New York City
Department of Environmental Protection

2009 Watershed Water Quality Monitoring Plan

Revised
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Acknowledgements

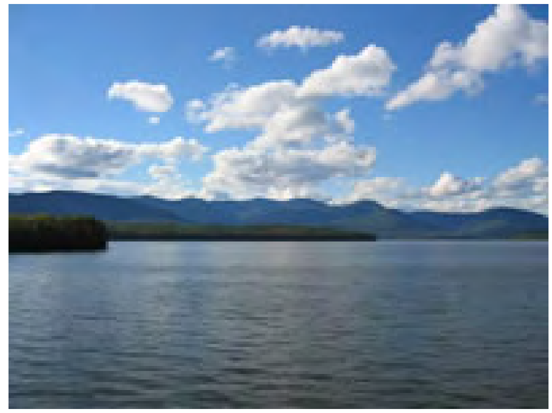
The Watershed Water Quality Monitoring Plan (WWQMP) represents a description of the water quality monitoring program that will be conducted by the Water Quality Directorate (WQD) beginning in 2009 and is one of the requirements of the 2007 Filtration Avoidance Determination for the NYC Water Supply. In this version, the chapters are arranged according to overarching categories of objectives. The overarching objectives include regulatory compliance, meeting NYC's 2007 Filtration Avoidance Determination requirements, modeling, and surveillance. These objectives are then arranged in order of Bureau priority, rather than organized by scientific discipline (as was done in the past). The reorganization of the monitoring plan mirrors the reorganization of the Water Quality Directorate which was implemented by Mr. Steven Schindler, Director of Water Quality in 2007. Mr. Schindler provides oversight of the Directorate's organization and operation performed by a group of over 200 water quality specialists.

The staff of Watershed Water Quality Science and Research (WWQSR), one of the four Divisions of the Directorate, was assigned the task of producing this revised plan. They are acknowledged for their extensive efforts to conduct this review and revision of DEP's large and complex monitoring program. The combination of their field and laboratory experience, and their statistical expertise, has allowed DEP to present a revised and updated program that will be effective in directly addressing the regulatory and operational needs of the Department. Individuals were involved as follows. As Chief of WWQSR, Dr. Lorraine Janus was responsible for guiding staff through the review, organization, and production of this report, as well as providing Chapter 1 (Introduction) for the WWQMP. She was also responsible for accommodating changes needed for implementation, critically reviewing the final plan, and coordinating presentations of the plan to management and regulators. Section Chiefs of WWQSR also participated in writing chapters, editing, and participating in presentations; this plan would not have materialized without their sincere efforts. Ms. Kerri Alderisio, Section Chief of Pathogen Planning and Assessment, provided oversight for the production of Chapter 2 on Regulatory Compliance, as well as objectives that require pathogen monitoring in other chapters. Mr. Jim Mayfield, Section Chief of Program Evaluation and Planning, provided oversight of Chapters 3 and 5. Together, he and Mr. Bryce McCann developed Chapter 3, which is devoted to defining the monitoring required to satisfy the many facets of the Filtration Avoidance Determination (FAD). Dr. Donald Pierson, Section Chief of Modeling, and his staff provided Chapter 4, which describes both the modeling work needed to fulfill the FAD requirements (related to evaluation of watershed protection and remediation programs) and guide the operational activities of the Bureau. Mr. Gerard Marzec was responsible for coordination and development of Chapter 5, which identifies monitoring needed for the ongoing surveillance of the water supply, in terms of both routine and special needs for operation of the system to consistently deliver safe, clean drinking water to ten million consumers. Mr. David Lounsbury, GIS Specialist, was responsible for production of the attractive maps throughout this report, which truly enhance the use and communication of the plan's content. Ms. Patricia Girard was responsible for initiating the Division’s use of SharePoint software, an innovation which allowed many staff to share materials needed for the production of the plan. She is responsible for the desktop publishing work which brought the plan into a final organized and visually appealing document. She and Mr. Martin Rosenfeld served as the final focal points in the compilation of many individual files to consolidate the plan and accommodate final editing. We are also indebted to Mr. Martin Rosenfeld for his scientific expertise to plan the benthic invertebrate monitoring included in this plan. Many other staff members of WWQSR contributed to this monitoring plan through their experience, data analysis, and writing, including: Dr. Elliot Schneiderman, Mr. Mark Zion, Mr. Donald Kent, Mr. Rich VanDreason, Dr. R. Yucel Tokuz, Mr. Radan Homolac, Mr. David Quentin, Mr. Steve DiLonardo, and Mr. Christian Pace. We also wish to thank the staff of Watershed Water Quality Operations (WWQO), directed by Ms. Lori Emery, for participation in meetings to review the monitoring plans in an effort to tailor the plans to current conditions and requirements. Ultimately, WWQO will be the Division responsible for implementation of the plan, so their input was essential in the development of this plan. 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 many 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. The staff is to be commended for their team effort. Finally, it should be acknowledged that this document stands on the shoulders of the monitoring plans that have preceded it and we thank all those, in particular Dr. David Smith and Mr. Rich Corradi, who contributed ideas through previous monitoring plans.

The Watershed Water Quality Operations (WWQO) Division is acknowledged for their technical input and their efforts in providing a thorough review of the plan. Of particular value was their expertise and input on the Regulatory Compliance and the Keypoint and Reservoir Surveillance Sections of this plan, both of which are long standing programs that are designed and managed by WWQO. Ms. Lori Emery, Chief of WWQO, will be responsible for the overall implementation of the plan with managerial assistance from Mr. Andrew Bader (Deputy Chief, WOH WWQO), Mr. Charles Cutietta-Olson (Deputy Chief, EOH WWQO), Mr. James Broderick (Deputy Chief, WWQO Compliance) and Mr. Chris Nadareski (Section Chief, Wildlife Studies). The operational Section Chiefs (Ms. Kirsten Lewis, Kingston WWQO, Mr. William Richardson, Grahamsville WWQO, Mr. Dale Borchert, Kensico WWQO and Dr. Romulo Aquino, Brewster WWQO) will provide on-site management of the regional components of the monitoring plan with assistance from their Laboratory and Field Directors. WWQO is comprised of three Field Operations Units, a Compliance Unit, a Wildlife Studies Section, a Pathogen Laboratory (accredited by the USEPA) 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 WWQO staff.

1. Introduction

1.1 Background and Organization of this Report


One of NYC's 19 Water Supply Reservoirs.

