Long Pond site 1, Town of Carmel. Collect sample upstream of Washington Road near reservoir inlet (Long Pond outflow). DEP staff gage mounted to rock at REW.	To meet requirements of CCD
BOYDR	Boyd Corners Reservoir release.	To meet requirements of CCD
WESTBRR	West Branch Reservoir release.	To meet requirements of CCD
WESTBR7	West Branch Croton River site 7, Town of Kent. Collect sample downstream of bridge crossing on Rt. 301 (near intersection of Ninham Road) adjacent to USGS gaging station (upstream of Boyd Corners Reservoir). USGS staff gage located at REW below station hut.	To meet requirements of CCD
CROSSRVVC	Cross River Reservoir release.	To meet requirements of CCD
CROSS2	Cross River site 2, Town of Lewisboro. Collect sample downstream of wooden bridge in Ward Pound Ridge Reservation off of Reservation Road, by Park Resident's private drive. USGS drop tape mounted to downstream bridge railing.	To meet requirements of CCD
TITICUSR	Titicus Reservoir release.	To meet requirements of CCD
TITICUS3	Titicus River site 3, Town of North Salem. Collect sample upstream of confluence with Crook Brook. Park in North Salem Post Office rear parking lot (near intersection of Rt. 124 (June Rd.) & Rt. 116 (Titicus Rd.)). Hike down to stream and sample at bedrock outcropping that extends the width of the stream	To meet requirements of CCD
MUSCOOT10	Muscoot River site 10, Town of Somers. Collect sample at USGS gaging station on Rt. 6, approximately 0.3 mile east of the intersection of Rt. 6 and Mahopac Ave. (upstream of Amawalk Reservoir). Sample upstream of bridge next to USGS staff gauge LEW.	To meet requirements of CCD
AMAWALKR	Amawalk Reservoir release.	To meet requirements of CCD

Table 2.8: (Cont.) Stream sites for CCD monitoring .

Site Code	Site Description	Reason for Site Selection
MIKE2	Michael's Brook site 2, Town of Carmel. Collect sample approximately 100 meters upstream of Hughson Road at DEP staff gauge (sample upstream of the small, easterly flowing tributary adjacent and to the north)	To meet requirements of CCD
CROFALLSVC	Croton Falls Reservoir release.	To meet requirements of CCD
STONE5	Stone Hill River site 5, Town of Bedford. Collect sample approximately 100 meters downstream of the confluence of Broad Brook with Stone Hill River: sample at DEP staff gage. Access sampling site via hiking path through Beaver Dam Sanctuary off Beaver Dam Road; entrance located northwest of bridge crossing Stone Hill River. DEP staff gage mounted to large rock at LEW.	To meet requirements of CCD
MIDBRR	Middle Branch Reservoir Release	To meet requirements of CCD
MUSCOOT5	Muscoot River site 5, Town of Somers. Collect sample downstream of overpass crossing Wood Street (downstream of Amawalk Reservoir and Hallocks Mill). DEP staff gage mounted to overpass abutment at REW.	To meet requirements of CCD
DIVERTR	Diverting Reservoir release.	To meet requirements of CCD
BOGEASTBRR	Bog Brook and East Branch Reservoir release.	To meet requirements of CCD
EASTBR	East Branch Croton River, Town of Southeast. Collect sample under overpass on County Rt. 65 (Doansburg Road). Park on County Rt. 65 by driveway for Green Chimneys Barn complex and walk to site. USGS drop tape mounted to downstream overpass railing.	To meet requirements of CCD
DIVERTCH	Diverting Reservoir spillway channel.	To meet requirements of CCD
MIDBR3	Middle Branch Croton River site 3, Town of Southeast. Collect sample adjacent to USGS gaging station. Park vehicle at small barn across from Centennial Links Golf Course and hike downhill approximately 500 meters along pasture; USGS station is streamside next to wooden fence. USGS staff gage at REW.	To meet requirements of CCD
KISCO3	Kisco River site 3, Town of New Castle. Collect sample at USGS gaging station near the intersection of Pines Bridge Road and Yeshiva Nitra Rd. USGS staff gage located at REW adjacent to station hut.	To meet requirements of CCD

Table 2.8: (Cont.) Stream sites for CCD monitoring .

Site Code	Site Description	Reason for Site Selection
HUNTER1	Hunter Brook site 1, Town of Yorktown. Collect sample upstream of bridge crossing on Baptist Church Road: sample near USGS staff gage, which is located approximately 1000 meters upstream of Baptist Church Road.	To meet requirements of CCD

Analytes and Frequencies

Table 2.9: Analytes and frequencies for CCD stream monitoring.

Analyte	Sampling Frequency	Rationale for Analyte
Fecal Coliform	Once per month	Decree Requirement
Total Coliform	Once per month	Decree Requirement

Data Analysis and Reporting

Data will be reviewed monthly and included in the monthly Croton Water System Consent Decree Monitoring Reports, until the terms of the CCD are satisfied.

2.4.2 Limnology: Croton Consent Decree Monitoring

Sites

Samples are to be collected at all EOH reservoirs monthly from April to November. The Third Supplement (2014) defines the "Croton Water Supply System" reservoirs as Amawalk, Bog Brook, Cross River, Croton Falls, Diverting, East Branch, Middle Branch, Muscoot, New Croton, and Titicus Reservoirs, as well as Kirk Lake, Lake Gleneida, and Lake Gilead ("controlled lakes"). Site locations are identified on maps in Appendix I.

Analytes and Frequencies

Coliform samples will be collected once each month for all reservoirs. Samples are to be collected April through November, except for New Croton, where samples are collected all year, as ice conditions permit.

Data Analysis and Reporting

Data will be reviewed monthly and included in the monthly Croton Water System Consent Decree Monitoring Reports, until the terms of the CCD are satisfied.

2.4.3 Keypoints: Croton Consent Decree Monitoring

Sites

The Third Supplement to the Consent Decree (2014), Section VII.A.6, stipulates "Coliform monitoring at the Croton Lake Gatehouse raw water keypoint location weekly…" (Table 2.10). The sample may also be collected at the optimal tap (CRO1T, CRP1B, CRO143, CRO163 or CRO183)

Table 2.10: Keypoint site for CCD monitoring.

Site Code	Site Description	Reason for Site Selection
CROGH	Raw effluent of New Croton Reservoir	Required by CCD

Analytes and Frequencies

The CCD dictates that the following site be monitored for coliforms at the specified frequencies for the term of the decree (Table 2.11)

Table 2.11: Analytes and frequencies for keypoint monitoring for the CCD.

Site Code	Analyte	Sampling Frequency	Rationale for Analyte
CROGH	Total Coliform	Weekly	Required by CCD
	Fecal Coliform	Weekly	Required by CCD

Data Analysis and Reporting

Data are reviewed monthly and included in the monthly Croton Water System Consent Decree Monitoring Reports, until the terms of the CCD are satisfied.

2.4.4 Pathogens: Croton Consent Decree Monitoring

Sampling for pathogens (protozoans and human enteric viruses) are a required component of the monitoring laid out by the Third Supplement to the Consent Decree (2014).

Sites

The following table outlines pathogen sampling sites for CCD monitoring (Table 2.12).

Table 2.12: Sites for pathogen monitoring for the CCD.

Site Code	Site Description	Reason for Site Selection
CROGH	Effluent of New Croton Reservoir	New Croton source water effluent
CROFALLSVC	Croton Falls Reservoir Release	Can be pumped into system for consumption
CROSSRVVC	Cross River Reservoir Release	Can be pumped into system for consumption

Analytes and Frequencies

The Third Supplement dictates that the following sites be monitored for pathogens (*Giardia*, *Cryptosporidium*, and human enteric viruses) and at specified frequencies for the term of the decree (Table 2.13).

Table 2.13: Analytes and frequencies for pathogen monitoring for the CCD.

Site Code	Analyte[1]	Sampling Frequency	Rationale for Analyte
CROGH	*Giardia*	Monthly	Required by CCD
	Cryptosporidium	Monthly	Required by CCD
	Human enteric viruses	Monthly	Required by CCD
CROFALLSVC	*Giardia*	Monthly but only when pumps are in operation	Required by CCD
	Cryptosporidium	Monthly but only when pumps are in operation	Required by CCD
	Human enteric viruses	Annually	Required by CCD
CROSSRVVC	*Giardia*	Monthly but only when pumps are in operation	Required by CCD
	Cryptosporidium	Monthly but only when pumps are in operation	Required by CCD
	Human enteric viruses	Annually	Required by CCD

[1]As with all other pathogen monitoring, the following analytes are required: sample volume, pH, turbidity, water temperature, pressure differential on sample filter, and flow rate through filter. Flow is not measured but where possible will be estimated through indexing.

Data Analysis and Reporting

Data are reviewed monthly and included in the monthly Croton Water System Consent Decree Monitoring Reports, until the terms of the CCD are satisfied.

2.4.5 Waste Water Treatment Plant (WWTP) Monitoring – CCD

Objective

This objective addresses the requirement to monitor East of Hudson WWTPs as required under the Third Supplement to the Consent Decree (2014). The data is reviewed and included in the quarterly Croton Wastewater Report until the terms of the CCD are satisfied.

Sites, Analytes, and Frequencies

Sites include all WWTPs in the Croton watershed. Sites are required to be monitored as per the requirements stated in their SPDES permits. See Table 2.14 for a list of sites (subject to change) and the sampling frequencies. For a detailed list of analytes see appendix XI.

Table 2.14: East of Hudson WWTP sites and frequencies for CCD monitoring[1]

WWTP Plant	Reason for Selection[1]	Frequency
Bedford Hills Correctional Facility	required by CCD	1/month
Bedford Hills Elderly Housing WWTP	required by CCD	1/month
Fox Lane Campus	required by CCD	1/month
Bedford Park Apartments at Westchester WWTP	required by CCD	1/month
Blackberry Hill	required by CCD	1/month
Southeast (T) Brewster Heights SD #1	required by CCD	1/month
Brewster High School	required by CCD	1/month
Brewster (V) STP	required by CCD	1/month
Bridleside WWTP	required by CCD	1/month
Camp Ludington	required by CCD	1/month
Town of Carmel SD #2	required by CCD	2/month
Clear Pool Camp	required by CCD	2/month
Country Manor STP	required by CCD	1/month
Fox Run Condominiums	required by CCD	1/month
George Fischer Middle School	required by CCD	1/month
Heritage Hills STP	required by CCD	1/month
Independent Sewage Works Inc., The Highlands	required by CCD	1/month
Hill Sparrow WWTP	required by CCD	2/month
Holly Stream Condominium STP	required by CCD	1/month
Hunter's Glen WWTP	required by CCD	1/month
Somers Office Building Complex	required by CCD	1/month
Increase Miller Elementary School	required by CCD	1/month
Katonah Elementary School	required by CCD	1/month
K'hal Adas Kashau	required by CCD	1/month
Kent Manor Condominiums	required by CCD	2/month
Putnam Nursing & Rehabilitation Center	required by CCD	1/month
Peach Lake Sewer District WWTP	required by CCD	1/month
Carmel Sewer District #4 STP	required by CCD	1/month
Lincoln Hall STP	required by CCD	1/month
Mahopac CSD WWTP	required by CCD	1/month
NYC DEP Mahopac (V) WWTP	required by CCD	1/month

Table 2.14: (Cont.) East of Hudson WWTP sites and frequencies for CCD monitoring[1]

WWTP Plant	Reason for Selection[1]	Frequency
Mahopac Village Center	required by CCD	1/month
Maple Hill Estates WWTP	required by CCD	1/month
Michelle Estates Reality Subdivision	required by CCD	2/month
Mount Ebo Associates STP	required by CCD	1/month
North Salem Middle & High School	required by CCD	1/month
Patterson Hamlet WWTP	required by CCD	1/month
Pepsi Co. Somers Office Facility	required by CCD	1/month
Putnam National Golf Club WWTP	required by CCD	1/month
Random Farms Subdivision	required by CCD	1/month
Reed Farm Condominiums	required by CCD	1/month
I-684 Rest Area -Comfort Station #45	required by CCD	1/month
Fox Hollow Sewer Corp., Inc.	required by CCD	1/month
Seven Springs Sewer Corporation	required by CCD	1/month
Society Hill at Mahopac	required by CCD	1/month
Somers Chase Sewer Co. - Voris Drive	required by CCD	1/month
Somers High School & Primrose Elem. Campus	required by CCD	1/month
Somers Manor Nursing Home, Inc.	required by CCD	1/month
Terravest Corporate Park	required by CCD	1/month
The Meadows At Cross River Condominiums	required by CCD	2/month
Thunder Ridge Ski Area	required by CCD	1/month
Brewster Towne Centre WWTP	required by CCD	1/month
Tracy Sewage Works Dist./Clock Tower Commons	required by CCD	1/month
Waccabuc Country Club	required by CCD	2/month
Walter Panas High School	required by CCD	1/month
Watchtower Educational Center	required by CCD	1/month
Wild Oaks Sewer District	required by CCD	1/month
Williamsburg Ridge STP	required by CCD	1/month
Yeshiva Kehilath Yakov School	required by CCD	1/month
Yorktown Heights SD WWTP	required by CCD	1/month

[1]For a list of analytes see appendix XI

Table 2.15: East of Hudson CCD WWTP analytes and frequencies.

Location/ WWTP Plant	Analytes (vary by SPDES)[1]	Frequency
Bedford Hills Correctional Facility	same as SPDES permit	1/mo
Bedford Hills Elderly Housing WWTP	same as SPDES permit	1/mo
Fox Lane Campus	same as SPDES permit	1/mo
Bedford Park Apartments at Westchester WWTP	same as SPDES permit	1/mo
Blackberry Hill Sanctuary SD STP	same as SPDES permit	1/mo
Southeast (T) Brewster Heights SD #1	same as SPDES permit	1/mo
Brewster High School	same as SPDES permit	1/mo
Brewster (V) STP	same as SPDES permit	1/mo
Bridleside WWTP	same as SPDES permit	1/mo
Camp Ludington	same as SPDES permit	1/mo
Town of Carmel SD #2	same as SPDES permit	2/mo
Clear Pool Camp	same as SPDES permit	2/mo
Country Manor STP	same as SPDES permit	1/mo
Fox Run Condominiums	same as SPDES permit	1/mo
George Fischer Middle School	same as SPDES permit	1/mo
Heritage Hills STP	same as SPDES permit	1/mo
Independent Sewage Works Inc., The Highlands	same as SPDES permit	1/mo
Hill Sparrow WWTP	same as SPDES permit	2/mo
Holly Stream Condominiums STP	same as SPDES permit	1/mo
Hunters Glen WWTP	same as SPDES permit	1/mo
Somers Office Building Complex	same as SPDES permit	1/mo
Increase Miller Elementary School	same as SPDES permit	1/mo
Katonah Elementary School	same as SPDES permit	1/mo
K'hal Adas Kashau	same as SPDES permit	1/mo
Kent Manor Condominiums	same as SPDES permit	2/mo
Putnam Nursing & Rehabilitation Center	same as SPDES permit	1/mo
Peach Lake Sewer District WWTP	same as SPDES permit	1/mo
Carmel Sewer District #4 STP	same as SPDES permit	1/mo
Lincoln Hall STP	same as SPDES permit	1/mo
Mahopac CSD WWTP	same as SPDES permit	1/mo
NYC DEP Mahopac (V) WWTP	same as SPDES permit	1/mo
Mahopac Village Center	same as SPDES permit	1/mo
Maple Hill Estates WWTP	same as SPDES permit	1/mo

Table 2.15: (Cont.)East of Hudson CCD WWTP analytes and frequencies.

Location/ WWTP Plant	Analytes (vary by SPDES)[1]	Frequency
Michelle Estates Realty Subdivision	same as SPDES permit	2/mo
Mount Ebo Associates STP	same as SPDES permit	1/mo
North Salem Middle & High School	same as SPDES permit	1/mo
Patterson Hamlet WWTP	same as SPDES permit	1/mo
Pepsi Co. Somers Office Facility	same as SPDES permit	1/mo
Putnam National Golf Club WWTP	same as SPDES permit	1/mo
Random Farms Subdivision	same as SPDES permit	1/mo
Reed FarmCondominiums	same as SPDES permit	1/mo
I-684 Rest Area - Comfort Station #45	same as SPDES permit	1/mo
Fox Hollow Sewer Corp., Inc.	same as SPDES permit	1/mo
Seven Springs Sewer Corporation	same as SPDES permit	1/mo
Society Hill at Mahopac	same as SPDES permit	1/mo
Somers Chase Sewer Co. - Voris Drive	same as SPDES permit	1/mo
Somers High School & Primrose Elem. Campus	same as SPDES permit	1/mo
Somers Manor Nursing Home, Inc.	same as SPDES permit	1/mo
Terravest Corporate Park	same as SPDES permit	1/mo
The Meadows At Cross River Condominiums	same as SPDES permit	2/mo
Thunder Ridge Ski Area	same as SPDES permit	1/mo
Brewster Towne Centre WWTP	same as SPDES permit	1/mo
Tracy Sewage Works Dist./Clock Tower Commons	same as SPDES permit	1/mo
Waccabuc Country Club	same as SPDES permit	2/mo
Walter Panas High School	same as SPDES permit	1/mo
Watchtower Educational Center	same as SPDES permit	1/mo
Wild Oaks Sewer District	same as SPDES permit	1/mo
Williamsburg Ridge STP	same as SPDES permit	1/mo
Yeshiva Kehilath Yakov School	same as SPDES permit	1/mo
Yorktown SD WWTP	same as SPDES permit	1/mo

[1]For a list of analytes see appendix XI

References

Croton Consent Decree. *United States v. City of New York*, CV 97-2154 (USDC, EDNY), Gershon, J. 1998.

Third Supplement to the Consent Decree. *U.States v. City of New York and NYC Dept. of Environmental Protection*, CV 97-2154 (USDC, EDNY), Gershon, J. and Gold, M.J. 2014.

2.5 Administrative Orders

2.5.1 Hillview Protozoan Monitoring

Objective

To fulfill the requirements of the Hillview Administrative Order by performing weekly monitoring of protozoa at Hillview Site 3 for the duration of the cover deferral period.

Background

The Hillview Administrative Order on Consent (Docket No. SDWA-02-2010-8027) is concerned with the requirement to cover Hillview Reservoir. This Order also requires *Cryptosporidium* and *Giardia* sampling at Hillview Reservoir Site 3.

Sites

DEP will collect weekly protozoan samples (*Giardia* and *Cryptosporidium*) at Hillview Reservoir Site 3 (Table 2.16).

Table 2.16: Sites for protozoan monitoring for the Hillview Administrative Order.

Site Code	Site Description	Rationale for Site	Frequency
Site 3	Hillview Reservoir Downtake #1	Required by Admin Order	Weekly

Analytes and Frequencies

DEP will collect protozoan samples (*Gia*rdia and *Crypt*osporidium) along with routine water quality data on a weekly basis (Table 2.17) at Hillview Site 3. If an elevated protozoan concentration is found, additional sampling would be performed as per the *Cryptosporidium* and *Giardia* Action Plan (CGAP). DEP will also collect a matrix spike sample for every eight samples collected, and a matrix spike duplicate sample will be collected twice annually.

Table 2.17: Analytes for pathogen monitoring at Hillview Reservoir.

Analyte	Frequency	Rationale for Analyte
Cryptosporidium oocysts $50L^{-1}$	Weekly	Required by Admin Order
Giardia cysts $50L^{-1}$	Weekly	Required by Admin Order
Sample Volume	Weekly	For determination of (oo)cyst concentration
Turbidity	Weekly	Recovery potential/ interference

Table 2.17: Analytes for pathogen monitoring at Hillview Reservoir.

Analyte	Frequency	Rationale for Analyte
Water Temperature	Weekly	Measured to determine potential seasonality
pH	Weekly	Required for method recovery information
Pressure differential on sample filter	Weekly	Recovery potential/ interference
Flow for filtered sample	Weekly	USEPA method requirement
Flow (cubic feet per second)	Weekly	Required to estimate loading
Weather (general conditions)	Weekly	Supporting data to explain possible protozoan results

Data Analysis and Reporting

Protozoan data collected for the Hillview Administrative Order are reported in weekly emails to the regulators, and in the Watershed Water Quality Annual Report.

References

Administrative Order AT 940772-CO. State of New York Department of Health. NYCDEP, Respondent

2.5.2 Hillview Enhanced Wildlife Management Program

Objective

To fulfill the requirements of the Hillview Administrative Order through the implementation of revised best management practices including bird census and harassment, nest removal, sanitation inspections, mammal trapping and other enhancements as outlined below.

Background

As per the requirements of the Administrative Order, DEP has supplemented the existing Waterfowl Management Program with targeted enhancements for the census, tracking, and management of wildlife residents at Hillview Reservoir. These enhancements include:

i. Increased bird census and harassment efforts from existing schedule (Tuesday, Wednesday, Thursday from pre-dawn to post-dusk and Friday, Saturday, Sunday, Monday during the daytime only) to daily pre-dawn to post-dusk surveys.

ii. Periodic sanitation inspections of the dividing wall, catwalks, rooftops, and immediate grassy buffer around the reservoir perimeter for evidence of wildlife droppings. Binoculars and spotting scopes will be used to conduct shaft building inspections for bird droppings. All fecal matter observed along the reservoir dividing wall and grassy buffer will be identified to species where possible, collected and disposed of off reservoir property.

iii. Identification of vulnerable areas and developing enhanced wildlife management plans where needed (e.g., mammal trapping on the dividing wall and reservoir perimeter and continued management of woodchucks along reservoir perimeter and on dikes).

iv. Development and oversight of targeted wildlife management programs as needed (e.g., fish entrainment monitoring, strategies for deterrence of nesting and perching Cliff Swallows, strategies for the minimization or elimination of Ruddy Duck populations).

v. Inspection, maintenance, and repair of bird wiring and bird deterrence systems.

Sites and Frequencies

Specific sites such as the dividing wall, catwalks, rooftops, grass buffer, etc. each have their own prescriptions and schedule.

Data Analysis and Reporting

Submission of monthly reports of wildlife management efforts to NYSDOH and EPA that include bird census data and other wildlife activities.

References

Administrative Order AT 940772-CO. State of New York Department of Health. NYCDEP, Respondent.

2.6 SPDES Permits

2.6.1 Waste Water Treatment Plants (WWTPs) SPDES Permits

Objective

This objective addresses the requirement to monitor New York City-owned Waste Water Treatment Plant (WWTP) effluents and required influents in the NYC watershed for specific water quality parameters as specified in each plant’s State Pollutant Discharge Elimination System (SPDES) permit.

Background

There are 24 non-City-owned WWTPs and 6 City-owned WWTPs that are monitored by DEP west of the Hudson River. There are 59 non-City owned WWTPs and 1 City-owned WWTP that are monitored by DEP east of the Hudson River.

Of these, only the 7 City-owned plants are required to be monitored by the City to meet their SPDES requirements. The other 83 non-City-owned plants are monitored by the City, but under the guidelines of the Revised 2007 FAD (NYSDOH 2014) (WOH plants – Chapter 3) and the CCD (EOH plants – Chapter 2) and not due to a compliance SPDES requirement.

Sites

The following city-owned WWTPs are required to be monitored by the City in accordance with SPDES permits (Table 2.18).

Analytes and Frequencies

See Appendix XI for a matrix of analytes organized by permit.

Table 2.18: WWTP SPDES sites and reasons for selection.

Location	WWTP Plant	Reason for Selection
WOH	Grahamsville (V) WWTP	SPDES permit requirement
WOH	Margaretville (V) WWTP	SPDES permit requirement
WOH	Tannersville (V) WWTP	SPDES permit requirement
WOH	Grand Gorge (V) WWTP	SPDES permit requirement
WOH	Pine Hill (V) WWTP	SPDES permit requirement
WOH	Port Jervis NYC-owned WWTP	SPDES permit requirement
EOH	NYC DEP Mahopac (V) WWTP	SPDES permit requirement

Data Analysis and Reporting

City-owned WWTP data are included in the Discharge Monitoring Reports (DMR) required by NYSDEC.

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

2.6.2 Shandaken Tunnel Outlet SPDES Permit

Objective

The outlet of the Shandaken Tunnel is regulated by a SPDES permit (#NY-026-8151). This permit requires a number of analyses to be reported in a monthly Discharge Monitoring Report (DMR). Additionally, these monitoring data are used to inform Schoharie Reservoir operational decisions.

Shandaken Tunnel Portal.

Background

The SPDES permit for the Shandaken Tunnel was issued on September 1, 2006, and sets the requirement for DEP to discharge waters from Schoharie Reservoir to Esopus Creek via the Shandaken Tunnel. The permit requirements focus mainly on maintaining flow, turbidity, and temperature levels consistent with fishery health and recreational uses of Esopus Creek between the Shandaken Tunnel Outlet and Ashokan Reservoir. The monitoring requirements, in large part, are based on flow, turbidity, and temperature goals.

The flow requirements are detailed in both the SPDES permit and in 6NYCRR Part 670. In addition to transferring water from Schoharie Reservoir to Ashokan Reservoir, the Shandaken Tunnel flow supplements Esopus Creek during low flow periods. In general, the flow requirements are for Esopus Creek just downstream from the Tunnel outlet. Measurements of flow are taken in Esopus Creek above the Tunnel outlet by the USGS (gage #01362200) and Tunnel flows are monitored by USGS (gage # 01362230). The sum of these two flows is used for the Esopus Creek downstream flow. The downstream flow is required to be maintained at a minimum of 160 mgd. During June-October, Tunnel flow should only be added such that the combined Esopus Creek flow below the Tunnel outlet does not exceed 300 mgd. There are a number of special situations, as specified further in Part 670 and the SPDES permit (e.g., emergencies, droughts), when these flow targets are not applied.

Tunnel outlet turbidity is required to be no more than 15 NTU above the turbidity in Esopus Creek upstream of the Tunnel outlet. Additionally, under both the interim and final permit requirements turbidity in the Tunnel outlet is to remain under 100 NTU. There are a number of special situations, as specified further in the SPDES permit, under which there are exemptions from these limits.

Daily maximum temperature of Tunnel outlet water is limited to 70^{o}F. In addition, DEP is required to calculate the cold water storage in Schoharie Reservoir within 7 days of June 15 each year. This cold water storage estimate is then used to develop a Schoharie Reservoir Release Plan for the July 1 – September 15 period. As with the other requirements, there are a number of special situations under which there are exemptions from the temperature limits.

Sites

Sampling sites are based on those specified by the SPDES permit (Table 2.19). Limnological sites are also based on the necessity to obtain an accurate measure of cold water storage volume in Schoharie Reservoir in June.

Table 2.19: Sites for Shandaken Tunnel Outlet SPDES permit.

Site Code[1]	Site Description	Reason for Site Selection
Water Quality Directorate		
SRR2CM	Outlet of Shandaken Tunnel	SPDES permit requirement
AEAP	Esopus Creek – above confluence of Shandaken Tunnel Outlet	SPDES permit requirement
3SS	Schoharie Reservoir limnology site	SPDES permit requirement
USGS		
01362230	Shandaken Tunnel Outlet	SPDES permit requirement
01362200	Esopus Creek at Allaben	SPDES permit requirement

1. Additional limnology sites may be requested by Operations for cold water bank calculation

Analytes and Frequencies

Analytes and frequencies for Shandaken Tunnel monitoring are specified by the SPDES permit (Table 2.20). See Appendix XI for a matrix of analytes organized by permit.

Table 2.20: Analytes and frequencies for Shandaken Tunnel Outlet SPDES permit.

Analyte	Sampling Frequency	Site(s)
Water Quality Directorate		
Total Phosphorus	Weekly	SRR2CM
Total Settleable Solids	Weekly	SRR2CM
Total Suspended Solids	Weekly	SRR2CM
Temperature	Annually, within 7 days of June 15	3SS[1]
Turbidity	Continuous[2]	SRR2CM, AEAP
Temperature	Continuous[2]	SRR2CM
USGS		
Flow	Continuous	01362230, 01362200

[1] Additional sites may be requested by DEP Operations.

[2] Grab samples will be collected 1x/day if continuous monitoring is unavailable.

Data Analysis and Reporting

The data collected by the Water Quality Directorate are transmitted to Operations staff via monthly data report. Operations staff use water quality data, combined with data collected by Operations, to develop and submit the DMR to NYSDEC as required by the permit.

2.6.3 Catskill Influent Chamber (CATIC) SPDES Permit

Objective

The outlet of the Catskill Aqueduct into Kensico Reservoir is regulated by a SPDES permit (#NY-026-4652). This permit requires a number of analyses to be reported in a monthly DMR.

Background

The SPDES permit for the CATIC was issued on January 1, 2007, and sets the requirements for DEP to discharge waters from the Catskill Aqueduct into Kensico Reservoir. Monitoring requirements for the permit differ based on whether or not alum is being used. Should turbidity in the water from Ashokan Reservoir become high enough to present a risk to the 5 NTU limit set by the SWTR for waters being sent to the City from Kensico Reservoir, then alum treatment would be necessary. Since the issuance of the SPDES permit, alum treatment has occurred during three time periods: January 31 - February11, 2011 (DEP 2011a); March 2 - May 20, 2011 (DEP 2011b); August 29, 2011 - May 15, 2012 (DEP 2012).

During all of these alum treatment events DEP implemented enhanced monitoring in addition to the requirements of the SPDES permit (DEP 2011a, DEP 2011b, DEP 2012). This enhanced monitoring is determined just prior to the commencement of alum treatment and may be adjusted according to prevailing conditions. This is done in close coordination with NYSDEC and NYSDOH, and sampling may be adjusted at the discretion of the agencies' managers. When alum treatment is required, this enhanced monitoring is conducted to ensure the efficacy of treatment and to ensure regulatory compliance of water quality entering into the distribution system.

Sites

Sampling sites are those required by the CATIC SPDES permit (Table 2.21).

Table 2.21: Required sites for CATIC SPDES permit.

Site Code	Site Description	Reason for Site Selection
CATALUM	Catskill Aqueduct Alum Plant	SPDES requirement
5BRK	Kensico Reservoir limnology site	SPDES requirement

Analytes and Frequencies

Analytes and frequencies are based on the requirements of the SPDES permit. Requirements are split into periods with and without alum addition (Table 2.22).

Table 2.22: Analytes and frequencies for CATIC SPDES permit.

Analyte	Sampling Frequency	Site(s)	Rationale for Analyte
Water Quality Directorate – Periods of no alum addition			
pH	Monthly	CATALUM	Required by permit
Total Phosphorus	Weekly	CATALUM	Required by permit
Turbidity	Monthly	CATALUM	Required by permit
Total Suspended Solids	Monthly	CATALUM	Required by permit
Temperature	Monthly	CATALUM	Required by permit
Water Quality Directorate – Periods of alum addition[1]			
pH	Weekly	5BRK	Required by permit
Total Aluminum	Weekly	5BRK	Required by permit
Dissolved Aluminum	Weekly	5BRK	Required by permit
Total Phosphorus	Weekly	CATALUM	Required by permit
Turbidity	Weekly	5BRK	Required by permit
Turbidity	Daily	CATALUM	Required by permit
Total Suspended Solids	Weekly	5BRK	Required by permit
Temperature	Weekly	CATALUM	Required by permit

Table 2.22: Analytes and frequencies for CATIC SPDES permit.

Analyte	Sampling Frequency	Site(s)	Rationale for Analyte
Operations Directorate			
Flow	Continuous	CATALUM	Required by permit

[1] During alum treatment, additional enhanced monitoring may be requested based on close coordination of NYSDEC and NYSDOH.

Data Analysis and Reporting

The data collected by the Water Quality Directorate are transmitted to Operations staff via monthly memo. Operations staff use water quality data, combined with data collected by Operations, to develop and submit the DMR to NYSDEC and NYSDOH as required by the permit. The permit also requires the submission of an after action report within 60 days post treatment which summarizes the daily dosages of alum and sodium hydroxide used as well as the daily flows from the Catskill Aqueduct into Kensico (DEP 2011a, DEP2011b, DEP 2012).

References

DEP 2011a. Alum Treatment After Action Report, January 31- February 11, 2011. Bureau of Water Supply, Division of Drinking Water Quality Control, Kingston, NY.

DEP 2011b. Alum Treatment After Action Report, March 2 - May 20, 2011. Bureau of Water Supply, Division of Drinking Water Quality Control, Kingston, NY.

DEP 2012. Alum Treatment After Action Report, August 29, 2011 - May 15, 2012. Bureau of Water Supply, Division of Drinking Water Quality Control, Kingston, NY.

2.6.4 Delaware Aqueduct SPDES Permits

Objective

The outlets of the Delaware Aqueduct into West Branch Reservoir and Kensico Reservoir are regulated by SPDES permits NY-026-8089 (DEL9) and NY-026-8224 (DEL17), respectively. These permits require a number of analyses to be reported in monthly DMRs. Additionally, these monitoring data are used to inform treatment decisions.

Background

The current SPDES permit for DEL9 took effect August 1, 2004, and sets the requirements for DEP to discharge waters from the Delaware Aqueduct into West Branch Reservoir. The current SPDES permit for DEL17 took effect March 1, 2005, and sets the requirements for DEP to discharge waters from the Delaware Aqueduct into Kensico Reservoir.

Sites

Sampling sites specified by the Delaware Aqueduct SPDES permits are listed in Table 2.23.

Table 2.23: SPDES permit required monitoring for sites along the Delaware Aqueduct.

Site Code	Site Description	Reason for Site Selection
DEL9	Delaware Aqueduct into West Branch	SPDES requirement
DEL17	Delaware Aqueduct into Kensico	SPDES requirement

Analytes and Frequencies

Analytes and frequencies are based on the requirements of the Delaware Aqueduct SPDES permits (Table 2.24).

Table 2.24: Delaware Aqueduct (DEL9 and DEL17) SPDES analytes and frequency of monitoring.

Analyte	Sampling Frequency
Flow	Daily
Chlorine (Total Residual)[1]	Daily
Dissolved Oxygen	Continuous
Total Phosphorus	Weekly

[1] Chlorine is only monitored during chlorination events.

Data Analysis and Reporting

Sample results are transmitted to Operations staff. Operations uses water quality data, combined with data collected by Operations, to develop and submit DMRs to NYSDEC as required by the permits.

2.6.5 Outfall SPDES Permits

Objective

This objective addresses the requirement to monitor the appropriate sample locations and specified analytes to fulfill the requirements of the SPDES permit for each location.

Sites

There are several outfall sample sites located within DEP facilities. The sites listed in Table 2.25 are those sampled and/or analyzed by Water Quality Directorate staff.

Table 2.25: Sites required by SPDES permits for DEP outfall monitoring.

Site Code	Site Description	Reason for Site Selection
NY0251305 Outfall 001	Ashokan Reservoir Headworks – Outfall 001, BNL D-Box	SPDES requirement
NY0251305 Outfall 005	Ashokan Reservoir Headworks – Outfall 005, Filter Backwash	SPDES requirement
EDTO Bypass Sump	East Delaware Tunnel Outlet building bypass chamber sump – Outfall 01A	SPDES requirement
EDTO Hydro Sump	East Delaware Tunnel Outlet building groundwater sump – Outfall 001	SPDES requirement

Analytes and Frequencies

Outfall monitoring analytes and frequencies are listed in Table 2.26.

Table 2.26: Analytes and frequencies for monitoring at DEP outfalls regulated by SPDES permits.

Site	Analyte	Frequency	Sample Type	Rationale for Analyte
NY0251305 Outfall 001	Mercury, Lead, Toluene (by contract lab)	2/Year	Grab	SPDES requirement
NY0251305 Outfall 005	Total chlorine residual, temperature, flow, pH, settleable solids	Monthly (or as needed during backwash)	Grab	SPDES requirement
NY0251305 Outfall 005	TSS	Monthly (or as needed during backwash)	Compos-ite of start, mid-cycle and finish	SPDES requirement
EDTO Bypass Sump	Temperature, pH	Annually	Grab	SPDES requirement
EDTO Hydro Sump	Temperature, pH	Annually	Grab	SPDES requirement

Data Analysis and Reporting

Data are reported to New York State in DMRs, as per SPDES permits.

2.6.6 Monitoring of Acid Neutralization Tanks for Compliance with NPDES pre-treatment standards for Discharges to WWTPs

Monitoring of acid neutralization tanks occurs at laboratory locations which discharge to WWTPs for the purpose of maintaining compliance with National Pollutant Discharge Elimination System (NPDES) pretreatment standards.

Sites

Acid neutralization tanks to be monitored for NPDES pretreatment standards are specified in Table 2.27.

Sites

Table 2.27: Acid neutralization tank monitoring sites.

Site	Site Description	Reason for Site Selection
Grahamsville	Grahamsville Lab Acid Neutralization Tank	NPDES Pretreatment Standard
Kingston	Kingston Lab Acid Neutralization Tank	NPDES Pretreatment Standard
Hawthorne	Kensico Lab Acid Neutralization Tank	NPDES Pretreatment Standard

Analytes and Frequencies

Analytes and frequencies for monitoring acid neutralization tanks are specified in Table 2.28.

Table 2.28: Acid neutralization tank monitoring analyte(s) and frequency.

Site	Analyte(s)	Frequency
Grahamsville	pH	Quarterly
Kingston	pH, metals	Quarterly
Hawthorne	pH	Quarterly

2.6.7 Ashokan Release Channel/Lower Esopus Stream Monitoring

Objective

This objective addresses the requirement to monitor the Ashokan Release Channel in accordance with the DEC approved Ashokan Interim Release Protocols.

Sites

Sites for Ashokan release channel and lower Esopus stream monitoring are specified in Table 2.29.

Table 2.29: Ashokan Release Channel and Lower Esopus Stream monitoring sites.

Site Code[1]	Site Description	Reason for Site Selection
M-1	Ashokan Release Channel	Regulatory requirement
ASP	Ashokan East Basin Spill	Regulatory requirement
ASP M-1 CONF	Ashokan Spill and Release Channel confluence	Regulatory requirement
LEC AS	Lower Esopus Creek above Sawkill	Regulatory requirement
Saugerties Beach	Lower Esopus Creek upstream of Saugerties Dam	Regulatory requirement
Plattekill	Plattekill, near Esopus Creek	Ancillary data; not required
Sawkill	Sawkill, near Esopus Creek	Ancillary data; not required

[1] If release channel is in operation, samples at Plattekill, Sawkill, M-1, LEC AS and Saugerties Beach are sampled. If Ashokan East Basin is spilling ASP and ASP M-1 CONF are monitored as well.

Analytes and Frequencies

Analytes and frequencies for monitoring Ashokan Release Channel/Lower Esopus Stream are specified in Table 2.30.

Table 2.30: Ashokan Release Channel/Lower Esopus analytes and frequency of monitoring.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Turbidity, temperature, total suspended solids, fecal coliform[2]	Weekly	Requirement of Ashokan Interim Release Protocol

[1] Samples collected when release channel is operational.

[2] Fecal coliforms are only collected at M-1 and, if spilling, at ASP.

Data Analysis and Reporting

The Ashokan Reservoir Release Report is issued weekly to DEC et al.

3. FAD Program Evaluation

New York City's water supply is one of the few large water supplies in the country that qualifies for Filtration Avoidance, based on objective water quality criteria and its watershed protection program. Given this status, USEPA has specified many other requirements in the Revised 2007 Filtration Avoidance Determination (FAD) (NYSDOH 2014) that must be met to protect public health. Watershed monitoring is addressed in Section 5.1 of the FAD, which states that "Over the longer term, the data generated through the City's monitoring program, in conjunction with other defensible scientific findings, are used to assess water quality status, water quality trends, and the overall effectiveness of the watershed protection program". This chapter is devoted to the monitoring required to meet the conditions of the FAD. These objectives form the basis for the City's ongoing assessment of watershed conditions, changes in water quality, and ultimately any modifications to the strategies, management, and policies of the watershed protection program (DEP 2011a).

The Revised 2007 FAD also requires that DEP conduct a watershed-wide monitoring program in accordance with Section 2.4.1 of DEP's Long-Term Watershed Protection Plan (DEP 2011b) and the milestones therein. The goals of this program include:

- Provide water quality results for keypoints (i.e., aqueduct locations), streams, and reservoirs collected through routine programs to guide operations, assess compliance, and provide comparisons with established benchmarks. Describe these results and ongoing research activities in Watershed Water Quality Annual Reports.
- Use water quality data to evaluate the source and fate of pollutants, and the effectiveness of watershed protection efforts at controlling pollutants. Provide a comprehensive evaluation of watershed water quality status and trends and other research activities to support assessment of the effectiveness of watershed protection programs.
- Actively participate in forums (e.g., seminars, discussion groups) for the exchange of information between DEP and outside agencies regarding watershed research activities and pathogen investigative work.
- Coordinate a technical working group on pathogen studies to discuss the latest research on pathogen sources, transport, and fate in the environment; effectiveness of management practices in reducing pathogen concentrations; and identifying additional monitoring and/or research needs.
- Provide after-action reports on all chemical treatment activities and other significant or unusual events.

The objectives described in this chapter are designed to provide the information needed to meet these goals and conduct the assessments of DEP's watershed protection programs. This will be accomplished by targeting specific watershed protection programs and examining overall status and trends of water quality in the water supply, which represent the cumulative effects of land use and DEP's watershed protection and remediation programs. The ultimate goal of these programs is to maintain the status of the City's water supply, as one of the few large unfiltered systems in the nation, far into the future.

References

DEP 2011a. 2011 Watershed Protection Program Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 384 p.

DEP. 2011b. 2011 Long-Term Watershed Protection Plan. Valhalla, NY. 92 p.

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nycfad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

3.1 FAD-Mandated Assessment of BMPs

3.1.1 Water Quality Improvements in Catskill Mountain Streams for Stream Management Plans

Objective

The objective of this program is to determine the effectiveness of best management practices (BMPs) used by DEP's Stream Management Program to address the turbidity and suspended sediment problems observed in Catskill Mountain streams. Together, turbidity and suspended sediment represent one of the challenging water quality issues facing DEP, so evaluating the effectiveness of methods intended to reduce them is important.

Background

The goal of DEP's Stream Management Program is to restore stream system stability and ecological integrity by:

- integrating stream management across watershed stream sub-basins, rather than at isolated erosion sites.
- integrating multiple objectives, like minimizing flood hazards, increasing fish habitat, and improving water quality.
- involving local communities, organizations, and affected landowners.
- using the science of river physical processes, called fluvial geomorphology, as the basis for management decisions.

A major goal of this objective is to determine the effectiveness of these management plans to reduce turbidity and suspended sediments. In order to accomplish this, appropriate sites must be chosen. Previous studies have shown that Stony Clove delivers a significant quantity of suspended sediment and turbid water to Esopus Creek, the main inflow to Ashokan Reservoir. This study will attempt to quantify any change in turbidity and sediment load which might occur due to the installation of these BMPs. This will be done by monitoring water quality above and below the sediment source area, before and after BMP installation.

DEP will establish monitoring at the Stream Management Program BMP site at Stony Clove in the Ashokan watershed. This stream will also be sampled above and below a restoration project before and after its implementation (Table 3.1). The Stony Clove BMP will be evaluated using all the analytes set forth in Table 3.2.

Sites

Table 3.1: Stream sample sites for Catskill/Delaware System BMP assessment.

Site Code	Site Description
SCL-A	Stony Clove upstream of the BMP zone.
SCL-B	Stony Clove downstream of the BMP zone.
Warner	Warner Creek, immediately upstream of confluence with Stony Clove, and within BMP zone.

Analytes and Frequencies

Table 3.2: Analytes for Catskill/Delaware System BMP assessment.

Analyte	Sampling Frequency	Rationale for Analyte
Total suspended solids (TSS)	Monthly+ Storm Events	To assess BMP effectiveness in reducing turbidity and suspended solids
Turbidity	Monthly + Storm Events	To assess BMP effectiveness in reducing turbidity and suspended solids
Turbidity	Continuous	To assess BMP effectiveness in reducing turbidity and suspended solids
Temperature	Continuous	Needed to assist with above assessments
Flow (USGS and WQD)[1]	Continuous	Needed to assist with above assessments

[1] If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow.

Data Analysis and Reporting

The data will be analyzed to determine if the BMP has a measurable impact on TSS and turbidity in the stream. Sediment load and turbidity quasi-loads will be calculated for selected high runoff event (rain storm, snowmelt, etc.) for which samples are analyzed. The "instantaneous" load is calculated for each sample analyzed, then summed to obtain total storm load. If there is no difference between the loads from different sites, the ratio of the sites would equal one. If the load is higher at the downstream site, then the ratio is greater than one. If the BMPs are effective, this ratio will decrease. The more effective the BMPs, the closer to one the ratio will become. The results from this monitoring will be reported in the FAD Program Summary and Assessment Report.

3.2 FAD Program Summary and Assessment

3.2.1 Status of Stream Water Quality

Objective

This monitoring effort is intended to assess current water quality conditions (i.e., status) for streams in the NYC water supply watershed. The water quality results from this program will be used to assess compliance and provide comparisons with established benchmarks.

Stream water quality sampling.

Background

The 2011 Long-Term Watershed Protection Plan (DEP 2011b) states that one of the goals of the Watershed Monitoring Program is to provide routine water quality data for keypoint, stream, reservoir, and pathogen sampling sites to guide operations, assess compliance, and provide comparisons with established benchmarks. Also, the NYC Watershed Rules and Regulations (which are officially titled Rules and Regulations for the Protection from Contamination, Degradation and Pollution of the New York City Water Supply and its Sources) (DEP 2010) state that: "It is the intention of the Department that the system specific characteristics be maintained at the stated levels by implementation and enforcement of these rules and regulations." The stated levels for reservoir stems (watercourse segments tributary to a reservoir and lying within 500 feet or less of the reservoir) are provided in Appendix IX.

Sites

Site selection for this objective focus primarily on reservoir inflows. These sites generally serve as "integrator" sites, which means the water quality is determined by the cumulative effects of various land uses, geochemical processes, and watershed remediation programs located upstream of the site. In addition, these sites serve as reservoir stem samples (main inflow) to assist in determining whether the system-specific characteristics are maintained at the levels stated in the NYC Watershed Rules and Regulations (WR&R). Table 3.3 provides the locations of the sites.

Table 3.3: Stream water quality status sites.

Site Code	Site Description	Reason for Site Selection
E10I	Bushkill	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
E16I	Esopus Creek at Coldbrook	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
E5	Esopus Creek at Allaben	Data are used in WQD Annual Report to assess status in regard to WR&R.
SRR2CM	Diversion from Schoharie Reservoir	Data are used in WQD Annual Report to assess status in regard to WR&R.
S5I	Schoharie Creek at Prattsville	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
S6I	Bear Kill at Hardenburgh Falls	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
S7I	Manor Kill	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
P-21	Platte Kill at Dunraven	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
P-60	Mill Brook near Dunraven	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
P-7	Terry Clove above Pepacton Reservoir	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
P-8	Fall Clove above Pepacton Reservoir	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
P-13	Tremper Kill above Pepacton Reservoir	Data are used in the Watershed Protection Program Summary and Assessment report.

Table 3.3: (Continued) Stream water quality status sites.

Site Code	Site Description	Reason for Site Selection
PMSB	East Branch Delaware River at Margaretville	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
NCG	Neversink River near Claryville	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
NK4	Aden Brook above Neversink Reservoir	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
NK6	Kramer Brook above Neversink Reservoir	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
RD1	Sugarloaf Brook at Lowes Corners	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
RD4	Sawkill Brook near Yagerville	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
RDOA	Rondout Creek near Lowes Corners	Data are used in WQD Annual, Watershed Protection Program Summary and Assessment reports.
RGA	Chestnut Creek above Grahamsville WWTP	Data are used in WQD Annual, Watershed Protection Program Summary and Assessment reports.
RGB	Chestnut Creek below Grahamsville WWTP	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
C-7	Trout Creek above Cannonsville Reservoir	Data are used in the Watershed Protection Program Summary and Assessment report.
C-8	Loomis Brook above Cannonsville Reservoir	Data are used in the Watershed Protection Program Summary and Assessment report.
WDBN	West Branch Delaware River at Beerston Bridge	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.

Table 3.3: (Continued) Stream water quality status sites.