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 2007 Filtration Avoidance Determination (FAD); 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 Pollution 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), and the 2003 Integrated Monitoring Plan (DEP 2003). 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. 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. Comprehensive Quality Assurance Project Plans are also part of the routine documentation associated with the analytical data from the water quality monitoring network which ensure that DEP's watershed laboratories provide scientifically defensible information. DEP's watershed water quality laboratories are accredited by ELAP to NELAP standards. The watershed pathogen laboratory is accredited by the USEPA. 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 state of the art Laboratory Information Management System (LIMS) suite is being installed and full implementation at WWQO labs is likely to occur during 2010. The LIMS product being implemented is a Web-based commercial off-the-shelf (COTS) LIMS designed for a wide variety of laboratory types, including water quality laboratories. Water Quality staff, which includes managerial and laboratory staff, research scientists, modelers, and QA/QC staff and field personnel, will all have the ability to interact directly or indirectly with the LIMS. Where possible, instrument data output from the laboratories and field programs will be directly integrated with the LIMS, which can then trigger additional calculations and validation prior to final database storage. The LIMS system will also improve upon laboratory and managerial reporting capabilities through the use of Crystal Reports (a software package), which is embedded in the LIMS. Some of the reports produced by DEP are reports that only require data listings. These are typical of the reports that are submitted to regulatory agencies. Others are more complex and require mathematical analysis and interpretation in relation to a theoretical framework. The latter are typical of reports for program and policy evaluation and often include modeling work. The way in which data are analyzed and reported has been specified for each objective in this monitoring plan.

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. The 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 samples, limnological sites, aqueducts, and wastewater treatment plants. 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.

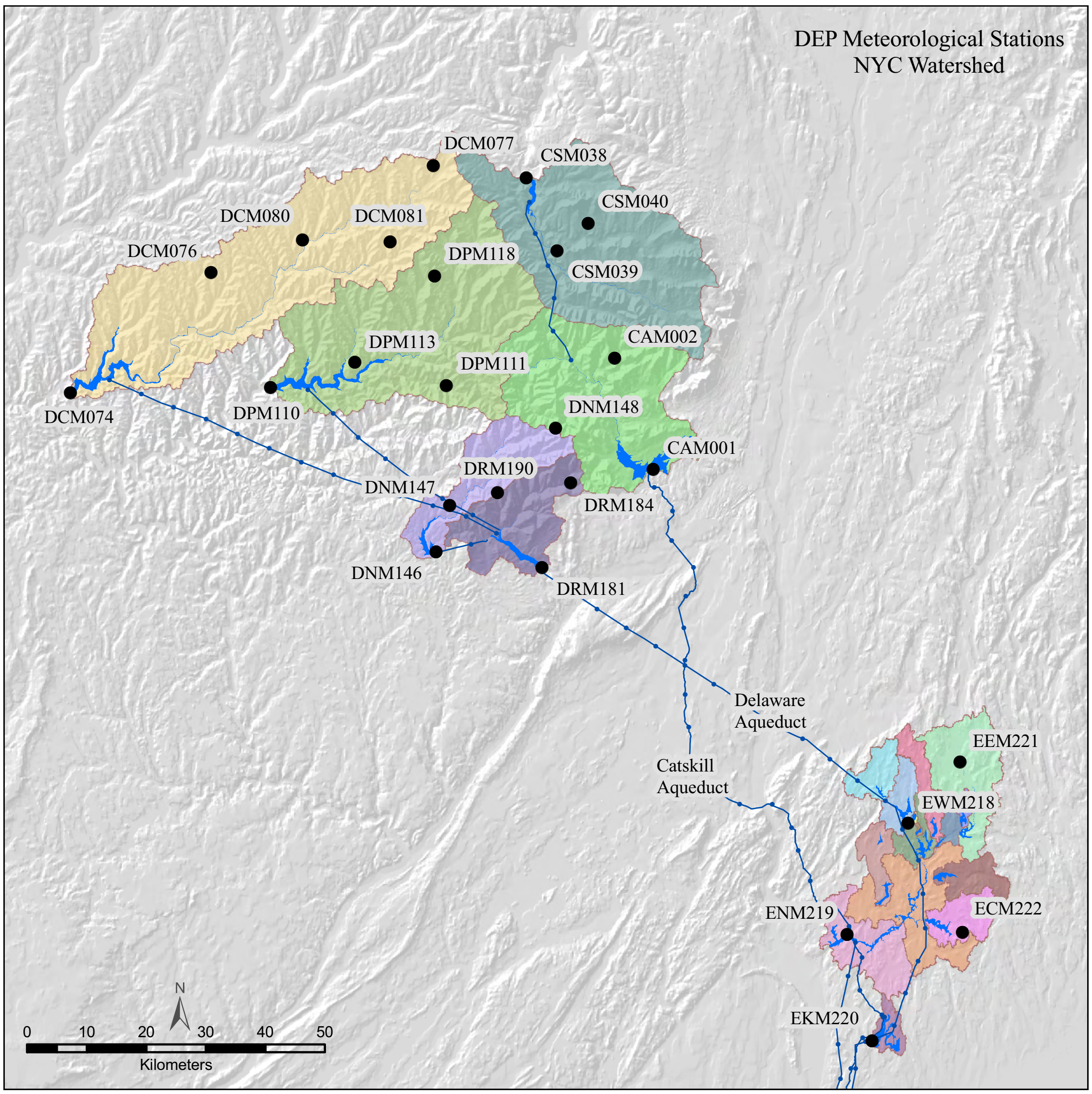


Figure 1.1 DEP meteorological stations in the NYC watershed.

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.

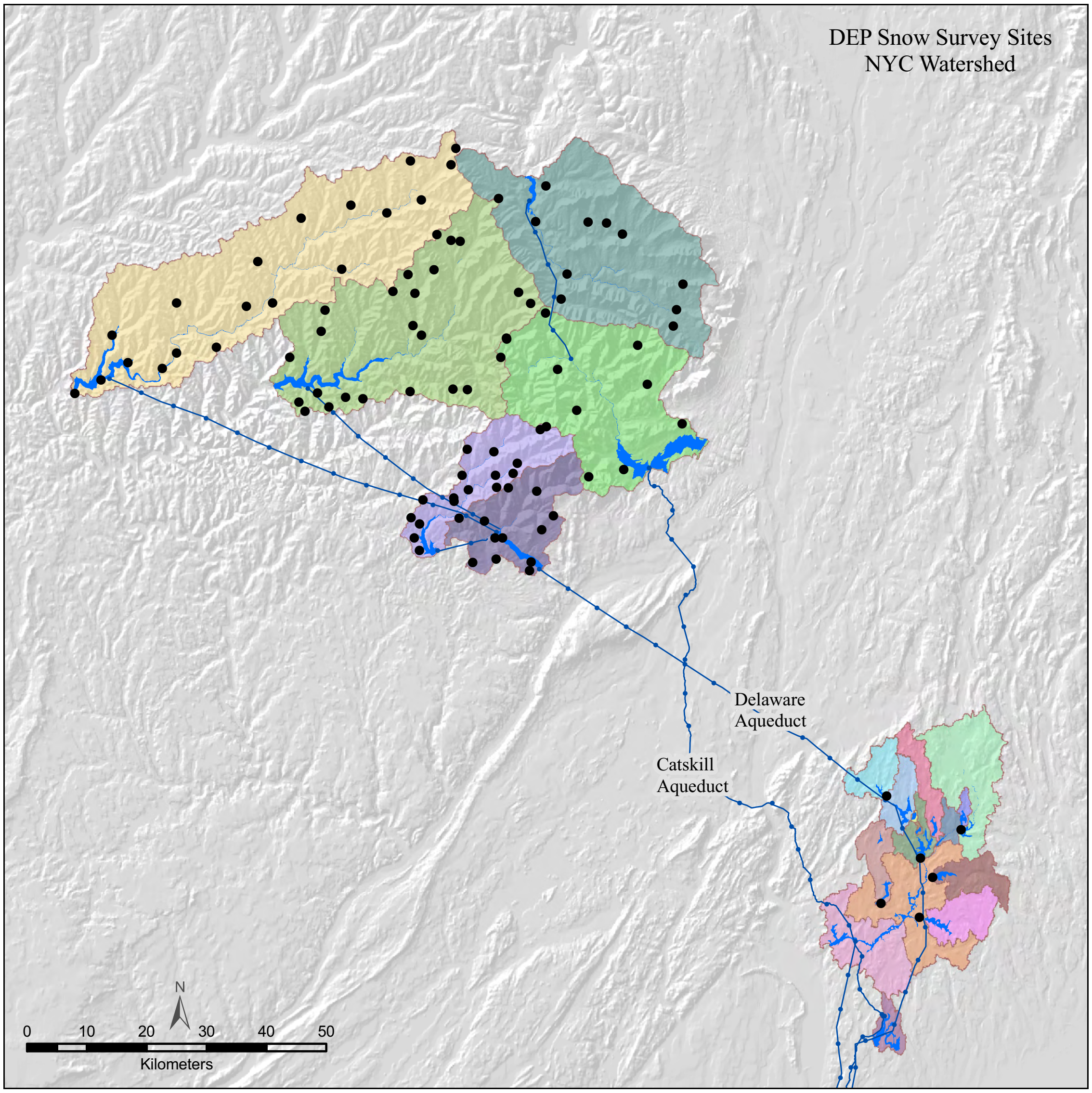


Figure 1.2 DEP snow survey sites in the NYC watershed.

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 Figure 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.

Typical Delaware System stream.

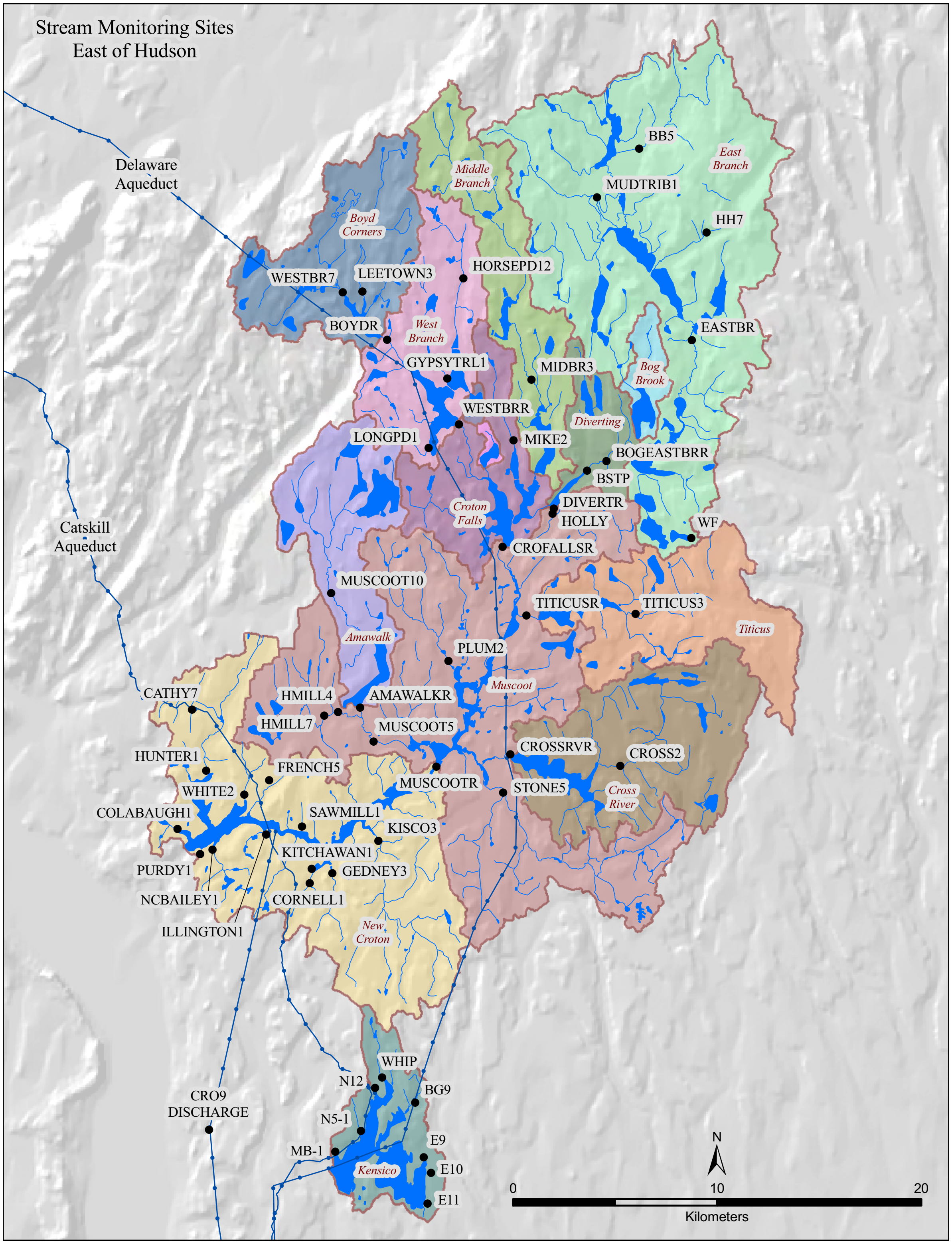


Figure 1.3 Stream sampling sites east of the Hudson River.