Site Code	Site Description	Reason for Site Selection
BOYDR	West Branch Croton River below dam near Kent Cliffs (Boyd Corners outflow)	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
CROFALLSVC	Croton Falls Reservoir Release	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
CROSS2	Cross River near Cross River	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
CROSSRVVC	Cross River Reservoir Release	Data are used in WQD Annual Report to assess status in regard to WR&R and are also used in the Watershed Protection Program Summary and Assessment report.
GYPSYTRL1	Gypsy Trail Brook	Inflow to reservoir.
HORSEPD12	Horse Pound Brook	Inflow to reservoir.
LONGPD1	Long Pond outflow	Inflow to reservoir.
MIKE2	Michael Brook	Inflow to reservoir.
WESTBR7	West Branch Croton River at Richardsville. Input to CBC.	Inflow to reservoir. Data are used in WQD Annual Report to assess status in regard to WR&R.
WESTBRR	West Branch Croton River near Carmel (West Branch outflow)	Data are used in WQD Annual Report to assess status in regard to WR&R.

Analytes and Frequencies

Water quality will be assessed by examining those analytes considered to be the most significant for the City water supply. These include turbidity (where values may not exceed Surface Water Treatment Rule (SWTR) limits), total phosphorus (for nutrient/eutrophication issues), and fecal coliform bacteria (where values may not exceed SWTR limits). In addition, analytes (or appropriate surrogates) specifically listed in Appendix 18-B of the WR&R are included for analysis. Sampling will be conducted on a monthly basis to address seasonal differences. However, as indicated by Table 3.4, some analytes will only be analyzed quarterly, where a review of previous data indicate a lack of seasonality.

Table 3.4: Stream water quality status analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Flow (USGS)[1]	Continuous	Explanatory variable needed for interpretation of water quality concentrations.
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system-specific characteristic in the WR&R.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water.
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity. Included as a system-specific characteristic in the WR&R.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids, which is included as a system-specific characteristic in the WR&R.
Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard.
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport. Included as a system-specific characteristic in the WR&R.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biological chemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures. Included as a system-specific characteristic in the WR&R.
Dissolved SO_4	Quarterly	End product of acid deposition. Included as a system-specific characteristic in the WR&R.

Table 3.4: (Continued) Stream water quality status analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Dissolved K	Quarterly	Na/K ratio used to determine and characterize hydrologic flow path
Dissolved Mg	Quarterly	Ca/Mg ratio used to determine and characterize hydrologic flow path
Dissolved Na	Quarterly	Major component of road salt. Included as a system-specific characteristic in the WR&R.
Dissolved Ca	Quarterly	Essential mineral for zebra mussels, Ca depletions observed in forested catchments
DOC	Monthly	Major source of energy to heterotrophic food webs.
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement. Included as a system-specific characteristic in the WR&R.
NO_x-N	Monthly	Essential aquatic life requirement. Included as a system-specific characteristic in the WR&R.
Total Dissolved N	Monthly	Pool of organic and inorganic dissolved N species
Total N	Monthly	Total pool of dissolved and particulate N. Will be used to estimate organic nitrogen, which is included as a system-specific characteristic in the WR&R.
Total Dissolved P	Monthly	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
Total P	Monthly	Pool of dissolved and particulate P
SRP	Monthly	Dissolved reactive P, most readily biologically available

[1]If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow.

Data Analysis and Reporting

Water quality results from the routine monitoring programs, including this objective, are presented yearly in the Watershed Water Quality Annual Report, which is a FAD requirement. A more rigorous evaluation of the routine monitoring data, including the appraisal of current water quality status and long-term water quality trends to demonstrate the effectiveness of ongoing watershed protection efforts, is presented in the Watershed Protection Program Summary and Assessment report. This document is produced every five years and is also a FAD requirement.

References

DEP. 2011b. 2011 Long-Term Watershed Protection Plan. Valhalla, NY. 92 p.

DEP. 2010. New York City Watershed Rules and Regulations. 1997, amended April 4, 2010. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf. (Accessed 12/10/14)

3.2.2 Status of Reservoir Water Quality

Objective

The objective is to assess current water quality conditions (i.e., status) for each NYC water supply reservoir located in a Catskill/Delaware Basin or potential Catskill/Delaware Basin. Status will be determined by evaluation of seasonal and spatial water quality patterns and by comparison with appropriate water quality benchmarks. This information will be used to identify the location and extent of degraded water within each water-body.

Background

The comparison of results to water quality standards, to a reference condition, or to some other benchmark is a common approach to evaluate current conditions in water quality monitoring systems (Ward et al. 2003). The evaluation of current conditions has many benefits, including (1) identification of water quality problems, (2) management planning, (3) regulatory assessments, and (4) project evaluations (Gibson et. al 2000).

As noted in the previous objective, an evaluation of status was required by the 2007 FAD (USEPA 2007). These requirements were met by the Watershed Protection Summary and Assessment reports in 2001 (DEP 2001), 2006 (DEP 2006), and 2011(DEP 2011a). The Revised 2007 FAD (NYSDOH 2014) requires continued analysis of status, with a report to be issued in 2016.

In addition, as per Section 18-48 of the Rules and Regulations for the Protection from Contamination, Degradation and Pollution of the New York City Water Supply and its Sources (DEP 2010), the DEP is required, on an annual basis, to determine if each reservoir and controlled lake meets the water quality goals listed in Appendix IX. To provide a more comprehensive assessment, DEP will evaluate additional analytes, although in some cases appropriate benchmarks have not yet been determined.

Sites

Samples are to be collected at each of the sites listed in Table 3.5. Because water quality analytes in reservoirs have considerable spatial variability, this sampling scheme is designed to produce an accurate assessment for each reservoir while still allowing analysis of individual strata (i.e., depths, sites) (Gaugush 1987). Status of individual or grouped strata is used to specify the location and extent of problems and to evaluate causality.

Table 3.5: Reservoir sampling sites for assessment of status.

Reservoir	Sites							
Catskill								
Ashokan	1EAW	2EAW	3EAW	4EAE	5EAE	6EAE		
Schoharie	1SS	2SS[1]	3SS	4SS				
Delaware								
Cannonsville	1WDC		3WDC	4WDC	5WDC	6WDC		
Pepacton	1EDP		3EDP	4EDP	5EDP	6EDP		
Neversink	1NN	2NN		4NN				
Rondout	1RR	2RR	3RR					
East of Hudson								
Kensico	1.1BRK	2BRK	2.9BRK	4BRK	5BRK	6BRK	7BRK	8BRK
Cross River	1.1CCR		3CCR					
Croton Falls	1.1CCF		3CCF		5CCF			
West Branch	1CWB	2CWB	3CWB	4CWB				
Boyd Corners	1.1CBC	2CBC[2]	3CBC[1]					

[1] These sites are not sampled for filtered nutrients or DOC.

[2] These sites are only sampled for fecal coliform.

The protocol for determining sampling depth is described in Appendix II. Depending on depth, one to four samples will be collected in the water column in order to represent the thermal zones. Analytes measured in situ (i.e., pH, specific conductivity, temperature, and dissolved oxygen) will be collected through the water column in 1-meter increments, but can be measured at 5-meter increments and all discrete sample depths after the loss of the thermocline in the fall.

Analytes and Frequencies

A list of analytes and reasons for their inclusion is provided in Table 3.6. Analytes that are only collected at certain depths, sites, or months (e.g., chlorophyll) are specified in the footnotes, while major cations and anions are specified in the title to Table 3.7. In general, samples will be collected monthly from April through November for each analyte unless otherwise noted. To avoid increases in temporal variability, efforts should be made to maintain a consistent time interval between sampling events.

Table 3.6: List of analytes for reservoir status objective.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Data provided by WQD:		
Color	Monthly (Apr.–Nov.)	Early alert to potential contravention of NYS health standard (SDWA)
Secchi depth, Z_{VB}	Monthly (Apr.–Nov.)	Indicator of water clarity, used to assess trophic state
Photic depth[2], I_Z	Monthly (Apr.–Nov.)	Identifies zone of active primary production
pH	Monthly (Apr.–Nov.)	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Temperature	Monthly (Apr.–Nov.)	Important in the regulation of biotic community structure and function, critical in regulating the chemical composition of water, regulates reservoir processes and distribution of constituents
Specific Conductivity	Monthly (Apr.–Nov.)	Measured surrogate for total inorganic ions
Turbidity	Monthly (Apr.–Nov.)	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard and to manage for compliance with SDWA standards
TSS[3]	Monthly (Apr.–Nov.)	Interferes with disinfecting processes, mechanism of pathogen transport, cause of decrease in clarity
Dissolved Oxygen	Monthly (Apr.–Nov.)	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/ Part 703 water quality standard
Dissolved Silica[4]	Monthly (Apr.–Nov.)	Essential requirement for diatoms
Dissolved Chloride[5]	May, August, November	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[5]	May, August, November	End product of acid deposition, source of S^{-2} during anoxia
Dissolved K[5]	May, August, November	Na/K ratio used to determine and characterize hydrologic flow path
Dissolved Mg[5]	May, August, November	Ca/Mg ratio used to determine and characterize hydrologic flow path

Table 3.6: (Continued) List of analytes for reservoir status objective.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Dissolved Na[5]	May, August, November	Major component of road salt
Dissolved Ca[5]	May, August, November	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity	May, August, November	A measurement of acid neutralizing capacity, buffering capacity, needed for chemical treatment activities
DOC	Monthly (Apr.–Nov.)	Major source of energy to heterotrophic food webs, provides insight into THM formation potential, potential source of color in humic waters
Fecal Coliform	Monthly (Apr.–Nov.)	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard, and to manage for compliance with SDWA standards
Total Coliform	Monthly (Apr.–Nov.)	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard, and to manage for compliance with SDWA standards
Chl *a*[6]	Monthly (Apr.–Nov.)	Useful in assessing primary productivity and trophic state
Phytoplankton[6]	Monthly (Apr.–Nov.)	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards
NH3-N	Monthly (Apr.–Nov.)	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement, indicative of anoxic conditions during which the toxic form (free ammonia) is produced.
NO_x-N	Monthly (Apr.–Nov.)	Essential aquatic life requirement
Total Dissolved Nitrogen (TDN)	Monthly (Apr.–Nov.)	Pool of organic and inorganic dissolved N species
Total Nitrogen (TN)	Monthly (Apr.–Nov.)	Total pool of dissolved and particulate N

Table 3.6: (Continued) List of analytes for reservoir status objective.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Total Dissolved Phosphorus (TDP)	Monthly (Apr.–Nov.)	Measurement of dissolved reactive phosphorus and dissolved organic and dissolved complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).This provides organic + complex inorganic P, also considered to be the total pool of biologically available P.
Total Phosphorus (TP)	Monthly (Apr.–Nov.)	Pool of dissolved and particulate P
Soluble Reactive Phosphorus (SRP)	Monthly (Apr.–Nov.)	Dissolved reactive P, most readily biologically available (almost exclusively inorganic P)
Data provided by Operations:		
Reservoir Elevation	Daily	Explanatory variable used to assist in interpretation of water quality variables
Total Storage	Daily	Explanatory variable used to assist in interpretation of water quality variables
Release Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables
Spill Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables
Diversion Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables

[1] In general, samples will be collected monthly from April through November for each analyte unless otherwise noted.

[2] Photic depth to be measured at sites 4WDC, 3EDP, 2NN, 1RR, 1SS, 1EAW, 5EAE, 1CWB and 1.1BRK.

[3] TSS analyzed monthly at dam and intake sites for Delaware District reservoirs and Kensico Reservoir, and at all sites and depths for Catskill District reservoirs. TSS to be analyzed quarterly at dam site for CWB.

[4] Si to be analyzed monthly at WOH reservoir dam sites only.

[5] Filtered: Ca, Na, K, Mg, Cl, SO_4. Samples collected in May, August, and November. See Table 3.7.

[6] Chlorophyll *a* and phytoplankton collected at depth of 3 meters. Total phytoplankton includes the total count, the first dominant genus and count, and the second dominant genus and count.

Table 3.7: Quarterly major cations, alkalinity, chloride, and sulfate for reservoir status objective.

District	Reservoir	Sites
West of Hudson	Cannonsville	3, 5
	Pepacton	1, 5
	Neversink	2
	Rondout	1
	Ashokan	1, 5
	Schoharie	1
East of Hudson	Kensico	1.1, 4
	West Branch	1, 4
	Boyd Corners	1.1
	Croton Falls	1.1, 3
	Cross River	1.1

Data Analysis and Reporting

Reservoir status will be evaluated by comparing results from each sampling stratum to its appropriate water quality benchmark listed in Appendix IX. Compliance with the benchmarks shall be measured in terms of the fraction of observations which do not meet the benchmark (i.e., excursions). The patterns of excursion occurrence will be described in the discussion of results.

Status will be determined annually and reported in the Department's Watershed Water Quality Annual Report due each July. In addition, a five-year compilation of the annual assessments will be provided in the Department's Watershed Protection Summary and Assessment reports in fulfillment of the the Revised 2007 FAD. Reports have been issued in 2001 (DEP2001), 2006 (DEP2006), and in 2011 (DEP 2011a). The next report is due in 2016.

References

DEP. 2001. New York City's 2001 Watershed Protection Program Summary, Assessment and Long-term Plan. New York City Department of Environmental Protection. Division of Water Quality Control. Valhalla, New York. 634 p.

DEP. 2006. 2006 Watershed Protection Program: Summary and Assessment. New York City Department of Environmental Protection. Valhalla, New York. 464 p.

DEP. 2010. New York City Watershed Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf. (Accessed 12/10/14)

DEP. 2011a. 2011 Watershed Protection Program: Summary and Assessment. New York City Department of Environmental Protection. Valhalla, New York. 384 p.

Gaugush, R.F. 1987. "Sampling Design for Reservoir Water Quality Investigations." Instruction Report E-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Gibson, G., R. Carlson, J. Simpson, E. Smeltzer, J. Gerritson, S. Chapra, S. Heiskary, J. Jones, R. Kennedy. 2000. Nutrient Criteria Technical Guidance Manual–Lakes and Reservoirs. First Edition. USEPA-822-B00-001. U.S. Environmental Protection Agency. Office of Water, Office of Science and Technology. Washington, DC.

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

USEPA [U. S. Environmental Protection Agency]. 2007. New York City Filtration Avoidance Determination. 92 p.

Ward, R.C., J.C. Loftis and G.B. McBride. 2003. Design of Water Quality Monitoring Systems. John Wiley and Sons, Inc. Hoboken, New Jersey.

3.2.3 Status of Keypoint Water Quality

Objective

This monitoring effort is intended to assess current water quality conditions (i.e., status) for keypoints in the NYC water supply watersheds. (Keypoints are sampling locations where water enters or leaves an aqueduct.). The water quality data collected will be used to assess compliance and provide comparisons with established benchmarks.

Background

DEP's Long-Term Watershed Protection Program (DEP 2011b) states that one of the goals of DEP's Watershed Monitoring Program is to collect routine water quality data for keypoint, stream, and reservoir sites to assess compliance and provide comparisons with established benchmarks.

Sites

The sites identified to assess current water quality conditions (i.e., status) for keypoints in the NYC water supply watersheds are listed in Table 3.8.

Table 3.8: Keypoint water quality sites.

Site Code	Site Description
RDRRCM	Rondout Reservoir effluent
NRR2CM	Neversink Tunnel Outlet (Neversink Reservoir effluent)
PRR2CM	East Delaware Tunnel Outlet (Pepacton Reservoir effluent)
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent)
EARCM	Ashokan Reservoir—raw effluent
SRR2CM	Portal (Shandaken Tunnel Outlet into Esopus Creek)
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.

Table 3.8: (Continued) Keypoint water quality sites.

Site Code	Site Description
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.
DEL17	Delaware Aqueduct, sampled at Shaft 17 uptake, influent to Kensico Reservoir.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL18DT	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.

Analytes and Frequencies

Table 3.9: Keypoint analytes and sampling frequency.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Color	M	Aesthetics
Scent	M	Aesthetics. Taste and odor concerns.
pH	M, C	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system-specific characteristic in the WR&R.
Specific Conductivity	M, C	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Temperature	M, C	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water.
Turbidity	M	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard
TSS	M	Interferes with disinfecting processes, mechanism of pathogen transport.
Alkalinity	M	A measurement of acid neutralizing capacity, buffering capacity.
Dissolved Chloride	Q	Major component of road salt, indicator of septic system failures.
Dissolved SO_4	Q	End product of acid deposition.
Dissolved K	Q	Na/K ratio used to determine and characterize hydrologic flow path

Table 3.9: (Continued) Keypoint analytes and sampling frequency.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Dissolved Mg	Q	Ca/Mg ratio used to determine and characterize hydrologic flow path
Dissolved Na	Q	Major component of road salt.
Dissolved Ca	Q	Essential mineral for zebra mussels, Ca depletions observed in forested catchments
DOC	M	Major source of energy to heterotrophic food webs.
NH_3-N	M	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement.
NO_x-N	M	Essential aquatic life requirement. Included as a system-specific characteristic in the WR&R.
Total Dissolved N	M	Pool of organic and inorganic dissolved N species
Total N	M	Total pool of dissolved and particulate N. Will be used to estimate organic nitrogen.
SRP	M	Dissolved reactive P, most readily biologically available
Total Dissolved P	M	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
Total P	M	Pool of dissolved and particulate P
Chlorophyll *a*	M[2]	Useful in assessing primary production and trophic state.
Total Coliform and Fecal Coliform	M	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation, Part 703 water quality standard
Total Phytoplankton and Dominant Genus	M	General indicator of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards

[1]Samples to be collected only when aqueduct is operational.
[2]April-November only.
C = Continuous
M = Monthly.
Q = Quarterly (February, May, August, November).

Data Analysis and Reporting

Water quality results from the routine monitoring programs, including this objective, are presented yearly in the Watershed Water Quality Annual Report, which is a FAD requirement. A more rigorous evaluation of the routine monitoring data, including the appraisal of current water quality status and long-term water quality trends to demonstrate the effectiveness of ongoing watershed protection efforts, is presented in the FAD Watershed Protection Program Summary and Assessment Report, which is produced every five years.

References

DEP. 2011b. 2011 Long-Term Watershed Protection Plan. Valhalla, NY. 92 p.

3.2.4 Biological Status of Benthic Invertebrates

Objective

Data obtained from the sampling, identification, and counting of benthic macroinvertebrates are used to monitor the ecological integrity of watershed streams, and to detect impacts of land use changes, development schemes, and point sources of pollution. Addendum E to the DEC/DEP Memorandum of Understanding (1997) specifies that if biomonitoring performed by DEP detects moderate to severe impacts in a stream reach, water quality in that reach will be considered adversely impacted. The results of adverse impact are reported annually and recommendations for remedial actions presented to the Watershed Enforcement Coordinating Committee (WECC).

Background

Benthic macroinvertebrate sampling.

Biological sampling of stream benthic communities was first undertaken in 1994, using protocols developed by the NYS Stream Biomonitoring Unit (NYSDEC 2014, DEP 2001). Benthic macroinvertebrates are collected from watershed streams using a kick net, identified, and counted, and the resulting data used to generate a series of metrics from which a Biological Assessment Profile is derived. The Profile's categories are non-impaired, slightly impaired, moderately impaired, and severely impaired. The majority of streams West of Hudson assess as non-impaired. Biomonitoring data have been used for a variety of purposes, among them the evaluation of the impact of Shandaken Tunnel discharges to the aquatic biota of

Esopus Creek, and documentation of the successful recolonization of Aden Brook following removal of riparian vegetation and riprapping of the streambank in the wake of damage caused by Hurricane Floyd.

Sites

To assess the status of benthic macroinvertebrates in watershed streams, sites have been established covering a wide geographic area and representing a broad array of physical and chemical conditions (Table 3.10 and Figures 3.1 and 3.2). Specific criteria considered when choosing these sites include:

1. Are there suspected water quality impacts from an existing pollution source?
2. Are land use changes or BMPs proposed or underway in the vicinity of the site which could change the character of the stream to a degree detectable by qualitative sampling of the benthos?
3. Is routine DEP water quality sampling conducted near the site, which would help explain the presence of the particular biological assemblage found there?
4. Is the site representative of relatively unimpaired and/or pristine (reference) conditions for the District?
5. May the site contain or has it been shown in the past to contain rare taxa?

New sites may be added to address specific water quality concerns. The new sites will be submitted in the year of implementation as an addendum to the WWQMP.

Table 3.10: Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
117	Whippoorwill Creek at WHIP	Inflow to reservoir; assess impacts to benthic macroinvertebrate community of stream stabilization project; rare taxa present; presence of nearby water quality sampling site	Year 1
123	Cross River in Ward Pound Ridge Reservation	Site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District; presence of nearby water quality sampling site; inflow to reservoir	Year 3
130	Michael Brook at MIKE2	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes; presence of nearby water quality sampling site	Year 2

Table 3.10: (Continued) Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
131	Gypsy Trail Brook upstream of GYPSYTRL1	Site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District; presence of nearby water quality sampling site	Year 2
133	Long Pond outflow at LONGPD1	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes; presence of nearby water quality sampling site; inflow to reservoir	Year 2
137	West Branch Croton River at WESTBR7	West Branch Croton River, immediately upstream of Boyd Corners Reservoir; main inflow site; presence of nearby water quality sampling site	Year 4
145	West Branch Croton River at Sagamore Lake inflow	West Branch Croton River headwaters; site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District	Year 4
150	Unnamed tributary to Croton Falls Reservoir	Examination of impacts to benthic macroinvertebrate community from land use changes; inflow to reservoir	Year 2
155	Whippoorwill Creek	Inflow to reservoir; assess impacts to benthic macroinvertebrate community of stream stabilization project; rare taxa present;	Year 1
203	Butternut Creek	Inflow to reservoir	Year 3
207	East Kill at SEK	Mainstem tributary; presence of nearby water quality sampling site	Year 4
210	Bear Kill below Grand Gorge WWTP	Examination of impacts to benthic macroinvertebrate community from pollution sources; inflow to reservoir	Year 4
213	Esopus Creek at E16I	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes	Year 2
217	Stony Clove at SCL	Examination of impacts to benthic macroinvertebrate community from pollution sources; presence of nearby water quality sampling site; mainstem tributary	Year 2

Table 3.10: (Continued) Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
218	Beaver Kill at BK	Examination of impacts to benthic macroinvertebrate community from pollution sources; presence of nearby water quality sampling site; mainstem tributary	Year 2
223	West Kill at SWK	Examination of impacts to benthic macroinvertebrate community from pollution sources; presence of nearby water quality sampling site; mainstem tributary	Year 4
224	Birch Creek near E3	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes	Year 2
232	Seneca Hollow at SENECA	Control stream for Crossroads Ventures sampling project	Year 1
237	Schoharie Creek at Elka Park Road	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 5
238	Schoharie Creek, west of Rt. 214	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 5
240	Schoharie Creek, west of Rt. 42/23A intersection	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 5
242	Schoharie Creek, east of Airport Road/Rt. 23A intersection	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 5
243	Little Beaver Kill near LBK	Mainstem tributary; rare taxa present	Year 3
246	Bush Kill at E10I	Inflow to reservoir; presence of nearby water quality sampling site	Year 2
251	Sugarloaf Brook at SSHG	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 4
252	Bushnellville Creek at BNV	Mainstem tributary; presence of nearby water quality sampling site	Year 3

Table 3.10: (Continued) Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
253	Mink Hollow	Headwater reference site	Year 3
254	Batavia Kill at S10-RF	Site was examined to assist in determining source of impacts to downstream Site 206	Year 1[1]
255	Esopus Creek above BK	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes	Year 2
256	Esopus Creek downstream of Big Indian	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes	Year 3
260	Esopus Creek at AEHG	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes; headwater reference site; presence of nearby water quality sampling site	Year 3
265	Esopus Creek downstream of the Shandaken Tunnel	Examination of impacts to benthic macroinvertebrate community from operation of the Shandaken Tunnel	Year 1
266	Esopus Creek upstream of confluence with Woodland Valley Creek	Examination of impacts to benthic macroinvertebrate community from operation of the Shandaken Tunnel	Year 1
267	Esopus Creek in Phoenicia	Examination of impacts to benthic macroinvertebrate community from operation of the Shandaken Tunnel	Year 1
268	Esopus Creek in Mt. Tremper	Examination of impacts to benthic macroinvertebrate community from operation of the Shandaken Tunnel	Year 1
302	West Branch Delaware River downstream of Delhi	Examination of impacts to benthic macroinvertebrate community in West Branch Delaware River from pollution sources and land use changes	Year 5
306	East Branch Delaware River at Cold Spring Road	Mainstem headwater	Year 5

Table 3.10: (Continued) Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
310	Rondout Creek at RDOA	Inflow to reservoir; presence of nearby water quality sampling site	Year 4
311	Kramer Brook downstream of NK6	Inflow to reservoir; presence of nearby water quality sampling site	Year 3
312	Neversink River at NCG	Inflow to reservoir; presence of nearby water quality sampling site	Year 3
313	West Branch Neversink River above confluence with mainstem	Major tributary to mainstem	Year 3
314	East Branch Neversink River above confluence with mainstem	Major tributary to mainstem; examination of impacts to benthic macroinvertebrate community from low pH	Year 3
315	Chestnut Creek near RGB	Inflow to reservoir; examination of impacts to benthic macroinvertebrates from wastewater treatment plant; presence of nearby water quality sampling site	Year 4
323	Batavia Kill upstream of P-50	Mainstem tributary; presence of nearby water quality sampling site	Year 2
324	Platte Kill at P-21	Inflow to reservoir; presence of nearby water quality sampling site	Year 2
325	Trout Creek at C-7	Inflow to reservoir; presence of nearby water quality sampling site	Year 1
326	Loomis Brook at C-8	Inflow to reservoir; presence of nearby water quality sampling site	Year 1
327	Tremper Kill at P-13	Inflow to reservoir; presence of nearby water quality sampling site	Year 2
328	Red Brook at RK	Tributary to Chestnut Creek	Year 4
333	Fall Clove at P-8	Inflow to reservoir; presence of nearby water quality sampling site	Year 2
334	Terry Clove at P-7	Inflow to reservoir; presence of nearby water quality sampling site	Year 2

Table 3.10: (Continued) Sites for assessment of biological status of benthic invertebrates in Catskill/Delaware System basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
335	Sawkill Brook at RD4	Inflow to reservoir; presence of nearby water quality sampling site	Year 4
336	West Branch Delaware River at Stamford	Headwater site; inflow to reservoir;	Year 1
339	Third Brook	Examination of impacts to benthic macroinvertebrate community from pollution sources; mainstem tributary	Year 1
340	Beers Brook	Mainstem tributary	Year 5
341	Emory Brook	Examination of impacts to benthic macroinvertebrate community from pollution sources; tributary to Bush Kill	Year 2
342	Mill Brook near P-60	Inflow to reservoir; presence of nearby water quality sampling site	Year 2
345	Tributary to Sherruck Brook	Tributary to reservoir inflow	Year 1
346	Little Delaware River upstream of CLDG	Mainstem tributary; presence of nearby water quality sampling site	Year 5
347	Sugarloaf Brook at RD1	Tributary to Rondout Creek; presence of nearby water quality sampling site	Year 4
348	Headwaters of East Brook at CEBHG	Site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District; presence of nearby water quality sampling site	Year 5
349	Headwaters of Little Delaware River at CCBHG	Site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District; presence of nearby water quality sampling site	Year 5

[1]Status sites are sampled on a 5-year rotating basis. Year 1 = 2015, Year 2 = 2016, Year 3 = 2017, Year 4 = 2018, Year 5 = 2019.

[2]Non-cyclical site. No further sampling is anticipated beyond 2015.

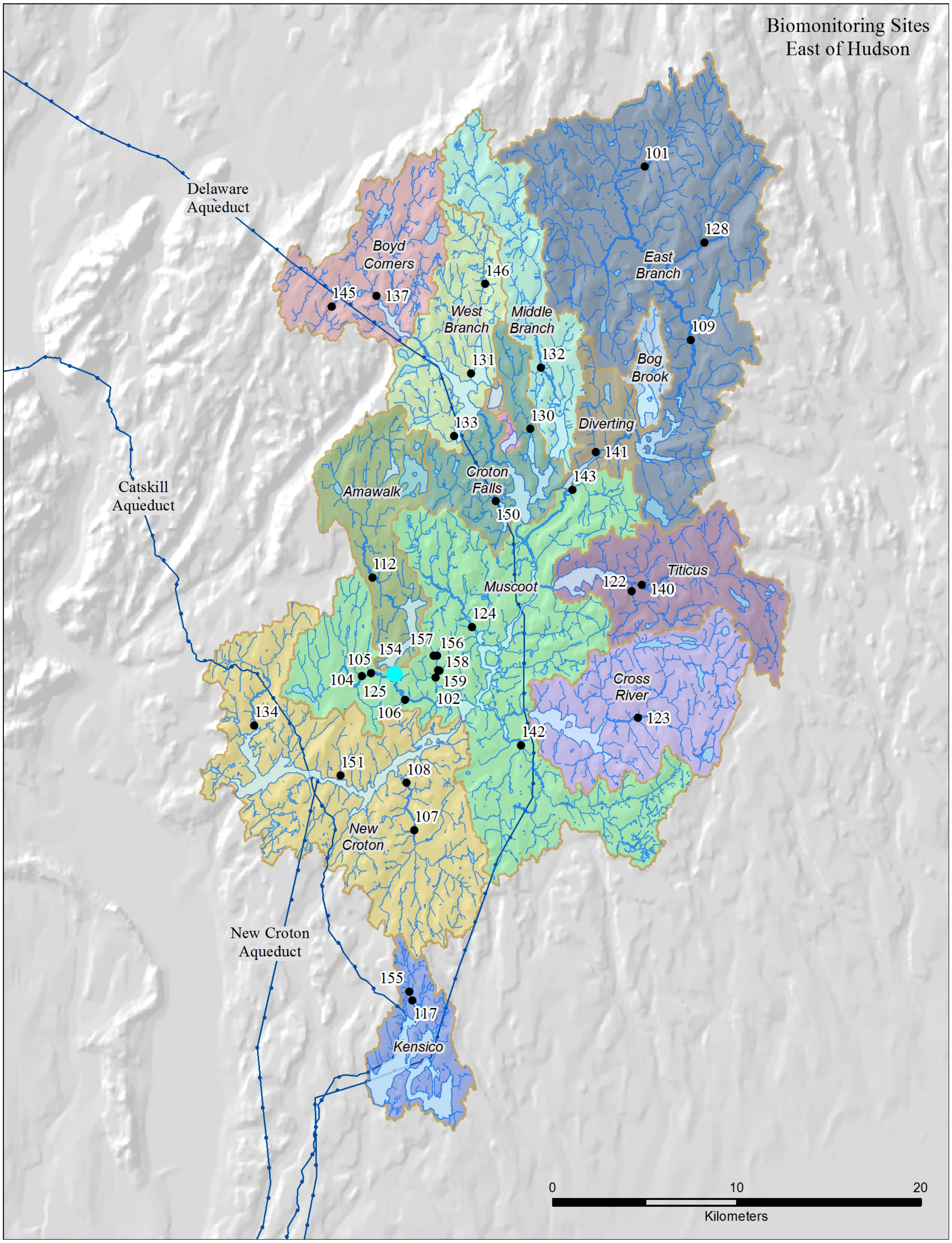


Figure 3.1 Biomonitoring sites, East of Hudson. Note that both FAD sites and surveillance sites (Ch. 5) are included.

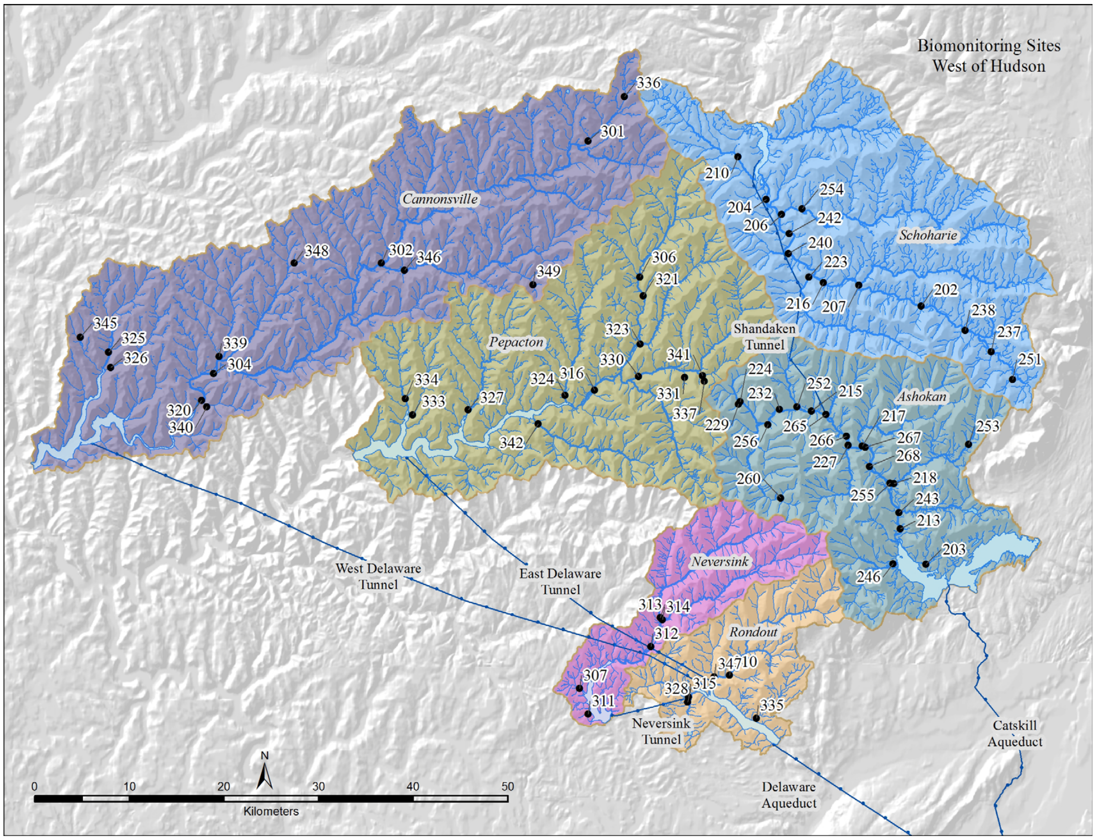


Figure 3.2 Biomonitoring sites, West of Hudson.

Analytes and Frequencies

Both biological and water quality analytes are measured. The biological "analyte" is a site's stream macroinvertebrate community. Samples are shipped to a contract laboratory, which subsamples the samples and identifies and enumerates the organisms found in the subsamples. From the tally of identified organisms, a series of metrics is generated (taxa richness; numbers of mayfly, caddisfly, and stonefly taxa present; Percent Model Affinity (a measure of the community's similarity to a model NYS stream community); the Hilsenhoff Biotic Index (a measure of organic pollution); and the Nutrient Biotic Index-Phosphorus (an indicator of nutrient enrichment in streams)), from which the site's Biological Profile Assessment is derived (DEP 2001). Changes to that assessment can be studied over time. The four analytes listed in Table 3.11 provide context for interpreting the invertebrate data. No additional sampling effort is required to collect these field analytes because in most cases collection occurs at the same time as biological sampling.

Table 3.11: Analytes for assessment of biological water quality status.

Analyte	Sampling frequency	Rationale for analyte
pH	Annually	Provides context for interpreting macroinvertebrate data
Dissolved oxygen	Annually	Provides context for interpreting macroinvertebrate data
Temperature	Annually	Provides context for interpreting macroinvertebrate data
Specific Conductivity	Annually	Provides context for interpreting macroinvertebrate data

Sites are sampled on a rotating basis, approximately once every five years, similar to NYSDEC's Rotating Intensive Basin Studies survey. While NYSDEC protocols provide for sampling anytime between July and September, DEP biomonitoring samples have historically been collected in September in the Catskill and Delaware watersheds.

Data Analysis and Reporting

Water quality results from this program are presented yearly in the Watershed Water Quality Annual Report, which is a FAD requirement. Additional reports will be issued as needed.

References

Addendum E to the Memorandum of Understanding Between the New York State Department of Environmental Conservation and the New York City Department of Environmental Protection Concerning the New York City Water Supply Watershed Protection Program. 1997. 7p.

NYSDEC [New York State Department of Environmental Conservation]. 2014. Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State. 171 p.

DEP. 2001. Quality Assurance Project Plan for Stream Benthic Macroinvertebrate Biomonitoring in the New York City Water Supply Watersheds. Valhalla, NY. 37 p.

3.2.5 Trends of Stream Water Quality

Objective

The objective is to collect data that will assist in determining long-term trends for the selected water quality analytes.

Background

DEP's Long-Term Watershed Protection Plan (DEP 2011b) states that one of the goals of DEP's Watershed Monitoring Program is to provide a comprehensive evaluation of watershed water quality status and trends and other research activities to support assessment of the effectiveness of watershed protection programs.

The intention of this objective is to be able to detect a monotonic trend for selected water quality analytes over a five-year period with reasonable confidence and power.

To ensure that trend analysis reflects environmental changes and not program changes, any planned method changes, such as equipment, filters, sampling, and analytical methods should be discussed by laboratory, field, and analysis personnel well in advance of implementation. The purpose of the discussion is to establish procedures for evaluating bias and precision. These procedures may include a period of side-by-side comparisons, review of ongoing quality control (QC), or a combination of the two. There should be a method overlap that includes an adequate number of samples to represent the expected concentration range.

Sites

Site locations have been chosen for a variety of reasons. Sites are selected to establish an indication of the cause of any trends detected such as FAD watershed programs. The selection is based on a wide distribution of current and predicted land use changes. They are selected on the main inputs as close as possible to the reservoir to provide an accurate indication of the trends. Sites have also been selected in appropriate contributing catchments to attempt to better establish causes of trends. Some sites high in the catchment are selected because they are presently little disturbed by humans and there is a high likelihood of minimal change in the future. These sites are affected mainly by meteorological events and other natural phenomena. Because flow measurement or assessment is required for all sites, a prerequisite for site location is an adjacent or nearby flow/stage recorder. Samples will be collected at or near a USGS gaging station. Flow at sample sites and sub-basins that do not have a USGS gaging station will be estimated via indexing to nearby sub-basins that do have a gaging station. Table 3.12 provides the details of the selected sites.

Table 3.12: Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
AEHG	Headwater of Esopus Creek	Small scale homogeneous forested catchment in the southwestern boundary of the Esopus basin.
ABCG	Birch Creek at Big Indian	Located at the downstream end of the Birch Creek sub-basin. This sub-basin differs from other sub-basins within the Esopus drainage with regard to land use. It contains the town center of Pine Hill and the Pine Hill Sewage Treatment Plant.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
BNV	Bushnellville Creek	Medium scale basin primarily forested. This sub-basin is broadly similar to and representative of several other sub-basins within the Esopus basin with regard to physiographic and demographic features.
E5	Esopus Creek at Allaben	Located on Esopus Creek at Allaben, this site divides the Upper Esopus Creek drainage from the lower Esopus Creek drainage. It represents an integrated site of moderate size and multiple land uses.
SRR2CM	Schoharie Reservoir Diversion	At times provides majority of water to Esopus Creek.
WDL	Woodland Valley Creek	Medium scale basin primarily forested. This sub-basin is broadly similar to and representative of several other sub-basins within the Esopus basin with regard to physiographic and demographic features.
BRD	Broad Street Hollow	Medium scale basin primarily forested. This sub-basin is broadly similar to and representative of several other sub-basins within the Esopus basin with regard to physiographic and demographic features.
ASCHG	Hollow Tree Brook near Lanesville (headwaters of Stony Clove)	Small scale homogeneous forested catchment in the northeastern boundary of the Esopus basin.
SCL	Stony Clove near Phoenicia	This sub-basin is broadly similar to and representative of several other sub-basins within the Esopus basin with regard to physiographic and demographic features.
BK	Beaver Kill	Medium scale basin of multiple land uses. This sub-basin is broadly similar to and representative of several other sub-basins within the Esopus basin with regard to physiographic and demographic features.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
LBK	Little Beaver Kill near Mt. Tremper	Located at the downstream end of the Little Beaver Kill sub-basin. This basin differs from other sub-basins within the Esopus drainage with regard to physiographic and demographic attributes. The basin possesses the greatest potential for urban development within this drainage.
E10I	Bush Kill	Medium scale sub-basin that is tributary to Ashokan Reservoir.
E16I	Esopus Creek at Cold Brook	Esopus Creek, immediately upstream of Ashokan Reservoir; main inflow site.
SSHG	Headwaters of Schoharie Creek	Small scale homogeneous forested catchment in the southeastern boundary of the Schoharie basin. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the Schoharie basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/ diverse land use monitoring station data.
S4	Schoharie Creek at Lexington	Located on Schoharie Creek below the confluence with the East Kill. This site is intended to divide the Lower Schoharie Creek drainage from the Upper Schoharie Creek drainage. It represents a basin of medium size and diverse land uses.
SEK	East Kill near Jewett Center	Located near the downstream end of the East Kill sub-basin. This sub-basin contains a mixture of urban dwellings, agricultural land uses, and one town center.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
SWKHG	West Kill below Hunter Brook, near Spruceton	Small scale homogeneous forested catchment in the southern boundary of the Schoharie basin. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the Schoharie basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.
SWK	West Kill near West Kill	Located on the West Kill near the confluence of Schoharie Creek. This sub-basin is currently under increasing development pressure.
SBKHG	Batavia Kill near Maplecrest	Small scale homogeneous forested catchment in the eastern boundary of the Schoharie basin. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the Schoharie basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.
S10	Batavia Kill	Located near the downstream end of the Batavia Kill sub-basin. This is the largest sub-basin within the Schoharie Creek drainage. It contains 4 town centers and 1 ski resort.
S5I	Schoharie Creek at Prattsville	Schoharie Creek, immediately upstream of Schoharie Reservoir; main inflow site.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
STHHG	Headwaters of Bear Kill	Small scale homogeneous forested catchment in the northwestern boundary of the Schoharie basin. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the Schoharie basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/ diverse land use monitoring station data.
S6I	Bear Kill near Prattsville	Located near the downstream end of the Bear Kill sub-basin, which includes the town center of Grand Gorge and the Grand Gorge STP. The site is located at the stream's confluence with Schoharie Reservoir.
S7I	Manor Kill near Conesville	Located near the downstream end of the Manor Kill sub-basin. This sub-basin has a proportionately larger agricultural land use than other gaged sub-basins within the Schoharie basin.
WDHOA	West Branch Delaware River above Hobart	Near the headwaters of the West Branch Delaware River. Medium scale catchment comprised of a mosaic of land uses.
CTNBG	Town Brook	Downstream site near the confluence with the West Branch Delaware River. Medium scale catchment, primarily agricultural.
CTNHG	Headwaters of Town Brook	Small scale homogeneous forested catchment The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
CDG	West Branch Delaware River near Delhi	Located on the West Branch Delaware River. This site is intended to divide the Lower West Branch Delaware River drainage from the Upper West Branch Delaware River drainage. It represents a basin of medium to large size and diverse land uses.
CLDG	Little Delaware River	Located near the downstream end of the sub-basin. This sub-basin is larger than other agricultural land use sub-basins within this system.
CCBHG	Headwaters of Little Delaware River	Small scale homogeneous forested catchment. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.
CEBG	East Brook	Located near the downstream end of East Brook near the confluence with the West Branch Delaware River. Medium scale sub-basin, primarily agricultural. This sub-basin is broadly similar to and representative of several other sub-basins within the West Branch Delaware River basin with regard to physiographic and demographic features.
CEBHG	Headwaters of East Brook	Small scale homogeneous forested catchment The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
WDBN	West Branch Delaware River at Beerston Bridge	West Branch Delaware River, immediately upstream of Cannonsville Reservoir; main inflow site.
C-7	Trout Creek	Located near the downstream end of Trout Creek near the confluence with Cannonsville Reservoir. Medium scale sub-basin, primarily agricultural. This sub-basin is broadly similar to and representative of several other sub-basins within the West Branch Delaware River basin with regard to physiographic and demographic features.
C-8	Loomis Creek	Medium Scale catchment with similar physiographic and demographic features to Trout Creek. Tributary to Cannonsville Reservoir.
PROXG	East Branch Delaware River near Roxbury	Located on the East Branch Delaware River. This site is intended to divide the Lower East Branch Delaware River drainage from the Upper East Branch Delaware River drainage. It represents a basin of medium to large size and diverse land uses.
P-50	Batavia Kill	Medium scale catchment with similar physiographic and demographic features to Platte Kill.
PBKG	Bush Kill	Medium scale basin of multiple land uses. This sub-basin is broadly similar to and representative of several other sub-basins within the Pepacton basin with regard to physiographic and demographic features.
PDRY	Dry Brook	Medium scale basin of multiple land uses. This sub-basin is broadly similar to and representative of several other sub-basins within the Pepacton basin with regard to physiographic and demographic features.
PMSB	East Branch Delaware River at Margaretville	East Branch Delaware River, immediately upstream of Pepacton Reservoir; main inflow site.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
P-21	Platte Kill	Medium scale sub-basin primarily of agricultural land use. Representative of other sub-basins within the Pepacton watershed. Tributary to Pepacton Reservoir.
P-60	Mill Brook	Medium scale sub-basin primarily forested.
P-13	Tremper Kill	Medium scale sub-basin primarily of agricultural land use. Representative of other sub-basins within the Pepacton watershed. Tributary to Pepacton Reservoir.
P-8	Fall Clove	Medium scale sub-basin primarily of agricultural land use. Representative of other sub-basins within the Pepacton watershed. Tributary to Pepacton Reservoir.
P-7	Terry Clove	Medium scale sub-basin primarily of agricultural land use. Representative of other sub-basins within the Pepacton watershed. Tributary to Pepacton Reservoir.
RRHG	Headwaters of Rondout Creek	Small scale homogeneous forested catchment. The data from this site will be 1) compared to and compiled with other small scale forested monitoring stations within the basin and regionally across other basins to characterize water quality in undisturbed forested catchments, and 2) used to compare regional forested monitoring station data to downstream/diverse land use monitoring station data.
RDOA	Rondout Creek	Rondout Creek, immediately upstream of Rondout Reservoir; main inflow site.
RD1	Sugarloaf Brook	Downstream monitoring site of Sugarloaf Brook above Rondout Reservoir.
RGB	Chestnut Creek	Downstream monitoring site of Chestnut Creek above Rondout Reservoir.
RD4	Trout Creek	Downstream monitoring site of Trout Creek above Rondout Reservoir.
NCG	Neversink River at Claryville	Neversink River, immediately upstream of Neversink Reservoir; main inflow site.

Table 3.12: (Continued) Stream trends sampling sites.

Site Code	Site Description	Reason for Site Selection
NK6	Kramer Brook	Downstream monitoring site of Kramer Brook above Neversink Reservoir.
WESTBR7	West Branch Croton River above Boyd Corners Reservoir	West Branch Croton River, immediately upstream of Boyd Corners Reservoir; main inflow site.
HORSEPD12	Horse Pound Brook headwaters	Upstream monitoring site of Horse Pound Brook above West Branch Reservoir.
GYPSYTRL1	Gypsy Trail Brook	Downstream monitoring site above West Branch Reservoir.
MIKE2	Michael Brook above Croton Falls Reservoir	Downstream monitoring site of Michael Brook above Croton Falls Reservoir.
CROSS2	Cross River above Cross River Reservoir	Cross River, immediately upstream of Cross River Reservoir; main inflow site.
BOYDR	Boyd Corners Reservoir Release	Because of the cascading design of the EOH District, each release constitutes the greatest contributor of water to the next downstream reservoir.
WESTBRR	West Branch Reservoir Release	Because of the cascading design of the EOH District, each release constitutes the greatest contributor of water to the next downstream reservoir.
CROFALLSVC	Croton Falls Reservoir Release	Because of the cascading design of the EOH District, each release constitutes the greatest contributor of water to the next downstream reservoir.
CROSSRVVC	Cross River Reservoir Release	Because of the cascading design of the EOH District, each release constitutes the greatest contributor of water to the next downstream reservoir.

Analytes and Frequencies

The analytes have been selected on the basis of what is most likely to be of practical consequence to the City in up to 10 years' time. It is impossible to foresee every contingency; therefore, best judgment has been applied. Table 3.13 provides the analytes and frequencies required.