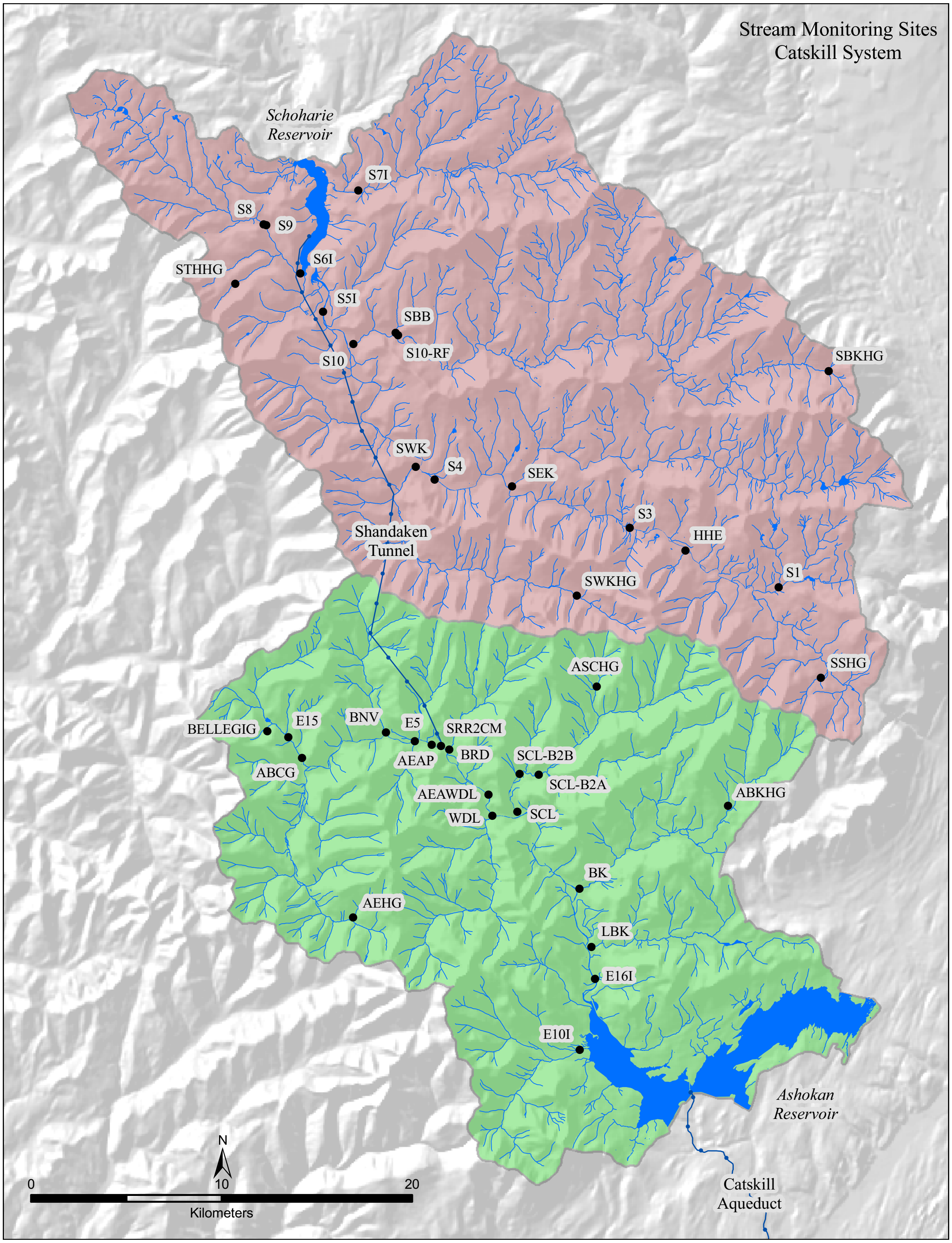


Figure 1.4 Stream sampling sites within the Catskill System drainage basins.

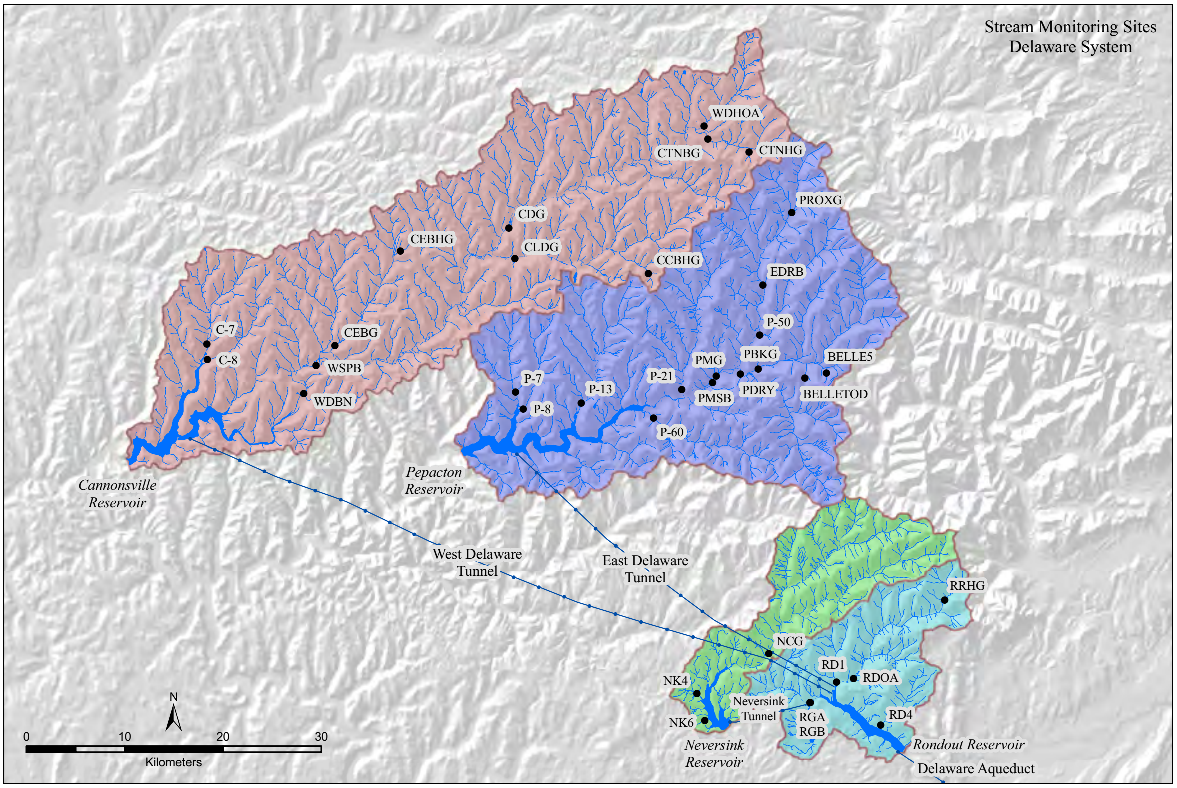


Figure 1.5 Stream sampling sites within the Delaware System drainage basins.