Table 3.13: Analytes and sampling frequency for determination of stream trends.

Analyte	Sampling Frequency	Rationale for Analyte
Flow (USGS)[1]	Continuous	Required for flow adjustment technique in trend detection.
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water.
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions.
Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard.
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/ Part 703 water quality standard.
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures.
Dissolved SO_4	Quarterly	End product of acid deposition.
Dissolved K	Quarterly	Na/K ratio used to determine and characterize hydrologic flow path.
Dissolved Mg	Quarterly	Ca/Mg ratio used to determine and characterize hydrologic flow path.
Dissolved Na	Quarterly	Major component of road salt.
Dissolved Ca	Quarterly	Essential mineral for zebra mussels, Ca depletions observed in forested catchments.

Table 3.13: (Continued) Analytes and sampling frequency for determination of stream trends.

Analyte	Sampling Frequency	Rationale for Analyte
DOC	Monthly	Major source of energy to heterotrophic food webs.
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement.
NO_x-N	Monthly	Essential aquatic life requirement.
Total Dissolved N	Monthly	Pool of organic and inorganic dissolved N species.
Total N	Monthly	Total pool of dissolved and particulate N.
Total Dissolved P	Monthly	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
Total P	Monthly	Pool of dissolved and particulate P.
SRP	Monthly	Dissolved reactive P, most readily biologically available.

[1]If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow.

When trends in data are sought, it must be recognized that there is no point in carrying out short-term intensive sampling because the effects of seasonality, extreme events, and non-uniform variance must be accounted for (Lettenmaier 1976, 1978; Loftis and Ward 1980). The practical consequence is that it is difficult to detect a trend on the order of the water quality variable's standard deviation for n smaller than 50-100 (Lettenmaier et al. 1982). This is supported by the work of Hirsch and Slack (1984) of the USGS who examined a robust nonparametric trend test and stated that reasonable power for trend detection for rivers may only be attainable after five years of sampling. More recently, Smith and McBride (1990) have confirmed these findings. After five years of monthly sampling ($n = 60$) the confidence and power to detect a trend of approximately 1.15 standard deviations is 85% ($\alpha = \beta = 15\%$) or 1.65 standard deviations if $\alpha = \beta = 5\%$. In other words, the higher the confidence and power required, the greater the trend must be before it can be detected. Thus for a trend to be detected with reasonable confidence and power, the network must stay fixed for at least five years to provide a sufficient sample size ($n > 60$). The time of sample collection must also be given careful consideration. Samples should be collected within ±2 days of the scheduled collection day. An attempt will be made to sample in approximately the same order to minimize variation due to diurnal cycles.

Data Analysis and Reporting

The protocol for trend detection in streams will use nonparametric statistics because with water quality data, the assumption of normally distributed data is often violated (e.g., Smith and Maasdam 1994). The statistical power to detect trends is also greatly diminished when using a linear regression with data that fail to account for data seasonality. The techniques used will be the seasonal Kendall Sen slope estimator to estimate trend magnitude accompanied by the seasonal Kendall trend test to indicate statistical significance. Because most water quality data are flow dependent, it is essential that any trend detection protocol include an analysis which removes that predictable portion of variability which is caused by flow. This may be accomplished using LOcally WEighted regression Scatterplot Smoothing (LOWESS) (Cleveland 1979). LOWESS is a robust technique (Lettenmaier et al. 1991) and has been used successfully by the USGS in its examination of national water quality trends (Lanfear and Alexander 1990, Helsel 1993) and by Smith et al. (1996) in New Zealand.

An appraisal of current water quality status and long-term water quality trends, to demonstrate the effectiveness of ongoing watershed protection efforts, will be presented in the Watershed Protection Program Summary and Assessment report, which is produced every five years and is a FAD requirement.

References

Cleveland, W.S., 1979. Robust locally weighted regression and smoothing scatterplots. Journal of the American Statistical Association. 74: 829-836.

DEP. 2011b. 2011 Long-Term Watershed Protection Plan. Valhalla, NY. 92 p.

Helsel, D.R. 1993. Statistical analysis of water quality data. In: National water summary 1990-91. US Geological Survey Water-Supply Paper 2400, pp 93-100. Washington, D.C. 590p.

Hirsch, R.M. and J.R. Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research. 20: 727-732.

Lanfear, K.J. and R.B. Alexander. 1990. Methodology to derive water-quality trends for use by the national water summary program of the US Geological Survey. US Geological Survey Open-File Report 90-359. 10p.

Lettenmaier, D.P. 1976. Detection of trends in water quality data from records with dependent observations. Water Resources Research. 12: 1037-1046.

Lettenmaier, D.P. 1978. Design considerations for ambient stream water quality monitoring. Water Resources Bulletin. 14: 884-892.

Lettenmaier, D.P., L.L. Conquest, and J.P. Hughes. 1982. Routine streams and rivers quality trend monitoring review. University of Washington, Department of Civil Engineering. Charles W. Harris Hydraulics Laboratory Report 75. Seattle, Washington. 233p.

Lettenmaier, D.P., E.R. Hooper, E.R. Wagoner, and K.B. Faris. 1991. Trends in water quality in the continental United States, 1978-1987. Water Resources Research. 27: 327-339.

Loftis, J.C. and R.C. Ward. 1980. Water quality monitoring—some practical sampling observations. Environmental Management. 4: 521-526.

Smith, D.G. and G.B. McBride. 1990. New Zealand's national water quality monitoring network—design and first year's operation. Water Resources Bulletin. 26: 767-775.
Smith, D.G. and R. Maasdam. 1994. New Zealand's national river water quality network. 1. Design and physico-chemical characterization. New Zealand Journal of Marine and Freshwater Research. 28:19-35.
Smith, D.G., G.B. McBride, G.G. Bryers, J. Wisse, and D.F.J. Mink. 1996. Trends in New Zealand's national river water quality network. New Zealand Journal of Marine and Freshwater Research. 30: 485-500.

3.2.6 Trends of Reservoir Water Quality

Objective

This monitoring effort is intended to provide 1) an objective assessment of whether water quality conditions are improving, worsening, or staying the same; 2) an estimate of the magnitude of change; and 3) identification of potential causes for the change. Trend analysis is important to identify and quantify water quality problems, to help decide if and what corrective actions are necessary, and to assess the effects of corrective actions taken. An example of the latter is DEP's use of trends to evaluate the effectiveness of the Watershed Protection Program (DEP 2001, 2006). Trend analysis may also be used to show that source waters continue to be of satisfactory quality and no corrective action is required.

DEP is required to report on water quality trends as per USEPA's Filtration Avoidance Determination in 1997 (USEPA 1997), 2002 (USEPA 2002) and 2007 (USEPA 2007). These requirements were met by the Watershed Protection Summary and Assessment reports in 2001 (DEP 2001), 2006 (DEP 2006), and 2011 (DEP 2011a). The Revised 2007 Filtration Avoidance Determination (NYSDOH 2014) requires continued analysis of trends with a report to be issued in 2016.

Background

The detection and interpretation of water quality trends is one of the universal objectives associated with the design of water quality monitoring systems (Ward et al. 1990). Trend analysis is frequently used to warn of worsening conditions (Aota et al. 2003, Burkholder et al. 2006) and to assess whether actions to improve water quality have been successful (DEQ 2007, Langland et al. 2000, Driscoll and Van Dreason 1992). Elements of the DEP's trend analysis program are summarized below. Additional details are provided in the Quality Assurance Project Plan for Trend Analysis of Reservoir Data (Van Dreason 2006).

Sites

Samples will be collected at each of the sites listed in Table 3.14 and at the depths described in Appendix II. Because water quality analytes in reservoirs display considerable spatial variability, this sampling scheme is designed to produce the most accurate representation for each reservoir as a whole while still allowing analysis of individual strata (i.e., depths and locations) (Gaugush 1987). Trend detection of individual or grouped strata is used to specify the location and extent of problems and to evaluate causality.

Table 3.14: Sampling sites for assessment of reservoir trends.

Reservoir	Sites							
Catskill								
Ashokan	1EA	2EA	3EA	4EA	5EA	6EA		
Schoharie	1SS	2SS[1]	3SS	4SS				
Delaware								
Cannonsville	1WDC		3WDC	4WDC	5WDC	6WDC		
Pepacton	1EDP		3EDP	4EDP	5EDP	6EDP		
Neversink	1NN	2NN		4NN				
Rondout	1RR	2RR[2]	3RR					
East of Hudson								
Kensico	1.1BRK	2BRK	2.9BRK	4BRK	5BRK	6BRK	7BRK	8BRK
Cross River	1.1CCR		3CCR					
Croton Falls	1.1CCF		3CCF		5CCF			
West Branch	1CWB	2CWB	3CWB	4CWB				
Boyd Corners	1.1CBC	2CBC[2]	3CBC[1]					

1. These sites do not get filtered nutrients or DOC.
2. These sites only get sampled for fecal coliform.

Analytes and Frequencies

A list of analytes and reasons for their inclusion are provided in Table 3.15. These have been selected on the basis of what is most likely to be of practical consequence to the City. Samples will be collected monthly from April through November for each analyte listed in Table 3.15. Water column profiles for temperature, dissolved oxygen, and specific conductivity will be collected every 1 m. The interval between monthly surveys shall be consistent until the reservoir become isothermal. During isothermal conditions the profile intervals goes from every 1 m to every 5m.

Table 3.15: List of analytes for reservoir trend objective.

Analytes	Reason for Inclusion
Data provided by WQD:	
Color	Early alert to potential contravention of NYS health standard (SDWA)
Secchi depth Z_{VB}	Indicator of water clarity, used to assess trophic state
Photic depth I_z[1]	Identifies zone of active primary production
pH	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Temperature	Important in the regulation of biotic community structure and function, critical in regulating the chemical composition of water, regulates reservoir processes and distribution of constituents
Specific Conductivity	Measured surrogate for total inorganic ions
Turbidity	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard and to manage for compliance with SDWA standards
TSS[2]	Interferes with disinfecting processes, mechanism of pathogen transport, cause of decrease in clarity
Dissolved Oxygen	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Dissolved Chloride[3]	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[3]	End product of acid deposition, source of S^{-2} during anoxia
Dissolved Na[3]	Major component of road salt
Dissolved Ca[3]	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity	A measurement of acid neutralizing capacity, buffering capacity, needed for chemical treatment activities
DOC	Major source of energy to heterotrophic food webs, provides insight into THM formation potential, potential source of color in humic waters
Fecal Coliform	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard, and to manage for compliance with SDWA standards
Chl *a*[4]	Useful in assessing primary productivity and trophic state

Table 3.15: (Continued) List of analytes for reservoir trend objective.

Analytes	Reason for Inclusion
Phytoplankton[4]	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards
NH_X-N	Utilized preferentially over NOx-N by autotrophs and bacteria, essential aquatic life requirement, indicative of anoxic conditions during which the toxic form (free ammonia) is produced.
NOx-N	Essential aquatic life requirement
Total Dissolved Nitrogen (TDN)	Pool of organic and inorganic dissolved N species
Total Nitrogen (TN)	Total pool of dissolved and particulate N
Total Dissolved Phosphorus (TDP)	Measurement of dissolved reactive phosphorus and dissolved organic and dissolved complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).This provides organic + complex inorganic P, also considered to be the total pool of biologically available P.
Total Phosphorus (TP)	Pool of dissolved and particulate P
Soluble Reactive Phosphorus (SRP)	Dissolved reactive P, most readily biologically available (almost exclusively inorganic P)
Data provided by Operations:	
Reservoir Elevation	Explanatory variable used to assist in interpretation of water quality variables
Total Storage	Explanatory variable used to assist in interpretation of water quality variables
Release Flow	Explanatory variable used to assist in interpretation of water quality variables
Spill Flow	Explanatory variable used to assist in interpretation of water quality variables
Diversion Flow	Explanatory variable used to assist in interpretation of water quality variables

[1] Photic depth to be measured at sites 4WDC, 3EDP, 2NN, 1RR, 1SS, 1EAW, 5EAE, 1CWB and 1.1BRK.

[2]TSS analyzed monthly at dam and intake sites for Delaware District reservoirs and Kensico Reservoir, and at all sites and depths for Catskill District reservoirs. TSS to be analyzed quarterly at dam site for CWB.

[3] Filtered: Ca, Na, Cl, SO_4. Samples collected in May, August, and November. See Table 3.7.

[4] Chlorophyll *a* and phytoplankton collected at depth of 3 meters.Total phytoplankton includes the total count, the first dominant genus and count, and the second dominant genus and count.

Data Analysis and Reporting

The protocol for reservoirs will use nonparametric statistics. Because the distribution of water quality data is often not normal, these distribution-free tests are more appropriate for reservoir data. The techniques used will be the seasonal Kendall Sen slope estimator to estimate long-term monotonic trend magnitude, accompanied by the Seasonal Kendall (SK) trend test (Hirsh et al. 1982) to indicate statistical significance. The SK test and the seasonal Kendall Slope Estimator can be calculated using the software WQStat Plus (Intelligent Decisions Technologies, Ltd., Longmont, CO) or by using a compiled Fortran program from Reckhow et al. (1993). Additional statistical analysis and graphics may be accomplished using (but not limited to) SAS (SAS Institute, Cary, NC), Minitab (Minitab Inc., State College, PA), and KaleidaGraph (Synergy Software, Reading, PA).

A visual trend assessment will be accomplished using LOcally WEighted regression Scatterplot Smoothing (LOWESS) (Cleveland 1979). Unlike the SK Test and the seasonal Kendall Sen slope estimator, LOWESS curves can be used to evaluate intermediate as well as long-term trends in the time series data. This feature is useful to describe, for example, how closely changes coincide with BMP implementation or whether long-term trends are cancelled out by competing short-term trends.

Sudden changes may produce step trends in the time series. If the source of the change is known, the Wilcoxon Rank Sum test (Wilcoxon 1945) will be used to test for significant change and the Hodges-Lehmann estimator (Hodges and Lehmann 1963) used to estimate the magnitude of the change.

The ability of statistical tests to detect trends is enhanced if sources of background variability (exogenous variables) can be identified and removed from the time series data prior to trend detection. Potential exogenous variables such as reservoir elevation/storage and diversion rate will be identified by plotting them against water quality analytes and observing the degree of covariance. The residuals resulting from a LOWESS curve through the data are an estimate of the water quality analyte minus the effects of the exogenous variable. The residuals, rather than the original data, will be used to test for trend and to estimate trend magnitude.

Trends will be evaluated on both pooled data and on individual strata (e.g., sites and depths). The trends on pooled data describe changing water quality conditions on the reservoir as a whole. Trends on individual strata provide insight on specific reservoir locations and depths and will be used to isolate factors controlling the trends.

To ensure that trend analysis reflects environmental changes and not program changes, any planned method changes, such as equipment, filters, sampling, and analytical methods should be discussed by laboratory, field, and analysis personnel well in advance of implementation. The purpose of the discussion is to establish procedures for evaluating bias and precision. These procedures may include a period of side-by-side comparisons, review of ongoing quality control (QC), or a combination of the two. There should be a method overlap that includes an adequate number of samples to represent the expected concentration range.

Trend analysis is performed for reservoirs and is used to keep management apprised of emerging water quality issues and in fulfillment of the FAD requirement for trend analysis. A subset of the most relevant results shall be discussed in detail every five years in the Watershed Protection Summary and Assessment report. Reports have been issued in 2001 (DEP 2001), 2006 (DEP 2006), and in 2011 (DEP 2011a). The next report is due in 2016.

References

Aota, Y., M. Kumagai, K. Ishikawa. 2003. Over twenty years trend of chloride ion concentration in Lake Biwa. J. Limnol. 62 (Suppl.1): 42-48.

Burkholder, J. M., D. Dickey, C. Kinder, R. Reed, M. Mallin, M. McIver, L. Cahoon, C. Brownie, J. Smith, N. Deamer, J, Springer, H. Glasgow, and D. Toms. 2006. Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. Limnol. Oceanogr. 51: 463-487.

Cleveland, W. S. 1979. Robust Locally Weighted Regression and Smoothing Scatterplots. J. A. Stat. Assoc. 74, 829-836.

DEP 2001. New York City's 2001 Watershed Protection Program Summary, Assessment and Long-term Plan. New York City Department of Environmental Protection. Division of Water Quality Control. Valhalla, NY. 634 p.

DEP 2006. 2006 Watershed Protection Program: Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 464 p.

DEP 2011a. 2011 Watershed Protection Program Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 384 p.

DEP 2011a. 2011 Watershed Protection Program Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 384 p.

DEQ 2007. Trend Analysis of Food Processor Land Application Sites in the Lower Umatilla Basin Groundwater Management Area. Oregon Department of Environmental Quality.

Driscoll, C. T. and R. Van Dreason. 1993. Seasonal and long-term temporal patterns in the chemistry of Adirondack lakes. Water, Air, and Soil Pollution. 67:319-344.

Gaugush, R. F. 1987. "Sampling Design for Reservoir Water Quality Investigations." Instruction Report E-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Hodges, J.L., Jr. and R. W. Lehmann. 1963. Estimates of location based on rank tests. Annals Mathematical Statistics. 34, 598-611.

Langland, M., J. Blomquist, L. A. Sprague, and R. Edwards. 2000. Trends and status of flow, nutrients and sediments for selected non-tidal sites in the Chesapeake Bay Watershed. 1995-98. U.S. Geological Survey Open-File Report 99-451. Lemoyne, Pennsylvania.46 p.

Newell, A. D. and M. L. Morrison. 1993. Use of overlap studies to evaluate method changes in water chemistry protocols. Water, Air and Soil Pollution. 67:457-468.

Reckhow, K. H., K. Kepford, and W. Warren Hicks. 1993. Methods for the Analysis of Lake Water Quality Trends. USEPA 841-R-93-003.

USEPA [U. S. Environmental Protection Agency]. 1997. New York City Filtration Avoidance Determination.

USEPA [U. S. Environmental Protection Agency]. 2002. New York City Filtration Avoidance

Determination.
USEPA [U. S. Environmental Protection Agency]. 2007. New York City Filtration Avoidance Determination.
Van Dreason, R. S. 2006. Quality Assurance Project Plan for Trend Analysis of Reservoir Data. New York City Department of Environmental Protection, Water Quality Directorate report. 69 pp.
Ward, R. C., J. C. Loftis, and G. B. McBride. 2003. Design of Water Quality Monitoring Systems. John Wiley and Sons, Inc. Hoboken, New Jersey.
Wilcoxon, F. 1945. Individual comparisons by ranking methods. Biometrics.1, 80-83.

3.2.7 Trends for Keypoint Water Quality

Objective

The objective is to collect data to establish long-term trends in selected water quality analytes.

Background

As noted above, DEP's Long-Term Watershed Protection Plan (DEP 2011b) states that one of the goals of DEP's Watershed Monitoring Program is to provide a comprehensive evaluation of watershed water quality status and trends and other research activities to support assessment of the effectiveness of watershed protection programs. The detection and interpretation of water quality trends is one of the universal objectives associated with the design of water quality monitoring systems (Ward et al. 1990). Trend analysis is frequently used to warn of worsening conditions (Aota et al. 2003, Burkholder et al. 2006) and to assess whether actions to improve water quality have been successful (DEQ 2007, Langland et al. 2000, Driscoll and Van Dreason 1992).

Sites

Samples collected at keypoints provide critical information on water quality. For example, data from the Kensico keypoints collected over time have been used to demonstrate the effectiveness of DEP's waterfowl management programs. See Table 3.16 for selected sites.

Table 3.16: Sites for keypoint water quality trends.

Site Code	Site Description
RDRRCM	Rondout Reservoir effluent
NRR2CM	Neversink Tunnel Outlet (Neversink Reservoir effluent)
PRR2CM	East Delaware Tunnel Outlet (Pepacton Reservoir effluent)
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent)
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent
SRR2CM	Portal (Shandaken Tunnel outlet into Esopus Creek), continuous monitoring

Table 3.16: (Continued) Sites for keypoint water quality trends.

Site Code	Site Description
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.
DEL17	Delaware Aqueduct, sampled at Shaft 17 uptake, influent to Kensico Reservoir.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL18DT	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.

Analytes and Frequencies

The analytes have been selected for those governed by regulations and on the basis of what is most likely to be of practical consequence to the City in up to 10 years' time. It is impossible to foresee every contingency, therefore best judgment has been applied. Table 3.17 provides the analytes of interest.

Table 3.17: Analytes and sampling frequency for determination of keypoint trends.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Color	Monthly	Early alert to potential contravention of NYS health standard (SDWA)
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system-specific characteristic in the WR&R.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport.

Table 3.17: (Continued) Analytes and sampling frequency for determination of keypoint trends.

Analyte	Sampling Frequency[1]	Rationale for Analyte
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity.
Dissolved Chloride	Quarterly	Major component of road salt, indicator of septic system failures.
Dissolved SO_4	Quarterly	End product of acid deposition.
Dissolved Na	Quarterly	Major component of road salt.
Dissolved Ca	Quarterly	Essential mineral for zebra mussels, Ca depletions observed in forested catchments
DOC	Monthly	Major source of energy to heterotrophic food webs.
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement.
NO_x-N	Monthly	Essential aquatic life requirement. Included as a system-specific characteristic in the WR&R.
Total Dissolved N	Monthly	Pool of organic and inorganic dissolved N species
Total N	Monthly	Total pool of dissolved and particulate N. Will be used to estimate organic nitrogen.
SRP	Monthly	Dissolved reactive P, most readily biologically available
Total Dissolved P	Monthly	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
Total P	Monthly	Pool of dissolved and particulate P
Chlorophyll *a*	Monthly[2]	Estimate of biomass, eutrophication indicator
Total Coliform and Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard
Total Phytoplankton/ Dominant Genus	Monthly	General indicator of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards

[1]Samples to be collected only when aqueduct is operational, [2]April–November only.

.

Quarterly samples are taken in February, May, August and November. For determining trends, in most cases, a monthly sample will provide adequate information over a 5-year period.

Data Analysis and Reporting

As detailed in the previous two sections, it is generally necessary to use nonparametric statistics when analyzing water quality data for trends.

To ensure that trend analysis reflects environmental changes and not program changes, any planned method changes, such as equipment, filters, sampling, and analytical methods should be discussed by laboratory, field, and analysis personnel well in advance of implementation. The purpose of the discussion is to establish procedures for evaluating bias and precision. These procedures may include a period of side-by-side comparisons, review of ongoing quality control (QC), or a combination of the two. There should be a method overlap that includes an adequate number of samples to represent the expected concentration range.

In order to demonstrate the effectiveness of ongoing watershed protection efforts, an appraisal of current water quality status and long-term water quality trends will be presented in the Watershed Protection Program Summary and Assessment report, which is produced every five years and is a FAD requirement. Reports have been issued in 2001 (DEP 2001), 2006 (DEP 2006), and 2011 (DEP 2011a) with another due in 2016.

References

Aota, Y., M. Kumagai, and K. Ishikawa. 2003. Over twenty years trend of chloride ion concentration in Lake Biwa. J. Limnol. 62 (Suppl.1): 42-48

Burkholder, J. M., D. Dickey, C. Kinder, R. Reed, M. Mallin, M. McIver, L. Cahoon, C. Brownie, J. Smith, N. Deamer, J, Springer, H. Glasgow, and D. Toms. 2006. Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. Limnol. Oceanogr. 51: 463-487.

DEP. 2001. New York City's 2001 Watershed Protection Program Summary, Assessment and Long-term Plan. New York City Department of Environmental Protection. Division of Water Quality Control. Valhalla, NY. 634 p.

DEP. 2006. 2006 Watershed Protection Program: Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 464 p.

DEP. 2011a. 2011 Watershed Protection Program Summary and Assessment. New York City Department of Environmental Protection. Valhalla, NY. 384 p.

DEP. 2011b. 2011Long-Term Watershed Protection Program. Valhalla, NY. 92 p.

DEQ. 2007. Trend Analysis of Food Processor Land Application Sites in the Lower Umatilla Basin Groundwater Management Area. Oregon Department of Environmental Quality.

Driscoll, C. T. and R. Van Dreason. 1993. Seasonal and long-term temporal patterns in the chemistry of Adirondack lakes. Water, Air, and Soil Pollution. 67:319-344.

Langland, M., J. Blomquist, L. A. Sprague, and R. Edwards. 2000. Trends and status of flow, nutrients and sediments for selected non-tidal sites in the Chesapeake Bay Watershed. 1995-98. U.S. Geological Survey Open-File Report 99-451. Lemoyne, Pennsylvania. 46 p.

Ward, R. C., J. C. Loftis, and G. B. McBride. 2003. Design of Water Quality Monitoring Systems. John Wiley and Sons, Inc. Hoboken, New Jersey.

3.2.8 Biological (Benthic Invertebrate) Trends

Objective

The objective is to examine the biological assessments of sites with a substantial historical record (at least five years) to determine whether the condition of the benthic community at these sites has remained stable, declined, or improved.

Background

Examination of biomonitoring data for evidence of long-term changes has been performed and reported on since 2005. Evidence of a downward trend has been observed at five sites (Anglefly Brook (Site 102), Titicus River (Site 112), Batavia Kill (Site 206), Stony Clove (Site 217), East Branch Delaware River (Site 321)), while one site (Hallocks Mill Brook (Site 105) has exhibited an upward trend.

Sites

Typically, sites selected for this analysis are integrator sites located on mainstems or on important reservoir tributaries, or are sites located on streams in whose watersheds there is a significant potential for land use changes with concomitant long-term impacts to water quality (Table 3.18 and Figures 3.1 and 3.2). Occasionally, sites with a long enough historical record that do not meet these criteria may be included in the analysis if they have experienced noticeable change. As circumstances warrant, additional trends sites may be added. The new sites will be submitted in the year of implementation as an addendum to the WWQMP.

Table 3.18: Sites for assessment of biological (benthic invertebrate) trends in Catskill/Delaware basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency
146	Horse Pound Brook at HORSEPD12	Major tributary to West Branch Reservoir in relatively undeveloped watershed	annually
202	Schoharie Creek below Town of Hunter (above S3)	Site established to monitor impacts to benthic macroinvertebrate community from Town of Hunter and ski resort	annually
204	Batavia Kill at S10	Located near the terminal end of the Batavia Kill sub-basin. This is the largest sub-basin within the Schoharie Creek drainage, containing 4 town centers and 1 ski resort.	annually

Table 3.18: (Continued) Sites for assessment of biological (benthic invertebrate) trends in Catskill/Delaware basins. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency
206	Schoharie Creek at S5I	Integrator site for Schoharie Creek drainage basin above Schoharie Reservoir.	annually
215	Esopus Creek at E5	Site established upstream of Shandaken Tunnel outlet to monitor impacts of Tunnel inputs to benthic macroinvertebrate community in Esopus Creek	annually
216	Schoharie Creek at Lexington, near S4	Site established to monitor recovery of benthic community following construction of streambank stabilization BMP	annually
227	Esopus Creek above confluence with Woodland Valley Creek	Site established below Shandaken Tunnel outlet to monitor impacts of Tunnel inputs to benthic macroinvertebrate community in Esopus Creek	annually
301	West Branch Delaware River above WDHOA	Near the headwaters of the West Branch Delaware River. Medium scale catchment comprised of a mosaic of landuses	annually
304	West Branch Delaware River below Walton WWTP	Site established to monitor impacts to benthic macroinvertebrate community from Walton WWTP	annually
307	Aden Brook at NK4	Site established to monitor recovery of benthic macroinvertebrate community following removal of riparian vegetation and riprapping of streambank to repair damage caused by Hurricane Floyd	annually
316	East Branch Delaware River below PMSB	Integrator site for East Branch Delaware River drainage basin above Pepacton Reservoir; location for monitoring impacts to benthic macroinvertebrate community from Margaretville WWTP	annually
320	West Branch Delaware River at WDBN	Integrator site for West Branch Delaware River drainage basin above Cannonsville Reservoir	annually
321	East Branch Delaware River at EDRB	Site established downstream of Roxbury Run Wastewater Treatment Plant	annually
330	Bush Kill at PBKG	Major tributary to East Branch Delaware River in basin of multiple land uses	annually

Analytes and Frequencies

Both biological and water quality analytes are measured. The biological "analyte" is a site's stream macroinvertebrate community. Samples are shipped to a contract laboratory, which subsamples the samples and identifies and enumerates the organisms found in the subsamples. From the tally of identified organisms, a series of metrics is generated (taxa richness; numbers of mayfly, caddisfly, and stonefly taxa present; Percent Model Affinity (a measure of the community's similarity to a model NYS stream community); the Hilsenhoff Biotic Index (a measure of organic pollution); and the Nutrient Biotic Index-Phosphorus (an indicator of nutrient enrichment in streams)). From these metrics, the site's Biological Profile Assessment is derived (DEP 2001), changes to which can be studied over time. Because physicochemical factors have a profound influence on the structure and function of benthic communities, changes to those variables can help explain long-term shifts in the benthos. Conversely, shifts in the benthic community can provide clues to changes in stream chemistry. (For example, increases in grazer taxa may be an indication of heightened nutrient inputs.) The list of water quality analytes sampled to investigate these changes is presented in Table 3.11. No additional sampling effort is required to collect these field analytes because in most cases collection occurs at the same time as biological sampling.

Sites are sampled annually, as per the NYSDEC protocols employed by DEP (NYSDEC 2014). While these protocols provide for sampling between July and September, DEP biomonitoring samples have historically been collected in September in the Catskill and Delaware watersheds.

Data Analysis and Reporting

Macroinvertebrate community data are examined for statistically significant trends, which are presented in the Watershed Protection Program Summary and Assessment Report. This report, produced every five years, is a FAD requirement.

References

DEP. 2001. Quality Assurance Project Plan for Stream Benthic Macroinvertebrate Biomonitoring in the New York City Water Supply Watersheds. Valhalla, NY. 37 p.

NYSDEC [New York State Department of Environmental Conservation]. 2014. Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State. 171 p.

3.3 Kensico Surveillance

Objective

The surveillance of Kensico Reservoir is a primary requirement of the Revised 2007 FAD under Section 4.10 "Kensico Water Quality Control". The purpose of this objective is to monitor the perennial streams of Kensico Reservoir for water quality and for the abundance of *Giardia* cysts and *Cryptosporidium* oocysts. The inclusion of *Cryptosporidium* monitoring in the watershed is also required by the IESWTR. These data will be used for the annual Kensico Water Quality Control Program Annual Report, which is a FAD requirement.

Background

Kensico Reservoir, the 2007 FAD stated, "protection of this reservoir is critically important to maintaining filtration avoidance for the City" and required "the City to implement its Kensico Water Quality Control program in accordance with section 2.3.10 of the City's 2006 Long-Term Watershed Protection Program and the milestones contained therein" (USEPA 2007). The 2007 FAD required DEP to submit a Kensico Programs Annual Report, to include a presentation, discussion, and analysis of monitoring data (e.g., keypoint, reservoir, stream, BMPs). The Revised 2007 FAD continued the reporting requirement by requiring DEP to submit "an integrated report on the progress implementing the Kensico Water Quality Control Program" (NYSDOH 2014).

Eight perennial streams flow into Kensico Reservoir and are currently sampled monthly for routine water quality analytes as well as *Giardia* and *Cryptosporidium*. Prior to June 2007, *Giardia* and *Cryptosporidium* sampling occurred on a weekly basis at Malcolm Brook (MB-1) due to its proximity to the Catskill Aqueduct intake.

An evaluation of the weekly data demonstrated that monthly *Giardia* and *Cryptosporidium* sampling at the eight perennial streams would be the most cost effective and most representative sample frequency.

Sites

Locations for stream sampling at Kensico Reservoir include all eight perennial streams that flow into Kensico: Malcolm Brook, N5, N12, Bear Gutter Creek, E9, E10, E11, and Whippoorwill Brook. They have been selected based on their perennial flow into a terminal reservoir for a drinking water supply (Table 3.19 and Figure 3.3).

Table 3.19: Sites for Kensico stream monitoring.

Site Code	Site Description	Reason for Site Selection
BG9	Discharge of Bear Gutter Creek, sample collected off of Rt. 22 downstream of BMP outlet and spillway in riprap channel near galvanized, chain-link fence.	Perennial tributary to terminal reservoir
E9	Discharge of stream E9, sample collected from stream off of King St.	Perennial tributary to terminal reservoir
E10	Discharge of stream E10, sample collected upstream of culvert under Rt. 120.	Perennial tributary to terminal reservoir

Table 3.19: (Continued) Sites for Kensico stream monitoring.

Site Code	Site Description	Reason for Site Selection
E11	Discharge of stream E11, sample collected from stream on east side of Rt. 684 north, heading north from 287 at mile marker 3.8.	Perennial tributary to terminal reservoir
MB-1	Discharge of Malcolm Brook, sample collected at the outlet of the attenuation basin (BMP) downstream of West Lake Dr.	Perennial tributary to terminal reservoir
N12	Discharge of stream N12, sample collected downstream of box culvert crossing Nannyhagen Rd.	Perennial tributary to terminal reservoir
N5-1	Discharge of stream N5, sample collected at the outlet culvert from BMP 37 (below BMP)	Perennial tributary to terminal reservoir
WHIP	Discharge of Whippoorwill Creek, sample collected upstream of the bridge crossing Nannyhagen Rd. near junction of Rt. 120.	Perennial tributary to terminal reservoir

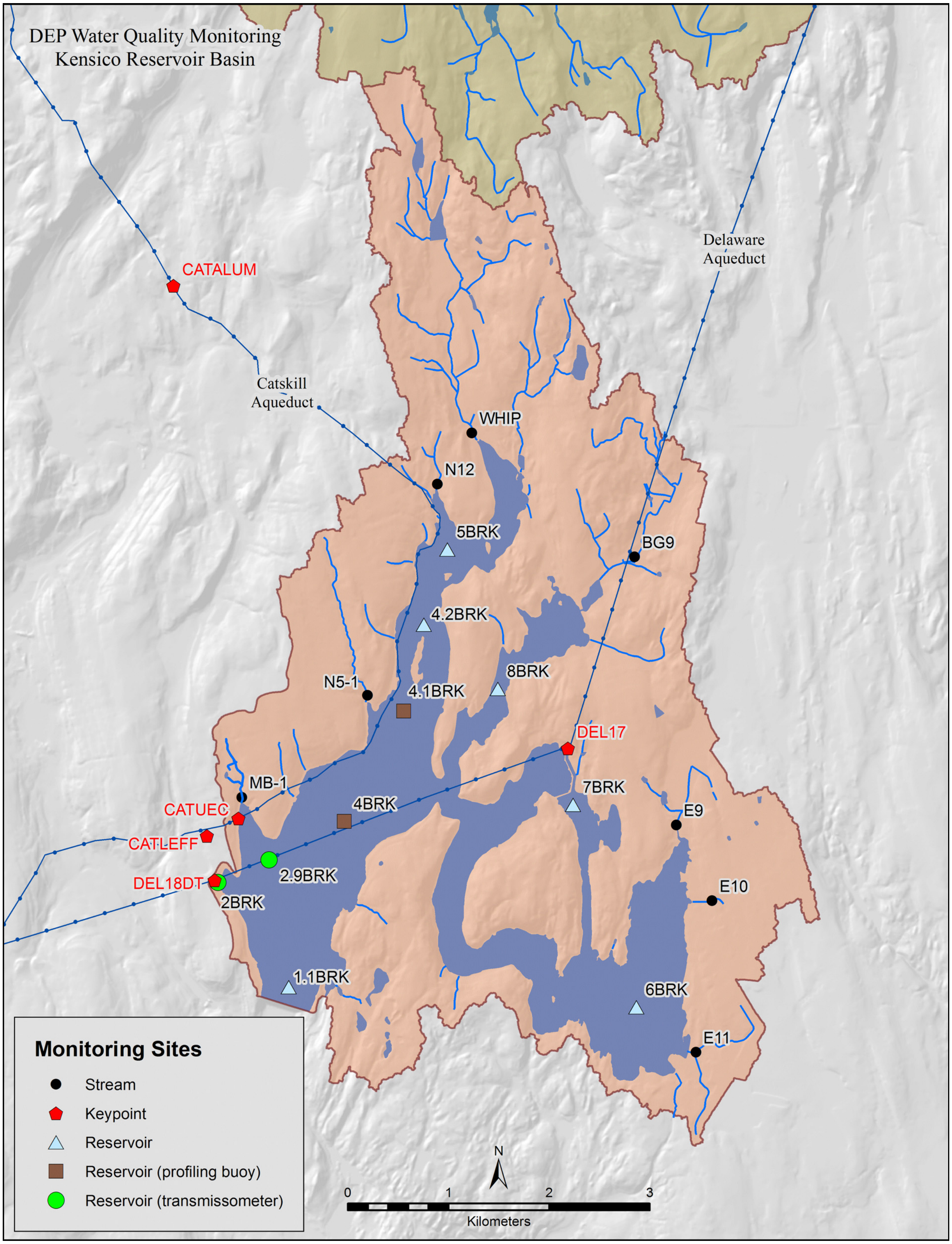


Figure 3.3 Water quality monitoring in the Kensico Reservoir basin.

Analytes and Frequencies

DEP will collect routine water quality data and pathogen (*Giardia* and *Cryptosporidium)* samples on a monthly basis (Table 3.20).

If an elevated pathogen concentration is found at any of these sites, additional sampling may be performed to substantiate the high result as well as determine a cause for the result. This is especially important in the terminal reservoir to the NYC water supply.

During events with elevated counts, genotyping of samples may be performed to identify a "source" of contamination. These results can link *Giardia* or *Cryptosporidium* to potential "source" organisms, and give DEP more information on whether the *Cryptosporidium* genotype is a risk for human health.

Table 3.20: List of Kensico watershed stream sampling analytes.

Analyte	Sampling Frequency	Rationale for Analyte
For all sites, except E9 and E10:		
Total Coliform and Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system-specific characteristic in the WR&R.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity.
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures.

Table 3.20: (Continued) List of Kensico watershed stream sampling analytes.

Analyte	Sampling Frequency	Rationale for Analyte
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement.
NO_x-N	Monthly	Essential aquatic life requirement. Included as a system-specific characteristic in the WR&R.
Total N	Monthly	Total pool of dissolved and particulate N. Will be used to estimate organic nitrogen.
DOC	Monthly	Major source of energy to heterotrophic food webs.
TP	Monthly	Pool of dissolved and particulate P
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport.
For Sites E9 and E10:		
Total Coliform and Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system-specific characteristic in the WR&R.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard

Table 3.20: (Continued) List of Kensico watershed stream sampling analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Analytes needed for *Giardia* and *Cryptosporidium* monitoring (all eight sites):		
Cryptosporidium oocysts $50L^{-1}$	Monthly	Surveillance
Giardia cysts $50L^{-1}$	Monthly	Surveillance
Sample volume (L)	Monthly	Required to calculate concentration
Flow (WQD)[1]	Continuous in situ measurement	Required for loading estimates
Stream rating curve[1]	As needed	Required for determination of flow
Weather (general conditions)	Monthly	Supporting data to explain possible protozoan results
Sample volume	Monthly	For determination of (oo)cyst concentration
pH	Monthly	Required for method recovery information
Water temperature	Monthly	Measured to ensure QA/QC
Pressure differential on sample filter	Monthly	Recovery potential/interference
Flow for filtered sample	Monthly	USEPA method requirement
Protozoan genotyping	As needed	Determination of source during unusual elevated count events, requires contract

[1]If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow. For example, at this time flow is not measured at the WHIP site.

Data Analysis and Reporting

DEP will report on the water quality results in the Kensico Programs Annual Report. The *Giardia* and *Cryptosporidium* results will also be reported on a semi-annual basis in accordance with the 2007 FAD, and included as part of the Watershed Water Quality Annual Report. The data will be used as a basic surveillance tool, and to add to the existing data at several of these sites to assist in the determination of why, at times, there is a higher pathogen level leaving Kensico Reservoir than entering the reservoir. In addition, the monthly sampling will strengthen the existing dataset for the determination of seasonal trends over the longer term (years).

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

USEPA [U. S. Environmental Protection Agency]. 2007. New York City Filtration Avoidance Determination. 92 p.

3.4 FAD-Required WWTP Monitoring West of Hudson

Objective

In accordance with the FAD, all surface-discharging WWTPs discharging to NYC's Catskill and Delaware watersheds west of the Hudson River are required to be monitored monthly by DEP.

Sites

West of Hudson WWTP sites required for monitoring under the Revised 2007 FAD (Section 6.2) are listed in Table 3.21. Grab samples are collected monthly from each non-City-owned facility and analyzed for all SPDES parameters. At least once annually, for the non-City-owned WWTPs, samples shall be collected and analyzed in accordance with the monitoring requirements of each facility's SPDES permit. Monitoring at all New York City-owned WWTPs is performed in accordance with their SPDES permits (see section 2.6.10).

Table 3.21: West of Hudson WWTP sites and frequencies required for FAD monitoring.

Location/ WWTP	SPDES Permit	Frequency[1]
Andes (T) WWTP	NY0262854	monthly/annually
Ashland	NY0263214	1/month
Boiceville WWTP	NY0274038	monthly/annually
L'man A'chai (Camp) WWTP	NY0104957	monthly/annually
Camp Oh-Neh-Tah	NY0205460	monthly/annually
Oorah Catskill Retreat	NY0069957	monthly/annually
Timberlake (Camp) WWTP	NY0240664	monthly/annually
Delhi (V) WWTP	NY0020265	monthly/annually
Elka Park WWTP	NY0092991	monthly/annually
Fleischmanns (V) WWTP	NY0261521	monthly/annually
Grahamsville (V) WWTP	NY0026549	1/month
Grand Gorge (V) WWTP	NY0026565	2/month
Hanah Country Club WWTP	NY0249777	monthly/annually
Hobart (V) WWTP	NY0029254	monthly/annually
Hunter (V) WWTP	NY0241075	monthly/annually
Machne Tashbar (Camp)	NY0263061	monthly/annually
Margaretville (V) WWTP	NY0026531	2/month
Mountain View Estates	NY0263052	monthly/annually
Mountainside Farms-Worcester Cremeries (Lagoon)	NY0084590	monthly/annually
Olive Woods (Woodstock Percussion) WWTP	NY0098281	monthly/annually
Pine Hill (V) WWTP	NY0026557	2/month
Prattsville (T) WWTP	NY0263028	monthly/annually

Table 3.21: (Continued) West of Hudson WWTP sites and frequencies required for FAD

Location/ WWTP	SPDES Permit	Frequency[1]
Roxbury Run Village WWTP	NY0099562	monthly/annually
Stamford (V) WWTP	NY0021555	monthly/annually
Tannersville (V) WWTP	NY0026573	2/month
Walton (V) WWTP	NY0027154	monthly/annually
Robert W. Harold Campus (BOCES)	NY0097446	monthly/annually
Windham (T) WWTP	NY0262935	monthly/annually

[1] The samples collected annually are composite samples collected in accordance with the monitoring requirements of the facility's SPDES permit while those collected monthly are grab samples.

Analytes

Analytes for WWTP monitoring are determined by the SPDES permit. See Appendix XI for a detailed list of the requirements.

Data Analysis and Reporting

Sample results are reported in accordance with FAD Section 6.2, Wastewater Treatment Plant Compliance and Inspection Program. In addition, total phosphorus (TP) and flow data from each WWTP are used by DEP to calculate phosphorus loadings to the reservoirs. Calculated TP loads are then used in determining waste load allocations (WLA) and total maximum daily loads (TMDL). TP loads are also utilized by DEP for model development. The Kensico influent and effluent data are reported weekly to NYSDOH, NYSDEC, USEPA, NYSOAG, NYCDOHMH, CWC, Westchester County, and the NRDC.

3.5 Pathogen FAD requirements

3.5.1 Pathogen - Keypoint Monitoring of Source Waters

Objective

This objective addresses the requirement to monitor the upstate reservoir effluents, and the Kensico Reservoir influents and effluent, for *Giardia* and *Cryptosporidium*. Additionally, CATALUM, DEL17, and DEL18DT need to be monitored for human enteric virus (HEV), for trends and information regarding water quality pathogen issues. The objective also addresses the requirement to include *Cryptosporidium* in the watershed monitoring plan for unfiltered systems as per the IESWTR.

Background

West of Hudson reservoirs contribute 90% (or greater) of the water delivered to NYC for municipal use, making them an integral part of the water supply system. Consequently, pathogen occurrence is monitored at these major reservoir keypoint locations to provide information about water the quality of water being sent to the downstream reservoirs and on the rare instance, potentially guide changes to the delivery process of high quality source water to the terminal reservoirs.

Monitoring at upstream reservoirs provides resolution of potential negative impacts on drinking water quality with respect to pathogen contamination within systems. This monitoring also refines DEP's ability to track the source of contamination to a single reservoir basin, which further sampling may narrow to the sub-basin level. Ultimately, protozoan sample results for the effluents of each of these upstate reservoirs can provide loading estimates for Kensico Reservoir.

Sites

Table 3.22: Pathogen monitoring keypoint sites of upstream source waters.

Site Code	Site Description	Reason for Site Selection
CATALUM	Catskill Aqueduct – Upstream of Kensico Reservoir	Terminal reservoir input
CROGH	Croton Reservoir Raw (untreated) Effluent	Terminal reservoir input

Table 3.22: Pathogen monitoring keypoint sites of upstream source waters.

Site Code	Site Description	Reason for Site Selection
DEL17	Delaware Aqueduct – Shaft 17 Influent to Kensico Reservoir	Terminal reservoir input
DEL18DT	Delaware Aqueduct – Shaft 18 effluent from Kensico Reservoir	Terminal reservoir outflow
SRR2CM	Schoharie Reservoir - Effluent at Shandaken Tunnel Outlet, Shandaken, NY.	Upstate reservoir release
RDRRCM	Rondout Reservoir Effluent at Rondout Effluent Chamber, Napanoch, NY.	Upstate reservoir release
NRR2CM	Neversink Reservoir Effluent, Grahamsville, NY.	Upstate reservoir release
PRR2CM	Pepacton Reservoir Effluent at East Delaware Tunnel Outlet	Upstate reservoir release
WDTOCM	Cannonsville Reservoir Effluent at West Delaware Tunnel Outlet	Upstate reservoir release

The site selection criteria took into account the representation of each upstate reservoir that supplies the source water for Catskill or Delaware systems or vital locations along the aqueducts which represent the Catskill or Delaware influent to and effluents from Kensico Reservoir.

Analytes and Frequencies

Table 3.23: Analytes for pathogen monitoring keypoint sites of upstream source waters.

Analyte	Frequency	Rationale for Analyte
Cryptosporidium oocysts $50L^{-1}$	Monthly[1]	Surveillance and trends
Giardia cysts $50L^{-1}$	Monthly[1]	Surveillance and trends
HEV[2]	Monthly	Surveillance and trends
Flow	Continuous[1]	Required to estimate loading
Weather (general conditions)	Monthly[1]	Supporting data to explain possible unusual protozoan results
Sample volume	Monthly[1]	For determination of (oo)cyst concentration
Turbidity	Continuous[1]	Recovery potential/interference
pH	Monthly[1]	Required by ICR Method (HEV)

Table 3.23: Analytes for pathogen monitoring keypoint sites of upstream source waters.

Analyte	Frequency	Rationale for Analyte
Water temperature	Monthly[1]	Measured to ensure QA/QC
Pressure differential on sample filter	Monthly1	Recovery potential/interference
Flow through filter	Monthly[1]	USEPA method requirement

[1]CATALUM, DEL17, and DEL18DT are sampled weekly.
[2]CATALUM, CROGH, DEL17, and DEL18DT only.

Data Analysis and Reporting

Reporting will be done on an annual basis in the Watershed Water Quality Annual Report in accordance with the Revised 2007 FAD (NYSDOH 2014). The Kensico influent and effluent data are reported weekly to NYSDOH, NYSDEC, USEPA, NYSOAG, NYCDOHMH, CWC, Westchester County, and the NRDC. Data will also be used to ensure drinking water quality is maintained, and to make operational changes as needed to protect source water from contamination. In addition, this monitoring will help indicate the degree of pathogen reduction (if any) over the long term as the water travels through the aqueduct systems.

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nycfad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

3.5.2 Watershed Pathogen Source Origin

Objective

This objective addresses the requirement to monitor eight stream indicator sites previously identified as part of the pathogen surveillance monitoring program, as having, on average, higher pathogen concentrations than most other locations studied in the NYC watershed in support of the IESWTR. Sample locations will be modified, as they have been in the past, to help identify potential pathogen sources.

Background

The NYC watershed has a wide diversity of land types and uses which influence water quality. For instance, the watershed includes several suburban communities, wastewater treatment plants, farms, wetlands, forests, and water bodies. In 2003, DEP set forth a pathogen surveillance monitoring program at 84 stream indicator sites to identify locations where pathogen levels were, on average, higher than most other locations in the NYC watershed. Results from this sampling effort allowed DEP to identify locations and monitor a subset of these to focus on those in need of continued monitoring. This monitoring is in support of the IESWTR and the LT2, which state that unfiltered water supplies must include *Cryptosporidium* monitoring in their watershed protection plan.

Sites

Eight locations have been selected for continued monitoring. The locations are distributed to represent five sites in the Catskill and three sites in the Delaware watersheds. The sample locations include, but are not limited to, the sites listed in Table 3.24. Other sites will be incorporated into the sampling plan if there is suspicion of a new potential pathogen source, or an upstream point source. Site descriptions are listed in Table 3.25.

Table 3.24: Stream sites and their basic statistics identified from 84 previous indicator sites as having relatively greater protozoan levels.

Aqueduct System	Site Code	*Cryptosporidium* oocysts $50L^{-1}$	*Giardia* cysts $50L^{-1}$	N	Max *Cryptosporidium* oocysts $50L^{-1}$	Max *Giardia* cysts $50L^{-1}$
Catskill	S4	0.73	48.66	75	7	249
	S5I	0.84	52.29	71	11	351
	S7I	0.85	225.92	11	5	1118
	S7IB					
	S7IDPond3					
Delaware	PROXG	1.29	145.39	7	5	4500
	CDG1	0.9	54.98	60	5	319
	WDBN	1.03	32.21	63	4	199

Table 3.25: Stream site descriptions and reasons for selection for protozoan analyses.

Site Code	Site Description	Reason for Site Selection
CDG1	West Branch Delaware River upstream of Delhi, NY and 1/8 mile below site CDG.	Identified as site for further monitoring
S5I	Schoharie Creek, below Prattsville.	Identified as site for further monitoring
S7I	Manor Kill.	Identified as site for further monitoring
S71B		
S71DPond3		

Table 3.25: (Continued)Stream site descriptions and reasons for selection for protozoan analyses.

Site Code	Site Description	Reason for Site Selection
S4	Schoharie Creek below Lexington.	Identified as site for further monitoring
PROXG	East Branch Delaware River at Roxbury, NY, USGS Gage #01413088. Sample collected on right bank approximately 50 feet upstream of bridge on State Highway 30 Roxbury.	Identified as site for further monitoring
WDBN	West Branch Delaware River at Beerston, NY. Sample taken upstream of the Beerston Bridge on NYS Route 10, downstream of the confluence with Beers Brook.	Identified as site for further monitoring

Analytes and Frequencies

Consistent with the original objectives in the earlier monitoring program relating to pathogen source origin, samples shall be taken monthly at each stream indicator site. Moreover, sampling shall span a three-year period, at which time this objective will be reevaluated. The evaluation will include a determination for the need to continue monitoring at these eight sites, as well as the potential to expand monitoring to targeted upstream areas based on results. The selected sample frequency will capture mean annual conditions across a given year, which will in turn reveal seasonal patterns over the multi-year effort.

Each site will be monitored for *Giardia* and *Cryptosporidium* (oo)cysts. *Giardia* and *Cryptosporidium* (oo)cyst samples will be analyzed using Method 1623.1with EasyStain (USEPA) or updated method if applicable. Further, additional associated supporting parameters will be included as part of the sampling plan (Table 3.26). All appropriate QA/QC requirements as outlined by DEP will be satisfied as part of this sampling effort.

Table 3.26: Analytes and frequencies for each selected stream indicator site.

Analyte	Reason for Inclusion	Frequency[1]
Giardia cysts 50 L^{-1}	Pathogen of interest	Bimonthly
Cryptosporidium oocysts 50 L^{-1}	Pathogen of interest	Bimonthly
Weather (general conditions)	Supporting data to explain possible protozoan results	Bimonthly
Sample volume	Required for calculating concentration	Bimonthly
pH	Method recovery effects	Bimonthly

Table 3.26: (Continued)Analytes and frequencies for each selected stream indicator site.

Analyte	Reason for Inclusion	Frequency[1]
Turbidity	Matrix recovery effects	Bimonthly
Water temperature	Required by method	Bimonthly
Pressure differential on sample filter	Matrix recovery effects	Bimonthly
Flow rate through the filter	Required by method	Bimonthly
Flow rate at sampling location	Required for loading estimates	Bimonthly

[1]Bimonthly monitoring except at sites which are being investigated for upstream sources or which have been designated as being next in line for upstream monitoring.

Data Analysis and Reporting

Reporting will be done on an annual basis in the Watershed Water Quality Annual Report in accordance with the Revised 2007 FAD. In addition to determining *Cryptosporidium* and *Giardia* (oo)cyst concentrations, possible point sources may be identified. In doing so, DEP will gain further knowledge to refine DEP's watershed protection strategy and, in turn, maintain or improve water quality.

3.5.3 Pathogen - Long-term (Oo)cyst Monitoring at Waste Water Treatment Plants (WWTPs)

Objective

The objective is to continue the long-term monitoring of selected WWTPs for *Giardia* cysts and *Cryptosporidium* oocysts and, as required by the Revised 2007 FAD, report the results of this monitoring effort. In addition, as part of DEP's surveillance of WWTPs, viruses are also monitored under this objective to assess plant performance.

Background

Over 100 WWTPs are located within the NYC watershed. As part of the 1997 WR&R (Chapter 18, Subchapter C, section 18-36) and the NYC Watershed Memorandum of Agreement, NYC was responsible to pay for the upgrade of over 100 public and private WWTPs. These regulatory upgrades included, but were not limited to, the following: phosphorus removal, sand filtration, disinfection, microfiltration or an equivalent technology, recording flow meters, and others.

As part of the 2002 FAD, DEP reported on the long-term monitoring of 10 selected upgraded wastewater treatment plants for *Cryptosporidium* and *Giardia* (oo)cysts, as well as human enteric viruses. Data analysis revealed very few detections of pathogens from the effluents of the upgraded plants; however, there were three plants that had a higher occurrence than the others on average, and they were kept as part of future plans for monitoring.

Sites

As with the previous WWQMP requirement, plants to be monitored are those that use microfiltration (or its equivalent). Accordingly, only the effluents from plants that have been upgraded will be included. This plan will outline the monitoring of 10 WWTPs which were selected based on whether they have been upgraded, geographical location, and whether previously monitored WWTPs had issues with detections. The new list of plants comprises three WWTPs from the previous monitoring plan (Stamford, Hunter Highlands, and Grahamsville) and 7 newly upgraded plants that were not part of DEP's previous monitoring plan (Table 3.27). All plants will be sampled at the final effluent, with the exception of the Grahamsville plant, which will be monitored directly after microfiltration due to suspected wildlife contamination of the open contact tank.

Table 3.27: Pathogen and Human Enteric Virus WWTP monitoring sites and descriptions.

Site	Location	Tertiary Treatment Types	Permitted Flow (mgd)
STP	Stamford FE (WOH)	Dual Sand	0.5
HHE	Hunter Highlands FE (WOH)	Dual Sand	0.08
RGMF	Grahamsville PMF (WOH)	Microfiltration	0.18
Hunter WTP	Hunter FE (WOH)	Dual Sand	0.3259
Windham WWTP	Windham FE (WOH)	CBUDS	0.375
PFTP	Fleischmanns FE (WOH)	Dual Sand	0.16
PANDE	Andes FE (WOH)	SBR, Membrane Filtration	0.062
Prattsville WTP	Prattsville FE (WOH)	SBR, Membrane Filtration	0.086
CARMEL STP	Carmel #2 FE (EOH)	Microfiltration	1.1
MAHOPAC STP	Mahopac FE (EOH)	MBR Microfiltration	0.3

FE= final effluent.

PMF = post micro-filter due to open tank prior to final effluent

Analytes and Frequencies

Consistent with previous monitoring, DEP will monitor each WWTP quarterly (at a minimum) for a period of five years, at which time the program would once again be re-evaluated. Each site will be monitored for *Giardia* and *Cryptosporidium* (oo)cysts. *Giardia* and *Cryptosporidium* (oo)cyst samples will be analyzed using Method 1623.1with EasyStain (USEPA) or updated method if applicable. If elevated pathogen concentrations are found in a particular sample, DEP will re-sample to determine if elevation was an isolated incident or should be the subject of further investigation. Further, additional associated supporting parameters may be included as part of the sampling plan (Table 3.28). All appropriate QA/QC requirements as outlined by DEP will be satisfied as part of this sampling effort.

Table 3.28: Analytes and frequencies for the pathogen monitoring performed at WWTPs.

Analyte	Reason for Inclusion	Frequency
Giardia cysts 50 L^{-1}	Pathogen of interest	quarterly
Cryptosporidium oocysts 50 L^{-1}	Pathogen of interest	quarterly
Weather (general conditions)	Supporting data to explain possible results	quarterly
Sample volume	Required for calculating concentration	quarterly
pH	Method recovery effects	quarterly
Turbidity	Matrix recovery effects	quarterly
Water temperature	Required by method	quarterly
Pressure differential on sample filter	Matrix recovery effects	quarterly
Flow through the filter	Required by method	quarterly
Flow at sampling location	Required by method	quarterly

Data Analysis and Reporting

Reporting will be done on a semi-annual basis in accordance with the Revised 2007 FAD. Results will be reported in the Annual Water Quality report as well as the annual and semiannual FAD reports. The data will be used to determine if the WWTP upgrades are effective in the removal of pathogens as per their design requirements. The ultimate goal is to monitor all the WWTPs to ensure that each WWTP performs well over the long term.

3.6 FAD-Mandated Waterfowl Management

Objective

The Waterfowl Management Program (WMP) is an ongoing FAD mandate and is addressed in Section 4.1 of the Revised 2007 FAD. The program was developed to identify potential effects from fecal pollution from waterbirds. In addition, an environmentally sensitive bird mitigation program is implemented to eliminate birds and prevent fecal coliform bacteria elevations which could threaten water quality.

Background

This program has been highly effective in helping DEP maintain the SWTR coliform limits since the early 1990s. The need for this program was determined through preliminary surveys conducted by DEP staff prior to initiating waterbird mitigation actions. The preliminary waterbird surveys identified both the spatial and temporal distributions and species richness and evenness of the waterbirds inhabiting the reservoirs.

Sites

The selection of waterbird observation sites was made on the basis of the most ideal location to get bird count data during diurnal and nocturnal hours. The original observation locations were identified from reservoir shoreline areas and from motorboats and airboats. The reservoirs identified under the FAD 4.1 Waterfowl Management Program, along with the corresponding number of Bird Zone designations for each reservoir, are as follows: Kensico Reservoir (8 Bird Zones); West Branch Reservoir (4 Bird Zones); Rondout Reservoir (9 Bird Zones); Ashokan Reservoir (6 Bird Zones); Cross River Reservoir (3 Bird Zones); Croton Falls Reservoir (5 Bird Zones); and Hillview Reservoir (2 Bird Zones). Maps of the birds zones for each reservoir are provided as Figures 3.4 through 3.10.

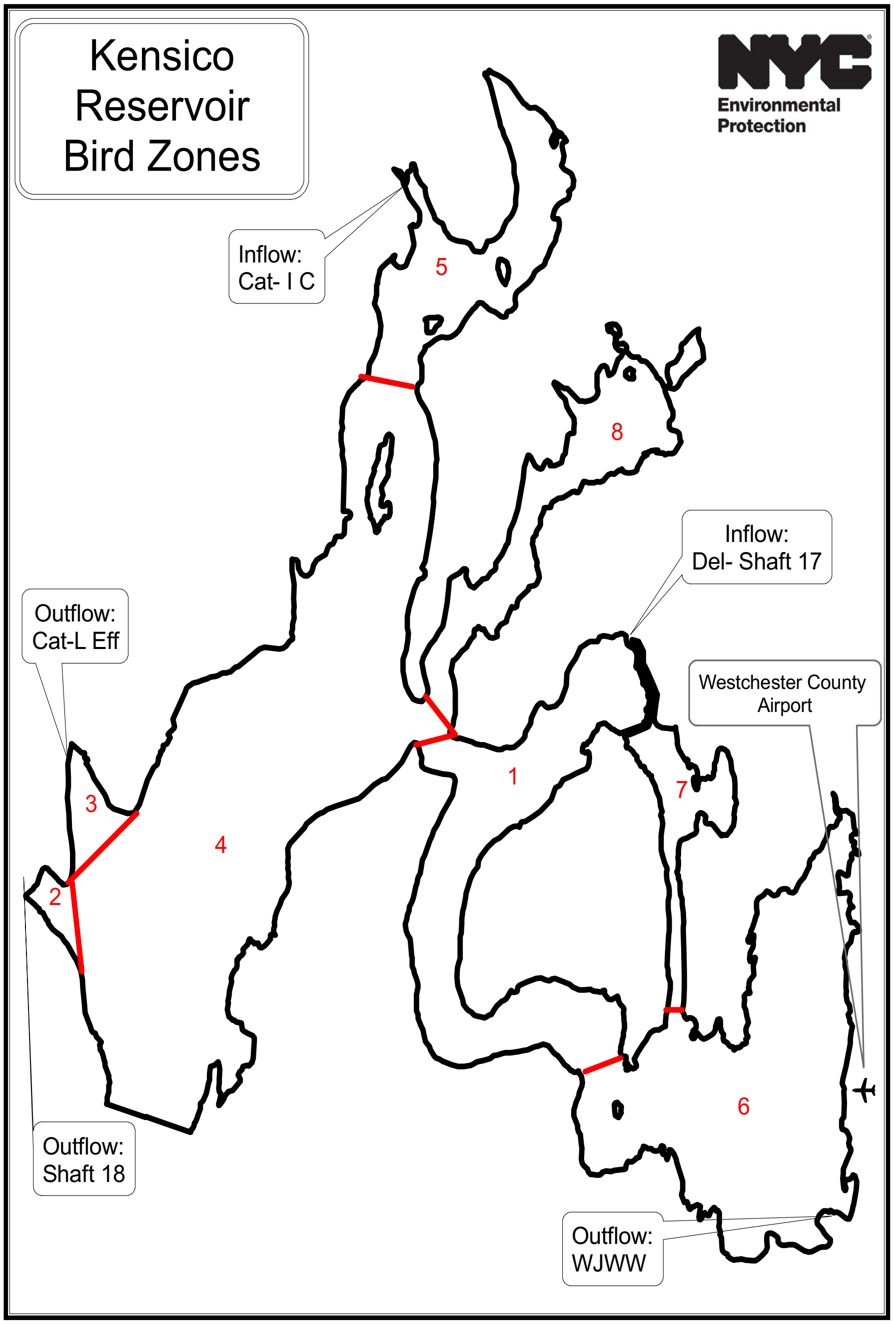


Figure 3.4 Kensico Reservoir bird zones.

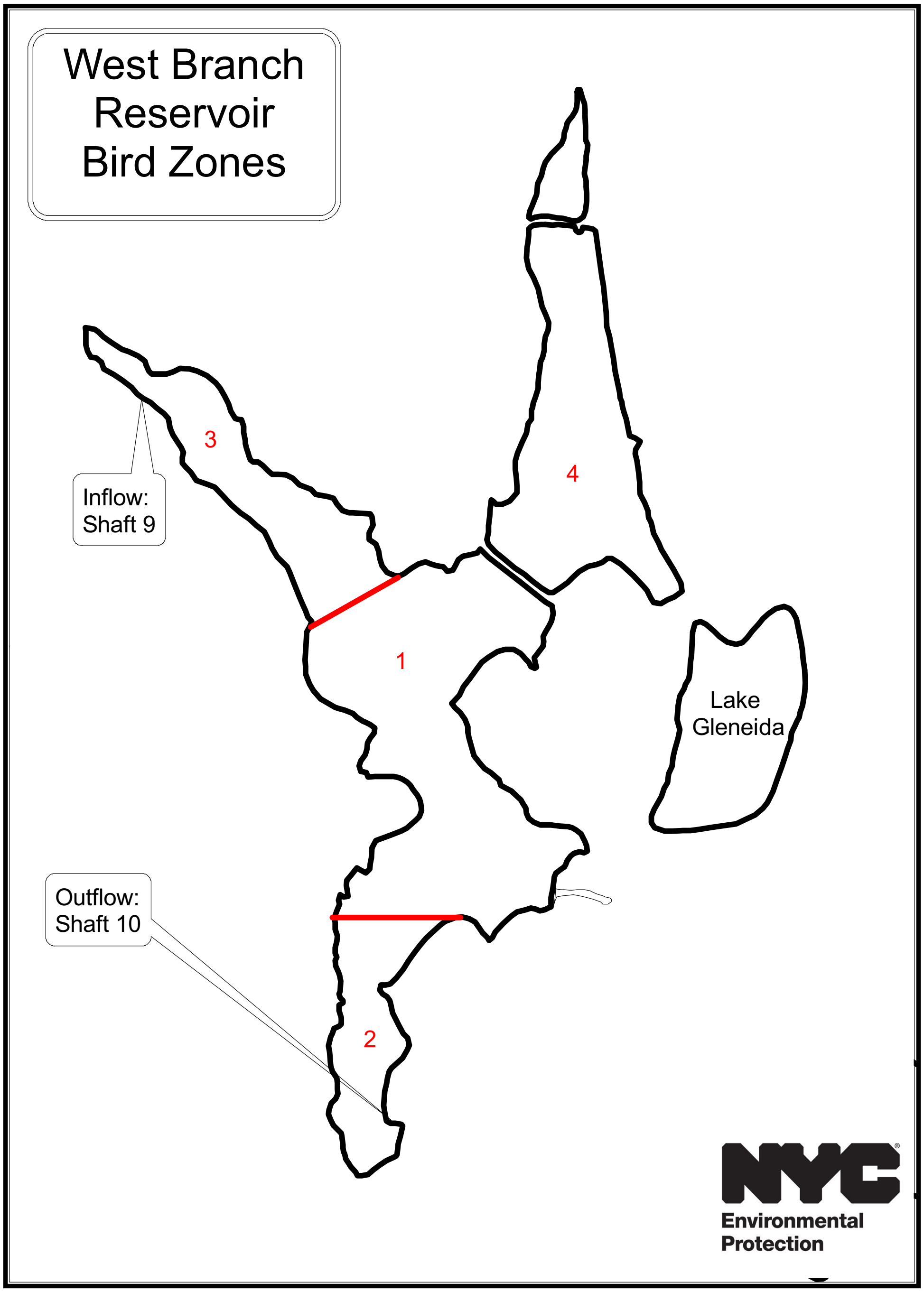


Figure 3.5 West Branch Reservoir bird zones.

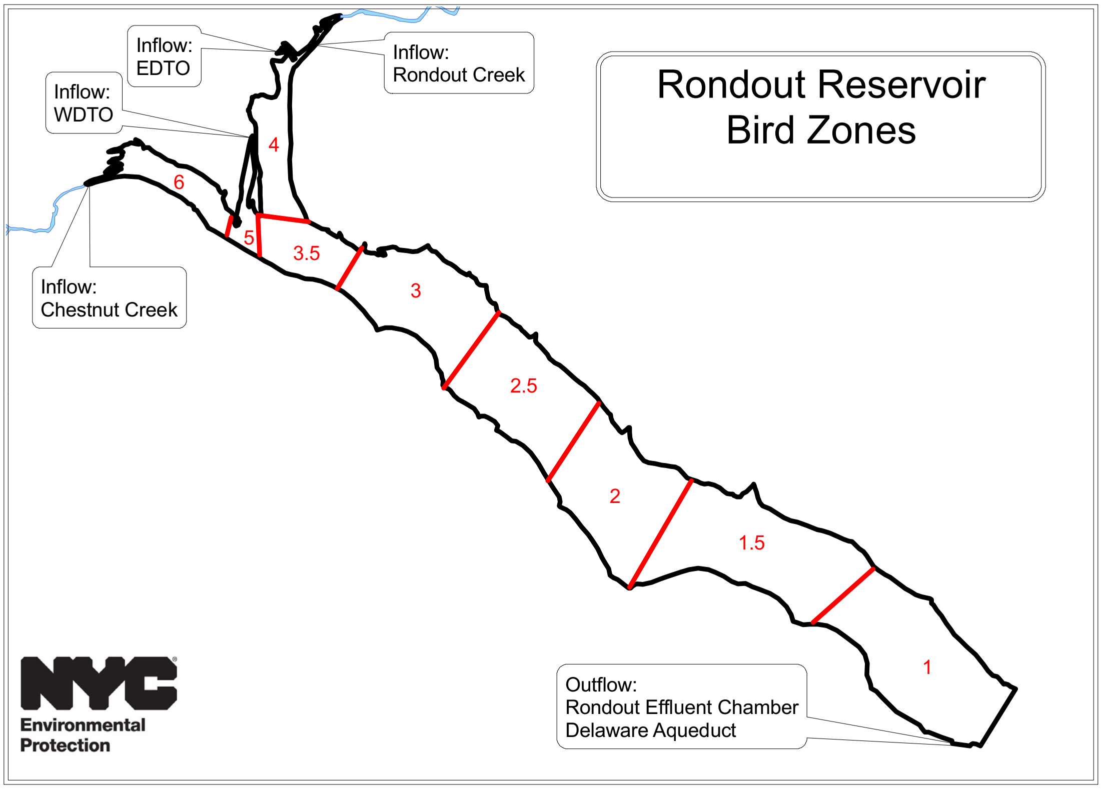


Figure 3.6 Rondout Reservoir bird zones.

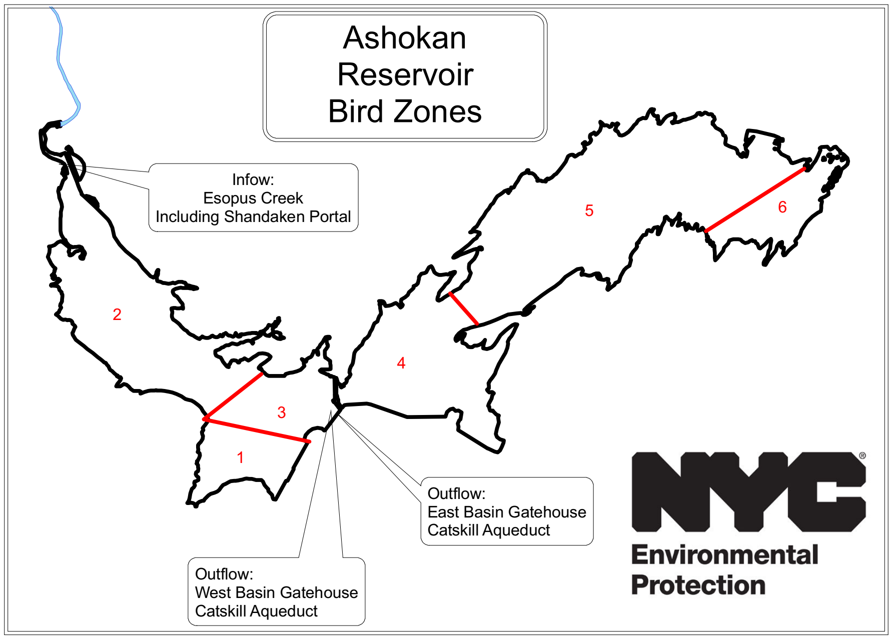


Figure 3.7 Ashokan Reservoir bird zones.

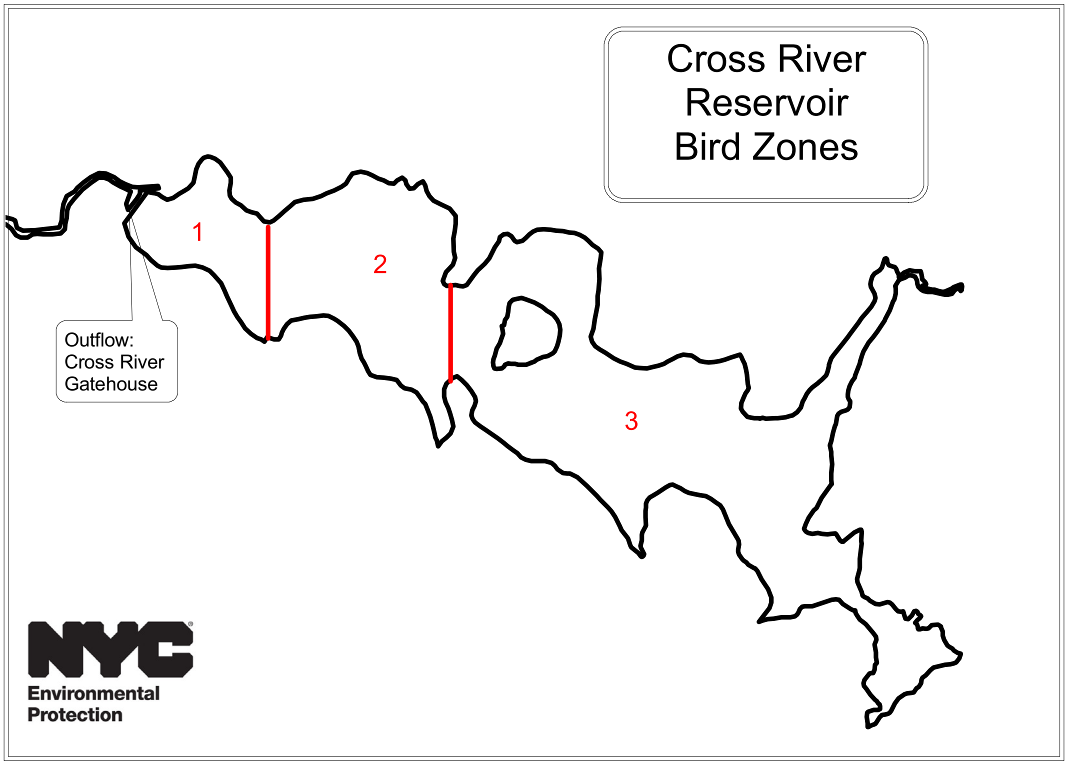


Figure 3.8 Cross River Reservoir bird zones.

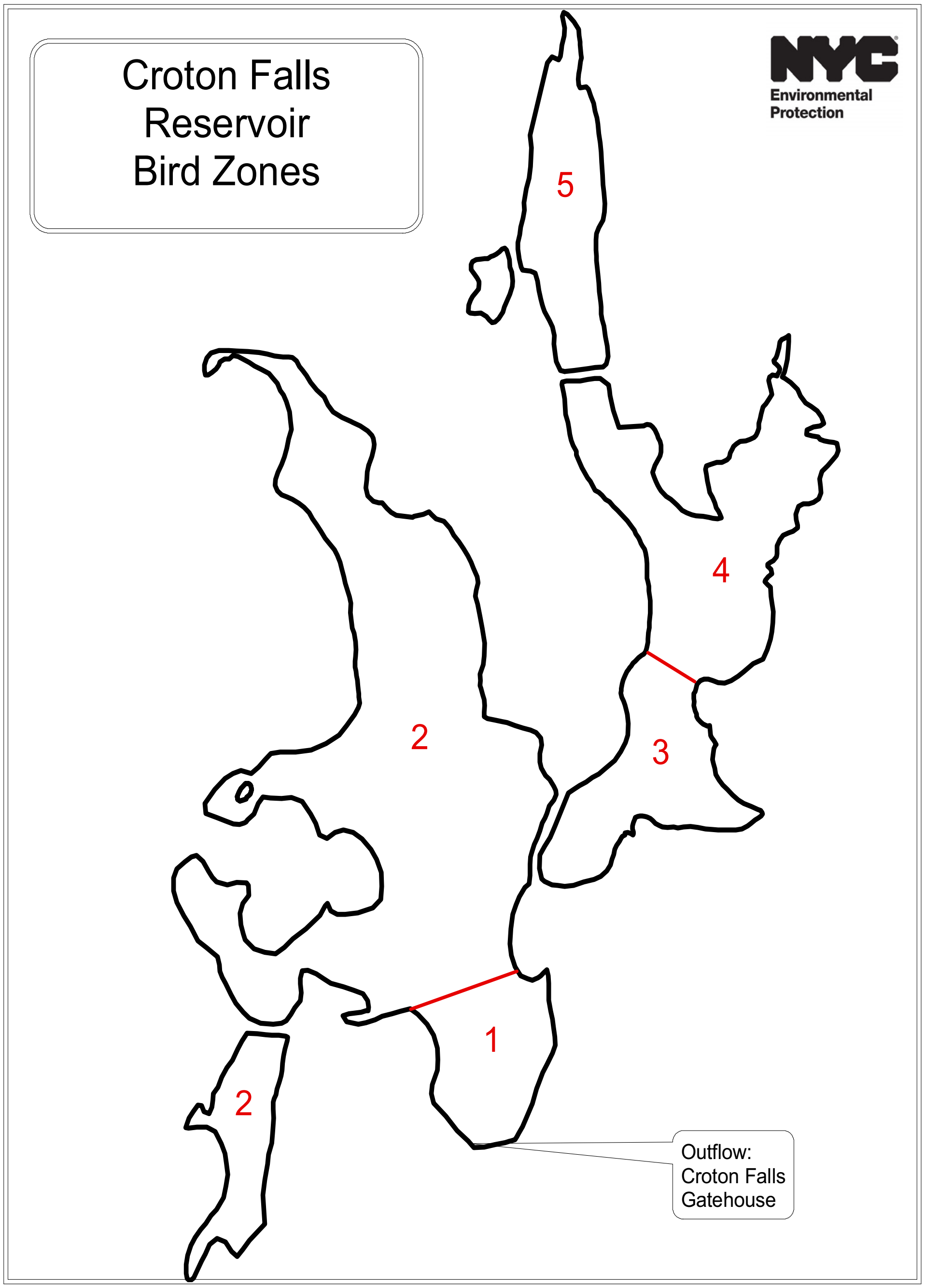


Figure 3.9 Croton Falls Reservoir bird zones.

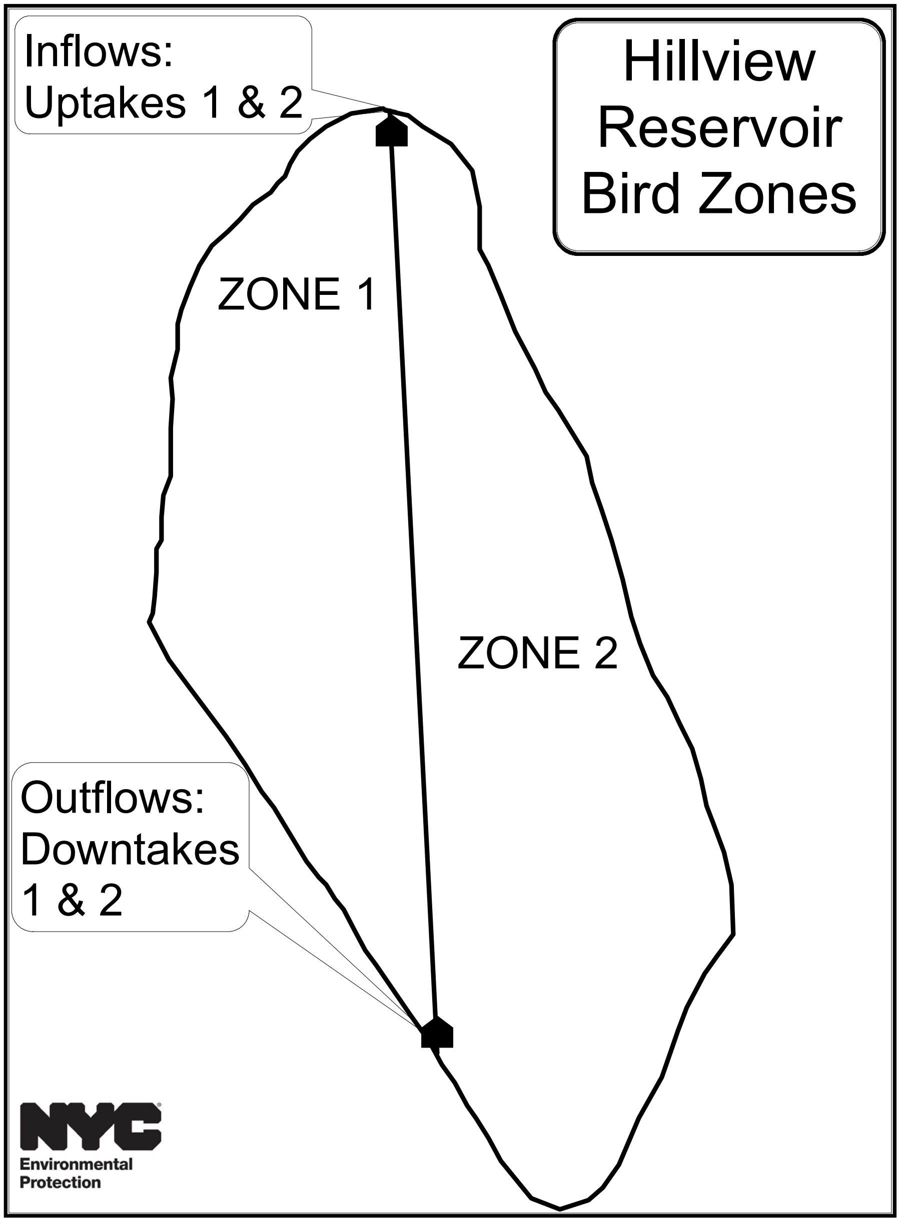


Figure 3.10 Hillview Reservoir bird zones.

Activities

The primary activities include avian population monitoring, avian deterrence and dispersal and egg and nest depredation. Fecal coliform bacteria levels are measured for other objectives and are then compared to waterbird counts.

Program Schedule

The annual schedules for program activities are outlined in the table below, and are based on waterbird population dynamics including migration and wintering movements throughout the reservoir system. Sampling frequency may also be increased in response to elevated fecal coliform levels in the listed reservoirs.

Table 3.29: Program Sampling Schedules

Task	Kensico	Hillview	West Branch	Rondout/ Ashokan	Cross River/ Croton Falls
Population Monitoring	8/1-3/31, daily; 4/1-7/31 weekly[1]	1/1-12/31, daily	8/1-4/15 biweekly[1]	AN	AN
Deterrence/ Dispersal	8/1-3/31 daily 4/1-7/31 as needed	1/1-12/31, daily	AN	AN	AN
Bird Observations	NR	NR	weekly	weekly	NR
Egg and Nest Depredation	4/1-5/31	4/1-5/31 daily	4/1-5/31	4/1-5/31	4/1-5/31

AN = as needed
NR = not required
1. Conducted back to back days, including 2 midday surveys and one evening survey on day one and 1 pre-dawn and 2 midday surveys on day two.

Data Analysis and Reporting

All waterbird data are compared to fecal coliform bacteria data. Data collected from this program are presented annually in the Waterfowl Management Program FAD report.

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

USEPA [U. S. Environmental Protection Agency]. 2007. New York City Filtration Avoidance Determination. 92 p.

3.7 Conversion of Septic to Sewer Evaluation

Objective

The objective of this plan is to determine the water quality effects of providing new or improved wastewater treatment. The Revised 2007 Filtration Avoidance Determination (FAD) (NYSDOH 2014) continues to support the comprehensive programs that serve to reduce the number of failing or potentially failing septic systems. Among the Environmental Infrastructure programs listed in the Revised 2007 FAD, the septic and sewer programs include: Septic Remediation and Replacement; Sewer Extension; and community wastewater management.

Background

In the first five years of the 2007 FAD, three areas were chosen for evaluation of water quality benefits from Environmental Infrastructure Programs. Since that time, one community chose not to participate in a septic to sewer conversion plan, and elected to rely on the Septic Remediation and Replacement program. Ongoing monitoring for this evaluation is focused on the remaining two areas where there is an extension in the sewer system with expected connection or completion dates in 2016. These sites include the Village of Margaretville (Town of Middletown) and Village of Tannersville (Town of Hunter).

Depending on the age of the septic systems, topography, housing density, groundwater hydrology, and the size of the receiving water, it may be difficult to determine what effects these programs may have on pre-construction conditions. This sampling objective will attempt to address these potential impacts in the design of the sampling plan.

Sites

Sites will be selected after field surveillance at streams that have a high density of homes on septic systems so that the likelihood of detecting an impact is high. Stream locations will have two sampling sites—one above and one below the area that will be sewered or served by a community septic system. West of Hudson (WOH), two projects (Margaretville, and Hunter) will be monitored where sewers will be extended into areas that were previously served by individual septic systems. Streams in these three areas will be monitored for water quality improvements following the removal of individual septic systems from the immediate watershed area. Table 3.30

provides a list of sites that will be evaluated.

Table 3.30: Sites for evaluation of conversion from septic systems to sewers.

Site	Reason for Site Selection	Tributary	Number of Sites
Margaretville A/B	Sewer extension	East Branch Delaware River	2
Hunter A/B	Sewer extension	Schoharie Creek	2

Analytes and Frequencies

The variables of interest for this objective are those that are typically indicative of septic system contamination. They include fecal coliform bacteria, total phosphorus, total nitrogen, ammonia, chloride, nitrate, and dissolved organic carbon. Additional variables include temperature, dissolved oxygen, pH, and specific conductivity. This suite of analytes will be compared between the upstream and downstream sites to determine detectable impacts.

Fecal coliforms are indicative of contamination from warm-blooded animals. Forms of phosphorus, nitrogen, and carbon are nutrients found in wastewater, and their concentrations are dependent on the degree of treatment. Chloride is present in wastewater at relatively high concentrations and can be used as an indicator of septic contamination. The difference between upstream and downstream sites can be used to indicate the relative contribution from septic systems along a stream reach.

To capture the effect of water quality improvements from new sewer connections and decommissioning of septic systems, samples will have to be collect for at least two years beyond completion of the projects. Sites will be sampled on a monthly basis. Details on the sites and analytes for monitoring that commenced in 2009 are given in Table 3.31.

Table 3.31: Sites and analytes for monthly monitoring for septic to sewer extension evaluation.

Site	Site Name	Tributary to	Analytes
Margaretville (Above)	PBRA	East Branch Delaware River	Temp., pH, DO, SpCond, Fcoli, TP, TN, NO_x, NH_3-N, Dissolved Cl, DOC
Margaretville (Below)	PBRB	East Branch Delaware River	Temp., pH, DO, SpCond, Fcoli, TP, TN, NO_x, NH_3-N, Dissolved Cl, DOC

Table 3.31: Sites and analytes for monthly monitoring for septic to sewer extension evaluation.

Site	Site Name	Tributary to	Analytes
Sawmill Creek (Above)	SSMA	Schoharie Creek	Temp., pH, DO, SpCond, Fcoli, TP, TN, NO_x, NH_3-N, Dissolved Cl, DOC
Sawmill Creek (Below)	SSMB	Schoharie Creek	Temp., pH, DO, SpCond, Fcoli, TP, TN, NO_x, NH_3-N, Dissolved Cl, DOC

Data Analysis and Reporting

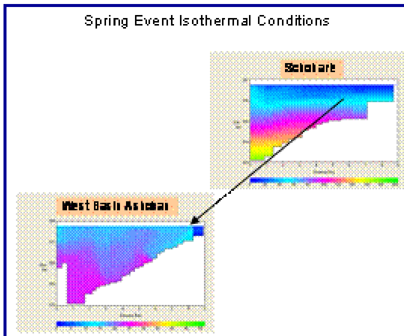
Data analysis will include both temporal plots and nonparametric statistics. Analytes for upstream and downstream sites will be plotted through time for visual assessment of differences. The Wilcoxon rank sum test will be used to compare upstream and downstream sites before and after construction periods on the downstream sites. Upon completion of the two-year post-construction monitoring period for each project, the data will be analyzed and reported.

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. Final Revised 207 FAD. 99p. http://www.health.ny.gov/environmental/water/drinking/nycfad/docs/final_revised_2007_fad_may_2014.pdf. (accessed 12/10/15).

4. Modeling

This section addresses the monitoring needs to meet the FAD-related goals for DEP's Water Quality Modeling Program and to guide operational strategies when unusual water quality events occur. These goals outline the continuation of modeling efforts from previous FAD projects including: implementation of watershed and reservoir model improvements based on ongoing data analyses and research results; ongoing testing of DEP's watershed and reservoir models; updating of data necessary for models including land use, watershed program implementation data, and time series of meteorological, streamflow and water chemistry; development of data analysis tools supporting modeling projects; and applications of DEP's models to support watershed management, reservoir operations, climate change analysis, and long-term planning as identified in DEP's Climate Change Task Force Action Plan (2008).



Thermal conditions in reservoirs govern flow pathways.

The monitoring data needs are divided into three major areas: stream monitoring, reservoir and aqueduct monitoring, and meteorological data. The stream monitoring includes flow monitoring and targeted water quality sampling to support watershed and reservoir model development, testing, and applications. Reservoir monitoring includes flow and reservoir operations data to support reservoir water balance calculations as necessary model input, and reservoir water quality monitoring to adequately continue to test, apply, and further develop DEP's 1D and 2D modeling tools. The meteorological data collection effort provides a critical input stream necessary to meet both watershed and reservoir modeling goals.

4.1 Stream Monitoring Support for Modeling

Objective

This objective addresses the requirement to provide streamflow and water quality data for the Modeling Program to validate, test, and support further development and improvement of watershed, reservoir, and supply system models that comprise the Multi-Tiered Modeling System. This objective is a FAD requirement.

Various components of the Modeling System are being developed, upgraded, and integrated for model applications that address the effects of land use, watershed management, reservoir operations, and climate change on water quantity and quality in the water supply system. These applications are used for both short-term decision making and long-term planning. Continued streamflow and water quality monitoring at multiple sites representing a range of watershed land use, management, physiographic, and meteorological conditions are required for model upgrading and development.

Background

Stream monitoring to support ongoing development, maintenance, and upgrading of the Multi-Tiered Modeling System has been a critical component of the Modeling Program since its inception and has been an explicit FAD requirement since the first FAD in 1993.

This objective is a specific requirement of the Revised 2007 FAD, Section 5.2 (NYSDOH 2014). Specific FAD requirements related to this objective include:

- "Continue model testing and development based on ongoing model simulations, data analyses, and research results"
- "Update land use, watershed programs, and time-series data (meteorological, stream flow and chemistry, reservoir chemistry) to support modeling"
- "Submit report on Modeling Analysis of FAD Programs in the Watershed Protection Program Summary and Assessment Report".

Previous streamflow and water quality monitoring have been used to calibrate, validate, and test GWLF watershed models, and 1D and 2D reservoir models for the Catskill and Delaware Systems. Ongoing and additional monitoring will be used to update these models, and to develop the following components of the Modeling System:

- spatially-distributed watershed models that account for sub-basin variability, channel flow routing, and utilize an ecosystem approach to simulating watershed and stream chemistry by dynamic simulation of storages and fluxes;
- improved sediment loading models that include channel processes, for estimation of sediment and turbidity loads to reservoirs and evaluation of stream channel sources of turbidity.
- forest ecosystem models that simulate soil-vegetation-atmosphere-water transfers in forests which comprise ~85% of the Catskill and Delaware System watersheds and which control watershed hydrology, nutrients, sediment transport, and carbon sequestration;
- reservoir response-function models that capture the salient behavior of reservoir response yet are computationally efficient for use in monte carlo simulations and probabilistic analyses; and
- integration of watershed and reservoir models in a supply system model framework.

Sites

Continued streamflow and water quality monitoring at multiple sites representing a range of watershed land use, management, physiographic, and meteorological conditions are required for model upgrading and development. Expansion of model calibration and testing data to account for changing conditions (e.g., climate change) and ranges of conditions not previously encountered is required to maintain model applicability.

Sites have been selected to support one or more of the following modeling program requirements:

A. Provide near-real-time reservoir model inputs for short-term reservoir operational support model applications
B. Support reservoir model development
C. Continued operation of existing monitoring sites to support sediment model and sediment rating curve development
D. Support watershed hydrologic model development
E. Water temperature monitoring only, for reservoir model development and applications

Flow and water quality quantification are essential for modeling.

These site selection reasons (A–E) are referenced in the following site and analyte tables.

Table 4.1: Stream water quality monitoring for modeling sites.

Site Code	Site Description	Reason for Site Selection
Routine Stream Monitoring Sites		
E10I	Bush Kill below Maltby Hollow Brook at Shokan	E
E16I	Esopus Creek at Coldbrook	A, B, C
P-13	Tremper Kill near Andes	E
P-60	Mill Brook near Dunraven	E
P-7	Terry Clove above Pepacton Reservoir	E
NK4	Aden Brook (aka Nauvoo Brook) near Aden	E
NCG	Neversink River near Claryville	E
RD4	Sawkill Brook (aka Trout Creek) near Sholam	E
RDOA	Rondout Creek near Lowes Corners	A, B, C
RGB	Chestnut Creek at Grahamsville	E
S5I	Schoharie Creek at Prattsville	A, B, C
S6I	Bear Kill near Prattsville	E
S7I	Manor Kill at West Conesville near Gilboa	E
C-7	Trout Creek, near Trout Creek	E
CBS	West Branch Delaware River at Beerston	A, B, C
Automated Stream and Keypoint Monitoring Sites (aka RoboHuts)		
CBS	West Branch Delaware River at Beerston	A, B, C
E16I	Esopus Creeek at Coldbrook	A, B, C
AEAP	Esopus Creeek at Allaben	C

Table 4.1: (Continued) Stream water quality monitoring for modeling sites.

Site Code	Site Description	Reason for Site Selection
SRR2CM	Shandaken Tunnel Outlet into Esopus Creek	A, B, C
NCG	Neversink River near Claryville	A, B, C
RDOA	Rondout Creek near Lowes Corners	A, B, C

Table 4.2: Streamflow monitoring for modeling sites.

Site Code	Site Description	Reason for Site Selection
Existing Contractor-Provided Data Sites: USGS		
01362200	Esopus Creek at Allaben	C, D
01362230	Diversion from Schoharie Reservoir (SRR2CM or SRR1CM)	A, B, C, D
01362342	Hollow Tree Brook at Lanesville (ASCHG)	D
01362380	Stony Clove near Phoenicia (SCL)	D
01362497	Little Beaver Kill at Beechford near Mt. Tremper	D
01362500	Esopus Creek at Coldbrook	A, B, C, D
01363382	Bush Kill below Maltby Hollow Brook at Shokan (E10I)	A, B, D
013621955	Birch Creek at Big Indian (E15)	D
136230002	Woodland Creek above mouth at Phoenicia	D
01349700	East Kill near Jewett Center	D
01349711	West Kill Below Hunter Brook near Spruceton	D
01349810	West Kill near West Kill	D
01349950	Batavia Kill at Red Falls near Prattsville	D
01350000	Schoharie Creek at Prattsville (S5I)	A, B, C, D
01350035	Bear Kill near Prattsville (S6I)	A, B, D
01350080	Manor Kill at West Conesville near Gilboa (S7I)	A, B, D
01350101	Schoharie outflow, stream (dam spill + release)	A, B, D
01413398	Bush Kill near Arkville	D
01413408	Dry Brook at Arkville	D
01413500	East Branch Delaware River at Margaretville (PMG)	B, D
01414000	Platte Kill at Dunraven (P-21)	B, D
01414500	Mill Brook near Dunraven (P-60)	B, D
01415000	Tremper Kill near Andes (P-13)	B, D
01417000	East Branch Delaware River at Downsville (Pepacton outflow) (PDB)	B, D
01434017	East Branch Neversink River near Claryville	D
01434021	West Branch Neversink River at Winnisook Lake near Frost Valley	D
01434025	Biscuit Brook above Pigeon Brook at Frost Valley	D
01434092	Shelter Creek below Dry Creek near Frost Valley	D
01434498	West Branch Neversink at Claryville	D
01435000	Neversink River near Claryville (NCG)	B, D

Table 4.2: (Continued) Streamflow monitoring for modeling sites.