Upper Rondout watershed stream.

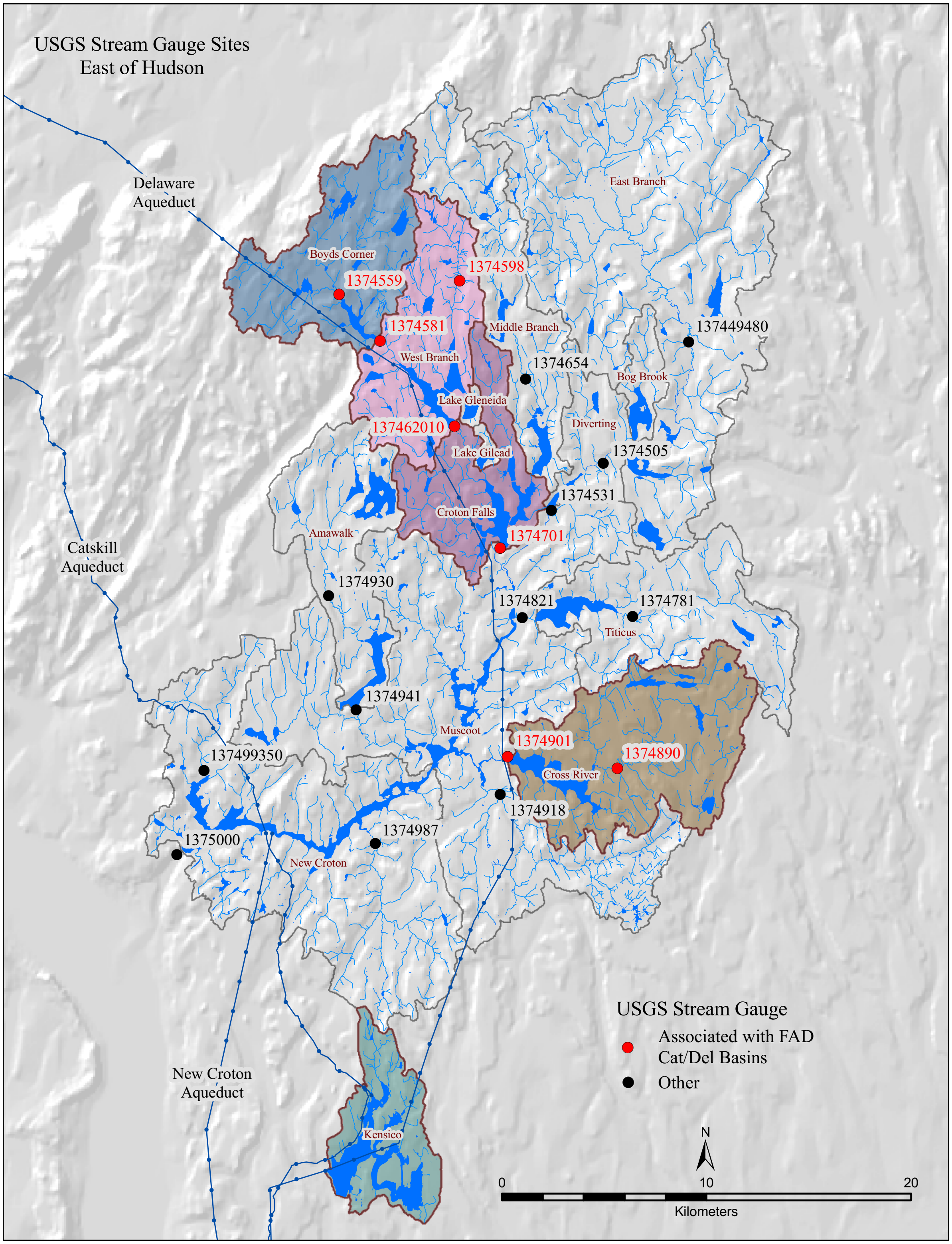


Figure 1.6 USGS stream gage sites east of the Hudson River.

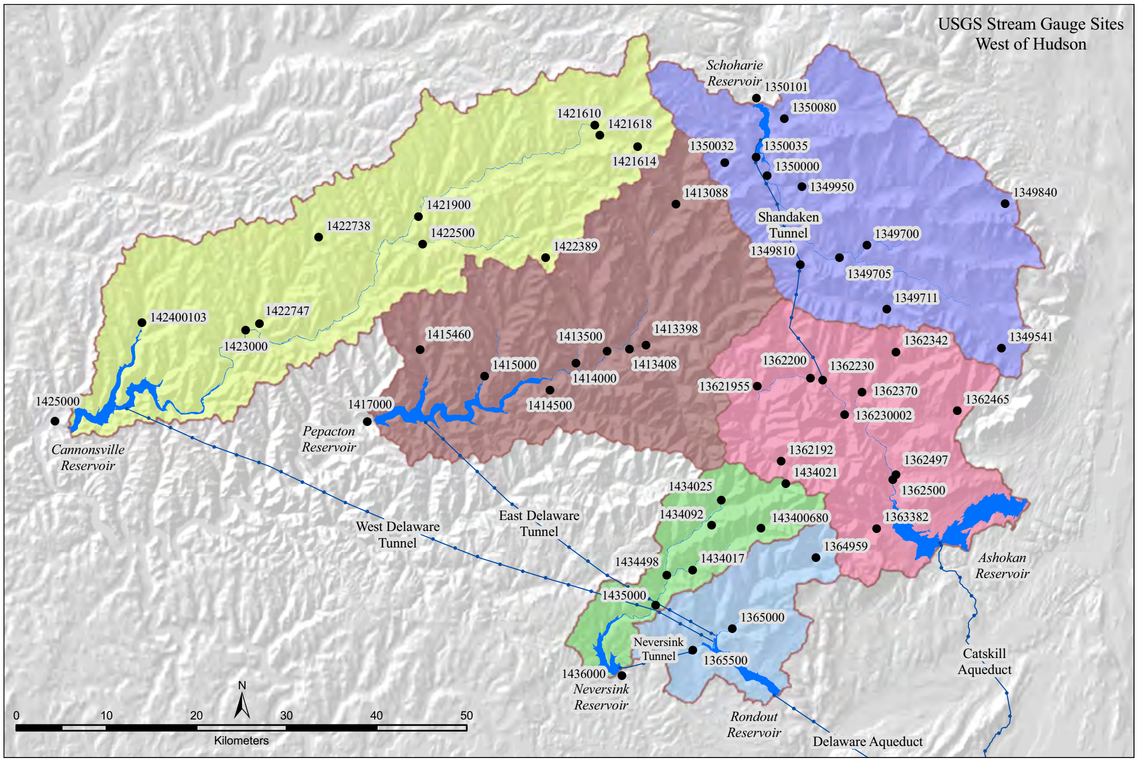


Figure 1.7 USGS stream gage sites west of the Hudson River.