Site Code	Site Description	Reason for Site Selection
01436000	Neversink River at Neversink (Neversink outflow) (NB)	B, D
0143400680	East Branch Neversink River northeast of Denning	D
01365000	Rondout Creek near Lowes Corners (RDOA)	A, B, D
01365500	Chestnut Creek at Grahamsville (RGB)	B, D
01421618	Town Brook southeast of Hobart (CTNBG)	D, E
01421900	West Branch Delaware River upstream from Delhi	D
01422500	Little Delaware River near Delhi	D
01423000	West Branch Delaware River at Walton	B, D, E
01425000	West Branch Delaware River at Stilesville (Cannonsville outflow) (CNB)	B, D
0142400103	Trout Creek, near Trout Creek	B, D

Analytes and Frequencies


Automated stream sampling.

Analytes required for modeling are in three major categories: suspended solids and turbidity, nutrients, and flow. Turbidity monitoring at existing and proposed robohuts is by automated high frequency optical measurement, with periodic laboratory analysis of TSS and turbidity for automated equipment calibration. Samples for turbidity and TSS laboratory analysis for instrument calibration will be the same as those used to fulfill routine surveillance and keypoint sampling objectives. In order to develop and maintain TSS/turbidity relationships and rating curves, samples for TSS and turbidity will need to be collected over the duration of two to five storm events per year, at each robohut site. For each storm event 10-15 samples will be required. These samples can be collected using automated sampling devices, and storm selection can be made taking into account other programs which impact laboratory and field group work load and scheduling. Nutrient monitoring includes P Series (TP, TDP and SRP), N Series (TDN, NOx and NH_3), TOC, DOC, and Silica sampled during storms and in inter-storm periods. Storm event monitoring at CBS is at a higher frequency (200 - 400 samples per year) to adequately construct nutrient budgets consistent with historical sampling. Flow monitoring is according to USGS flow gage protocol.

The following table summarizes the analytes, frequency, and rationale.

Table 4.3: Analytes and frequencies for stream monitoring for modeling.

Site Code	Analytes	Sampling Program	Rationale for Analyte
Routine grab sampling			
E10I	Temperature	routine	E
P-13	Temperature	routine	E
P-60	Temperature	routine	E
P-7	Temperature	routine	E
NK4	Temperature	routine	E
RD4	Temperature	routine	E
RGB	Temperature	routine	E
S6I	Temperature	routine	E
S7I	Temperature	routine	E
C-7	Temperature	routine	E
NCG	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC, TOC[1]	routine and selected storms	A, B, C
CBS	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC, TOC[1]	routine and selected storms	A, B, C
RDOA	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC	routine	A, B, C
NB	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC, TOC[1]	routine	A, B, C
CNB	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC, TOC[1]	routines	A, B, C
PMSB/PMG	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC	routine	A, B, C
M-1	N series, P series, DO, temperature, turbidity, SC, TSS, flow, DOC	routine	A, B, C
SRR2CM	TSS, turbidity	routine	C
Automated Sampling at Robohuts			
E16I	Flow, temperature, turbidity, conductivity	continuous	A, B, C

Table 4.3: Analytes and frequencies for stream monitoring for modeling.

Site Code	Analytes	Sampling Program	Rationale for Analyte
NCG	Flow, temperature, turbidity	continuous	A, B, C
CBS	Flow, temperature, turbidity	continuous	A, B, C
RDOA	Flow, temperature, turbidity, conductivity	continuous	A, B, C
SRR2CM	Flow, temperature, turbidity, conductivity	continuous	A, B, C
AEAP	turbidity	continuous	C
Existing Contractor-Provided Data: USGS			
USGS gage stations	flow	instantaneous	A, B, C, D

[1] TOC analysis on monthly routine samples only.

Data Analysis and Reporting

Daily loads will be calculated by multiplying concentration by mean daily flow. Linear interpolation will be used to estimate analyte concentration between sampling days. The product of mean daily flow and estimated concentration from linear interpolation will be the estimated daily load. Storm loads will be partitioned between days such that daily loads will reflect the contribution from baseflow and stormflow for that day.

Modeling activities, including model development, applications, and related data analyses, will be reported in the annual FAD status report for Modeling.

References

DEP 2008. The NYCDEP Climate Change Program. Report 1: Assessment and Action Plan—A Report Based on the Ongoing Work of the DEP Climate Change Task Force. New York, NY. 100 p. http://www.nyc.gov/html/dep/html/dep_projects/climate_change.shtml

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

4.2 Reservoir Monitoring to Support Water Quality Modeling

Objective

This objective addresses the requirement to provide data that are needed to support the development, testing, and ongoing use of DEP reservoir models. Data collected at differing frequencies are used for several purposes.

- Driving the reservoir models - driving data consists of key inputs such as inflowing water volumes and nutrient loads, operational data specifying the rate of water withdrawal or release, and meteorological data.

- Data used to better define model parameters through model calibration, and to test the performance of calibrated models. These data are independent measurement of variables predicted by the model, such as reservoir water temperature, chlorophyll concentrations, and nutrient concentrations.

As part of DEP's modeling program, it is essential to collect these data in order to evaluate ongoing events, and to allow DEP to calibrate and test its models over the widest possible range of conditions.

Background

Reservoir models used by DEP fall into three categories, each with different data requirements:

1. One-dimensional models used to simulate long-term trends in reservoir eutrophication, i.e., levels of key nutrients and phytoplankton biomass. These models have been used to demonstrate the effects of DEP watershed management and wastewater treatment plant upgrades on reservoir trophic status. The models have played a key role in the 2001 and 2006 and 2011 FAD evaluation reports (DEP 2001, 2006, 2011), and model-based evaluations of the effects of watershed management, land use change, and climate change will again be part of the FAD evaluation process in 2016.
2. Two-dimensional models (CE Qual W2) used to simulate the transport of turbidity through the reservoirs. These models are used to provide short-term simulations in response to storm-related turbidity increases, and long-term simulations to evaluate the effects of reservoir operations and management on reservoir and aqueduct turbidity levels. Reservoir turbidity simulations have played a key role in justifying the need for alum use during large turbidity events (DEP 2005), in minimizing the length of alum treatment when needed (DEP 2007a), and for avoiding alum treatment altogether by adjusting reservoir operations (DEP 2007b).
3. Reservoir system models (OASIS) used to simulate operation and hydrologic condition of an entire reservoir system, i.e., the storage water in each reservoir and the flows of water into, out of, and between all reservoirs in the system. This model is used to examine long-term trends in water storage and reservoir operations and evaluate reservoir operation strategy.

One key finding of the Catskill Turbidity Control Study (DEP 2007c) was that model simulations can provide valuable information to guide reservoir operations so as to minimize the impacts of elevated Catskill System turbidity on the water supply as a whole, and to minimize the need for alum treatment while maintaining acceptable levels of turbidity entering the water distribution system. The CAT 211 implementation plan (DEP 2008a) recommends developing an operations support tool (OST) that will be based on a coupled OASIS – CE Qual W2 model. Data to test calibrate, validate, and routinely run these models will therefore also need to be collected to support the development and ongoing use of the OST.

Evaluating the effects of climate change on the quantity and quality of water in the NYC water supply is a task assigned to the Bureau of Water Supply in the NYCDEP Climate Change Program Assessment and Action Plan (DEP 2008b). Estimation of future conditions, out of necessity, must be based on model simulations, and all three of the reservoir models described above will be used for climate change simulations. Model estimation of future conditions intensifies the need for model testing and evaluation, particularly in regard to performance under present day extreme conditions, or for aspects of the model (e.g., reservoir thermal stratification, temperature-related processes influencing phytoplankton growth) that would be sensitive to expected changes in climate. Climate change is occurring today, and ongoing reservoir monitoring is needed to both document this change and to provide data sets covering the widest possible range of conditions for model development and testing.

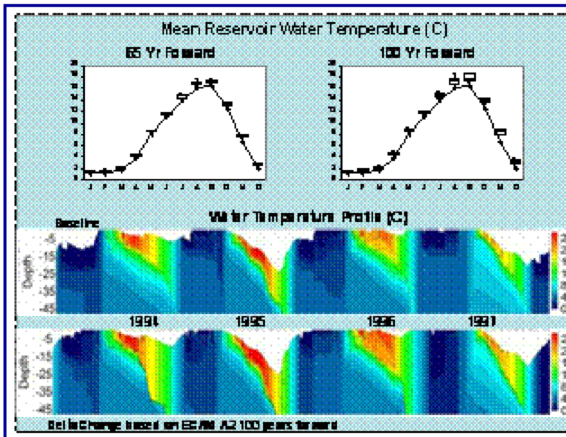
FAD Requirement

Continued testing and updating of DEP reservoir models is a FAD requirement as specified in the Revised 2007 FAD (NYSDOH 2014).

Furthermore, the 2014 FAD also specifies a model-based assessment of DEP FAD programs as part of the Watershed Protection Program Summary and Assessment Report. This is a FAD deliverable due in March 2016. In order to accomplish these FAD-mandated requirements, an ongoing program of data collection to support reservoir modeling is needed. These monitoring needs are described below.

In-Reservoir Monitoring

Monitoring of in-reservoir parameters is needed to provide data which support three different aspects of reservoir modeling.



Water temperature profiles are the basis of hydrodynamic models.

- To provide near-real-time monitoring of reservoir thermal structure and turbidity levels. These data are especially valuable to support turbidity simulations in response to ongoing events.
- To provide data for ongoing reservoir model development and testing of 1D eutrophication and 2D turbidity reservoir models. Comparison of measured and simulated values are used to test, calibrate, and verify the models' performance.
- To provide the initial conditions to a model simulation. Initial conditions are most valuable for event-specific simulations where the model needs to be run from a specific time and over a relatively short time period.

Data are derived from collected water samples followed by laboratory analysis, from in situ measurement of physical parameters concurrent with sample collection, or by automated buoy-based monitoring systems. Automated monitoring data are put to the same use as the data derived from manual monitoring efforts, namely, providing initial model conditions and data for calibration and verification. These data are collected much more frequently than manually collected data, but are restricted to parameters that lend themselves to in situ measurement, e.g., optical properties and water temperature.

Sites have been selected to support one or more of the following modeling program requirements and are listed in Table 4.4 below. Note, however, that sites and frequencies are subject to change depending on conditions that arise.

A. Provide near-real-time reservoir model inputs for short-term reservoir operational support model applications

B. Support reservoir model development

Table 4.4: Sites for support of reservoir modeling.

Reservoir Code	Site Number	Reason for Site Selection
Routine Reservoir Monitoring Surveys		
EAW(Ashokan West Basin)	1, 2, 3	A, B
EAE (Ashokan East Basin)	4, 5, 6	A, B
SS (Schoharie)	1.5, 2, 3, 4	A, B
NN (Neversink)	1, 2, 3, 4	B
RR (Rondout)	1, 2, 3	B
EDP (Pepacton)	1, 3, 4, 5, 6	B
WDC (Cannonsville)	1, 3, 4, 5, 6	B
BRK (Kensico)	1.1, 2, 2.9, 4, 5, 6, 7, 8	A, B
CWB (West Branch)	1, 2, 3, 4	A, B
Routine Operations Monitoring Surveys		
EAW (Ashokan West Basin)	1, 2, 3, 3.2	A, B
EAE (Ashokan East Basin)	4	A, B
RR (Rondout)	1, 2, 3	B
BRK (Kensico)	1.1, 2, 2.9, 4, 5	A, B
CWB (West Branch)	1, 2, 3	A, B
Turbidity Event-BasedReservoir Monitoring Surveys		
EAW(Ashokan West Basin)	2, 1.4, 3.2	A
EAE (Ashokan East Basin)	4	A
SS (Schoharie)	2, 3, 4	A
RR (Rondout)	1	A

Table 4.4: (Continued)Sites for support of reservoir modeling.

Reservoir Code	Site Number	Reason for Site Selection
CWB (West Branch)	1, 2, 3	A
BRK (Kensico)	1.1, 2, 2.9, 3.1, 4, 4.1, 4.2, 5	A
NN (Neversink)	1.5	A, B
WDC (Cannonsville)	4	A, B
Automated Reservoir Monitoring Buoys		
EAW(Ashokan West Basin)	3.1 (Profiling and Under Ice) 1.4 (Profiling and Under Ice)	A, B
EAE (Ashokan East Basin)	4.2 (Profiling and Under Ice)	A, B
SS (Schoharie)	3 (Profiling)	A, B
NN (Neversink)	1.5 (Profiling)	A, B
RR (Rondout)	1 (Profiling)	A
WDC (Cannonsville)	4 (Profiling)	A, B
BRK (Kensico)	2 (Fixed Depth), 2.9 (Fixed Depth), 4 (Profiling), 4.1 (Profiling)	A, B

Analytes and Frequencies for Reservoir Monitoring

Most of the data collected from in-reservoir monitoring activities will be used for model testing and development, and for providing initial conditions for running models, especially for running the turbidity model in response to an ongoing turbidity event. The one exception is the monitoring of changes in photosynthetically active radiation (PAR) with depth. PAR profiles are used to estimate the vertical extinction coefficient of PAR (K_d). Temporal variations in K_d are used to drive the hydrothermal and phytoplankton components of both 1D and 2D reservoir models.

The sampling frequency for all routine in-reservoir monitoring analyses are the same as that for reservoir status monitoring (Chapter 5). It is anticipated that more frequent sampling will not be needed given the long time series of previous reservoir monitoring data, and given the possibilities of supplementing these data with automated measurements. Operational monitoring data and data collected in response to elevated turbidity levels at the sites listed in Table 4.4 will also be used. All in-reservoir monitoring is carried out to meet modeling and other objectives, and does not require additional resources

.

Table 4.5: Analytes and frequencies for support of reservoir modeling.

Site	Analyte	Sampling Frequency	Rationale for Analyte[1]
Reservoir Routine Monitoring Surveys			
All routine reservoir monitoring sites[2] (Table 4.4)	TDN, Total P, TDP, SRP, NOX, NH_3, TN, SiO2[3], DOC, DO, chlorophyll a[4], phytoplankton counts, Secchi depth	Monthly	Eutrophication model development and testing
	TSS, temperature, conductivity	Monthly	Turbidity and eutrophication model testing and development
	Turbidity	Monthly	Turbidity model development and testing. Initial conditions for turbidity model
Routine Operations Monitoring Surveys			
All reservoir operations monitoring sites (Table 4.4)	Turbidity, temperature	Monthly or twice monthly	Turbidity and eutrophication model testing and development. Initial conditions for Turbidity Model.
	DO	Monthly	Eutrophication model testing and development
In Situ Measurements Concurrent with Routine Reservoir and Operations Monitoring			
All reservoir operations monitoring sites (Table 4.4)	Sonde: Temperature, dissolved oxygen, conductivity, depth	Monthly	Testing and development. Initial conditions (all reservoir models)
	Photometer: PAR – light extinction coefficient[5]	Monthly	Driving data for eutrophication and turbidity model
Turbidity Event-Based Sampling (all sites and analytes at management's discretion)			
All turbidity event-based reservoir monitoring sites (Table 4.4)	Temperature, conductivity, turbidity, TSS, beam attenuation coefficient[6]	Special surveys of turbidity events	Driving data and initial conditions for turbidity model
Automated Buoy Measurements			
All reservoir monitoring buoys (Table 4.4)	Temperature, turbidity, conductivity, depth	4 times per day (conditions permitting); 1 meter vertical resolution	Testing and development. Initial conditions (all reservoir models)

Table 4.5: (Continued) Analytes and frequencies for support of reservoir modeling.

Site	Analyte	Sampling Frequency	Rationale for Analyte[1]
Buoys 1.5NN and 4WDC[7]	In addition to analytes listed above: DO, Chl *a,* phycocyanin and fDOM, TOC, phytoplankton	Monthly	Eutrophication model testing and development

[1]Refer to Table 3.6 for additional information on the role each analyte plays in assessing water quality.

[2]Sites 2RR and 2SS are not sampled for filtered nutrients or DOC.

[3]SiO2 is collected at WOH dam sites only; it is not collected on EOH reservoirs.

[4]Chlorophyll a is collected at 3-m depth only.

[5]Light extinction is measured at sites 1RR, 2NN, 3EDP and 4 WDC, at 1-m intervals.

[6]Beam attenuation coefficient is measured when possible.

[7]Additional grab samples are collected when buoy maintenance is performed.

References

NYSDOH [New York State Department of Health]. 2014. Final Revised New York City Filtration Avoidance Determination. http://www.health.ny.gov/environmental/water/drinking/nyc-fad/docs/final_revised_2007_fad_may_2014.pdf. 99 p.

4.3 Monitoring of Reservoir Operations; Aqueducts and Reservoir Releases

Objective

Unlike lakes, the flows entering and leaving reservoirs are controlled by operational decisions as well as the timing of hydrologic processes. Monitoring of reservoir operations and aqueduct conditions are therefore needed in order to specify the driving data needed by the reservoir models. Driving data are those which vary on a frequent basis and which affect temporal variations in reservoir model output. For example, variations in input flow, temperature, and turbidity must be specified in order for a reservoir model to predict temporal variations of in-reservoir turbidity levels. In addition to the data described here, stream inputs (Section 4.1) and meteorological measurements (Section 4.4) are also needed to drive the reservoir models.

As with the in-reservoir monitoring there are two reasons for monitoring operations or aqueducts, and these are:

A. To provide near-real-time reservoir model inputs, specifically to support turbidity simulations in response to ongoing events.

B. To provide data for ongoing reservoir model development and testing of 1D eutrophication and 2D turbidity reservoir models.

Reservoir operation and aqueduct flow data are collected by a variety of manual and automated measurement programs maintained by WQD and Operations. These are described below.

Aqueduct Monitoring

Aqueduct monitoring documents significant inputs and outputs which are controlled by operational decisions. The flows of water, nutrients, turbidity, and heat moving through the aqueducts must be specified in order to drive reservoir model simulations.

Table 4.6: Sites for aqueduct monitoring to support reservoir modeling.

Site Code	Site Description	Reason for Site Selection
Routine Grab Sampling		
SRR2CM	Portal (Shandaken Tunnel Outlet into Esopus Creek), continuous monitoring	A, B
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent	A, B
NRR2CM	Neversink Tunnel Outlet (Neversink Reservoir effluent)	A, B
PRR2CM	East Delaware Tunnel Outlet (Pepacton Reservoir effluent)	A, B
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent)	A, B
RDRRCM	Rondour Reservoir effluent	A, B
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.	A, B
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.	A, B
DEL17	Delaware Aqueduct, sampled at Shaft 17 uptake, influent to Kensico Reservoir.	A
DEL18DT	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.	A
CATALUM	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.	A
RB	Rondout Reservoir Release	B
NB	Neversink Reservoir Release	B
PDB	Pepacton Reservoir Release	B
CNB	Cannonsville Reservoir Release	B
M-1	Ashokan Release Channel	B

Table 4.6: (Continued) Sites for aqueduct monitoring to support reservoir modeling.

Site Code	Site Description	Reason for Site Selection
Automated Monitoring Sites		
EARCM	Catskill Aqueduct withdrawal at Ashokan Reservoir	A, B
NRR2CM	Neversink Tunnel inflow to Rondout Reservoir	A, B
PRR2CM	Pepacton Tunnel inflow to Rondout Reservoir	A, B
RDRRCM	Delaware Aqueduct withdrawal from Rondout Reservoir	A, B
SRR1CM	Schoharie flow into Shandaken Tunnel	A, B
SRR2CM	Shandaken Tunnel outflow	A, B
WDTOCM	Cannonsville Tunnel inflow to Rondout Reservoir	A, B
CATALUM	Catskill Aqueduct alum plant (inflow)	A
DEL9	Delaware Aqueduct inflow to West Branch Reservoir	A, B
DEL10	Delaware Aqueduct outflow from West Branch Reservoir	A, B
DEL17	Delaware Aqueduct inflow to Kensico Reservoir	A
DEL18DT	Delaware Aqueduct outflow from Kensico Reservoir	A

Table 4.7: Analytes and frequencies for aqueduct monitoring to support reservoir modeling.

Site	Analyte	Sampling Frequency	Rationale for Analyte
Routine Grab Sampling			
Aqueduct keypoint sites (Table 4.6)	Turbidity	Daily (EOH), Weekdays (WOH)[1]	Turbidity model testing and development. Initial conditions for Turbidity model
	TSS[2]	Monthly	Turbidity and eutrophication model testing and development
	Temperature and flow	Daily (EOH), Weekdays (WOH)[3]	Testing and development. Initial conditions (all reservoir models)
Major aqueduct inputs, outputs, and controlled releases of reservoirs: SRR2CM, EARCM, NRR2CM[4], PRR2CM, WDTOCM[4], RDRRCM, DEL9, DEL10, RB, NB, PDB, CNB, M-1	Total P, TDP, SRP, NO_X, NH_3, TN, DOC, TOC[4], chlorophyll *a*[5], temp., conductivity, turbidity, TSS, TDN, pH, DO	Monthly	Eutrophication model testing and development
Automated Monitoring			
All automated monitoring sites (Table 4.6)	Temperature, conductivity, turbidity, and flow	Continuous	Testing and development. Initial conditions (all reservoir models). Data to drive turbidity simulations in near real time.

[1] Turbidity is sampled weekly at DEL9 and DEL10.

[2] TSS is not collected at DEL9 and DEL10.

[3] Temperature is sampled weekly at DEL9 and DEL10.

[4] TOC analyzed monthly.

[5] Not on releases

Operations Monitoring

In addition to defining the flows associated with the aqueducts, there are other operational data that need to be monitored in order to support reservoir model simulations. In addition to aqueduct flows, there are other major flows of water which leave the reservoirs which must be specified as model driving data. These data specify the discharge of water released in a controlled way to downstream rivers, or spilled to these rivers during storm events. It is also important to know the current water withdrawal depth for reservoirs with multiple effluent levels, since during thermally stratified conditions the depth of withdrawal will influence the quality of the water withdrawn. Reservoir water level is not used to drive the models, but is a predicted value of the models. This parameter is of critical importance for verifying that the reservoir water balance is being correctly simulated. Operational monitoring data listed in Table 4.8 is obtained to support modeling.

Table 4.8: Reservoir operations data to support reservoir modeling.

Site	Measurement	Frequency	Reason for Site Selection[1]
Existing Data From Operations Division			
SS (Schoharie)	Depth of withdrawal	Daily	A,B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	
EAW(Ashokan West Basin)	Depth of withdrawal	Daily	A,B
	Release channel discharge	Daily	
	Dividing weir spill discharge	Daily	
	Dividing weir gate discharge	Daily	
	Water elevation	Daily	
EAE (Ashokan East Basin)	Depth of withdrawal	Daily	A,B
	Spill discharge	Daily	
	Water elevation	Daily	
EDP (Pepacton)	Depth of withdrawal	Daily	B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	
WDC (Cannonsville)	Depth of withdrawal	Daily	B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	

Table 4.8: (Continued) Reservoir operations data to support reservoir modeling.

Site	Measurement	Frequency	Reason for Site Selection[1]
NN (Neversink)	Depth of withdrawal	Daily	B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	
RR (Rondout)	Depth of withdrawal	Daily	A,B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	
CWB (West Branch)	Depth of withdrawal	Daily	A,B
	Controlled release discharge	Daily	
	Spill discharge	Daily	
	Water elevation	Daily	
	Reservoir operation mode	Daily	
BRK (Kensico)	Depth of withdrawal at Delaware Shaft 18	Daily	A,B
	Water elevation	Daily	
	Reservoir operation mode	Daily	

[1] A. To provide near-real-time reservoir model inputs, specifically to support turbidity simulations in response to ongoing events.
B. To provide data for ongoing reservoir model development and testing of 1D eutrophication and 2D turbidity reservoir models.

Data Analysis and Reporting

Flows associated with the aqueducts, reservoir releases, and reservoir spills are used to drive model simulations. Characteristics of these flows are important because daily variations in the inputs and outputs of water, materials, and heat from these flows are major factors that determine day-to-day variations in model output. These monitoring data are therefore transformed to input files for both the 1D eutrophication model and 2D turbidity transport model that DEP routinely uses for water quality simulations. When modeling ongoing turbidity events, it is especially important to be able to obtain aqueduct flow, water temperature, and turbidity data in a timely manner so that the reservoir turbidity transport models can be run to reflect current conditions.

Data collected throughout the water column of the reservoirs as a result of both routine and automated monitoring activities provide information that can be used to provide the initial conditions for a reservoir model simulation and to judge the accuracy of reservoir model predictions. Initial conditions are especially important for short-term simulations of ongoing events. Longer-term multi-year simulations that begin at times of isothermal mixing are less sensitive to the need for accurate initial conditions. For example, when starting a short-term reservoir simulation during thermally stratified conditions it is necessary to specify an initial temperature profile. Monitoring parameters that are key predictions of the reservoir models (e.g., water temperature, turbidity, chlorophyll) provides an independent verification of model performance. Furthermore, as data are continually collected over a wider range of environmental conditions, or as improvements are made to model algorithms, it can be valuable to reassess the values of model coefficients. Typically this is done by adjusting or optimizing the coefficient(s) in order to minimize the difference between simulated and measured parameters. It is important to realize that the DEP modeling program is continually testing and updating a variety of models in this manner. Monitoring plays a critical role in ongoing maintenance and development of DEP's reservoir water quality models.

Modeling activities, including model development, applications, and related data analyses, will be reported in the annual FAD status report describing water quality modeling activities. In response to turbidity events, special reports are often prepared and distributed to DEP management and regulators. These outline the potential impacts, and the effects of mitigating actions, on reservoir turbidity levels. The modeling group also publishes on all aspects of its work in peer reviewed journals.

References

DEP 2001 New York City's 2001 Watershed Protection Program Summary, Assessment and Long-term Plan. 611 pp. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York.

DEP 2005 Multi Tiered Water Quality Modeling Program Semi-Annual Status Report. 34 pp. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York. July 2005.

DEP 2006 Watershed Protection Program Summary and Assessment. 425 pp. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York.

DEP 2007a Multi Tiered Water Quality Modeling Program Semi-Annual Status Report. 13 pp. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York January 2007.

DEP 2007b Multi Tiered Water Quality Modeling Program Annual Status Report. 34 pp. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York. October 2007.

DEP 2007c. Catskill Turbidity Control Study Phase III Implementation Plan. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York.

DEP 2008a. Catskill Turbidity Control Study Phase III Final Report. New York City Department of Environmental Protection, Bureau of Water Supply. Valhalla, New York. 106 pp.

DEP 2008b. The NYCDEP Climate Change Program. Report 1: Assessment and Action Plan—A Report Based on the Ongoing Work of the DEP Climate Change Task Force. New York, NY. 100 p. http://www.nyc.gov/html/dep/html/dep_projects/climate_change.shtml

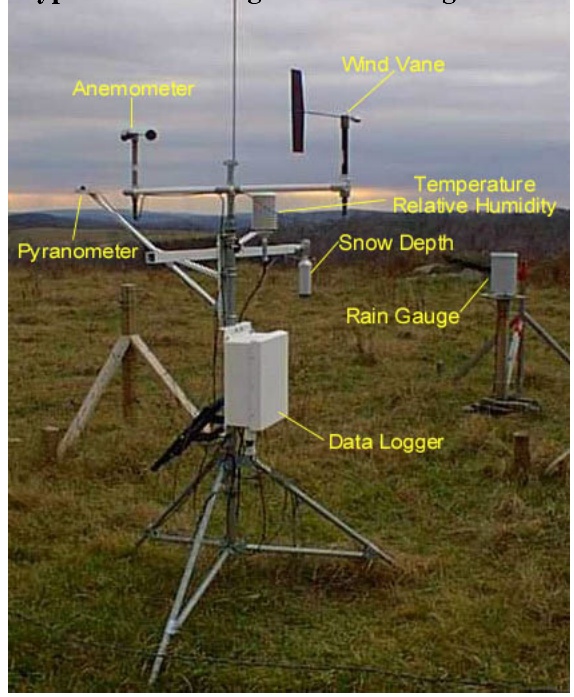
DEP 2011 Watershed Protection Program Summary and Assessment.NYCDEP, BWS. Valhalla,NY

4.4 Meteorological Monitoring Support for Modeling

Objective

A critical input for both watershed and reservoir models is meteorological data including precipitation, temperature, wind speed and direction, relative humidity, incoming solar radiation, PAR (photosynthetically active radiation), and snow water equivalent (SWE) measurements. As such, all of the modeling goals, as described in previous sections, require meteorological data.

Typical Meteorological Monitoring Station



Background

For the watershed models, meteorological inputs determine critical water balance quantities, which control water quality issues. Precipitation is the major input for calculation of streamflow, direct runoff, baseflow, and soil moisture. Temperature is used to help determine evapotranspiration, snow pack development, and melting. Humidity, incoming radiation, and wind speeds determine evapotranspiration rates. SWE estimates can be used to check model performance during winter periods.

Meteorological measurements for the watershed models should be located throughout the watershed to adequately capture the spatial variability of these model inputs. For WOH watersheds, annual precipitation varies from 100 to 150 cm, due to a combination of meteorological patterns and the orographic effects of the Catskill Mountains. This variability is even more pronounced on an event-by-event basis. Due to this wide spatial variability, the meteorological network is required to include enough station locations to provide a representative sample of event precipitation. It is important to obtain meteorological measurements representative of sub-basins in order to meet turbidity modeling objectives.

To achieve long-term modeling goals, DEP modeling applications have used daily precipitation and temperature data from the National Weather Service co-operator network. These data have been particularly useful due to their long period of record and because they contain winter precipitation data. However, this network is slowly losing stations—only 8 out of the original 18 stations are still reporting. As such, modeling applications will need to rely even more on DEP meteorological station data to continue to meet modeling obligations. Recent improvements to the DEP meteorological stations, including the upgrade of precipitation equipment to allow for more reliable winter precipitation measurement, allows for greater use of these data.

For the reservoir models, meteorological inputs are critical for determining thermal structure of the reservoir, internal transport of constituents, development of phytoplankton, and water balance calculations. Temperature is critical to determining thermal structure. Incoming radiation is used both for evaporation calculations and as a determinant of algal growth. Wind speed and direction are critical to calculating wave action, mixing depths, and internal reservoir transport. Humidity is used to calculate evaporation and precipitation, both of which are used for water balance calculations.

Meteorological measurements for reservoir models are taken at or near the dams for each reservoir. In the event that meteorological stations at the dam sites are not operating properly or that the data are otherwise unavailable, data collected at the closest airport location as supplied by the Northeast Regional Climate Center (NRCC) are used to fill in these gaps.

Data from the DEP meteorological network also allows for a further check of climate change parameters for the watershed areas. With this network in place, long-term data can be collected to predict the effects of climate change on critical factors affecting water balance and water quality.

Sites

Meteorological stations are listed in Tables 4.9-4.13.

Table 4.9: Operations Directorate meteorological stations.

Site Code	Site Description	Reason for Site Selection
CAM001	Ashokan Dam	Reservoir and watershed models
CAM002	Rouff Farm near Chichester	Watershed models
CSM038	Schoharie Dam	Reservoir and watershed models
CSM040	Batavia Kill near Ashland	Watershed models
CSM048	DEP Property #5621 near Prattsville	Watershed models
DCM074	Cannonsville Dam	Reservoir and watershed models
DCM076	Tymeson Farm, Dunk Hill Road near Walton	Watershed models
CSM079	DEP Property near West Delhi	Watershed models
CSM082	DEP Property, Town Brook Rd. near Hobart	Watershed models
CSM083	DEP Property #4860, Rt. 10 near Bloomville	Watershed models
CSM085	DEP Property #3771, Munn Rd. near West Delhi	Watershed models
DRM181	Merriman (Rondout) Dam	Reservoir and watershed models
DRM190	DEP Property at Red Hill near Denning	Watershed models
DRM191	DEP Property #900, East Mountain Rd., Grahamsville	Watershed models
DPM110	Pepacton Dam near Downsville	Reservoir and watershed models

Table 4.9: (Continued) Operations Directorate meteorological stations.

Site Code	Site Description	Reason for Site Selection
DPM114	DEP Property #2294, near Perch Lake	Watershed models
DPM118	DEP Property #634 near New Kingston	Watershed models
DNM146	Neversink Dam	Reservoir and watershed models
DNM148	Winnisook Club at Winnisook Lake near Frost Valley	Watershed models
DNM152	DEP Property #5382 near Houghtaling	Watershed models
EWM218	West Branch Reservoir Dam	Reservoir and watershed models
ENM219	New Croton Reservoir south of Yorktown	Reservoir and watershed models
EKM220	Kensico Reservoir (Shaft 18)	Reservoir models
EEM221	Watchtower Training Center near Patterson	Watershed models
ECM222	Ward Pound Ridge	Watershed models

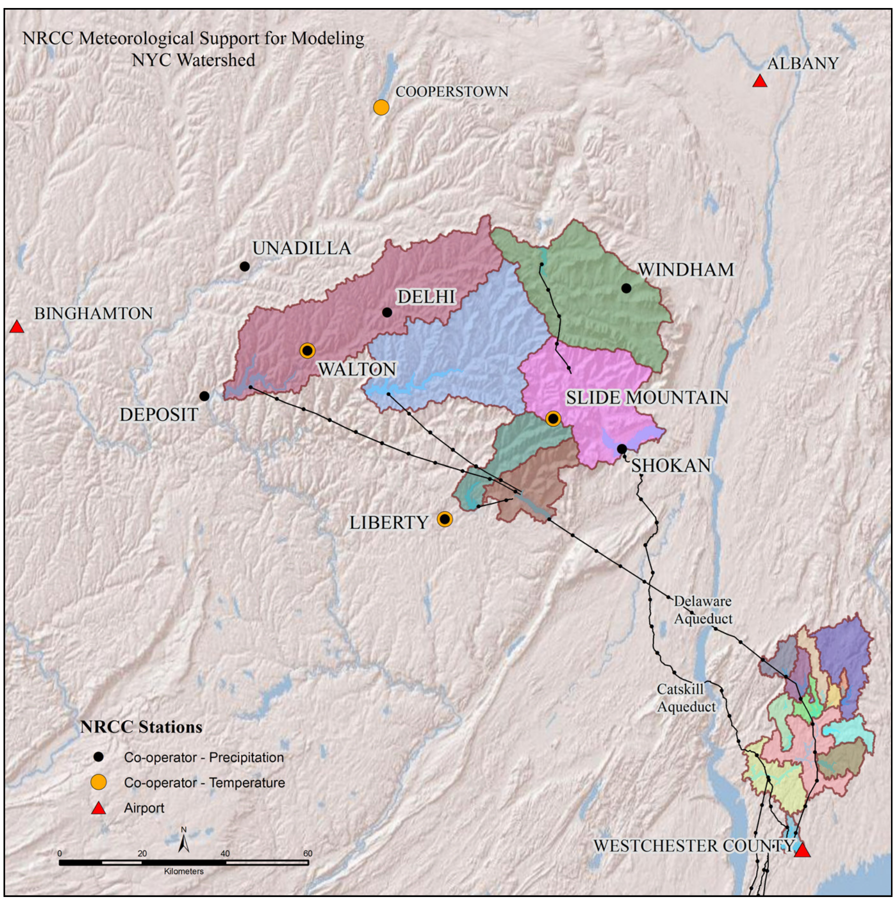


Figure 4.1 NRCC meteorological support for modeling, New York City watershed.

Table 4.10: Operations Directorate snow survey sites for SWE calculations

Site Code	Site Description
A-3	Lanesville
A-4	Bushnellville
A-5 (see P-4/A-5)	Highmount on Pepacton/Ashokan divide
A-6 (see N-20/A-6)	Winnisook Lk. on Neversink/Ashokan divide near Frost Valley
A-12	Ohayo Mountain Road
A-13	Lake Hill
A-14	Fox Hollow Road
A-15	Woodland Valley
A-16	Kanape Brook Trailhead
A-17	Route 28A at McMillan Road
S-1	Route 42 and Spruceton Road
S-2	Lexington
S-3	Route 30 and Ferris Hill Road
S-4	West Conesville
S-5	Prattsville
S-6	Batavia Kill near Ashland
S-7	Route 10 and Case Road
S-8	Windham
S-9	East Jewett
S-10	Elka Park
S-11	DEP WWTP, Allen Lane and Route 23A
C-1	Near Cannonsville Dam at Rt. 10 lookout area
C-4	Rt.10 at Cannonsville boat launch
C-5	Trout Creek Road near Mormon Hollow Road
C-7	Rt 10 near Granton
C-10	Rt. 10, Rock Rift near W. Chase Brook Rd.
C-11	Beerston
C-12	2.6 miles northwest of Walton
C-14	Bear Spring Mountain State Campground
C-15	Hawleys
C-16	DeLancey Andes Rd. near DeLancey
C-17	Fraser
C-18	Lee Hollow Road
C-19	4 miles north of Delhi
C-20	Bloomville
C-21	Rt. 18 near South Kortright
C-22	Town Brook Road
C-23	Whisky Hollow Road and Odell Lake Road
C-24	Rt. 23 near Stamford

Table 4.10: (Continued) Operations Directorate snow survey sites for SWE calculations

Site Code	Site Description
C-25	Stamford
P-2	Huntley Hollow/Skip Way Road
P-3	Holiday Brook Rd.at Knuckles estate
P-4/A5	Highmount on Pepacton/Ashokan divide
P-8	Fall Clove Road South of Camp Nubar
P-9	Holiday Brook Road near intersection of BWS Rd.
P-10	Fall Clove Rd, above cemetery
P-11	Beech Hill Rd.
P-14	Old Winter Hollow Rd., New Kingston
P-16	New Kingston
P-17	Mary Smith Hill Rd.
P-18	Weaver Hollow Road and New Kingston Road
P-19	County Route 49 at Balsam Lake Trailhead
P-20	Intersection of Routes 30 and 28
P-21	Mill Brook Road
P-22	John Burroughs Memorial Picnic Area
P-24	Mountain Rd. (Rt. 3)
P-26	Hard Scrabble Rd./Rt. 30
P-30	Brock Mountain
P-32	Swart Road and Margaretville Mountain Road
P-34	New Kingston Mountain Road
P-35	Elk Creek Road
P-36	Cross Mountain Road
P-37	Weaver Hollow Road
P-39	on the Pepacton/Ashokan divide
N-2	Aden Road
N-4	Husson Road
N-6	Aden Hill Road near St. John’s Brook
N-8	Aden Hill Road and Smith Road
N-10	Woodard Road
N-11	Frost Valley Road near County Route 19
N-13	Denning Road
N-14A	Blue Hill Road
N-15	Denning Road and Strauss Road
N-16	Round Pond Road and Wild Meadow Road
N-17	Red Hill Knolls Road
N-18	Frost Valley Road near High Falls Brook
N-20/A-6	Winnisook Lk. on Neversink/Ashokan divide near Frost Valley
N-30	Wild Meadow Road
N-32	Red Hill Road

Table 4.10: (Continued) Operations Directorate snow survey sites for SWE calculations

Site Code	Site Description
R-1	Sherman Road and Spook Hollow Road
R-3	Route 55 near Sherman Road
R-4	Yagerville Road and Greenville Road
R-5	Route 42 and Thunder Hill Road
R-6	Yagerville Road and Greeenville Road
R-7	South Hill Road
R-8	Route 55A
R-9	Route 55 and Smith Lane
R-11	Cummings Road near Wyman Hill Road
R-13	Moore Hill Road near Bungalow Road
R-15	Sugarloaf Road near Red Hill Road
R-16	Peekamoose Road near Bear Hole Brook
R-18	Peekamosse Notch
Amawalk	Lake Rd, off Rt. 35
Boyds	Rt 301 at Boyds Dam
Cross River	Rt 35 near Cross River Garagae
Croton Falls	Hemlock Rd.
East Branch	Rt. 22 at East Branch Dam
Titicus	Rt. 116 near Titicus Dam

Table 4.11: NRCC Co-operator stations—precipitation.

Site Code	Site Description	Reason for Site Selection
302060	Deposit	Watershed models
302036	Delhi	Watershed models
304731	Liberty	Watershed models
307721	Shokan	Watershed models
307799	Slide Mountain	Watershed models
308670	Unadilla	Watershed models
309516	Windham	Watershed models
308932	Walton	Watershed models

Table 4.12: NRCC Co-operator stations—temperature.

Site Code	Site Description	Reason for Site Selection
301753	Cooperstown	Watershed models

Table 4.12: (Continued)NRCC Co-operator stations—temperature.

Site Code	Site Description	Reason for Site Selection
304731	Liberty	Watershed models
307799	Slide Mountain	Watershed models
308932	Walton	Watershed models

Table 4.13: NRCC airport stations.

Site Code	Site Description	Reason for Site Selection
KALB	Albany Airport	Reservoir and watershed models
KBGM	Binghamton Airport	Reservoir and watershed models
KHPN	Westchester County Airport	Reservoir and watershed models

Analytes and Frequencies

Analytes and frequencies for meteorological stations are listed in Tables 4.14-4.18.

Table 4.14: Analytes and frequencies for Operations Directorate meteorological stations.

Analyte	Sampling Frequency	Rationale for Analyte
Precipitation	Continuous with hourly average, minimum and maximum	Watershed and reservoir model input
Air temperature	Continuous with hourly min, max and avg.	Watershed and reservoir model input
Relative humidity	Continuous with hourly min, max and avg.	Watershed and reservoir model input
Incoming solar radiation	Continuous with hourly min, max and avg.	Watershed and reservoir model input
PAR	Continuous with hourly min, max and avg.	Watershed and reservoir model input
Wind speed	Continuous with hourly min, max and avg.	Watershed and reservoir model input
Wind direction	Continuous with hourly min, max and avg.	Watershed and reservoir model input

Table 4.15: Analytes and frequencies for Operations Directorate snow survey sites.

Analyte	Sampling Frequency	Rationale for Analyte
Snow water equivalent	Twice per month in winter	Watershed model validation

Table 4.16: Analytes and frequencies for NRCC daily precipitation stations.

Analyte	Sampling Frequency	Rationale for Analyte
Precipitation	Daily total	Watershed model input

Table 4.17: Analytes and frequencies for NRCC daily temperature stations.

Analyte	Sampling Frequency	Rationale for Analyte
Air temperature	Daily minimum and maximum	Watershed model input

Table 4.18: Analytes and frequencies for NRCC airport stations.

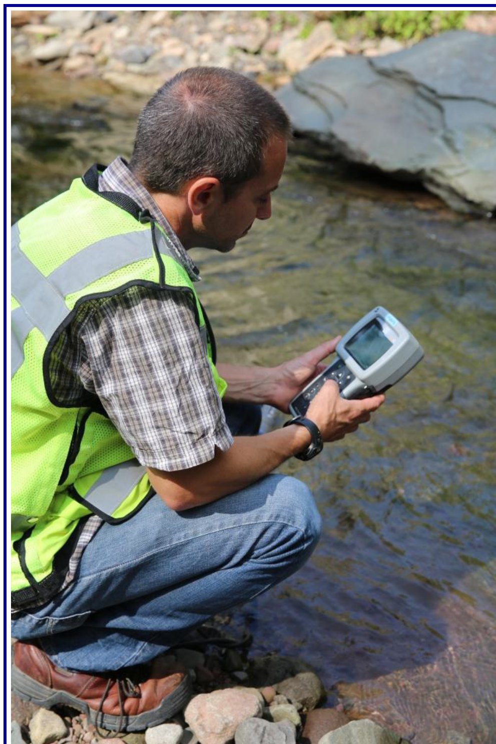
Analyte	Sampling Frequency	Rationale for Analyte
Air temperature	Hourly	Reservoir model input
Dew point	Hourly	Reservoir model input
Incoming solar radiation	Daily	Reservoir model input
Pan evaporation	Daily	Reservoir model input
Wind speed	Hourly	Reservoir model input
Wind direction	Hourly	Reservoir model input

Data Analysis and Reporting

Meteorological data are collected by DEP Operations and stored on an FTP site available for download within DEP. Snow survey data collected by DEP Operations are reported in twice monthly reports that are emailed to the DEP modeling group. Data from NRCC are delivered annually, under contract, to the modeling group. The modeling group further processes the data to produce appropriate formats, time steps, and spatial averages for model input.

5. Surveillance

This chapter has 12 objectives that fall under the category of "surveillance monitoring." Essentially, surveillance monitoring is performed to define existing water quality conditions and to be aware of any changing conditions that may threaten the quality of water traveling to the distribution system. This type of monitoring is used most frequently to confirm that water quality is excellent and no special action is required. Alternatively, it may be used to identify developing problems, such as turbidity or bacterial increases that must be tracked, excluded from the system through operational (routing) changes, or in extreme situations, treated appropriately. Surveillance monitoring therefore guides operation of the system to maintain excellent water quality in distribution.



Physical measurements are made on site and samples collected for laboratory analysis.

The first objective of this chapter is focused on monitoring for management and operational decisions. The network of sampling points consists of key locations along the aqueducts and was developed to track the overall quality of water as it flows through the system. The second objective concerns reservoir monitoring consisting of monthly grab samples and high frequency monitoring at key locations using robotic platforms. These results are used to select the elevation of highest water quality and when necessary, optimize the balance between water quality and quantity. A third objective pertains to monitoring the integrity of a physical barrier, i.e. a turbidity curtain, which is meant to protect an intake on Kensico Reservoir from local impacts of streams that may cause problems during storm events. The fourth objective relates to developing a baseline understanding of potential contaminants that include various organic compounds and trace metals. The fifth objective is devoted to potable water monitoring at DEP facilities. The sixth objective summarizes how DEP monitors for the presence of zebra mussels in the system – a measure that is meant to trigger actions to protect the infrastructure from becoming clogged by mussels. Spiny water flea monitoring is described in the seventh objective. The last six objectives in the surveillance chapter pertain to the determination of recent water quality status and long-term trends for reservoirs, streams, and benthic macroinvertebrates in the Croton System. It is important to track the long-term quality of these reservoirs to be aware of developing problems and to pursue appropriate management for efficient operation of the new Croton water filtration plant that is scheduled for completion in 2015. Together, these objectives allow DEP to maintain an awareness of water quality for the purpose of managing the system to provide the highest quality drinking water possible.

5.1 Monitoring for Operations Support

Objective

The primary objective of monitoring for operations is to provide water quality information for management and operational decisions to provide the highest quality water possible to consumers.

Background

The design of the reservoirs and aqueducts provides DEP with numerous options for optimizing the quality of water that is supplied to the consumers. Common operational strategies include selective diversion (e.g. shutdown, bypass, or float operations) and selective withdrawal (changing intake elevations), and occasionally, during extreme conditions, blending (Catskill-Croton blend) and treatment (alum). Monitoring for operations also provides data for other Bureau objectives including long-term trend detection, modeling support, toxic and other metals monitoring, as well as coliform restricted basin monitoring.

Sites

Approximately 94% of NYC's water comes from the Catskill and Delaware reservoirs, located in Delaware, Greene, Schoharie, Sullivan, and Ulster counties, which are located west of the Hudson River. Under normal operations, water from the Catskill System's Ashokan Reservoir and the Delaware System's Rondout Reservoir travel through the Catskill and Delaware Aqueducts and under the Hudson River to Kensico Reservoir. Delaware water may also pass through West Branch Reservoir before reaching Kensico.

West Branch Reservoir functions primarily as part of the Delaware System, serving as a supplementary settling and balancing basin for the water which arrives from Rondout Reservoir via the Delaware Aqueduct. West Branch Reservoir also receives water from its own small watershed and Boyd Corners Reservoir, both located in the Croton watershed. In addition, the West Branch is connected to adjacent Lake Gleneida, one of the three controlled lakes that are part of the City's water supply. Another function of West Branch Reservoir is to receive water pumped in from the Hudson River during drought emergencies. This water enters the West Branch from the City's Chelsea Pumping Station in Dutchess County, 65 miles up the Hudson River from New York City. Water withdrawn from the West Branch ordinarily flows via the Delaware Aqueduct into Kensico Reservoir in Westchester County for further settling and water balancing.

The major function of Kensico Reservoir is to receive water from all six Catskill and Delaware System reservoirs, and to make those waters available for the fluctuating daily demands of New York City water users. Ordinarily, Kensico is the last stop for all Catskill and Delaware system waters before those waters flow into the much smaller Hillview Reservoir in Yonkers (just north of the City line) for distribution throughout New York City. As such, it is called a terminal, rather than a collecting, reservoir. Kensico's own watershed is relatively small (25.5 km^2), representing only about 0.6% of the total watershed area that contributes water to this reservoir.

Because of the numerous possible operational permutations that can be used to deliver water to the City, a large number of sites needs to be monitored across the NYC Water Supply System. These are summarized in Table 5.1.

Table 5.1: Site descriptions for operations support monitoring.

Site Code	Site Description
	Routine Grab Sampling:
RDRRCM	Rondout Reservoir Effluent taken from the continuous monitoring equipment.
RR1	Rondout Reservoir Elevation Tap taken, in the upper level of the Rondout Effluent Chamber (Elev. 730').
RR2	Rondout Reservoir Elevation Tap, taken in the upper level of the Rondout Effluent Chamber (Elev. 763').
RR3	Rondout Reservoir Elevation Tap taken, in the upper level of the Rondout Effluent Chamber (Elev. 795').
RR4	Rondout Reservoir Elevation Tap taken, in the upper level of the Rondout Effluent Chamber (Elev. 827').
NRR2CM	Neversink Tunnel Outlet continuous monitoring tap, located on the north side of the upstream butterfly valve.
NR1	Neversink Reservoir Elevation Tap, taken in Valve Chamber B at the Neversink Release Chamber (Elev. 1320').
NR2	Neversink Reservoir Elevation Tap, taken in Valve Chamber B at the Neversink Release Chamber (Elev. 1350').
NR3	Neversink Reservoir Elevation Tap, taken in Valve Chamber B at the Neversink Release Chamber (Elev. 1380').
NR4	Neversink Reservoir Elevation Tap, taken in Valve Chamber B at the Neversink Release Chamber (Elev. 1410').
PRR2CM	East Delaware (Pepacton) Tunnel Outlet continuous monitoring tap, located on the last bypass valve into the hydroelectric plant on Route 55A.
PR1	Pepacton Reservoir Elevation Tap, taken in the pump room of the East Delaware Intake Chamber (Elev. 1152').

Table 5.1: (Continued) Site descriptions for operations support monitoring.

Site Code	Site Description
PR2	Pepacton Reservoir Elevation Tap, taken in the pump room of the East Delaware Intake Chamber (Elev. 1186’).
PR3	Pepacton Reservoir Elevation Tap, taken in the pump room of the East Delaware Intake Chamber (Elev. 1222’).
PR4	Pepacton Reservoir Elevation Tap, taken in the pump room of the East Delaware Intake Chamber (Elev. 1259’).
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent) continuous monitoring tap in the tunnel outlet works building on Route 55A.
CR1	Cannonsville Reservoir Elevation Tap, taken from tap located in the pump room of the West Delaware Intake Chamber (Elev. 1037’).
CR2	Cannonsville Reservoir Elevation Tap, taken from tap located in the pump room of the West Delaware Intake Chamber (Elev. 1083’).
CR3	Cannonsville Reservoir Elevation Tap, taken from tap located in the pump room of the West Delaware Intake Chamber (Elev. 1120’).
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent .
ES	Ashokan Reservoir, East Basin - surface elevation (S) - collected out gatehouse window (Elev. ~ 559’).
EM	Ashokan Reservoir, East Basin - middle elevation (M) - collected out gatehouse window (Elev. ~ 541’).
EB	Ashokan Reservoir, East Basin - bottom elevation (B) - collected out gatehouse window (Elev. ~ 511’).
WS	Ashokan Reservoir, West Basin - surface elevation (S) - collected out gatehouse window (Elev. ~ 570’).
WM	Ashokan Reservoir, West Basin - middle elevation (M) - collected out gatehouse window (Elev. ~ 549’).
WB	Ashokan Reservoir, West Basin - bottom elevation (B) - collected out gatehouse window (Elev. ~ 511’).
E16I	Esopus Creek, at Boiceville from bridge, below gaging station.
SRR2CM	Portal (Shandaken tunnel outlet into Esopus Creek), continuous monitoring, located in shed on upstream side of Rt. 28.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL17	Delaware Aqueduct, sampled at Shaft 17 uptake, influent to Kensico Reservoir.
DEL18DT	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.

Table 5.1: (Continued) Site descriptions for operations support monitoring.

Site Code	Site Description
DEL19LAB	Delaware Aqueduct treated supply. Sample tap located at Shaft 19.
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.
CWB1.5	West Branch Reservoir sampled at shed on the balcony of Delaware Aqueduct Shaft 10.
CROGH	Raw (untreated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Laboratory at level 213.
CROGH1CM	Effluent from Gatehouse No.1 that may be blended with water from the elevations in front of the Croton Lake Gate house as it enters the aqueduct. Sample tap is located in Croton Gate House Lab at level 213. The pump elevation is 128.
CRO1B	Croton Reservoir selective withdrawal intake at elevation 116 feet above sea level. Located at Cornell Dam, west of Croton Gate House. Sample tap is located in Gate House No.1 at elevation 152.
CRO1T	Croton Reservoir selective withdrawal intake at elevation 166 feet above sea level. Located at Cornell Dam, west of Croton Gate House. Sample tap is located in Gate House No. 1 at elevation 152.
CRO143	Croton Reservoir selective withdrawal intakes located at elevation 143 feet above sea level. Operational intake bays are capable of drafting water from points East, Center, and West in the building. However only one sample tap, located in Croton Gate House Lab at level 213, exists which can provide sample from the East or the West intake at this elevation. Therefore, the sample is further designated E or W to indicate the sample draft.
CRO163	Croton Reservoir selective withdrawal intakes located at elevation 163 feet above sea level. Operational intake bays are capable of drafting water from points East, Center and West in the building. However only one sample tap, located in Croton Gate House Lab at level 213, exists which can provide sample from the East or the West intake at this elevation. Therefore, the sample is further designated E or W to indicate the sample draft.

Table 5.1: (Continued) Site descriptions for operations support monitoring.

Site Code	Site Description
CRO183	Croton Reservoir selective withdrawal intakes located at elevation 183 feet above sea level. Operational intake bays are capable of drafting water from points East, Center, and West in the building. However only one sample tap, located in Croton Gate House Lab at level 213, exists which can provide sample from the East or the West intake at this elevation. Therefore, the sample is further designated E or W to indicate the sample draft.
BOYDSR	Release of Boyds Corner Reservoir.
CROSSRVVC	Release for Cross River Reservoir.
CROFALLSVC	Release for Croton Falls Reservoir.
	Automated Monitoring Keypoint Sites:
RDRRCM	Rondout Reservoir Effluent taken from the continuous monitoring equipment.
NRR2CM	Neversink Tunnel Outlet continuous monitoring tap, located on the north side of the upstream butterfly valve.
PRR2CM	East Delaware (Pepacton) Tunnel Outlet continuous monitoring tap, located on the last bypass valve into the hydroelectric plant on Rt. 55A.
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent) continuous monitoring tap in the tunnel outlet works bldg. on Rt. 55A.
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent .
SRR2CM	Portal (Shandaken tunnel outlet into Esopus Creek), continuous monitoring, located in shed on upstream side of Rt. 28
SRR1CM	Schoharie Reservoir—tap in gatehouse for continuous monitoring.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL17	Delaware Aqueduct, sampled at Shaft 17 uptake, influent to Kensico Reservoir.
DEL18DT	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.
DEL19LAB	Delaware Aqueduct treated supply. Sample tap located at Shaft 19.
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.

Table 5.1: (Continued) Site descriptions for operations support monitoring.

Site Code	Site Description
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.
DELSFBLAB	Delaware Aqueduct UV treated supply. Sample tap located in UV plant laboratory.
CCCLAB	Catskill Aqueduct UV treated supply. Sample tap located in UV plant laboratory.
BOYDSR	Release of Boyds Corner Reservoir.
CROSSRVVC	Release for Cross River Reservoir.
CROFALLSVC	Release for Croton Falls Reservoir.

Analytes and Frequencies

Each site is sampled for a suite of analytes at various frequencies based on operational needs. These are listed in Table 5.2.

Table 5.2: Analytes, frequencies, and corresponding sites for operations monitoring.

Analytes	Frequency[1]	Sites	Inclusion
		Routine Grab Sampling:	
Temperature, Color, Scent, pH, Specific Conductivity, Turbidity	5D	RDRRCM, NRR2CM, PRR2CM, WDTOCM, EARCM, SRR2CM, CATALUM, DEL17, CWB1.5,	Operational decisions
	7D	DEL18DT, DEL19LAB	
	W	RR1–RR4, NR1–NR4, PR1– PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, DEL9, DEL10, CRO1B, CRO1T, CRO143, CRO163, CRO183, CROGH	
Temperature, Turbidity	W	E16i	
Chlorine Residual	7D	DEL19LAB	
T Coli/F Coli	W	RR1–RR4, NR1–NR4, PR1– PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, DEL9, DEL10, CRO1B, CRO1T	
	4D	RDRRCM, NRR2CM, PRR2CM, WDTOCM, EARCM, SRR2CM	
	5D	CATALUM, DEL17, CWB1.5, CROGH1CM, CRO143, CRO163, CRO183	
	7D	DEL18DT, DEL19LAB	
T. Coli non-sheen	W	DEL19LAB	
	M	RDRRCM, NRR2CM, PRR2CM, WDTOCM, SRR2CM, CROGH	Supplemental Water Quality Information
HPC	W	DEL19LAB	

Table 5.2: Analytes, frequencies, and corresponding sites for operations monitoring.

Total/Genus Phytoplankton	W	RR1–RR4, NR1–NR4, PR1–PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, CATALUM, DEL17, DEL9, DEL10, CWB1.5, CROGH1CM, CRO1B, CRO1T, CRO143, CRO163, CRO183	Supplemental Water Quality Information
	3D	RDRRCM, NRR2CM, PRR2CM, WDTOCM, EARCM, SRR2CM, DEL18DT, CROGH	
UV254, DOC[2]	W	CWB1.5, DEL17, CATDEL HFS, DEL19LAB, CRO183, CRO163, CRO143, CRO1T, CRO1B, CROGH, RDRRCM, NRR2CM, PRR2CM, WDTOCM, EARCM, SRR2CM, BOYDSR, CROSS-RVVC, CROFALLSVVC	Operational decisions
TOC	W	CRO1B, CRO1T, CRO183, CROGH[1], CRO143, CRO163	
Specific conductivity, turbidity	W	BOYDSR, CROSSRVVC, CRO-FALLSVC	
Fluoride assay	Bi-weekly	DEL18DT	Verify purity
Fluoride	Daily	DEL19LAB, DELSFBLAB, CCCLAB	Verify dose
		Automated Monitoring:	
Temperature, pH, Specific Conductivity, Turbidity	Continuous	RDRRCM, NRR2CM, PRR2CM, WDTOCM, EARCM, SRR2CM, CATALUM, DEL17, CWB1.5-DEL18DT, DEL19LAB, DELSF-BLAB	Operational decisions
Chlorine Residual	Continuous	DEL19LAB, DELSFBLAB, DEL9[3], DEL17[3]	
Fluoride	Continuous	DEL19LAB	

[1]3D = 3 days/week, 4D = 4 days/week, 5D = 5 days/week, 7D = 7 days/week, W = weekly, M = Monthly.
[2]An elevation or basin elevation will be substituted for a diversion if the reservoir is off-line. More frequent analysis may occur to capture unusual water quality events.
[3]During chlorine treatment only.

Data Analysis and Reporting

The data for operational support are included in various daily, weekly, and monthly reports.

5.2 Reservoir and Stream Monitoring for Operations Support

Objective

Data collected for this objective provides management with reservoir water quality data necessary for the operation of reservoir aqueducts, releases, and diversions. These data are used to optimize a balance of both water quality and quantity.

Background

Proper water quality management practice requires knowledge of existing reservoir conditions. The data collected for this objective assist managers in choosing water sources that will meet existing standards. In addition to monthly grab samples, high frequency measurements are made at key locations using a variety of robotic platforms. For example, reservoir profiling buoys take measurements through the water column at one-meter increments from surface to bottom every six hours.

Sites

Management has selected the sites provided in Table 5.3 for determining existing water quality conditions. The protocol for determining sampling depths is described in Appendix II. Intermediate sites (i.e., 1.4EA, 3.2EA) are included as special sites that are sampled during turbidity events as requested by management. Robotic platforms are deployed year-round at Kensico Reservoir, and from April through November on Ashokan, Rondout, Neversink, Cannonsville, and Schoharie Reservoirs. Locations are shown on the reservoir maps provided in Appendix I.

Table 5.3: Reservoir sampling sites for management and operations support.

Reservoir	Sites					
Catskill						
Ashokan[3]	1EAW	1.4EAW[1]	2EAW	3EAW	3.2EAW[2]	4EAE
Schoharie[3]	2SS	3SS				
Delaware						
Rondout[3]	1RR	2RR	3RR			
Neversink[3]	1NN	2NN	3NN			
Pepacton[3]	3EDP	4EDP	5EDP			

Table 5.3: (Continued) Reservoir sampling sites for management and operations support.

Reservoir	Sites				
Cannonsville[3]	3WDC	4WDC	5WDC		
East of Hudson					
Kensico	1.1BRK	2BRK	2.9BRK[4]	4BRK	5BRK
West Branch	1CWB	2CWB	3CWB		

[1]Site monitored on an as needed basis for temperature and turbidity only.

[2]Site monitored on an as needed basis for turbidity only. Site 3 multiparameter sonde readings are used as a surrogate for Site 3.2 to avoid dividing weir area entanglements.

[3] March through December (weather permitting)

[4] New site (5/1/2014), located in main basin just outside Malcolm Brook Cove. With shutdown of Catskill Aqueduct Site 2.9BRK replaces Site 3BRK. Site 2.9BRK is situated to represent the mixture of Malcolm Brook and reservoir water that flows to Shaft 18.

Analytes and Frequencies

The analytes selected for operations support surveys are those that are commonly used for determining drinking water quality. They include turbidity, specific conductivity, color, temperature, pH, dissolved oxygen, scent, total coliform and fecal coliform.

Operations support surveys generally occur monthly on the terminal reservoirs: Kensico, West Branch, Rondout, and Ashokan. Operations support surveys also occur in March and December on Delaware headwater reservoirs and Schoharie Reservoir, but only if weather conditions permit access. Note that one additional and more comprehensive (i.e. more sites and analytes) monthly survey is conducted on each reservoir from April to November. The comprehensive surveys are described in the status and trends objectives of this report.

The robotic network is configured with sensors that measure an array of parameters particularly related to features of pollutant transport (e.g. temperature, specific conductivity, and turbidity). Some of the buoys are also equipped with meteorological stations. Reservoir profiling buoys take measurements through the water columns at one-meter increments from surface to bottom every six hours. Kensico's program also includes one fixed-depth buoy equipped with three transmissometers each measuring water transparency near the Delaware Aqueduct intake site. During the 2014-15 winter "under-the-ice" buoys were deployed and tested in Ashokan Reservoir to provide subsurface data during winter ice cover conditions. In 2015, DEP expanded the robotic network for Neversink and Cannonsville Reservoirs to include chlorophyll, phycocyanin, dissolved oxygen and colored dissolved organic matter.

Water quality robotic monitoring huts (RoboHuts) are also located on the major stream inflows for the Ashokan, Rondout, Neversink, and Cannonsville Reservoirs. The stream RoboHuts capture temperature and turbidity data every 15 minutes.

Data Analysis and Reporting

Results of these surveys will be reported to management each week that a survey occurs in the Reservoir Weekly Water Quality Report. Data from the robotics network is generally consulted daily.

5.3 Kensico Turbidity Curtain Surveillance

Objective

To monitor the integrity of the turbidity curtain in the Catskill Upper Effluent cove in Kensico Reservoir. Data will also be collected to monitor meteorological conditions such as temperature, cloud cover, wind speed and direction and the reservoir surface condition.

Background

The turbidity curtain in the Catskill Upper Effluent Cove was installed to divert potentially turbid water from Malcolm Brook and Young's Brook away from the Catskill Upper Effluent Chamber (CATUEC). The integrity of this curtain is important for maintaining high water quality upstream of the intake. Periodic inspections will be performed to ascertain that the curtain is intact.

Site

The turbidity curtain is inspected from the shore of Kensico Reservoir in the vicinity of CATUEC.

Analytes and Frequencies

Once a month, the condition of the turbidity curtain will be examined along with weather conditions at the time of inspection. These include ambient temperature, cloud cover, wind direction, wind speed and reservoir water surface conditions (wave height). Photos may also be taken to document the condition.

Data Analysis and Reporting

After completion of the inspection the information collected will be sent to WWQO and EOH Operations staff via e-mail.

5.4 Supplemental Contaminant Monitoring

5.4.1 Volatile (VOC) and Semi-Volatile (SVOC) Organic Compounds

Objective

The purpose of this objective is to supplement required distribution system monitoring of volatile and semi-volatile organic compounds. These supplemental samples collected in the WOH and EOH systems are needed to better determine more specific contaminant source(s) if and when these organic compounds are detected in the distribution system.

Background

VOCs are operationally defined as organic compounds that can be extracted from water by purging with an inert gas, then contained and determined by GC/MS (Lopes and Dionne 1998). VOCs occur in many products including fuels, solvents, paints and adhesives. Most VOCs tend to readily volatilize into the air. For this reason VOCs are unlikely to be detected in surface waters.

SVOCs are operationally defined as solvent-extractable organic compounds that can be determined by gas chromatography/mass spectrometry (GC/MS). SVOCs occur in many products, including plastics, disinfectants, dyes, and some pesticides and herbicides. Examples of SVOCs include phenols, phthalates and polycyclic aromatic hydrocarbons. Most SVOCs are hydrophobic with a moderate tendency to volatilize. SVOCs are an environmental concern because some can persist for years and may accumulate in sediments at levels that could adversely impact benthic organisms.

Potential human health effects of long-term exposure above the maximum contaminant level for some VOCs and SVOCs include: increased risk of cancer; kidney and liver problems; reproductive difficulties etc. (EPA 2009).

Sites

Organic contaminants are measured at the nine keypoint sites listed in Table 5.4.

Table 5.4: Sampling sites for VOC and SVOC monitoring.

Site Code	Site Description	Reason for Site Selection
East of Hudson		
CROGH	Raw (untreated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Laboratory at level 213	Represents New Croton water
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir[1]	Represents mixture of West Branch/Rondout water[1]
DEL18DT	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 downtake.	Represents Kensico water
West of Hudson		
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent	Represents Ashokan water

Table 5.4: (Continued) Sampling sites for VOC and SVOC monitoring.

Site Code	Site Description	Reason for Site Selection
NRR2CM	Neversink Tunnel Outlet continuous monitoring tap, located on the north side of the upstream butterfly valve	Represents Neversink water
PRR2CM	East Delaware (Pepacton) Tunnel Outlet continuous monitoring tap, located on the last bypass valve into the hydroelectric plant on Route 55A.	Represents Pepacton water
SRR2CM	Portal (Shandaken tunnel outlet into Esopus Creek), continuous monitoring, located in shed on upstream side of Rt. 28	Represents Schoharie water
RDRRCM	Rondout Reservoir Effluent taken from the continuous monitoring equipment.	Represents Rondout water
WDTOCM	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent), taken at the tunnel outlet on Route 55A	Represents Cannonsville water

[1]If West Branch Reservoir is bypassed, DEL10 water is 100% Rondout

Note: In the event that one of these diversions is off 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.

Analytes and Frequencies

Sampling for SVOCs and VOCs occur once per year in October. SVOCs used as pesticides/herbicides are typically applied from April to September and the October sample collection is intended to capture the total accumulation for the year. The remaining SVOCs are also expected to be highest in the fall. SVOCs typically adsorb to sediment particles which can become suspended in the water column following reservoir turnover and/or following late summer/fall storm events. A list of the SVOCs, VOCs and pesticides sampled is provided in Appendix X. Samples are collected by DEP personnel and delivered to a contract lab for analysis.

Data Analysis and Reporting

Results will be summarized in the Watershed Water Quality Annual Report

References

Lopes, T.J. and S. Dionne 1998. A review of Semi volatile and Volatile Organic Compounds in Highway Runoff and Urban Stormwater. U.S Geological Survey Open-File Report 98-409.

EPA 2009. National Primary Drinking Water Regulations. EPA 816-F-09-004. http://water.epa.gov/drink/contaminants/index.cfm#Organic

5.4.2 Glyphosate Monitoring

Objective

The purpose of this objective is to determine the occurrence of the commonly used herbicide glyphosate in the WOH and EOH watersheds.

Background

Glyphosate is probably the most common systemic herbicide used in the watershed. It is applied along highways, golf courses, lawns and driveways for non-selective weed control. Glyphosate undergoes rapid microbial degradation in natural surface waters (half-life of several days) and is considered moderately persistent in soils (half-life of 20-100 days, depending on soil conditions) with a low propensity for leaching into groundwater (Health Canada 1995, EPA 2009). Long-term exposure to glyphosate levels of 0.7 mg/L (MCL) has the potential to cause kidney damage and reproductive effects (EPA 2009). Although long-term exposure approaching this level is highly unlikely in drinking water, concern by the public justifies that glyphosate be monitored.

Sites

Glyphosate samples are collected at the nine keypoint sites sampled for SVOCs and VOCs (Table 5.4).

Analytes and Frequencies

Sampling for glyphosate occurs once per year in October. These samples are collected by DEP personnel in conjunction with SVOC and VOC samples and delivered to a contract lab for analysis.

Data Analysis and Reporting

Results will be summarized in the Watershed Water Quality Annual Report

References

Health Canada 1987. Guidelines for Canadian Drinking Water Quality-Supporting documents-Glyphosate. http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/glyphosate/index-eng.php. (accessed 1/16/2015).

EPA 2009. National Primary Drinking Water Regulations. EPA 816-F-09-0004. http://water.epa.gov/drink/contaminants/index.cfm#Organic

5.4.3 Pepacton Keypoint Total Petroleum Hydrocarbon (DRO) Monitoring

Objective

To monitor for the presence of DRO in Pepacton Reservoir

Background

A submerged oil tank was discovered in 2012 at Pepacton Reservoir, approximately 100 yards from the intake chamber. Although the site was remediated in 2012, residual oil sheens have been occasionally observed in the vicinity.

Sites

Pepacton Reservoir Effluent Keypoint PRR2CM.

Analytes and Frequencies

PRR2CM will be sampled monthly for DRO. DRO, in this case will refer to petroleum hydrocarbon mixtures composed of compounds with carbon numbers ranging from C_{10}-C_{44}. This range includes diesel range organic compounds C_{10}-C_{28} as well as higher molecular weight compounds C_{29}-C_{44}. The wide range was chosen to ensure that we would increase the likelihood of detecting the greatest number of hydrocarbon products as possible. A hydrocarbon sample and a trip blank will be collected by DEP personnel as part of the normal monthly keypoint run. The sample and trip blank will then be shipped to a contract laboratory for analysis. The remediation site will be inspected weekly by observing it from the East Delaware Intake Chamber during routine keypoint sample collections. Closer inspections will occur monthly during routine reservoir limnology surveys when the reservoir is ice-free. Surveillance monitoring will continue until visual inspections indicate no sheen on the reservoir for 6 months and that laboratory results indicate the absence of hydrocarbons.

Data Analysis and Reporting

Results will be summarized in the Watershed Water Quality Annual Report

5.4.4 Metals Monitoring

Objective

The purpose of this objective is to supplement distribution system monitoring of selected total metal contaminants. While the distribution monitoring is required as per National Primary Drinking Water Regulations and NYS Part 703.5 Standards, additional, non-required sampling in the WOH and EOH systems is needed to better determine more specific contaminant source(s) if and when these metals are detected at unacceptable concentrations in the distribution system.

Background

Common sources of metal contaminants in drinking water and potential health effects are provided in Table 5.5. Information is from the National Primary Drinking Water Regulations.

Table 5.5: Sources and potential health effects of monitored metal contaminants.

Analyte	Common sources of contaminant in drinking water	Potential health effects from long-term exposure above the MCL
Silver (Ag)		
Aluminum (Al)	Erosion of natural deposits	
Arsenic (As)	Erosion of natural deposits; runoff from orchards; runoff from glass & electronics production wastes	Skin damage or problems with circulatory systems, and may increase cancer risk
Barium (Ba)	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	Increase in blood pressure
Beryllium (Be)	Discharge from metal refineries and coal- burning factories; discharge from electrical, aerospace, and defense industries	Intestinal lesions
Cadmium (Cd)	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	Kidney damage
Chromium (Cr)	Discharge from steel and pulp mills; erosion of natural deposits	Allergic dermatitis
Copper (Cu)	Corrosion of household plumbing systems; erosion of natural deposits	Liver of kidney damage
Iron (Fe)	Erosion of natural deposits	
Mercury (Hg)	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	Kidney damage
Manganese (Mn)	Erosion of natural deposits	

Table 5.5: (Continued)Sources and potential health effects of monitored metal contaminants.

Analyte	Common sources of contaminant in drinking water	Potential health effects from long-term exposure above the MCL
Nickel (Ni)	Widely used in metallurgical, chemical, petroleum and food processing industries.	No MCL established
Lead (Pb)	Corrosion of household plumbing systems; erosion of natural deposits	Delays in physical or mental development; kidney problems; high blood pressure
Antimony (Sb)	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	
Selenium (Se)	Discharge from petroleum and metal refineries; erosion of natural deposits; discharge from mines	
Thallium (Tl)	Leaching from ore processing sites; discharge from electronics, glass, and drug factories	
Zinc (Zn)	Naturally occurring	

Sites

Total metals are monitored at the seventeen keypoint sites listed in Table 5.6.

Table 5.6: Keypoint sampling sites for trace and other metal occurrence monitoring.

Reservoir Basin	Site(s)
Catskill	
Ashokan	EARCM
Schoharie	SRR2CM
Delaware	
Cannonsville	WDTOCM
Pepacton	PRR2CM
Neversink	NRR2CM
Rondout	RDRRCM
East of Hudson	
Kensico	CATALUM, DEL17, CATDEL HFS, DEL19LAB

Table 5.6: (Continued) Keypoint sampling sites for trace and other metal occurrence monitoring.

Reservoir Basin	Site(s)
Croton[1]	CROGH, CROGH1CM[2]
West Branch	DEL9, DEL10, CWB1.5

[1]Elevation tap samples will be collected when the reservoir is offline.
[2] Only sampled when blending of Croton waters occurs.

Analytes and Frequencies

The following metals will be analyzed on a quarterly basis. Turbidity is also required to assist in data interpretation.

Total: Ag, Al, As, Ba, Be, Cd, Cr, Cu, Fe, Hg, Mn, Pb, Sb, Se, Tl and Zn.

Samples are to be collected during the months of February, May, August, and November. Due to aesthetic concerns (i.e. color) CROGH and other Croton sites may be sampled for Fe and Mn at a higher frequency on an as-needed basis.

Data Analysis and Reporting

Data will be reviewed on an annual basis and compared to the Health (Water Source) standard as stipulated in the New York State, Department of Environmental Conservation, Water Quality Regulations, Title 6, Chapter X, Part 703.5 and the USEPA National Primary and Secondary Drinking Water Standards. Selected metals standards are presented in Tables 5.7 and 5.8. The results from the data will be reported in the Watershed Water Quality Annual Report..

Table 5.7: USEPA National Primary and Secondary Drinking Water Quality Standards.

Analyte	Primary Standard (μg L^{-1})	Secondary Standard (μg L^{-1})
Ag		100
Al		50-200
As	10	
Ba	2000	
Be	4	
Cd	5	
Cr	100	
Cu	1300	1000
Fe		300
Hg	2	
Mn		50
Pb	15	
Sb	6	

Table 5.7: (Continued) USEPA National Primary and Secondary Drinking Water Quality Standards.

Analyte	Primary Standard (µg L^{-1})	Secondary Standard (µg L^{-1})
Se	50	
Tl	0.5	
Zn		5000

Table 5.8: Water quality standards for metals from Part 703.5.

Analyte (class waters)	Type	Standard (µg L^{-1})
Total Ag (A,AA)	H(WS)	50
Total As (A,AA)	H(WS)	50
Total Ba (A,AA)	H(WS)	1,000
Total Cd (A,AA)	H(WS)	5
Total Cr (A,AA)	H(WS)	50
Total Cu (A,AA)	H(WS)	200
Total Hg (A,AA)	H(WS)	0.7
Total Mn (A,AA)	H(WS)	300
Total Ni (A, AA)	H(WS)	100
Total Pb (A,AA,)	H(WS)	50
Total Sb (A,AA)	H(WS)	3
Total Se (A,AA)	H(WS)	10

5.5 DEP-Required Potable Water Monitoring

Objective

This objective addresses the need to sample potable water at upstate DEP facilities at which potable water is provided by DEP, as required by DEP's Compliance Directorate.

Background

This monitoring is required at a number of DEP facilities at which potable water is regularly provided.

Sites

Table 5.9 provides the DEP-required potable water sample sites..

Table 5.9: DEP-required potable water sample sites.

Site Code	Location	Reason for Site	#Employees
FLDNOR	Carmel HQ	DEP EH&S rules	9
CRGAR	Cross River Garage	DEP EH&S rules	13
CLGHEP2	Croton Lake Gatehouse - End Point	DEP EH&S rules	23
EDICDW	East Delaware Intake Chamber	DEP EH&S rules	4
EDRCDW	East Delaware Release Chamber	DEP EH&S rules	

Table 5.9: DEP-required potable water sample sites.

Site Code	Location	Reason for Site	#Employees
EDTODW	East Delaware Tunnel Outlet	DEP EH&S rules	
GILBOA PRECINCT	Gilboa Precinct	DEP EH&S rules	12
GAB	Grahamsville Annex	DEP EH&S rules	13
GPB	Grahamsville Police Precinct	DEP EH&S rules	9
GSTPKS	Grahamsville WTP	DEP EH&S rules	9
GGOR STP	Grand Gorge WTP	DEP EH&S rules	8
HRPSTAP	Hudson River Pump Station	DEP EH&S rules	2
KENMAN	Kensico Manor	DEP EH&S rules	5
LNDMGMT2	Mahopac Land Mgmt. Office	DEP EH&S rules	7
NICDW	Neversink Intake Chamber	DEP EH&S rules	
BPB	New Beerston Precinct	DEP EH&S rules	10
PINEHILL STP	Pine Hill WTP	DEP EH&S rules	10
RECDW	Rondout Effluent Chamber	DEP EH&S rules	
DELSH13	Shaft 13 DA	DEP EH&S rules	
SCHOH GH	Shandaken Tunnel Intake	DEP EH&S rules	15
TANN STP	Tannersville WTP	DEP EH&S rules	8
WDICDW	West Delaware Intake Chamber	DEP EH&S rules	
WDTODW	West Delaware Tunnel Outlet	DEP EH&S rules	

Analytes and Frequencies

Table 5.10 provides DEP-required potable water analytes.

Table 5.10: DEP-required potable water analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Temperature	Quarterly	OSHA/EH&S
Specific Conductivity	Quarterly	OSHA/EH&S
pH	Quarterly	OSHA/EH&S
Color	Quarterly	OSHA/EH&S
Scent	Quarterly	OSHA/EH&S
Turbidity	Quarterly	OSHA/EH&S
Total Coliform/*E. coli*[1]	Quarterly	OSHA/EH&S
Nitrate	Annually	OSHA/EH&S

Table 5.10: DEP-required potable water analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Cyanide	Once every 3 years	OSHA/EH&S
Fluoride	Once every 3 years	OSHA/EH&S
Antimony	Once every 3 years	OSHA/EH&S
Arsenic	Once every 3 years	OSHA/EH&S
Barium	Once every 3 years	OSHA/EH&S
Beryllium	Once every 3 years	OSHA/EH&S
Cadmium	Once every 3 years	OSHA/EH&S
Chromium	Once every 3 years	OSHA/EH&S
Mercury	Once every 3 years	OSHA/EH&S
Nickel	Once every 3 years	OSHA/EH&S
Selenium	Once every 3 years	OSHA/EH&S
Thallium	Once every 3 years	OSHA/EH&S
Copper	Annually	OSHA/EH&S
Lead	Annually	OSHA/EH&S

[1]*E. coli* required only if total coliform is positive.

Data Analysis and Reporting

DEP laboratories send drinking water quality reports to the Operations Directorate. In addition to the written report, WWQO staff provide notification of test results above the regulatory limits to Operations by telephone and email. The water system operator is responsible for corrective action, public notification, and follow-up in the event that a limit is exceeded.

References

http://www.health.state.ny.us/environmental/water/drinking/part5/subpart5.htm

5.6 Zebra Mussel Monitoring

The objective of this contract is to monitor all New York City reservoirs for the presence of zebra mussel larvae (veligers) and for settlement of adults during the months of May through October, when zebra mussels are most active. It is important to monitor for these mollusks because they reproduce quickly and are capable of clogging pipes, which would seriously impair DEP's operations, preventing an adequate flow of water from the reservoirs to the City and those upstate communities dependent on the New York City water supply. In addition zebra mussels also create taste and odor problems in the water. It is DEP's responsibility to monitor New York City's water supply for zebra mussels, since early detection will make it possible to gain control of the problem quickly. This in turn will allow DEP to preserve the excellent water quality of the system, and prevent unnecessary expenditure of funds in the future.

Background

Zebra mussels were first introduced to North America in the mid-1980s, and first identified on this continent in 1988. It is believed that they were transported by ships from Europe in their freshwater ballast, which was discharged into freshwater ports of the Great Lakes. Since their arrival in the United States, zebra mussels have been reproducing rapidly and migrating to other bodies of water at a much faster rate than predicted. They have been found as far west as California, as far south as Louisiana, as far east as New York State, and north well into Canada. They have been found in all of the Great Lakes and many major rivers in the Midwest, the South, and the Western region of the United States. In New York State, in addition to Lakes Erie and Ontario, zebra mussels have migrated throughout the Erie Canal, and are found in the Mohawk River, the St. Lawrence River, the Susquehanna River, the Hudson River, and several other lakes. DEP is concerned about infestation of New York City's reservoirs by this mollusk. Zebra mussels have not been identified in NYC's reservoirs during routine monitoring. However, in July 2007, four zebra mussels were found in a cove on Kensico Reservoir. An in-depth study was performed in and around the cove and no zebra mussels were found during this special study. The conclusion was that these four zebra mussels were isolated, and most likely accidentally introduced into the reservoir.

Sites

All 19 New York City reservoirs are monitored for the presence of zebra mussel larvae (veligers) using pump sampling and settlement by artificial substrate sampling.

The East of Hudson reservoirs sampled include: New Croton, West Branch, East Branch, Croton Falls, Bog Brook, Boyd Corners, Middle Branch, Titicus, Cross River, Amawalk, Muscoot, Diverting, and Kensico Reservoirs.

The West of Hudson Reservoirs sampled include: Ashokan, Schoharie, Rondout, Neversink, Pepacton, and Cannonsville.

The sample sites have been set up to include areas where introduction is likely to occur (e.g., boat or fishing access points) and near structures likely impacted by any introduced mussels (e.g., dams, shafts, other water conveyances). Table 5.11 provides the location of the substrate (S), pump sampling (P), and bridal veil (BV) sites.

Table 5.11: NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method[1]	Reason for Selection
Sampling Conducted by Contractors				
K-1	Kensico	Shaft 18 Area	S,P	Impact area
K-2	Kensico	Effluent Chamber	S,P	Impact area
K-3	Kensico	Rye Bridge Area	BV	Likely area of introduction
K-4	Kensico	Pleasantville Cove	S,P	Likely area of introduction
CR-1	Cross River	Causeway/Fishing Access Area	S,P	Impact area
CR-2	Cross River	Boat Ramp/Fishing Access Area	BV,P	Impact area
CR-3	Cross River	Dam Area	S	Impact area
M-1	Muscoot	Spillway Area	BV,P	Impact area
M-2	Muscoot	Rt. 35 Bridge Area	S,P	Likely area of introduction
M-3	Muscoot	Gate House	S	Impact area
T-1	Titicus	Dam Area	BV,P	Impact area
T-2	Titicus	Boat Ramp/Island Access Area	S,P	Likely area of introduction
T-3	Titicus	Dam Area	S	Impact area
NC-1	New Croton	Dam Area	S,P	Impact area
NC-2	New Croton	Gate House/Water Quality Buoy	BV,P	Impact area
NC-3	New Croton	Rt. 129 Bridge Area	S	Likely area of introduction
W-1	West Branch	Shaft 10/Dam Area	S,P	Impact area
W-2	West Branch	S. of Rt. 301/Boat Ramp Area	BV,P	Likely area of introduction
W-3	West Branch	Spillway Area	S	Impact area
W-4	West Branch	Pleasantville Cove	P	Likely area of introduction
AM-1	Amawalk	Dam/Spillway Area	BV,P	Impact area
AM-2	Amawalk	Dam/Spillway Area	S,P	Impact area
AM-3	Amawalk	Rt. 202 Fishing Access Area	S	Likely area of introduction
A-1	Ashokan	East Gate House	P	Impact area
A-2	Ashokan	West Gate House	P	Impact area
S-4	Schoharie	Boat Ramp Area	P	Likely area of introduction
S-5	Schoharie	Gate 22 Area	P	Impact area
C-1	Cannonsville	2 WDC, DEP Launch	P	Likely area of introduction
C-2	Cannonsville	3 WDC, Dry Brook launch	P	Likely area of introduction
P-1	Pepacton	1 EDP, Dam Area	P	Impact area

Table 5.11: (Continued) NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method[1]	Reason for Selection
P-2	Pepacton	3 EDP Rt. 30 Fishing Access	P	Likely area of introduction
R-1	Rondout	1 RR Dam Area	P	Impact area
R-2	Rondout	3 RR Monument Area	P	Impact area
BC-1	Boyd Corners	Dam Area	BV,P	Impact area
BC-2	Boyd Corners	Boat Ramp/FishingAccess Area	S,P	Likely area of introduction
BC-3	Boyd Corners	Dam Area	S	Impact area
MB-1	Middle Branch	Dam Area	BV,P	Impact area
MB-2	Middle Branch	Boat Ramp/Fishing Access Area	S,P	Likely area of introduction
MB-3	Middle Branch	Pumphouse	S	Impact area
CF-1	Croton Falls	Dam Area	BV,P	Impact area
CF-2	Croton Falls	Boat Ramp/Fishing Access Area	S,P	Likely area of introduction
CF-3	Croton Falls	Fishing Access By Bay Area	S	Likely area of introduction
D-1	Diverting	Spillway Area	BV,P	Impact area
D-2	Diverting	Rt. 6 Fishing Access Area	S,P	Likely area of introduction
D-3	Diverting	Gate House	S	Impact area
N-1	Neversink	1 NN Dam Area (P)	P	WQD sampling site
N-2	Neversink	Dam, southwest side	P	Impact area
EB-1	East Branch	Dam Area	BV,P	Impact area
EB-2	East Branch	Boat Ramp/Fishing Access Area	S	Likely area of introduction
EB-3	East Branch	Spillway Area	S	Impact area
BB-1	Bog Brook	Dam Area	BV,P	Impact area
BB-2	Bog Brook	Rt. 312 Fishing Access Area	S	Likely area of introduction
BB-3	Bog Brook	Gate Area	S	Impact area
BB-4	Bog Brook	Rt. 202 Fishing Access Area	P	Likely area of introduction
Sampling Conducted by WQD Personnel				
4EAE	Ashokan	4EAE	S	WQD sampling site
3EAW	Ashokan	3EAW	S,BV	WQD sampling site
3SS	Schoharie	3SS	S,BV	WQD sampling site
1SS	Schoharie	1SS	S	WQD sampling site
C-1	Cannonsville	1WDC	S	WQD sampling site
C-2	Cannonsville	3WDC	S	WQD sampling site
C-4	Cannonsville	4WDC	S,BV	WQD sampling site
P-1	Pepacton	1EDP	S	WQD sampling site
P-2	Pepacton	3EDP, Rt. 30 Fishing Access	BV	WQD sampling site
P-3	Pepacton	6EDP	S	WQD sampling site

Table 5.11: (Continued) NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method[1]	Reason for Selection
P-4	Pepacton	5EDP	S	WQD sampling site
N-1	Neversink	1NN	S	WQD sampling site
N-2	Neversink	Dam, southwest side	S	WQD sampling site
N-3	Neversink	3NN	BV	WQD sampling site
R-1	Rondout	1RR	S	WQD sampling site
R-2	Rondout	3RR	S	WQD sampling site
R-3	Rondout	4RR	BV	WQD sampling site

[1]Sampling methods are designated S, for substrate, P, for pump/plankton net samples and BV, for bridal veil samples.

Analytes and Frequencies

Integrated pump/plankton net samples are collected to monitor veligers. Plate substrate samples as well as bridal veil samples are collected to monitor for juveniles and adults. Samples are collected more frequently during the warm water months when zebra mussels are reproducing and any veligers present would be in the water column. Settlement also occurs during this period.

Two integrated pump samples (0-5m) are collected July and September from each West of Hudson reservoir. Two integrated pump samples (0-5m) are collected monthly (May– October) from each East of Hudson reservoir and once per month during July, August, and September. However, Kensico Reservoir has two additional integrated pump samples collected at the frequency of the other East of Hudson reservoirs. The East of Hudson reservoirs are sampled more frequently than the West of Hudson reservoirs because water quality conditions East of Hudson are more supportive of zebra mussel survival. Introduction is also more likely given the close proximity of the East of Hudson reservoirs to waterbodies where zebra mussel populations are known to be present (eg. Hudson River).

Sampling for settled juveniles and adults is assessed using artificial substrates (minimum of two per reservoir) and bridal veils (one per reservoir) set at key locations where zebra mussels are likely to be found in each of the nineteen (19) reservoirs. All artificial substrates are conditioned for a period of time prior to sampling to build up a biological conditioning layer; these conditioned artificial substrates are plates with dimensions of 6 inches by 6 inches. The bridal veil substrate sampler is constructed as described by the National Biological Service and consists of a one square foot piece of bridal veil (white) enclosed in a one foot high by three inch wide cylindrical cage made of non-toxic material suspended in the water similar to the substrate plates. For the East of Hudson reservoirs the artificial substrates and bridal veils are pulled once per month for analysis and replaced at that time. The contractor will set and retrieve the substrates and bridal veils and DEP will provide the boat and boat operator. For West of Hudson reservoirs the substrate plates and bridal veils are deployed in

May and July and are retrieved after two months. This work is done solely by DEP personnel. For both reservoir systems water clarity and water temperature are measured at each sampling location on a monthly basis as part of the routinely scheduled water quality monitoring surveys.

Data Analysis and Reporting

The data are collected purely as a surveillance measure and evaluated for absence or presence of zebra mussels. The consultants notify DEP on a monthly basis through a written report that provides the results of their routine sampling of the reservoirs. Zebra mussels have not been found in routine sampling since the inception of the monitoring in the early 1990s. However, if they were found in any of the reservoirs, the Project Manager would be notified immediately of this problem.

5.7 WOH Spiny Water Flea Monitoring

Objective

Monitor for the presence of the spiny water flea on Cannonsville, Pepacton, Neversink, Rondout, Ashokan, and Schoharie Reservoirs. These specific reservoirs are monitored because of the increase risk of spiny water flea introduction due to boat traffic associated with the Recreational Boating Program.

Background

Spiny water fleas *(Bythotrephes longimanus)* are large predatory crustacean zooplankton indigenous to parts of Europe and Asia. They have been established in all of the Great Lakes since 1992 and have begun moving into inland lakes in Ontario, Minnesota, Ohio, Michigan, Wisconsin, and New York.

The introduction of the spiny water flea has been found to disrupt the ecosystems they invade. Spiny water fleas prey on smaller, herbivorous zooplankton including species of Daphnia. Native zooplankton species are both important food sources for juvenile fishes as well as consumers of phytoplankton. Introduction of these invasives has resulted in a decline in zooplankton species richness and abundance. The disturbance of natural zooplankton communities has led to unfavorable changes in both fish and phytoplankton communities of infested water bodies.

Sites

Sample sites are provided in Table 5.12 with site map locations provided in Appendix I. Sites are routine limnology sites sampled at least monthly and were selected based on water depth and flow. Depth requirements were at least 10 meters so priority was given to sites near the dam.

Table 5.12: Sampling locations for spiny water flea

Reservoir	Site
Rondout	1RR, 2RR, 3RR

Table 5.12: Sampling locations for spiny water flea

Reservoir	Site
Neversink	1NN, 2NN, 3NN
Pepacton	1EDP, 3EDP, 5EDP
Cannonsville	1WDC, 3WDC, 4WDC
Ashokan	1.4EAW, 3.1EAW, 4.2EAE
Schoharie	1SS, 2SS, 3SS

Analytes and Frequencies

Monthly sampling will be for three consecutive months starting when surface water temperatures reach 12 °C. Samples will be obtained using plankton net and submitted to the Kingston lab where the presence/absence of the spiny fleas will be determined. Approximately 45 samples will be collected annually.

Sampling protocols were based on a number of sources: Wisconsin Department of Natural Resources Water Flea Monitoring Protocol, Lake Champlain Long-Term Water Quality and Biological Monitoring Program, Minnesota Sea Grant/Citizen Lake Monitoring Network Water flea Monitoring Protocol, and Adirondack Park Invasive Plant Program Invasive Water flea Monitoring Protocol, USFWS and HDR's Feasibility Study of Control Methods for Prevention of Spiny Water Flea Spread from Great Sacandaga Lake to Lake Champlain.

Data Analysis and Reporting

Positive finds will be reported internally through the NYC DEP Invasive Species Working Group and externally through the New York State Partnerships for Regional Invasive Species Management (PRISM) networks.

5.8 Croton System Streams - Water Quality Status

Objective

This monitoring effort is intended to assess current water quality conditions (i.e., status) for streams in the NYC water supply watershed. The water quality results from this program will be used to assess compliance and provide comparisons with established benchmarks.

Background

DEP's Long-Term Watershed Protection Program (DEP 2006) states that one of the goals of DEP's Watershed Monitoring Program is to provide routine water quality results for keypoint, stream, reservoir, and pathogens sites to assess compliance and provide comparisons with established benchmarks. As per Section 18-48 of the Rules and Regulations for the Protection from Contamination, Degradation and Pollution of the New York City Water Supply and its Sources (DEP 2010), the NYC Department of Environmental Protection is required, on an annual basis, to determine if each reservoir stem meets certain water quality goals listed in Appendix IX. To provide a more comprehensive assessment, DEP will evaluate additional analytes, although in some cases appropriate benchmarks have not yet been determined.

Sites

Samples are to be collected at each of the sites listed in Table 5.13.

Site selection for this objective will focus primarily on reservoir inflows. These sites generally serve as "integrator" sites, which means the water quality is determined by the cumulative effects of various land uses, geochemical processes, and watershed programs located upstream of the site. Also, these sites serve as reservoir stem samples to assist in determining whether the system specific characteristics are maintained at the levels stated in the NYC Watershed Rules and Regulations. Reservoir release sites are included because of the cascading design of the EOH District, where each release constitutes the greatest contributor to the next downstream reservoir.

Table 5.13: Sampling sites for Croton streams (non-FAD watersheds) status objective.

Site Code	Site Description	Reason for Site Selection
AMAWALKR	Muscoot River below dam at Amawalk (Amawalk outflow)	Data are used in WQD Annual Report
BOGEASTBRR	East Branch Croton River downstream of confluence of East Branch Reservoir and Bog Brook Reservoir releases in the Town of Southeast	Data are used in WQD Annual Report
DIVERTR	East Branch Croton River near Croton Falls (Diverting outflow)	Data are used in WQD Annual Report
EASTBR	East Branch Croton River, near Putnam Lake	Data are used in WQD Annual Report
KISCO3	Kisco River below Mt. Kisco	Data are used in WQD Annual Report
MUSCOOT10	Muscoot River at Baldwin Place	Data are used in WQD Annual Report
TITICUSR	Titicus River at Purdys Station (Titicus outflow)	Data are used in WQD Annual Report

Analytes and Frequencies

A list of analytes, reasons for their inclusion, and sampling frequency are provided in Table 5.14. Most analytes will be sampled on a monthly basis to address seasonal differences. Analytes which have not demonstrated seasonal variability will only be analyzed quarterly.

Table 5.14: List of analytes for Croton streams (non-FAD watersheds) status objective.