Example of a USGS stream gage: S5I Schoharie Creek at Prattsville, NY

Limnology survey in progress.

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.

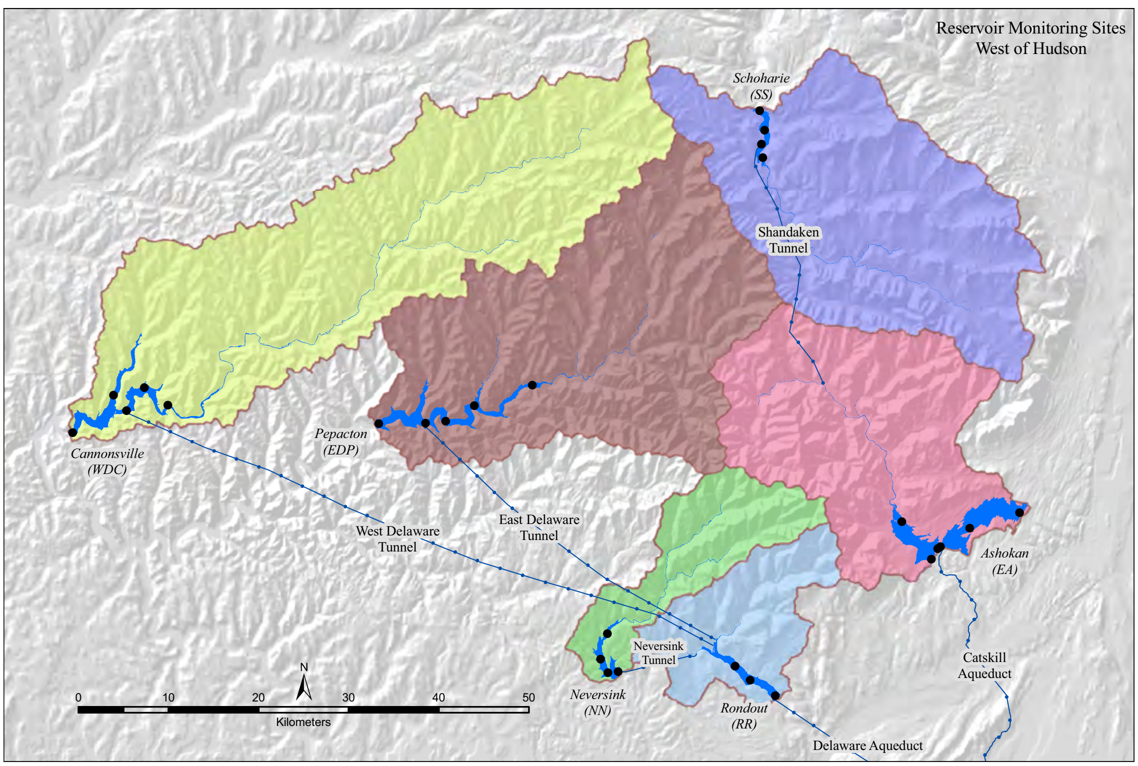


Figure 1.8 Limnological sampling sites for reservoirs west of the Hudson River.