Analyte	Sampling Frequency	Rationale For Analyte
Flow (USGS)[1]	Continuous	Explanatory variable needed for interpretation of water quality concentrations.
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids, which is included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYS-DEC Water Quality Regulation/Part 703 narrative standard
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Dissolved SO_4	Quarterly	End product of acid deposition. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Dissolved K	Quarterly	Na/K ratio used to determine and characterize hydrologic flow path
Dissolved Mg	Quarterly	Ca/Mg ratio used to determine and characterize hydrologic flow path
Dissolved Na	Quarterly	Major component of road salt. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Dissolved Ca	Quarterly	Essential mineral for zebra mussels, Ca depletions observed in forested catchments
DOC[2]	Monthly	Major source of energy to heterotrophic food webs.

Table 5.14: List of analytes for Croton streams (non-FAD watersheds) status objective.

Analyte	Sampling Frequency	Rationale For Analyte
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
NO_x-N	Monthly	Essential aquatic life requirement. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Total Dissolved N	Monthly	Pool of organic and inorganic dissolved N species
Total N	Monthly	Total pool of dissolved and particulate N. Will be used to estimate organic nitrogen, which is included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Total Dissolved P	Monthly	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
TP	Monthly	Pool of dissolved and particulate P
SRP	Monthly	Dissolved reactive P, most readily biologically available

[1]If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow.

[2]The NYC Rules and Regulations value is for TOC, but DOC will be used as a surrogate.

Data Analysis and Reporting

Stream status will be evaluated by comparing results from each sample to appropriate water quality benchmarks, e.g., the NYC Watershed Rules and Regulations System Specific Water Quality Characteristics for Croton (see Appendix IX). To provide a more comprehensive assessment, DEP will evaluate additional analytes listed in Table 5.14, although in some cases appropriate benchmarks have not yet been determined. Compliance with the benchmarks shall be measured in terms of the fraction of observations which do not meet the benchmark (i.e., excursions). Status will be determined annually and reported in the Department's Watershed Water Quality Annual Report due each July. The patterns of excursion occurrence will be described in the discussion of results.

References

DEP. 2006. 2006 Long-Term Watershed Protection Program. Valhalla, NY. 66 p.

DEP. 2010. New York City Watershed Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf (Accessed 12/10/14).

5.9 Croton System Reservoirs - Water Quality Status

Objective

This monitoring effort is intended to assess current water quality conditions (i.e., status) for NYC water supply reservoirs and controlled lakes in the Croton System. Status will be determined by evaluation of seasonal and spatial water quality patterns and by comparison with appropriate water quality benchmarks. This information will be used to identify the location and extent of degraded water within each water body.

Background

The comparison of sample results to a water quality standard, to a reference condition, or to some other benchmark is a common approach to evaluate current conditions in water quality monitoring systems (Ward et al. 2003). The evaluation of current conditions has many benefits including (1) identification of water quality problems, (2) management planning, (3) regulatory assessments, and (4) project evaluations (e.g., BMPs) (Gibson et al. 2000).

As per Section 18-48 of the Rules and Regulations for the Protection from Contamination, Degradation and Pollution of the New York City Water Supply and its Sources (DEP 2010), the DEP is required, on an annual basis, to determine if each reservoir and controlled lake meets certain water quality goals listed in Appendix IX. To provide a more comprehensive assessment and assist in interpretation of the data, DEP will also evaluate additional analytes.

Sites

Samples are to be collected at each of the sites listed in Table 5.15. Site locations can be viewed on maps provided in Appendix I. Because water quality analytes in reservoirs display considerable spatial variability, this sampling scheme is designed to produce an accurate assessment of each reservoir while still allowing analysis of individual strata (i.e., depths, sites) (Gaugush 1987). Status of individual or grouped strata is used to specify location and extent of problems and to evaluate causality.

The protocol for determining sampling depth is described in Appendix II. Depending on depth, one to four samples will be collected in the water column in order to represent the thermal zones. Analytes measured in situ (i.e., pH, conductivity, temperature, and dissolved oxygen) will be collected through the water column.

Table 5.15: Sampling sites for Croton reservoirs (non-FAD reservoirs) status objective.

Reservoir	Sites						
New Croton	1CNC	2CNC	3CNC	4CNC	5CNC	6CNC	8CNC
Muscoot	1CM	2CM	4CM	6CM			
Amawalk	1.1CA	3CA					

Table 5.15: (Continued) Sampling sites for Croton reservoirs (non-FAD reservoirs) status objective.

Reservoir	Sites	
Titicus	1.1CT	3CT
Diverting	1.1CD	2CD
Middle Branch	1.1CMB	3CMB
East Branch	1CEB	3CEB[1]
Bog Brook	1CBB	3CBB[1]
Kirk Lake	1CKL	
Lake Gleneida	1CGLEN[2]	
Lake Gilead	1CGIL[3]	

[1]These sites only get sampled for fecal coliform.
[2]Site 1CGL was renamed 1CGLEN in June 2014.
[3]Site 1CGD was renamed 1CGIL in June 2014.

Analytes and Frequencies

A list of analytes and reasons for their inclusion are provided in Table 5.16. Analytes that are only collected at certain depths, sites or months (e.g., chlorophyll) are specified in the footnotes, while major cations and anions will only be collected at site 1. In general, samples will be collected monthly from April through November for each analyte unless otherwise noted. The controlled lakes, however, will only be sampled in May, August and October. To avoid increases in temporal variability, efforts should be made to maintain a consistent time interval between sampling events.

Table 5.16: List of analytes for Croton reservoirs (non-FAD reservoirs) status objective.

Analyte[1]	Sampling Frequency[2]	Rationale for Analyte
Data provided by WQD:		
Color	Monthly (Apr.–Nov.)	Early alert to potential contravention of NYS health standard (SDWA)
Secchi depth, Z_{VB}	Monthly (Apr.–Nov.)	Indicator of water clarity, used to assess trophic state
Photic depth[3], I_z	Monthly (Apr.–Nov.)	Identifies zone of active primary production
pH	Monthly (Apr.–Nov.)	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard
Temperature	Monthly (Apr.–Nov.)	Important in the regulation of biotic community structure and function, critical in regulating the chemical composition of water, regulates reservoir processes and distribution of constituents
Specific Conductivity	Monthly (Apr.–Nov.)	Measured surrogate for total inorganic ions

Table 5.16: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status

Analyte[1]	Sampling Frequency[2]	Rationale for Analyte
Turbidity	Monthly (Apr.–Nov.)	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard and to manage for compliance with SDWA standards
TSS[4]	Monthly (Apr.–Nov.)	Interferes with disinfecting processes, mechanism of pathogen transport, cause of decrease in clarity
Dissolved Oxygen	Monthly (Apr.–Nov.)	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part703 water quality standard
Dissolved Chloride[5]	May, August, November	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[5]	May, August, November	End product of acid deposition, source of S^{-2} during anoxia
Dissolved K[5]	May, August, November	Na/K ratio used to determine and characterize hydrologic flow path
Dissolved Mg[5]	May, August, November	Ca/Mg ratio used to determine and characterize hydrologic flow path
Dissolved Na[5]	May, August, November	Major component of road salt
Dissolved Ca[5]	May, August, November	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity	May, August, November	A measurement of acid neutralizing capacity, buffering capacity, needed for chemical treatment activities
DOC	Monthly (Apr.–Nov.)	Major source of energy to heterotrophic food webs, provides insight into THM formation potential, potential source of color in humic waters
Fecal coliform	Monthly (Apr.–Nov.)	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard, and to manage for compliance with SDWA standards
Chla[6]	Monthly (Apr.–Nov.)	Useful in assessing primary productivity and trophic state
Phytoplankton[6]	Monthly (Apr.–Nov.)	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards

Table 5.16: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status

Analyte[1]	Sampling Frequency[2]	Rationale for Analyte
Nitrogen	Monthly (Apr.–Nov.)	The determination of the various forms of nitrogen assists in the understanding of the relationship between the readily bioavailable nitrogen fractions and the pool from which they were derived. Sources of nitrogen include atmospheric input, runoff from anthropogenic activities, WWTP effluents, and agricultural fertilizers. Nitrogen is a fundamental building block required for growth by algae and other plants.
NH_x-N	Monthly (Apr.–Nov.)	Utilized preferentially over NOx-N by autotrophs and bacteria, essential aquatic life requirement, indicative of anoxic conditions during which the toxic form (free ammonia) is produced.
NO_x-N	Monthly (Apr.–Nov.)	Essential aquatic life requirement
Total Dissolved Nitrogen (TDN)	Monthly (Apr.–Nov.)	Pool of organic and inorganic dissolved N species
Total Nitrogen (TN)	Monthly (Apr.–Nov.)	Total pool of dissolved and particulate N
Phosphorus	Monthly (Apr.–Nov.)	Productivity in lakes and reservoirs is most often limited by the supply of inorganic phosphorus. The determination of the various forms of phosphorus assists in the understanding of the relationship between readily bioavailable forms and the pool from which they were derived. This understanding can assist watershed managers and planners in decisions concerning phosphorus control.
Total Dissolved Phosphorus (TDP)	Monthly (Apr.–Nov.)	Measurement of dissolved reactive phosphorus and dissolved organic and dissolved complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).This provides organic + complex inorganic P, also considered to be the total pool of biologically available P.
Total Phosphorus (TP)	Monthly (Apr.–Nov.)	Pool of dissolved and particulate P
Soluble Reactive Phosphorus (SRP)	Monthly (Apr.–Nov.)	Dissolved reactive P, most readily biologically available (almost exclusively inorganic P)
Data provided by Operations:		
Reservoir Elevation	Daily	Explanatory variable used to assist in interpretation of water quality variables

Table 5.16: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status

Analyte[1]	Sampling Frequency[2]	Rationale for Analyte
Total Storage	Daily	Explanatory variable used to assist in interpretation of water quality variables
Release Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables
Spill Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables
Diversion Flow	Daily	Explanatory variable used to assist in interpretation of water quality variables

[1]Analytes measured at Middle Branch, Diverting, Titicus and Amawalk include: Secchi depth, filed profiles (pH, temperature, DO), turbidity, specific conductivity, total phosphorus, total nitrogen, total and fecal coliform, phytoplankton (3m only) and chlorophyll *a* (3m only). Dissolved nutrients are no longer measured.

[2]In general, samples will be collected monthly from April through November for each analyte unless otherwise noted. The three controlled lakes (Gilead, Gleneida, and Kirk), however, will only be sampled in May, August, and October.

[3]Photic depth to be measured at dam sites only, at 1-m intervals.

[4]TSS analyzed monthly at dam and intake sites for New Croton Reservoir. TSS to be analyzed quarterly at dam sites for other EOH reservoirs and controlled lakes.

[5]Filtered: Ca, Na, K, Mg, Cl, SO_4. Samples collected in May, August, and November for Sites 1 and 3 on Croton Falls Reservoir, and at Site 1 on all other EOH reservoirs and controlled lakes.

[6]Chlorophyll *a* and phytoplankton collected at depth of 3 meters. Total phytoplankton includes the total count, the first dominant genus and count, and the second dominant genus and count.

Data Analysis and Reporting

Reservoir status will be evaluated by comparing results from each sampling stratum to its appropriate water quality benchmark listed in Appendix IX. Compliance with the benchmarks shall be measured in terms of the fraction of observations which do not meet the benchmark (i.e. excursions). The patterns of excursion occurrence will be described in the discussion of results.

Status will be determined annually and reported in DEP's Watershed Water Quality Annual Report due each July.

References

DEP. 2010. New York City Watershed Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply and its Sources. RCNY Title 15, Chapter 18. http://www.nyc.gov/html/dep/pdf/recrules/regulations.pdf. (Accessed 12/10/14)

Gibson, G., R. Carlson, J. Simpson, E. Smeltzer, J. Gerritson, S. Chapra, S. Heiskary, J. Jones, R. Kennedy. 2000. Nutrient Criteria Technical Guidance Manual-Lakes and Reservoirs. First Edition. USEPA-822-B00-001. U.S. Environmental Protection Agency. Office of Water, Office of Science and Technology. Washington, DC.

Gaugush, R. F. 1987. "Sampling Design for Reservoir Water Quality Investigations." Instruction Report E-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Ward, R.C., J. C. Loftis and G.B. McBride. 2003. Design of Water Quality Monitoring Systems. John Wiley and Sons, Inc. Hoboken, New Jersey

5.10 Croton System Biological (Benthic Invertebrate) Status

Objective

Data obtained from the sampling, identification, and counting of benthic macroinvertebrates are used to monitor the ecological integrity of streams in the Croton System, and to detect impacts of land use changes, development schemes, and point sources of pollution. Addendum E to the DEC/DEP Memorandum of Understanding (1997) specifies that if biomonitoring performed by DEP detects moderate to severe impacts in a stream reach, water quality in that reach will be considered adversely impacted. The results of adverse impact are reported annually and recommendations for remedial actions presented to the Watershed Enforcement Coordinating Committee (WECC).

Background

Biological sampling of stream benthic communities was first undertaken in 1994, using protocols developed by the NYS Stream Biomonitoring Unit (NYSDEC 2014, DEP 2001). Benthic macroinvertebrates are collected from watershed streams using a kick net, identified, and counted, and the resulting data used to generate a series of metrics from which a Biological Assessment Profile is derived. The Profile's categories are non-impaired, slightly impaired, moderately impaired, and severely impaired. Most East of Hudson streams assess as slightly impaired. Biomonitoring data have been used, among other things, to assess impacts to the benthic community from construction projects (e.g., the impacts of golf course construction on Anglefly Brook), to investigate spills, and to select sites for inclusion in Priority Waterbody List submissions to NYSDEC. Sampling of Hallocks Mill Brook both before and after the Yorktown Heights WWTP upgrade will be used to help determine whether the improvements to the stream's water quality have led to improvements in the benthic community.

Sites

To assess the status of benthic macroinvertebrates in Croton streams, sites have been established covering a wide geographic area and representing a broad array of physical and chemical conditions (Table 5.17 and Figure 3.1). Specific criteria considered when choosing these sites include:

- Are there suspected water quality impacts from an existing pollution source?
- Are land use changes or BMPs proposed or underway in the vicinity of the site which could change the character of the stream to a degree detectable by qualitative sampling of the ben-

thos?

- Is routine WQD water quality sampling conducted near the site, which would help explain the presence of the particular biological assemblage found there?
- Is the site representative of relatively unimpaired and/or pristine (reference) conditions for the District?
- May the site contain or has it been shown in the past to contain rare taxa?

New sites may be added to address specific water quality concerns. The new sites will be submitted in the year of implementation as an addendum to the WWQMP.

Table 5.17: Sites for assessment of biological status of benthic invertebrates in the Croton System basin.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
101	Brady Brook above Rte. 22 bridge	Tributary to East Branch Croton River near river's headwaters	Year 2
104	Hallocks Mill Brook above Yorktown Heights WWTP	Monitor impact to benthic macroinvertebrate community of upgrade to wastewater treatment plant	Year 5
105	Hallocks Mill Brook below Yorktown Heights WWTP	Evaluation of benthic macroinvertebrate recolonization of Hallocks Mill Brook downstream of Yorktown Heights WWTP following plant upgrade	Year 5
106	Muscoot River at MUSCOOT5	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes; presence of nearby water quality sampling site	Year 5
107	Kisco River at Rte. 133, Mt. Kisco	Monitoring site for Kisco River in Mt. Kisco	Year 4
108	Kisco River at KISCO3	Inflow to reservoir	Year 4
122	Crook Brook	Major tributary to Titicus River, immediately upstream of Titicus Reservoir	Year 3
124	Plum Brook at PLUM2	Inflow to reservoir; presence of nearby water quality sampling site	Year 4
125	Hallocks Mill Brook near Muscoot River confluence	Monitor impact of upgrade to wastewater treatment plant	Year 5

Table 5.17: (Continued) Sites for assessment of biological status of benthic invertebrates in the Croton System basin.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency[1]
128	Haviland Hollow Brook	Site is believed to represent relatively unimpaired and/or pristine (reference) conditions for the District; presence of nearby water quality sampling site	Year 1
132	Middle Branch Croton River at Town of Southeast/Carmel border	Inflow to reservoir	Year 3
140	Titicus River upstream of June Road crossing	Inflow to reservoir	Year 3
141	Tonetta Brook	Examination of impacts to benthic macroinvertebrate community from pollution sources	Year 3
143	Holly Stream	Main tributary to East Branch Croton River below Diverting Reservoir; examination of impacts to benthic macroinvertebrates from wastewater treatment plant	Year 4
151	Saw Mill Brook at Rte. 118, Yorktown	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes; inflow to reservoir	Year 4
154	Muscoot River upstream of confluence with Hallocks Mill Brook	Monitor impact to benthic macroinvertebrate community of upgrade to wastewater treatment plant	Year 5
156	Anglefly Brook in Anglefly Preserve, Somers	Isolate source of impairment to trends site at Rte. 35	Year 1[2]
157	Anglefly Brook in Anglefly Preserve, Somers	Isolate source of impairment to trends site at Rte. 35	Year 1[2]
158	Anglefly Brook in Anglefly Preserve, Somers	Isolate source of impairment to trends site at Rte. 35	Year 1[2]
159	Anglefly Brook in Anglefly Preserve, Somers	Isolate source of impairment to trends site at Rte. 35	Year 1[2]

[1]Status sites are sampled on a 5-year rotating basis. Year 1 = 2015, Year 2 = 2016, Year 3 = 2017, Year 4 = 2018, Year 5 = 2019.

[2]Non-cyclical site. No further sampling is anticipated beyond 2015.

Analytes and Frequencies

Both biological and water quality analytes are measured. The biological "analyte" is a site's stream macroinvertebrate community. Samples are shipped to a contract laboratory, which subsamples the samples and identifies and enumerates the organisms found in the subsamples. From the tally of identified organisms, a series of metrics is generated (taxa richness; numbers of mayfly, caddisfly, and stonefly taxa present; Percent Model Affinity (a measure of the community's similarity to a model NYS stream community); the Hilsenhoff Biotic Index (a measure of organic pollution); and the Nutrient Biotic Index-Phosphorus (an indicator of nutrient enrichment in streams)). From these metrics, the site's Biological Profile Assessment is derived (DEP 2001), changes to which can be studied over time. The four analytes listed in Table 3.11 (temperature, pH, conductivity, and dissolved oxygen) provide context for interpreting the invertebrate data. No additional sampling effort is required to collect these field analytes because in most cases collection occurs at the same time as biological sampling.

Sites are sampled on a rotating basis, approximately once every five years, similar to NYSDEC's Rotating Intensive Basin Studies survey. While NYSDEC protocols provide for sampling anytime between July and September, DEP biomonitoring samples have historically been collected in late August in the Croton watersheds.

Data Analysis and Reporting

Water quality results from this program are presented yearly in the Watershed Water Quality Annual Report, which is a FAD requirement. Additional reports are issued as circumstances warrant.

References

Addendum E to the Memorandum of Understanding Between the New York State Department of Environmental Conservation and the New York City Department of Environmental Protection Concerning the New York City Water Supply Watershed Protection Program. 1997. 7p.

DEP. 2001. Quality Assurance Project Plan for Stream Benthic Macroinvertebrate Biomonitoring in the New York City Water Supply Watersheds. Valhalla, NY. 37 p.

NYSDEC [New York State Department of Environmental Conservation]. 2014. Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State. 171 p.

5.11 Croton System Streams - Water Quality Trends

Objective

The objective is to collect appropriate data so that long-term trends in the most important water quality analytes for the New York City potable water supplies can be determined.

Trend analysis is important for NYC as a tool to identify and quantify actual or potential water quality problems, to help decide if and what corrective actions are necessary, and to assess the effects of corrective actions taken. These activities support the policy outlined in New York City Rules and Regulations “to protect the public health by averting future contamination to and degradation of the water supply and by remediating existing sources of pollution or degradation of the New York City water supply (DEP 2002).” Although the Croton supply will be filtered in the near future, DEP recognizes that a multiple barrier approach which includes source water protection is the best way to ensure the highest possible water quality.

Background

The intention of this objective is to be able to detect statistical trends in water quality to determine if water quality is improving, degrading, or remaining the same. In order to ensure the statistical validity of the results, data must be collected and analyzed in an appropriate fashion.

To ensure that trend analysis reflects environmental changes, and not artificially-induced program changes, ideally, there should be no changes in any aspect of the monitoring program which may induce a step-trend. Such changes include alterations to field sampling techniques, sample site locations, and time of sampling. Any method changes, such as equipment, filters, and analytical methods, should be carefully considered well in advance of implementation because of the possible ramifications for data analysis. If a change is necessary, preferably there should be a method overlap for an appropriate length of time at the selected sites to determine the impact of the change.

Sites

Samples are to be collected at each of the sites listed in Table 5.18. Most sites were selected on important reservoir inputs and as close to the reservoirs as possible to provide an indication of the trends in water which feed immediately into the reservoir. Reservoir release sites are also included because of the cascading design of the EOH System, where each release constitutes the greatest contribution to the next downstream reservoir. Because flow measurement is required to determine the effect of flow on water quality conjunctions, a prerequisite for site location is an adjacent or nearby flow/stage recorder. Where possible, samples will be collected at or near a USGS gaging station. Flow at sample sites and sub-basins that do not have a USGS gage station will be estimated via indexing to nearby sub-basins that do have a gage station. Due to the absence of suitable index sites, stream discharge rating curves will be developed at five sites: KISCO3; STONE5; HUNTER1; MIDBR3; MUSCOOT5. A yearly minimum of three discharge measurements per site at low, medium and high flows are required to create meaningful rating curves.

Table 5.18: Sampling sites for Croton streams (non-FAD watersheds) trends objective.

Site Code	Site Description	Reason for Site Selection
EASTBR	East Branch Croton River above East Branch Reservoir	East Branch Croton River, immediately upstream of East Branch Reservoir; main inflow site.
MIDBR3	Middle Branch Croton River above Middle Branch Reservoir	Middle Branch Croton River immediately upstream of Middle Branch Reservoir; main inflow site.
MUSCOOT10	Muscoot River above Amawalk Reservoir	Muscoot River, immediately upstream of Amawalk Reservoir; main inflow site.
MIDBRR	Middle Branch Reservoir Release	Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next down stream reservoir.
TITICUS3	Titicus River above Titicus Reservoir	Titicus River, immediately upstream of Titicus Reservoir; main inflow site.
STONE5	Stone Hill River above Muscoot Reservoir	Downstream monitoring site of Stone Hill Brook above Muscoot Reservoir.
KISCO3	Kisco River above New Croton Reservoir	Downstream monitoring site of Kisco River, above New Croton Reservoir.
HUNTER1	Hunter Brook above New Croton Reservoir	Downstream monitoring site of Hunter Brook, above New Croton Reservoir.
MUSCOOT5	Muscoot River above Muscoot Reservoir	Downstream monitoring site of Muscoot River, below Amawalk Reservoir and above Muscoot Reservoir.
BOGEASTBRR	Combined releases of East Branch and Bog Brook Reservoirs	Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next down stream reservoir.
DIVERTR	Diverting Reservoir Release	Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next downstream reservoir.
DIVERTCH		Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next downstream reservoir.

Table 5.18: (Continued) Sampling sites for Croton streams (non-FAD watersheds) trends objective.

Site Code	Site Description	Reason for Site Selection
TITICUSR	Titicus Reservoir Release	Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next downstream reservoir.
AMAWALKR	Amawalk Reservoir Release	Because of the cascading design of the EOH System, each release constitutes the greatest contributor of water to the next downstream reservoir.

Analytes and Frequencies

A table of analytes and reasons for their inclusion are provided in Table 5.19. The analytes have been selected on the basis of what is most likely to be of practical consequence to the City in up to 10 years' time. It is impossible to foresee every contingency, therefore best judgment has been applied.

For most analytes samples will be collected monthly, which should provide appropriate data to detect a trend after five years of 1.15 standard deviations at a confidence and power of 85%. Additional details are provided in Section 3.2.5.

Table 5.19: List of analytes for Croton streams (non-FAD watersheds) trends objective.

Analyte	Sampling Frequency	Rationale for Analyte
Flow (USGS)[1]	Continuous	Required for flow adjustment technique in trend detection.
pH	Monthly	Specific range required to support aquatic life and regulating chemical composition of water, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water.
Alkalinity	Monthly	A measurement of acid neutralizing capacity, buffering capacity.
Specific Conductivity	Monthly	Measured surrogate for total inorganic ions.
Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard.

Table 5.19: (Continued) List of analytes for Croton streams (non-FAD watersheds) trends objective.

Analyte	Sampling Frequency	Rationale for Analyte
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard.
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport.
Dissolved Oxygen	Monthly	Essential aquatic life requirement, used as an indicator of chemical and biochemical activities in water, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures.
Dissolved SO_4	Quarterly	End product of acid deposition.
Dissolved K	Quarterly	Na/K ratio used to determine and characterize hydrologic flow path.
Dissolved Mg	Quarterly	Ca/Mg ratio used to determine and characterize hydrologic flow path.
Dissolved Na	Quarterly	Major component of road salt.
Dissolved Ca	Quarterly	Essential mineral for zebra mussels, Ca depletions observed in forested catchments.
DOC	Monthly	Major source of energy to heterotrophic food webs.
NH_3-N	Monthly	Utilized preferentially over NO_x-N by autotrophs and bacteria, essential aquatic life requirement.
NO_x-N	Monthly	Essential aquatic life requirement.
Total Dissolved N	Monthly	Pool of organic and inorganic dissolved N species.
Total N	Monthly	Total pool of dissolved and particulate N.
Total Dissolved P	Monthly	Measurement of dissolved reactive phosphorus and dissolved organic complex phosphorus, used to determine dissolved organic P (DOP = TDP - SRP).
TP	Monthly	Pool of dissolved and particulate P.
SRP	Monthly	Dissolved reactive P, most readily biologically available.

[1]If gage is not available for a site, stream rating curves will be used; when rating curves are not available, indexing or other methods may be used to estimate flow.

Data Analysis and Reporting

The techniques used will be the Seasonal Kendall Sen slope estimator to estimate trend magnitude accompanied by the Seasonal Kendall trend test to indicate statistical significance. Because most water quality data are flow dependent, it is essential that any trend detection protocol includes an analysis which removes that predictable portion of variability which is caused by flow. This may be accomplished using LOcally WEighted regression Scatterplot Smoothing (LOWESS) (Cleveland 1979). LOWESS is a robust technique (Lettenmaier et al. 1991) and has been used successfully by the USGS in its examination of national water quality trends (Lanfear and Alexander 1990, Helsel 1993) and by Smith et al. (1996) in New Zealand.

To keep management apprised of emerging water quality issues, results from trend analysis for the EOH streams will be reported annually in the Watershed Water Quality Annual Report.

References

DEP. 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.

Cleveland, W.S., 1979. Robust locally weighted regression and smoothing scatterplots. Journal of the American Statistical Association 74: 829-836.

Helsel, D.R. 1993. Statistical analysis of water quality data. In: National water summary 1990-91. US Geological Survey Water-Supply Paper 2400, pp 93-100. Washington, D.C. 590p.

Lanfear, K.J., Alexander, R.B. 1990. Methodology to derive water-quality trends for use by the national water summary program of the US Geological Survey. US Geological Survey Open-File Report 90-359. 10p.

Lettenmaier, D.P., Hooper, E.R., Wagoner, E.R., Faris, K.B. 1991. Trends in water quality in the continental United State, 1978-1987. Water Resources Research 27: 327-339.

Smith, D.G., McBride, G.B., Bryers, G.G., Wisse, J., Mink, D.F.J. 1996. Trends in New Zealand's national river water quality network. New Zealand Journal of Marine and Freshwater Research 30: 485-500.

5.12 Croton System Reservoirs - Water Quality Trends

Objective

This monitoring effort is intended to provide 1) an objective assessment of whether water quality conditions are improving, worsening, or staying the same; 2) an estimate of the magnitude of change; and 3) identification of potential causes for the change. Trend analysis is important for NYC as a tool to identify and quantify actual or potential water quality problems, to help decide if and what corrective actions are necessary, and to assess the effects of corrective actions taken. These activities support the policy outlined in the New York City Rules and Regulations "to protect the public health by averting future contamination to and degradation of the water supply and by remediating existing sources of pollution or degradation of the New York City water supply" (DEP 2002). Although the Croton supply will be filtered in the near future, DEP recognizes that a multiple barrier approach which includes source water protection is the best way to ensure the highest possible water quality.

Background

The detection and interpretation of water quality trends is one of the universal objectives associated with the design of water quality monitoring systems (Ward et al. 1990). Trend analysis is frequently used to warn of worsening conditions (Aota et al. 2003, Burkholder et al. 2006) and to assess whether actions to improve water quality have been successful (DEQ 2007, Langland et al. 2000, Driscoll and Van Dreason 1992). Elements of DEP's trend analysis program are summarized below. Additional details are provided in the Quality Assurance Project Plan for Trend Analysis of Reservoir Data (Van Dreason 2006).

Sites

Samples are to be collected at each of the following sites listed in Table 5.20 and at the depths described in Appendix II. Site locations can be viewed on maps provided in Appendix I. Because water quality analytes in reservoirs display considerable spatial variability, this sampling scheme is designed to produce an accurate representation for each reservoir while still allowing analysis of individual strata (i.e., depths, locations) (Gaugush 1987). Trend detection of individual or grouped strata is used to specify location and extent of problems and to evaluate causality.

Table 5.20: Sampling sites for Croton reservoirs (non-FAD reservoirs) trends objective.

Reservoir	Sites						
New Croton	1CNC	2CNC	3CNC	4CNC	5CNC	6CNC	8CNC
Muscoot	1CM	2CM	4CM	6CM			
Amawalk	1.1CA	3CA					
Titicus	1.1CT	3CT					
Diverting	1.1CD	2CD					
Middle Branch	1.1CMB	3CMB					
East Branch	1CEB	3CEB[1]					
Bog Brook	1CBB	3CBB[1]					
Kirk Lake	1CKL						
Lake Gleneida	1CGLEN						
Lake Gilead	1CGIL[3]						

[1]These sites are sampled for fecal coliform only.

[2]Site 1CGL was renamed 1CGLEN in June 2014.

[3]Site 1CGD was renamed 1CGIL in June 2014.

Analytes and Frequencies

A list of analytes and reasons for their inclusion are provided in Table 5.16. These have been selected on the basis of what is most likely to be of practical consequence to the water supply. Analytes measured in situ (i.e., pH, specific conductivity, temperature, and dissolved oxygen) will be collected through the water column. The time interval between monthly surveys shall be consistent.

Data Analysis and Reporting

See Section 3.2.6 for data analysis details.

To keep management apprised of emerging water quality issues, results from trend analysis for all reservoirs and analytes will be reported annually in the Watershed Water Quality Annual Report.

References

Aota, Yasuaki, M. Kumagai, K. Ishikawa. 2003. Over twenty years trend of chloride ion concentration in Lake Biwa. J. Limnol., 62 (Suppl.1): 42-48

Burkholder, J. M., D. Dickey, C. Kinder, R. Reed, M. Mallin, M. McIver,L, Cahoon, C.Brownie, J. Smith, N. Deamer, J, Springer, H. Glasgow, D. Toms. 2006. Comprehensive trend analysis of nutrients and related variables in a large eutrophic estuary: A decadal study of anthropogenic and climatic influences. Limnol. Oceanogr., 511, part 2) 463-487.

DEP. 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.

DEQ. 2007. Trend Analysis of Food Processor Land Application Sites in the LowerUmatilla Basin Groundwater Management Area. Oregon Department ofEnvironmental Quality.

Driscoll, C. T. and R. Van Dreason. 1993. Seasonal and Long-term temporal patterns in the chemistry of Adirondack lakes. Water, Air, and Soil Pollution, 67:319-344.

Gaugush, R. F. 1987. "Sampling Design for Reservoir Water Quality Investigations."Instruction Report E-87-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Langland, M., J. Blomquist, L. Spraque, and R. Edwards. 2000. Trends and status of flow, nutrients and sediments for selected non-tidal sites in the Chesapeake Bay Watershed. 1995-98. U.S. Geological Survey Open-File Report 99-451. Lemoyne, Pennsylvania. 46 pages.

Reckhow, K. H., K. Kepford, and W. Warren Hicks. 1993. Methods for the Analysis of Lake Water Quality Trends. USEPA 841-R-93-003.

Van Dreason, R. S. 2006. Quality Assurance Project Plan for Trend Analysis of Reservoir Data. NYC-DEP, DWQ report. 69 pp.

Ward, R. C., J. C. Loftis, G.B. McBride. 2003. Design of Water Quality Monitoring Systems. John Wiley and Sons, Inc. Hoboken, New Jersey

5.13 Croton System Biological (Benthic Invertebrate) Trends

Objective

The objective is to examine the biological assessments of sites with a substantial historical record (at least five years) to determine whether the condition of the benthic community at these sites has remained stable, declined, or improved.

Background

Examination of biomonitoring data for evidence of long-term changes has been performed and reported on since 2005. Evidence of a downward trend has been observed at only a single site, Anglefly Brook (Site 102).

Sites

Typically, sites subjected to this analysis are integrator sites located on mainstems or on important reservoir tributaries, or are sites located on streams in whose watersheds there is a significant potential for land use changes with concomitant long-term impacts to water quality (Table 5.21 and Figure 3.1). Occasionally, sites with a long enough historical record that do not meet these criteria may be included in the analysis if they have experienced noticeable change. As circumstances warrant, additional trends sites may be added. The new sites will be submitted in the year of implementation as an addendum to the WWQMP.

Table 5.21: List of sites for Croton System biological (benthic invertebrate) trends.

Site Code	Site Description	Reason for Site Selection	Sampling Frequency
102	Anglefly Brook at Rte. 35, Somers	Undisturbed tributary to Muscoot Reservoir in sub-basin of mixed land use subject to continuing development pressure	annually
109	East Branch Croton River at EASTBR	Integrator site for East Branch Croton River above East Branch Reservoir	annually
112	Muscoot River at Mahopac Avenue, Somers	Integrator site for Muscoot River above Amawalk Reservoir	annually
134	Hunter Brook at HUNTER1	Integrator site for Hunter Brook above New Croton Reservoir	annually
142	Stone Hill River at STONE5	Integrator site for Stone Hill River above Muscoot Reservoir	annually

Analytes and Frequencies

Both biological and water quality analytes are measured. The biological “analyte” is a site’s stream macroinvertebrate community. Samples are shipped to a contract laboratory, which subsamples the samples and identifies and enumerates the organisms found in the subsamples. From the tally of identified organisms, a series of metrics is generated (taxa richness; numbers of mayfly, caddisfly, and stonefly taxa present; Percent Model Affinity (a measure of the community’s similarity to a model NYS stream community); the Hilsenhoff Biotic Index (a measure of organic pollution); and the Nutrient Biotic Index-Phosphorus (an indicator of nutrient enrichment in streams)). From these metrics, the site’s Biological Profile Assessment is derived (DEP 2001), changes to which can be studied over time. Because physicochemical factors have a profound influence on the structure and function of benthic communities, changes to those variables can help explain long-term shifts in the benthos. Conversely, shifts in the benthic community can provide clues to changes in stream chemistry. (For example, increases in grazer taxa may be an indication of heightened nutrient inputs.) The list of water quality analytes sampled to investigate these changes is presented in Table 3.11. No additional sampling effort is required to collect these field analytes because in most cases collection occurs at the same time as biological sampling.

Sites are sampled annually, as per the NYSDEC protocols employed by DEP (NYSDEC 2014). While these protocols provide for sampling between July and September, DEP biomonitoring samples have historically been collected in late August in the Croton watersheds.

Data Analysis and Reporting

Macroinvertebrate community data are examined for statistically significant trends, which are presented in the Watershed Protection Program Summary and Assessment Report. This report, produced every five years, is a FAD requirement.

References

DEP. 2001. Quality Assurance Project Plan for Stream Benthic Macroinvertebrate Biomonitoring in the New York City Water Supply Watersheds. Valhalla, NY. 37 p.

NYSDEC [New York State Department of Environmental Conservation]. 2014. Standard Operating Procedure: Biological Monitoring of Surface Waters in New York State. 171 p.

Appendix I – Limnological Sampling Site Maps

(All sites are displayed. Sites required for specific objectives are listed in the text.)

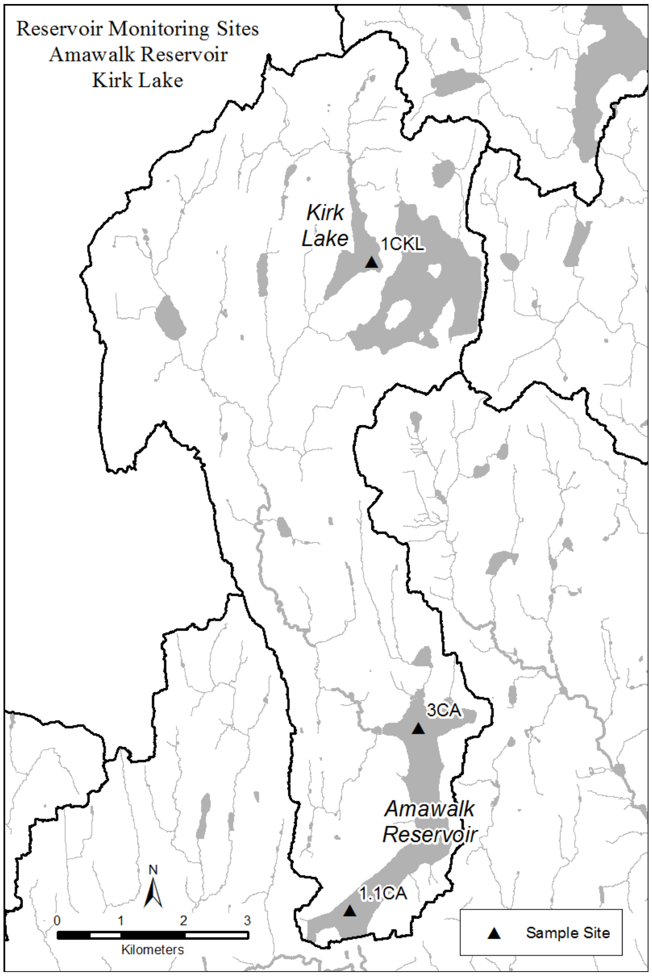


Figure A.1 Reservoir monitoring sites - Amawalk Reservoir - Kirk Lake

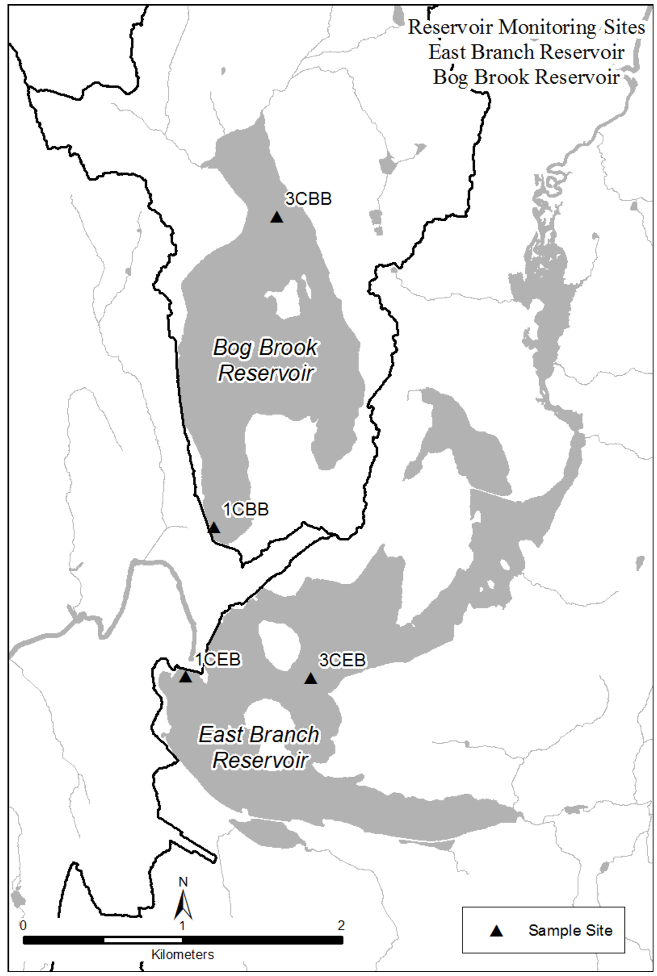


Figure A.2 Reservoir monitoring sites - East Branch Reservoir - Bog Brook Reservoir.

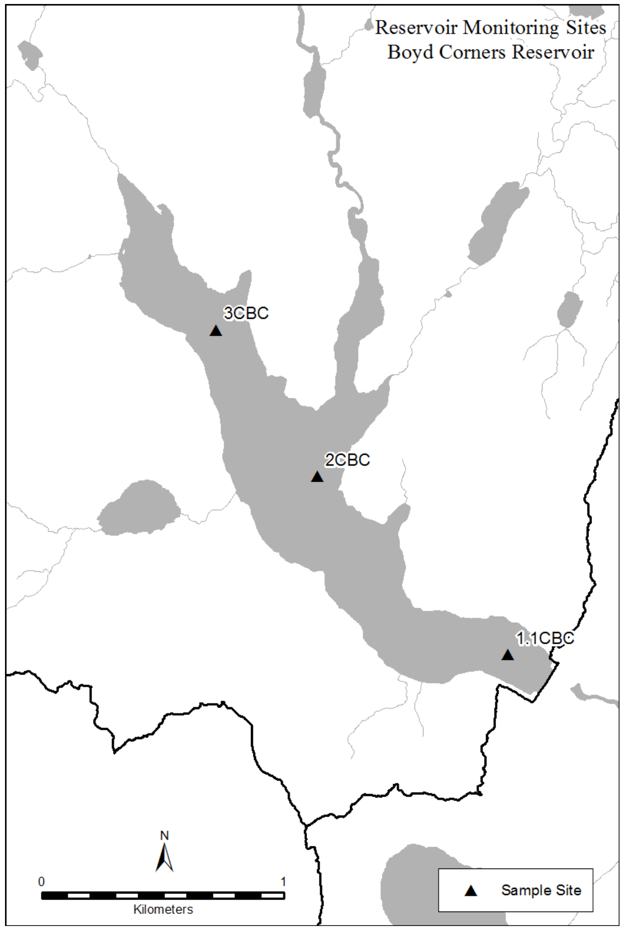


Figure A.3 Reservoir monitoring sites - Boyd Corners Reservoir.

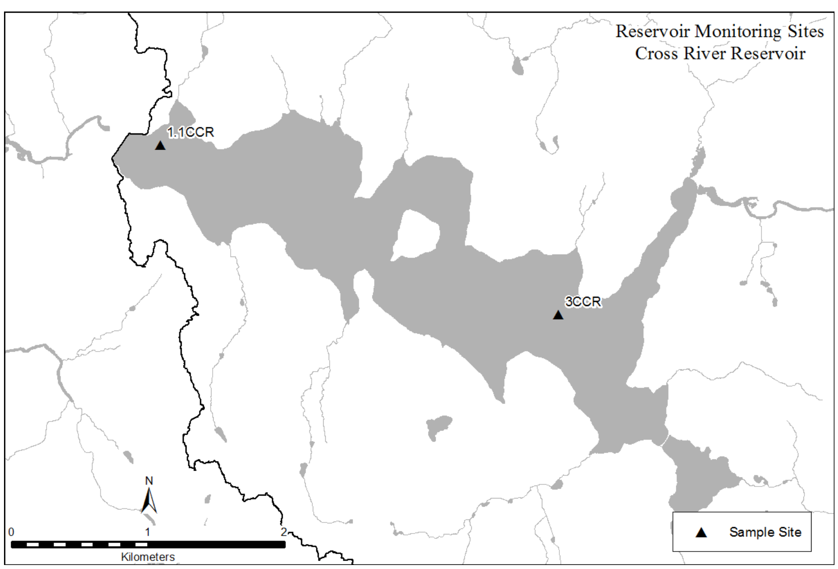


Figure A.4 Reservoir monitoring sites - Cross River Reservoir.

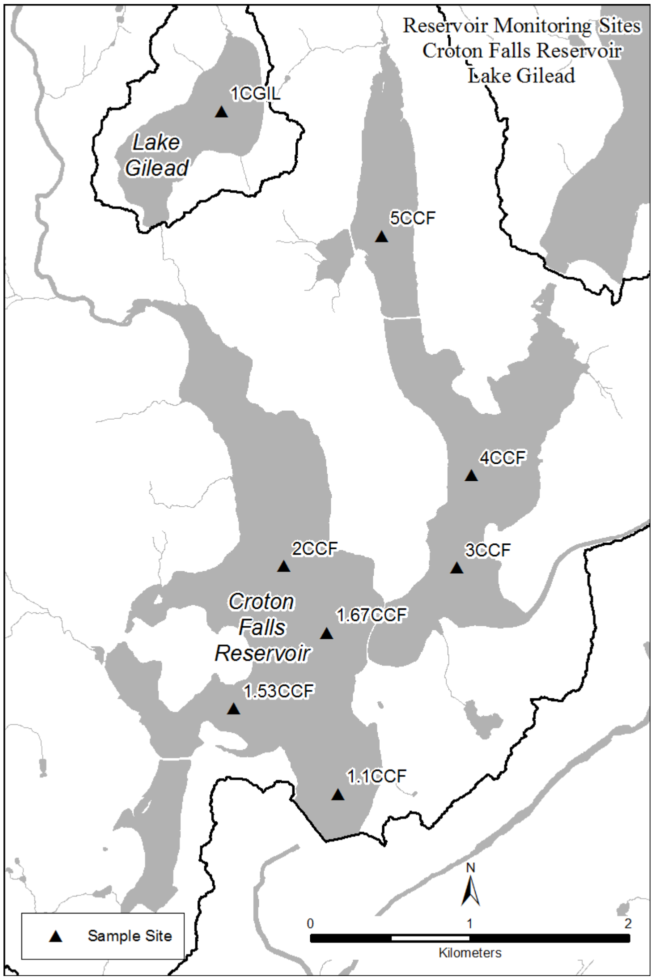


Figure A.5 Reservoir monitoring sites - Croton Falls Reservoir - Lake Gilead.

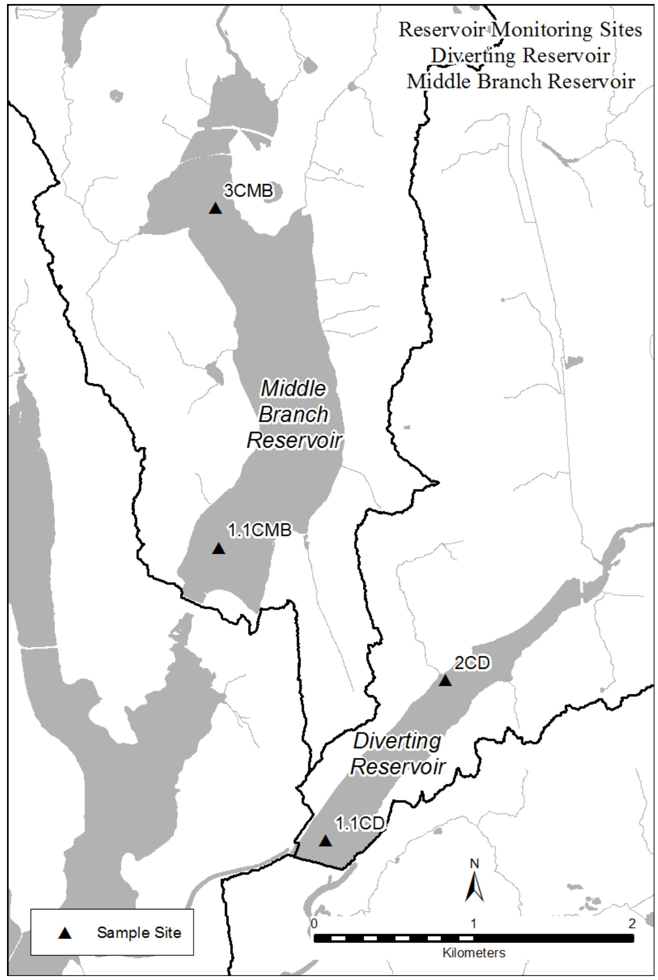


Figure A.6 Reservoir monitoring sites - Diverting Reservoir - Middle Branch Reservoir.