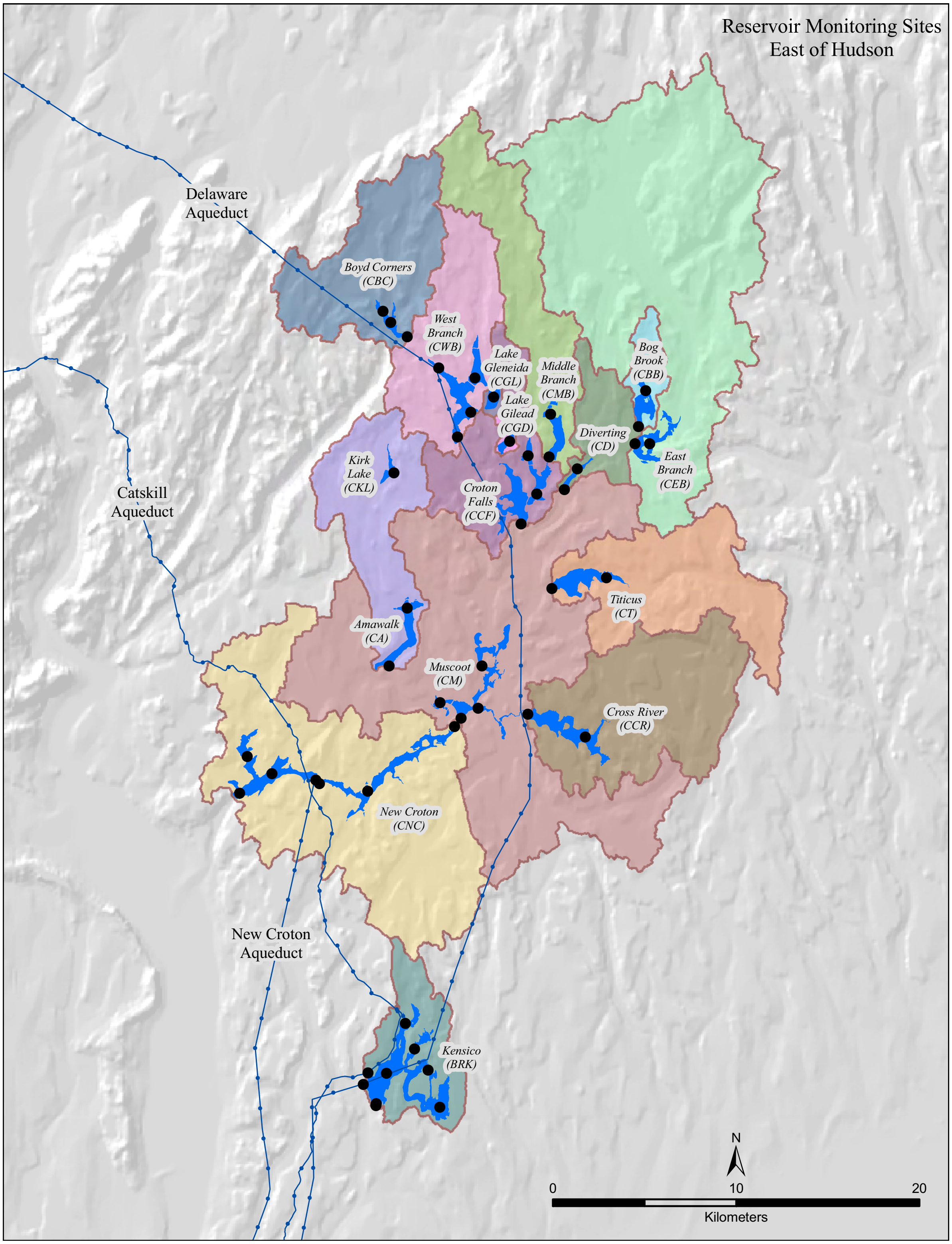


Figure 1.9 Limnological sampling sites for reservoirs east of the Hudson River.

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".

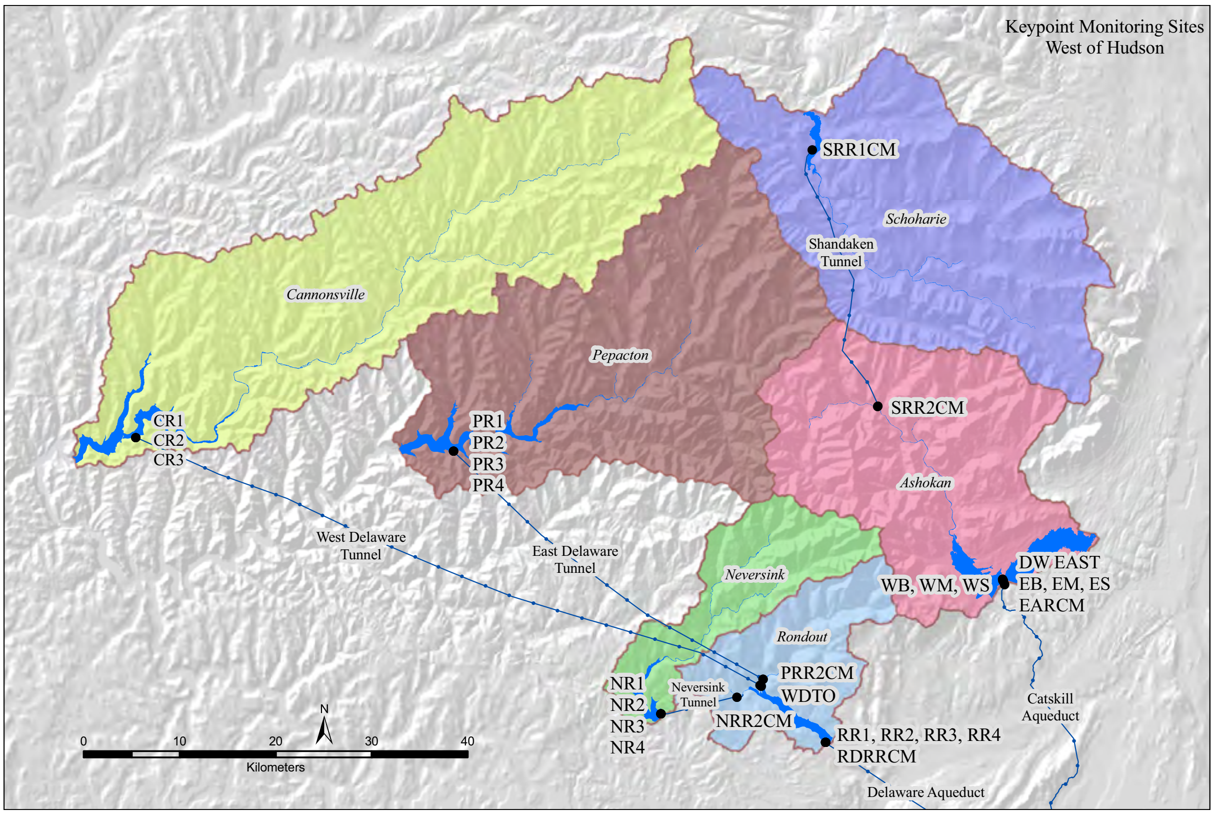


Figure 1.10 Aqueduct keypoint sampling sites west of the Hudson River.