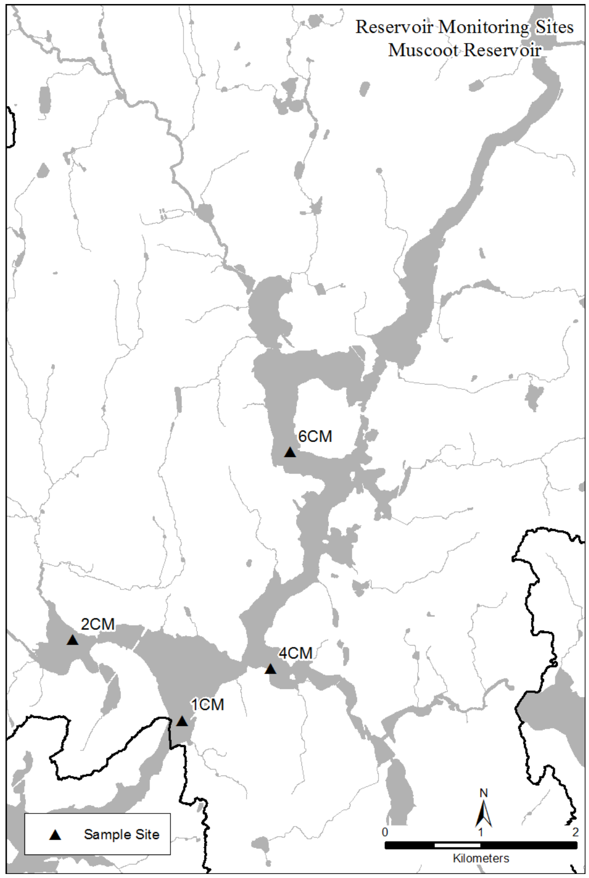


Figure A.7 Reservoir monitoring sites - Muscoot Reservoir.

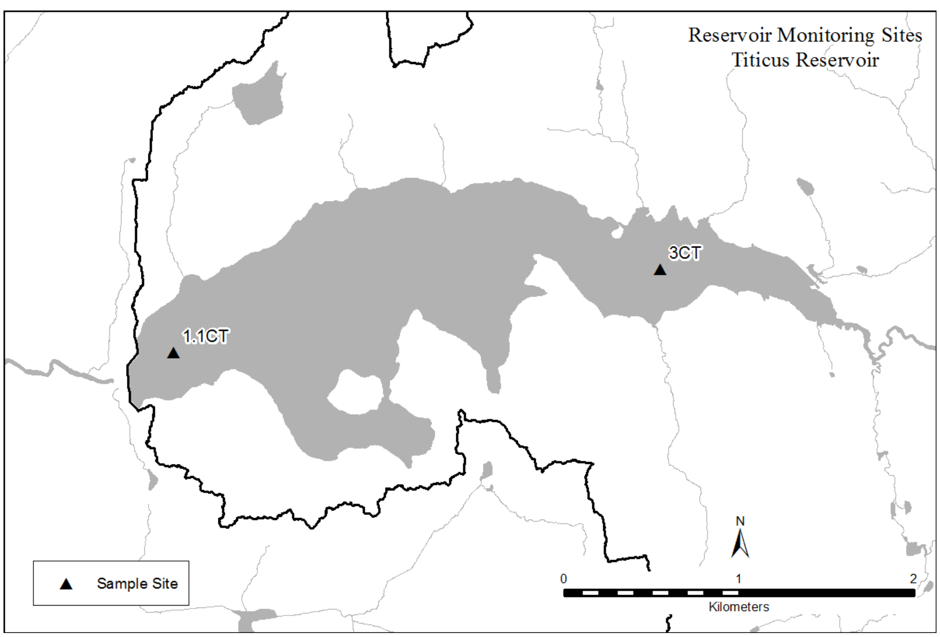


Figure A.8 Reservoir monitoring sites - Titicus Reservoir.

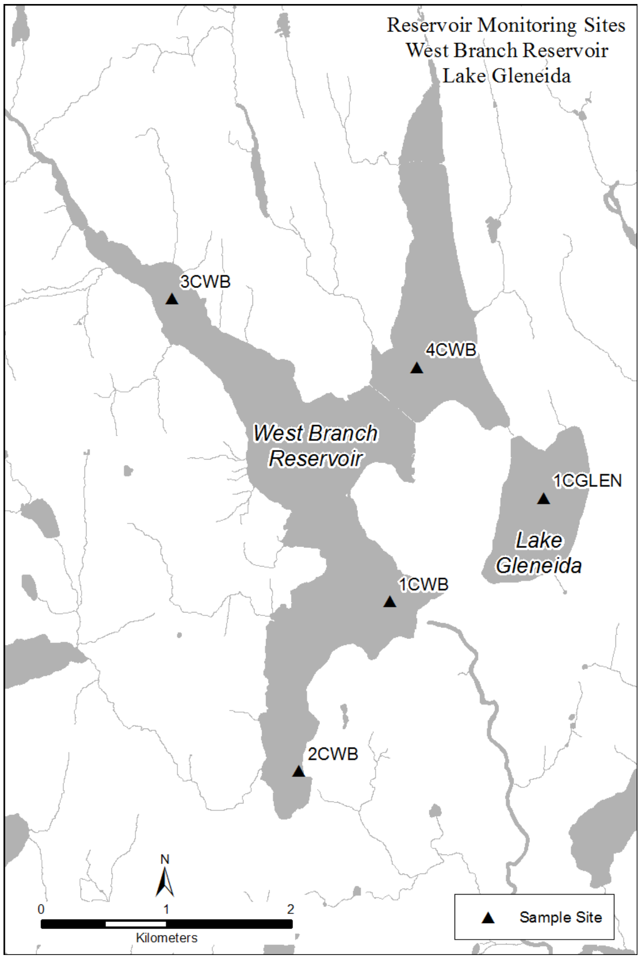


Figure A.9 Reservoir monitoring sites - West Branch Reservoir - Lake Gleneida.

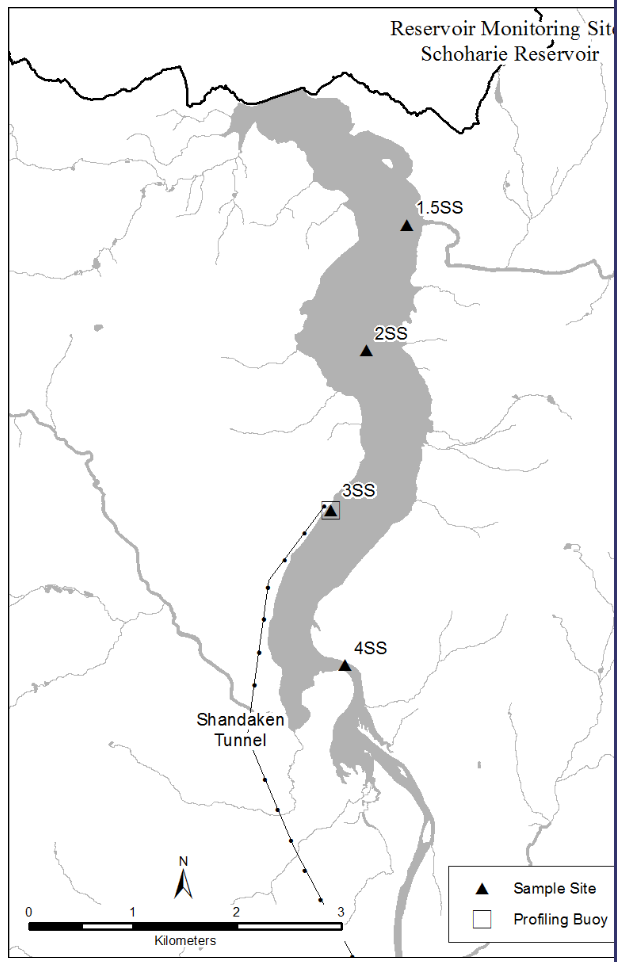


Figure A.10 Reservoir monitoring sites - Scho-

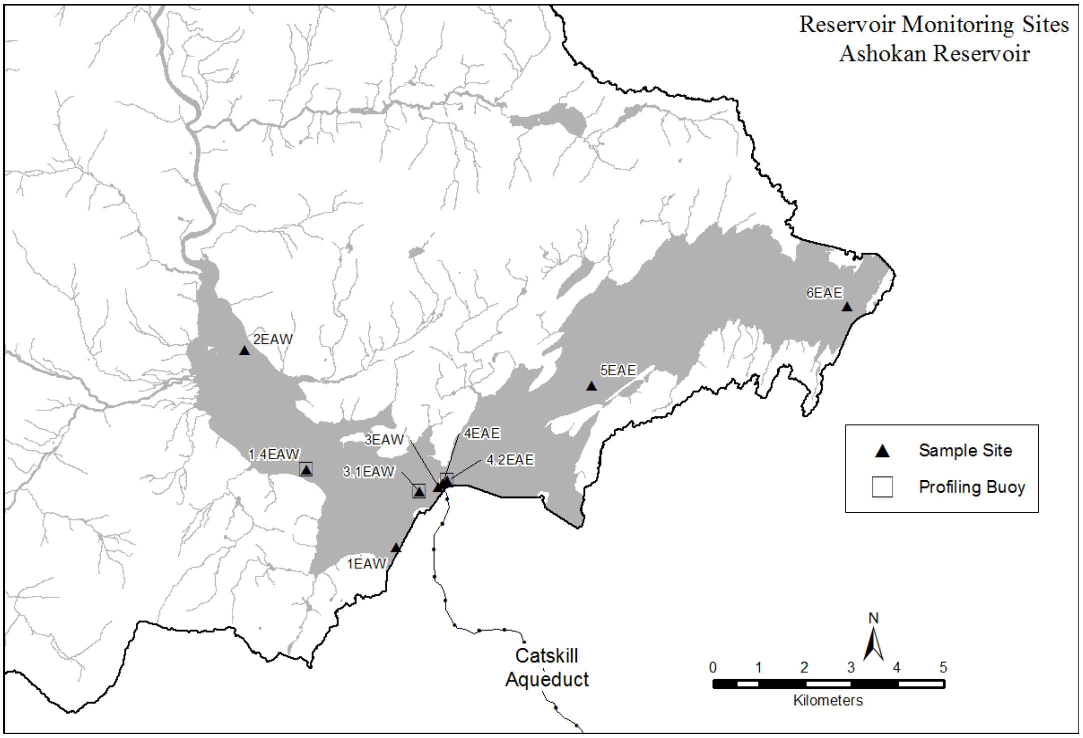


Figure A.11 Reservoir monitoring sites - Ashokan Reservoir.

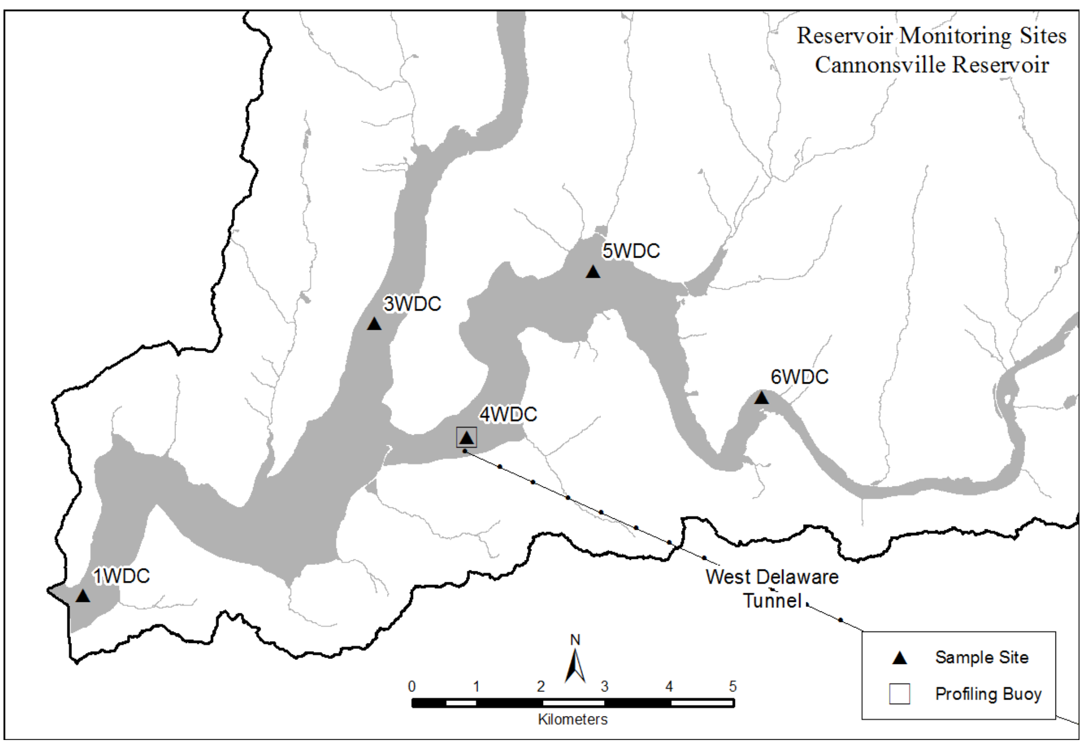


Figure A.12 Reservoir monitoring sites - Cannonsville Reservoir.

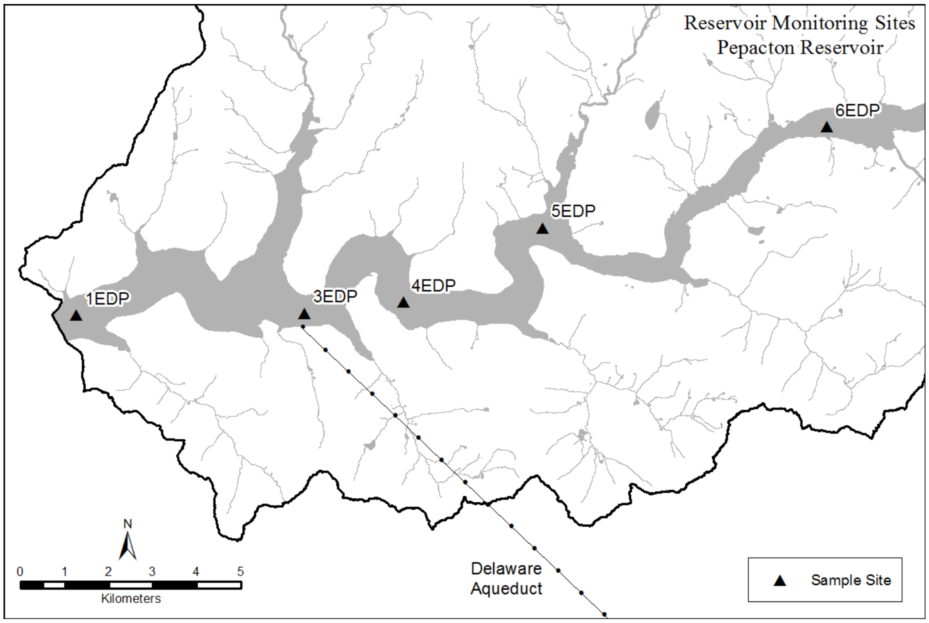


Figure A.13 Reservoir monitoring sites - Pepacton Reservoir.

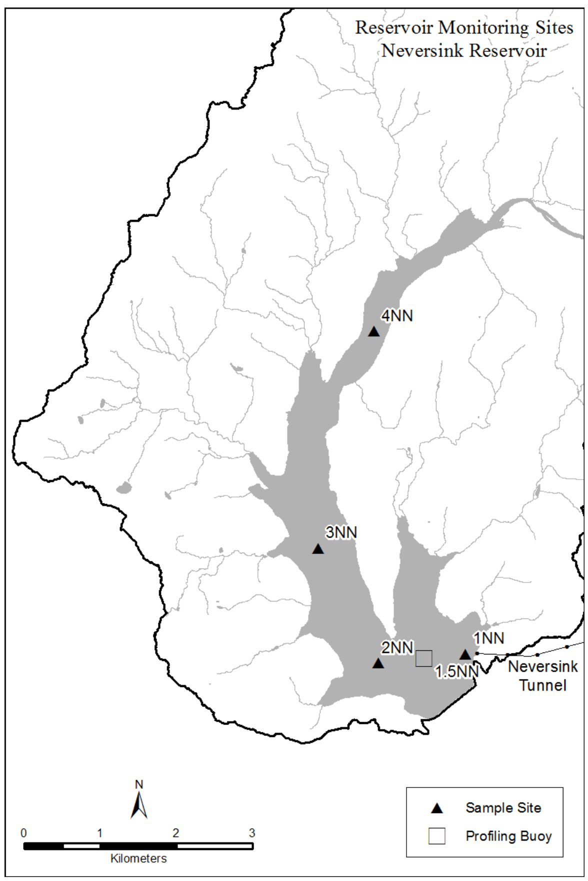


Figure A.14 Reservoir monitoring sites - Neversink Reservoir.

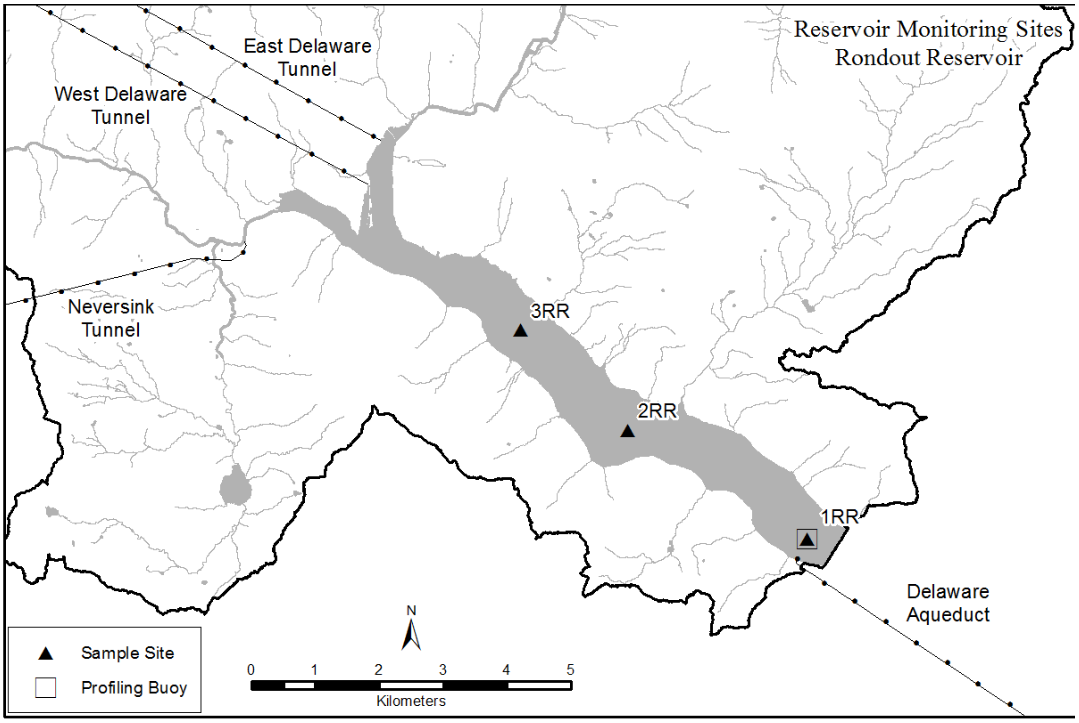


Figure A.15 Reservoir monitoring sites - Rondout Reservoir.

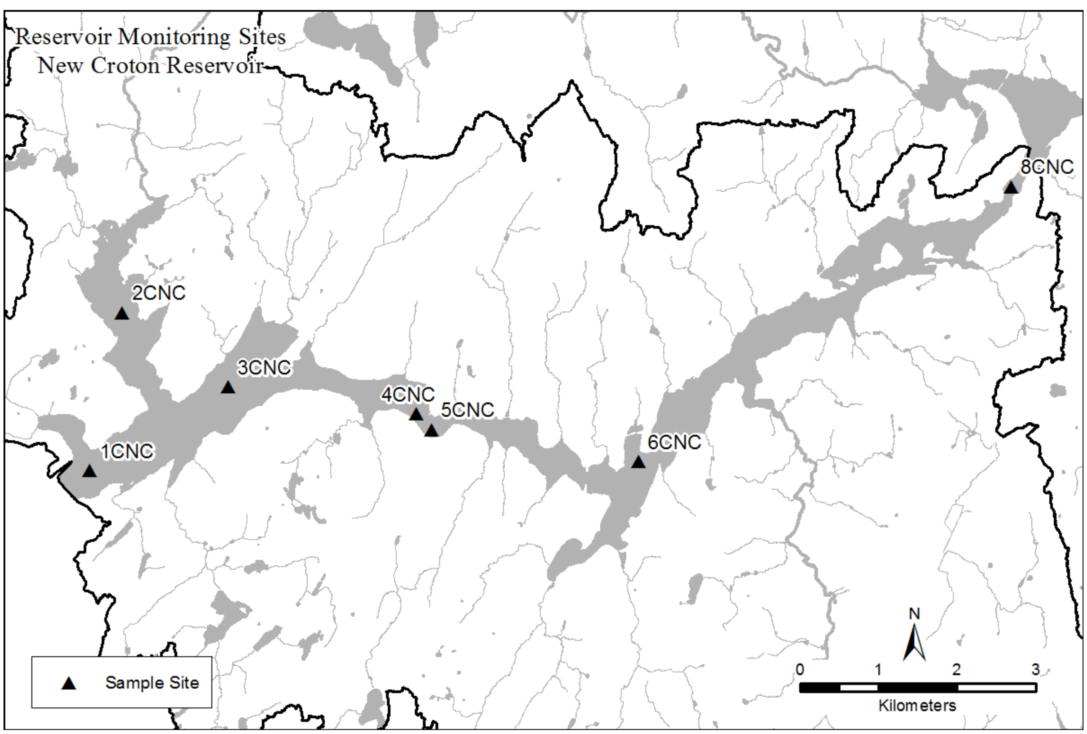


Figure A.16 Reservoir monitoring sites - New Croton Reservoir.

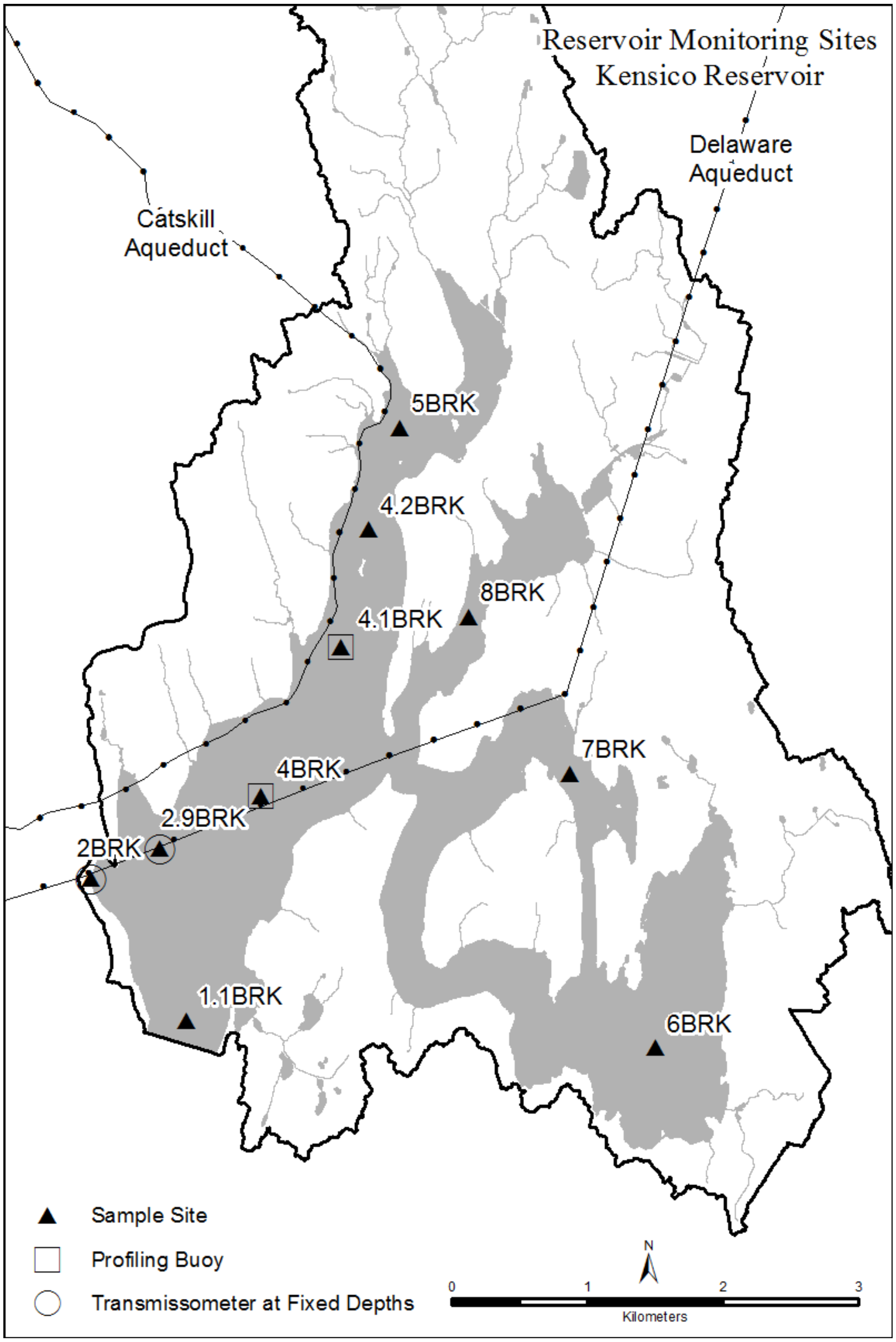


Figure A.17 Reservoir monitoring sites - Kensico Reservoir.

Appendix II – Reservoir Depth Sampling Criteria

Sampling Criteria

(Important: Zmax (maximum depth) should be rounded to the nearest whole number before use in the calculations below)

If Zmax is 1-3 meters collect one discrete sample at Zmax-1 and proceed to the next site.

If Zmax is 4-6 meters collect one discrete sample at 3m and proceed to the next site.

If Zmax is 7-12 meters:

Collect one discrete sample at 3m and one discrete sample at Zmax-2.

If Zmax is 13-39 meters: *

Collect one discreet sample at 3m and one at Zmax-2.

If 3≤ Zth ≤ Zmax-4 then collect a third sample at Zth+1 ELSE collect the sample at Zmax /2.

If Zmax is ≥ 40 meters:

Collect one discrete sample at 3m and one at Zmax-2.

If 3≤ Zth ≤ Zmax-4 and Zth ≤ Zmax/2 (**shallow thermocline**) collect:

A third sample at Zth+1

A fourth sample halfway between thermocline sample and bottom sample as per Zsp= (-1+ Zmax + Zth) /2

If 3≤ Zth ≤ Zmax-4 and Zth > Zmax/2 (**deep thermocline**) collect:

A third sample at Zth+1

A fourth sample halfway between the 3m sample and the thermocline sample as per Zsp= (Zth+4)/2

ELSE

Collect the samples at 1/3(Zmax) +1.5 and at 2/3(Zmax).

Notes

* Limno samples 1CNC and 4BRK are sampled according to ≥ 40 meters criteria

Rounding Reminder

If Zmax = 41.4m, the bottom sample would be collected at Zmax-2 or 41.4 - 2.0 = 39.4m. The nearest whole meter (39m) would be the bottom sample.
If Zmax = 41.5m, the bottom sample would be 41.5 - 2.0 = 39.5m. After rounding, the bottom sample becomes 40m.

Appendix III ─ Special Event Monitoring - Turbidity

Below is a list of reports that describe monitoring activities.

Turbidity Reports

Alum Post-Treatment Report
Water Quality and System Operations
Catskill Water Supply
October 13, 2005 - May 24, 2006
Volume I

Alum Post-Treatment Report
Water Quality and System Operations
Catskill Water Supply
October 13, 2005 - May 24, 2006
Volume II

Alum Post-Treatment Report
Water Quality and System Operations
Catskill Water Supply
Addendum Report
June 28, 2006 - August 2, 2006

Turbidity, Suspended Sediment, and Water Clarity: A Review

Appendix IV ─ Special Event Monitoring - Microbiology

2007 Vibrio cholerae Summary

New York City - Cryptosporidium Action Plan: Guidance For Interagency Coordination - September 6, 2006

Quality Assurance Project Plan for Monitoring Vibrio cholerae in Chlorinated Water Samples

Appendix V ─ Pilot Projects for Emerging Water Quality Issues

Pharmaceuticals and Personal Care Products (PPCP) Monitoring Plan for the New York City Water Supply (DEP 2008).

Reference

DEP. 2008. Pharmaceuticals and Personal Care Products Monitoring Program – Quality Assurance Project Plan. QAPP701. Flushing, NY. 12 p.

Appendix VI – Legal Documentation

Croton Consent Decree

Rules, Regulations, and Agreements

2007 Filtration Avoidance Determination
http://bwsintranet.ws.dep.nycnet/Documents/Reports/EPA_Deliverables/2007_FADFinal.pdf

Appendix VII – SPDES Permit Documentation

Wastewater Treatment Plant Compliance Inspection Reports Summary - 2nd Quarter 2008

The State Environmental Quality Review Act and Watershed Protection - A Guide for Reviewing Projects Approved, Funded or Undertaken By the Department of Environmental Protection in the Watershed and Standard Operating Procedures for Internal SEQRA Coordination

The City of New York: Public Water System Covering of Hillview Reservoir – Administrative Order

Appendix VIII – Watershed Water Quality Monitoring Plan Addendum

Summary:

This document describes the procedure for making changes, edits, additions or subtractions to the 2015 Watershed Water Quality Monitoring Plan (WWQMP). Future modifications to the WWQMP will be documented on this form, approved by the Director of WQD and then appended to the existing WWQMP as an addendum.

These changes will be compiled by the Supervisor of Publications and Reporting and made available as part of the 2015 WWQMP on the BWS computer network.

Procedure:

The following steps should be taken to make a change to the WWQMP.

1. There should be general discussion on the proposed change, and agreement of all involved parties. (This includes the Director, Chiefs, Deputy Chiefs, Section Chiefs, and Lab/Field Directors.)
2. Once general agreement is reached, the proposed change needs to be formalized and documented. WQ uses the Addendum form (below) to document these changes.
3. E-mail this form to Director and Chiefs of WQSR & WWQO and await final review and approval. Final review and approval is expected within 1 week.
4. Following receipt of final approval, e-mail the completed form (as provided above) to the Supervisor of Publications and Reporting, with copies to:
    a. Director
    b. Chiefs
    c. Deputy Chiefs
    d. Section Chiefs
    e. Field Operations Program Directors/Assistant Directors
    f. Laboratory Operations Directors
5. **Please use the email title of:** "**WWQMP Changes; 20X Addendum**" **for easy sorting** (where x represents the current year).
6. The Supervisor of Publications and Reporting will archive the completed, approved forms in a folder entitled: "WWQMP Changes; 20X Addendum," and make these available on the BWS Intranet as addenda to the electronic version of the WWQMP.

NYC Environmental Protection

WWQMP Changes; 20__ Addendum (indicate current year)

Program: ______________________
Program Supervisor:____________________
WWQMP Objectives affected:__________________

Description of specific change: (Include: site names, map of sites, # of samples, list of analytes, frequency, etc.)(Provide rationale for site selection, analytes chosen and frequency of collection. Cite references and/or SOPs and QAPPs if available)

____
____
____

Justification for change: (Why are we doing this sampling?)

____
____
____

Data analysis requirements: (For example: will results be compared to a threshold value?)

____
____
____

Reporting requirements: (Where will results be reported? Indicate deadlines and group responsible for reporting.)

____
____
____

Anticipated impact on WWQO:
(Does the change represent an increase or decrease? Will we need more, or less, manpower, equipment, and supplies? How much?)

____
____
____

Effective date:__________________________

Final Approval confirmation by:
a. Director (yes/no) _______________
b. Watershed Division Chiefs:
WQSR (yes/no) _______________WWQO (yes/no) _______________

Appendix IX – Water quality Benchmarks for Reservoirs, Controlled Lakes and Streams

Appendix Table 1: Reservoir and Controlled Lake Water Quality Benchmarks.

Analyte	Croton System		Catskill/Delaware System		
	Annual Mean	Single Sample Maximum	Annual Mean	Single Sample Maximum	Basis
Alkalinity (mg $CaCO_3L^{-1}$)	≥40.00		≥40.00		(a)
Ammonia-N (mg L^{-1})	0.05	0.10	0.05	0.10	(a)
Dissolved Chloride (mg L^{-1})	30.00	40.00	8.00	12.00	(a)
Chlorophyll *a* (mg L^{-1})	0.010	0.015	0.007	0.012	(a)
Color (Pt-Co units)		15		15	(b)
Dom. Genus (SAU)		1000		1000	(c)
Fecal coliform (CFU 100 mL^{-1})		20		20	(d)
Nitrite+nitrate (mg L^{-1})	0.30	0.50	0.30	0.50	(a)
pH (units)		6.5-8.5		6.5-8.5	(b)
Phytoplankton (SAU)		2000		2000	(c)
Dissolved Sodium (mg L^{-1})	15.00	20.00	3.00	16.00	(a)
Sol. Reactive Phosphorus (µg L^{-1})		15		15	(c)
Sulfate (mg L^{-1})	15.00	25.00	10.00	15.00	(a)
TDS (µg L^{-1})	150.00	175.00	40.00	50.00	(a)
TOC (mg L^{-1})	6.00	7.00	3.00	4.00	(a)
Total Diss. Phosphorus (µg L^{-1})		15		15	(c)
Total Phosphorus (µg L^{-1})		15		15	(c)
Total Susp. Solids (µg L^{-1})	5.00	8.00	5.00	8.00	(a)
Turbidity (NTU)		5		5	(d)

(a) NYC Rules and Regulations (pg. 123) – based on 1990 water quality results
(b) NYSDOH Drinking Water Secondary Standard
(c) DEP Internal standard/goal
(d) NYSDOH Drinking Water Primary Standard
Note also that additional benchmarks may be developed.

Appendix Table 2: Stream Water Quality Status Benchmarks.

Analyte	Croton System		Catskill/Delaware System (including Kensico)	
	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 Nitrogen	0.1	0.2	0.05	0.25
Chloride	35	100	10	50
Nitrite + Nitrate – N	0.35	1.5	0.4	1.5
Organic Nitrogen	0.5	1.5	0.5	1.5

Appendix Table 2: (Continued) Stream Water Quality Status Benchmarks.

Analyte	Croton System		Catskill/Delaware System (including Kensico)	
	Annual Mean	Single Sample Maximum	Annual Mean	Single Sample Maximum
Sodium	15	20	5	10
Sulfate	15	25	10	15
Total Diss. Solids	150	175	40	50
Dissolved Organic Carbon	9	25	9	25
Total Susp. Solids	5	8	5	8

Appendix X– Semi-volatile and Volatile Organic Compounds

EPA 525.2 – Semi-volatiles

2,4-Dinitrotoluene, 2,6-Dinitrotoluene, 4,4-DDD, 4,4-DDE, 4,4-DDT, Acenaphthene, Acenaphthylene, Acetochlor, Alachlor, Aldrin, Alpha-BHC, alpha-Chlordane, Anthracene, Atrazine, Benz(a)Anthracene, Benzo(a)pyrene, Benzo(b)Fluoranthene, Benzo(g,h,i)Perylene, Benzo(k)Fluoranthene, Beta-BHC, Bromacil, Butachlor, Butylbenzylphthalate, Caffeine, Chlorobenzilate, Chloroneb, Chlorothalonil(Draconil,Bravo), Chlorpyrifos (Dursban), Chrysene, Delta-BHC, Di-(2-Ethylhexyl)adipate, Di(2-Ethylhexyl)phthalate, Diazinon, Dibenz(a,h)Anthracene, Dichlorvos (DDVP), Dieldrin, Diethylphthalate, Dimethoate, Dimethylphthalate, Di-n-Butylphthalate, Di-N-octylphthalate, Endosulfan I (Alpha), Endosulfan II (Beta), Endosulfan Sulfate, Endrin, Endrin Aldehyde, EPTC, Fluoranthene, Fluorene, gamma-Chlordane, Heptachlor, Heptachlor Epoxide (isomer B), Hexachlorobenzene, Hexachlorocyclopentadiene, Indeno(1,2,3,c,d)Pyrene, Isophorone, Lindane, Malathion, Methoxychlor, Metolachlor, Metribuzin, Molinate, Naphthalene, Parathion, Pendimethalin, Pentachlorophenol, Permethrin (mixed isomers), Phenanthrene, Propachlor, Pyrene, Simazine, Terbacil, Terbuthylazine, Thiobencarb, trans-Nonachlor, Trifluralin, 1,3-Dimethyl-2-nitrobenzene, Acenaphthene-d10, Chrysene-d12, Perylene-d12, Phenanthrene-d10, Triphenylphosphate

EPA 524.2 - Volatile Organics

1,1,1,2-Tetrachloroethane, 1,1,1-Trichloroethane, 1,1,2,2-Tetrachloroethane, 1,1,2-Trichloroethane, 1,1-Dichloroethane, 1,1-Dichloroethylene, 1,1-Dichloropropene, 1,2,3-Trichlorobenzene, 1,2,3-Trichloropropane, 1,2,4-Trichlorobenzene, 1,2,4-Trimethylbenzene, 1,2-Dichloroethane, 1,2-Dichloropropane, 1,3,5-Trimethylbenzene, 1,3-Dichloropropane, 2,2-Dichloropropane, 2-Butanone (MEK), 4-Methyl-2-Pentanone (MIBK), Benzene, Bromobenzene, Bromochloromethane, Bromodichloromethane, Bromoethane, Bromoform, Bromomethane (Methyl Bromide), Carbon disulfide, Carbon Tetrachloride, Chlorobenzene, Chlorodibromomethane, Chloroethane, Chloroform (Trichloromethane), Chloromethane(Methyl Chloride), cis-1,2-Dichloroethylene, cis-1,3-Dichloropropene, Dibromomethane, Dichlorodifluoromethane, Dichloromethane, Di-isopropyl ether, Ethyl benzene, Hexachlorobutadiene, Isopropylbenzene, m,p-Xylenes, m-Dichlorobenzene (1,3-DCB), Methyl Tert-butyl ether (MTBE), Naphthalene, n-Butylbenzene, n-Propylbenzene, o-Chlorotoluene, o-Dichlorobenzene (1,2-DCB), o-Xylene, p-Chlorotoluene, p-Dichlorobenzene (1,4-DCB), p-Isopropyltoluene, sec-Butylbenzene, Styrene, tert-amyl Methyl Ether, tert-Butyl Ethyl Ether, tert-Butylbenzene, Tetrachloroethylene (PCE), Toluene, Total 1,3-Dichloropropene, Total THM, Total xylenes, trans-1,2-Dichloroethylene, trans-1,3-Dichloropropene, Trichloroethylene (TCE), Trichlorofluoromethane, Trichlorotrifluoroethane(Freon 113), Vinyl chloride (VC), 1,2-Dichloroethane-d4 4-Bromofluorobenzene, Toluene-d8

Appendix XI – East and West of Hudson WWTP Analytes.

East of Hudson WWTP analytes for CCD monitoring

Location	BOD	CBOD	TSS	SS	FC	TC	TP	NH3	NO3	PH	Cl	Fl	DO	T	Turb
Bedford Hills Correctional Facility		x	x	x	x	x	x			x		x	x	x	x
Bedford Hills Elderly Housing WWTP	x		x	x	x		x	x		x	x	x	x		
Bedford Park Apartments Westchester WWTP			x	x	x					x	x	x			
Blackberry Hill Sanitary SD STP		x	x		x		x	x		x		x	x		x
Southeast (T) Brewster Heights SD #1		x	x	x	x		x	x		x		x	x		x
Brewster High School		x	x	x	x		x	x		x	x	x	x		x
Brewster (V) STP		x	x	x	x		x	x		x	x	x	x		x
Bridleside WWTP		x	x	x			x			x		x			
Camp Ludington	x		x	x	x		x			x	x	x			x
Town of Carmel SD # 2		x	x	x	x		x	x		x	x	x	x		x
Clear Pool Camp		x	x	x	x		x	x		x		x	x		x
Country Manor STP		x	x	x	x		x	x		x		x	x		x
Fox Lane Campus		x	x	x	x		x	x		x	x	x	x		x
Fox Run Condominiums		x	x	x	x		x	x		x	x	x	x		x
George Fischer Middle School	x		x	x	x		x			x		x			x
Heritage Hills STP		x	x	x	x		x	x		x	x	x	x		x
Independent Sewage Works Inc., Highlands	x		x	x	x		x	x		x	x	x	x		x
Hill Sparrow WWTP		x	x	x	x		x	x		x		x	x		x
Holly Stream Condominium STP	x		x	x	x		x			x	x	x			x
Hunter’s Glen WWTP STP		x	x	x	x		x	x		x	x	x	x		x
Somers Office Building Complex		x	x	x	x		x	x		x	x	x	x	x	
Increase Miller Elementary School	x		x	x	x		x	x		x	x	x	x		x

East of Hudson WWTP analytes for CCD monitoring

Location	BOD	CBOD	TSS	SS	FC	TC	TP	NH3	NO3	PH	Cl	Fl	DO	T	Turb
Katonah Elementary School District	x		x	x	x	x				x	x	x			
K'hal Adas Kashau		x	x	x	x		x	x		x		x	x		x
Kent Manor Condominiums	x		x	x	x		x	x		x	x	x	x		x
Putnam Nursing and Rehabilitation Center		x	x	x	x		x	x		x	x	x	x		x
Peach Lake Sewer District WWTP	x		x	x	x		x	x		x	x	x	x		
Carmel Sewer District #4 STP		x	x	x	x		x	x		x	x	x	x		x
Lincoln Hall STP		x	x	x	x		x	x		x		x	x		x
Mahopac CSD WWTP	x		x	x	x		x	x		x	x	x	x		x
NYC DEP Mahopac (V) WWTP		x	x	x	x		x	x		x	x	x	x	x	x
Mahopac Village Center	x		x	x	x		x	x		x		x	x		x
Maple Hill Estates WWTP		x	x	x	x		x	x		x		x	x		x
Michelle Estates Realty Subdivision		x	x	x	x		x	x		x		x	x		x
Mount Ebo Associates STP		x	x	x	x		x	x		x		x	x		x
North Salem Middle & High School	x		x	x	x	x				x	x	x			
Patterson Hamlet WWTP		x	x	x	x		x	x		x	x	x	x		x
Pepsi Co. Somers Office Facility		x	x	x	x		x	x	x	x	x	x			
Putnam National Golf Club	x		x	x	x		x	x		x	x	x	x		x
Random Farms Subdivision		x	x					x		x					
Reed Farm Condominiums		x	x	x	x		x	x		x	x	x	x		x
I-684 Rest Area - Comfort Station #45		x	x	x	x		x	x		x	x	x	x		x
Fox Hollow Sewer Corp Inc.		x	x	x	x		x	x		x	x	x	x		
Seven Springs Sewer Corp.		x	x	x	x		x	x		x	x	x	x		x
Society Hill at Mahopac		x	x	x	x		x	x		x	x	x	X		x
Somers Chase Sewer Co. - Voris Drive	x		x	x	x		x	x	x	x	x				

East of Hudson WWTP analytes for CCD monitoring

Location	BOD	CBOD	TSS	SS	FC	TC	TP	NH3	NO3	PH	Cl	Fl	DO	T	Turb
Somers High & Primrose Elementary Campus		x	x	x	x	x	x	x		x	x	x	x		x
Somers Manor Nursing home, Inc.		x	x	x	x		x	x		x	x	x	x	x	x
Terravest Corporate Park							x		x		x	x			
Meadows At Cross River Condominiums		x	x	x	x		x	x		x		x	x		x
Thunder Ridge Ski Area		x	x	x	x					x	x	x			
Brewster Towne Center WWTP	x		x	x	x		x	x		x	x	x	x		
Tracy Sew.Works Dist./ClockTower Commons		x	x	x	x		x	x		x		x	x		x
Waccabuc Country Club		x	x	x	x		x	x		x	x	x	x		x
Walter Panas High School	x		x	x	x					x	x	x			
Watchtower Educational Center		x	x	x	x		x	x		x	x	x	x		x
Wild Oaks Sewer District		x	x	x	x		x	x		x		x	x		x
Williamsburg Ridge STP		x	x	x	x		x	x		x		x	x		x
Yeshiva Kehilath Yakov School	x		x	x	x		x	x		x	x	x			x
Yorktown Sewer District WWTP		x	x	x	x		x	x		x	x	x	x	x	x

Note: TSS=Total Suspended Solids, SS=Settleable Solids, FC=Fecal Coliform, TC=Total Coliform, Cl=Chlorine Residual, Fl=Flow, T=Temperature, Turb=Turbidity

West of Hudson WWTP analytes for FAD monitoring.

Location/Basin	BOD	CBOD	TSS	SS	FC	TD	TP	NH3	NO3	PH	Cl	Fl	DO	Surf	T	Turb
Andes (Pepacton)	x		x	x	x		x	x		x		x	x		x	x
Ashland (Schoharie)																
Batavia Kill Recreation Area (Schoharie)	x		x	x	x		x			x	x	x			x	x
Boiceville WWTP	x			x	x					x		x				
Camp L'man A'chai (Pepacton)		x	x	x	x		x	x		x	x	x	x		x	x
Camp Oh-neh-tah (Schoharie)		x	x	x	x		x	x		x	x	x	x			x
Golden Acres (Schoharie)		x	x		x			x		x	x	x	x			
Camp Timberlake (Ashokan)	x		x	x	x					x	x	x	x			
Crystal Pond (Schoharie)		x	x	x	x		x	x		x		x	x		x	x
Delhi (Cannonsville)			x	x	x					x	x	x				
Elka Park (Schoharie)		x	x	x	x		x	x		x	x	x	x			x
Fleischmanns (Pepacton)	x		x	x	x			x		x	x	x	x			
Grahamsville (Rondout)		x	x	x	x		x	x		x	x	x	x			x
Grand Gorge (Schoharie)		x	x	x	x		x	x		x	x	x	x		x	x
Hobart (Cannonsville)	x		x	x	x		x	x		x	x	x	x			x
Hunter Highlands (Schoharie)		x	x	x	x		x	x		x		x				x
Hunter WWTP (Schoharie)		x	x	x	x		x	x		x	x	x	x			
																x
Machne Tashbar (Schoharie)	x		x	x	x		x	x		x	x	x				x
Margaretville (Pepacton)		x	x	x	x		x	x		x	x	x	x		x	x
Mountain View (Schoharie)		x	x	x	x		x	x		x	x	x	x			x
Mountainside Farms (Pepacton)		x	x	x	x		x	x		x		x	x			x
Olive Woods (Ashokan)	x		x	x	x		x		x	x	x	x		x		

West of Hudson WWTP analytes for FAD monitoring.

Location/Basin	BOD	CBOD	TSS	SS	FC	TD	TP	NH3	NO3	PH	Cl	Fl	DO	Surf	T	Turb
Onteora Central School (Ashokan)		x	x	x	x		x	x		x		x	x		x	x
Pine Hill (Ashokan)		x	x	x	x		x	x		x	x	x				x
Port Jervis	x	x	x	x	x		x	x		x	x	x	x		x	x
Prattsville (Schoharie)	x		x	x	x					x	x	x				
Roxbury Run (Pepacton)		x	x	x	x		x			x		x	x			x
Stamford (Cannonsville)	x	x	x	x	x		x	x		x	x	x	x		x	x
Tannersville (Schoharie)		x	x	x	x		x	x		x	x	x	x			x
Walton (Cannonsville)		x	x	x	x		x	x		x	x	x	x		x	x
R. W. Harold Campus (BOCES) (C'ville)		x	x	x	x		x	x		x	x	x			x	
Windham WWTP (Schoharie)		x	x	x	x	x	x	x		x		x			x	x
	x		x	x	x		x	x		x	x	x	x		x	

Note: TSS=Total Suspended Solids, SS=Settleable Solids, FC=Fecal Coliform, TD=Total Dissolved Solids, Cl=Chlorine Residual, Fl=Flow, Surf=Surfactants, T=Temperature, Turb=Turbidity