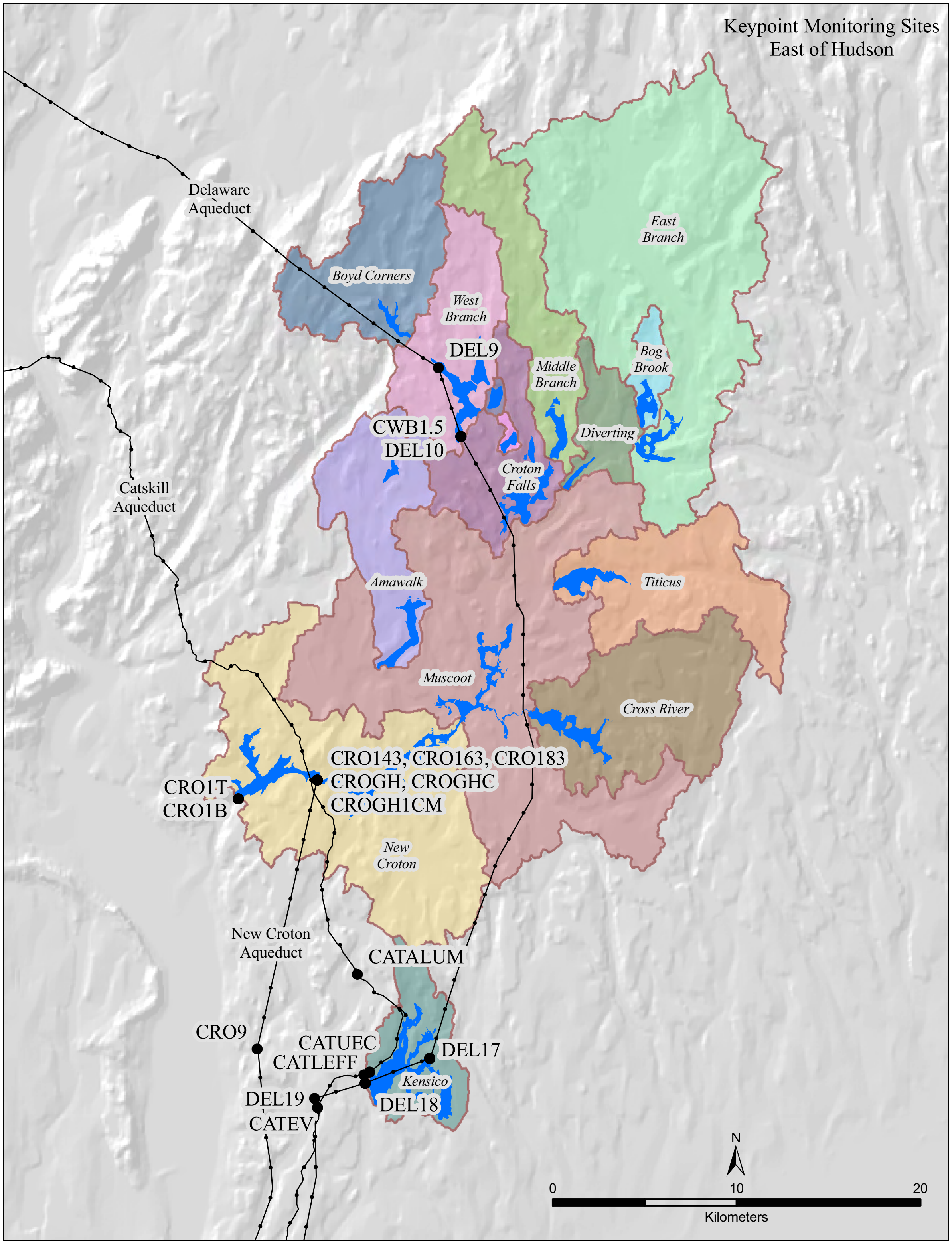
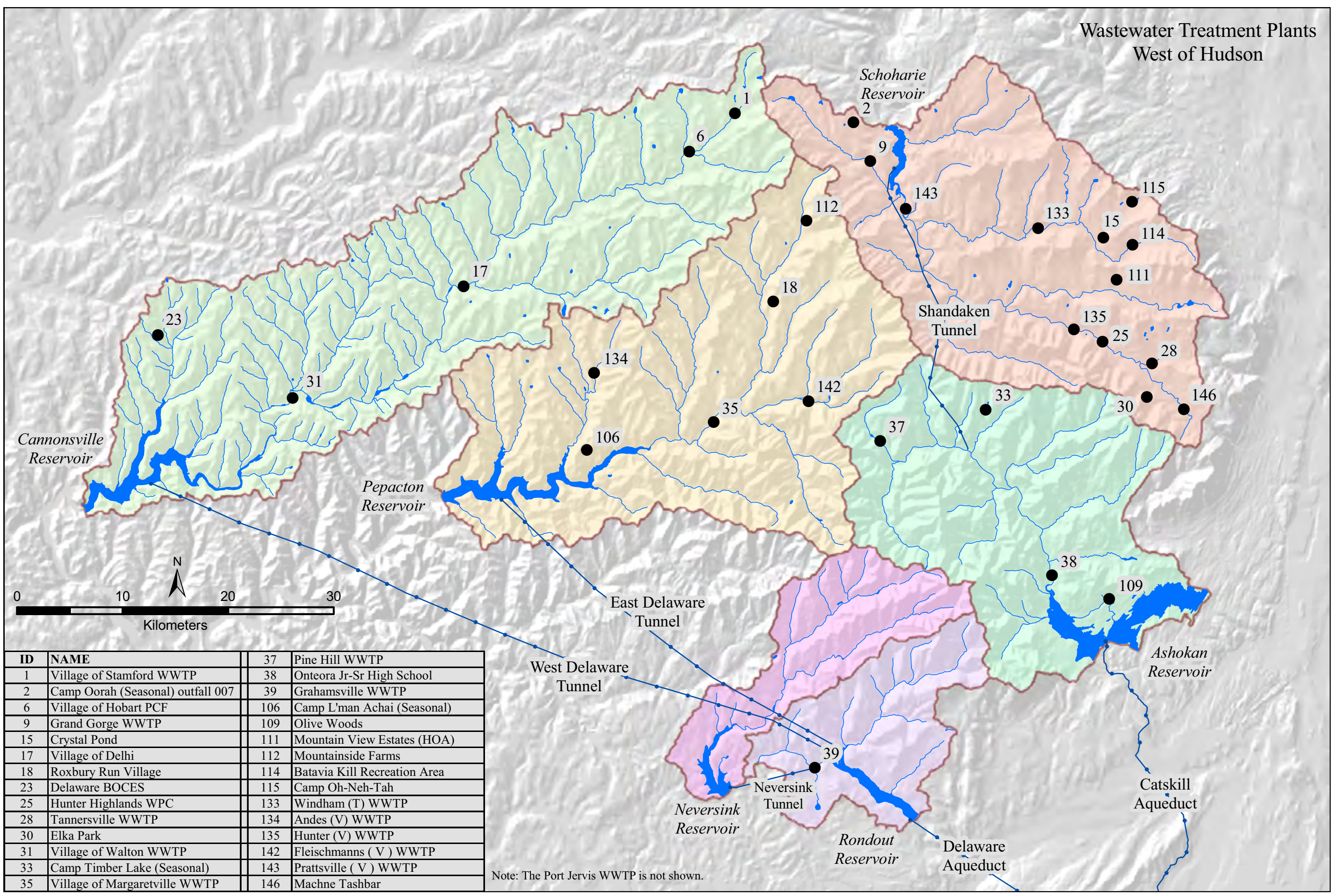


Figure 1.11 Aqueduct keypoint sampling sites east of the Hudson River.

Finally, wastewater treatment plants (WWTPs) located throughout the watershed are shown in Figures 1.12 and 1.13. The locations of these treatment plants are potential sites of impairment, however, this risk has been enormously 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 compliance 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 to confirm that no problems arise.



ID	NAME	ID	NAME
1	Village of Stamford WWTP	37	Pine Hill WWTP
2	Camp Oorah (Seasonal) outfall 007	38	Onteora Jr-Sr High School
6	Village of Hobart PCF	39	Grahamsville WWTP
9	Grand Gorge WWTP	106	Camp L'man Achai (Seasonal)
15	Crystal Pond	109	Olive Woods
17	Village of Delhi	111	Mountain View Estates (HOA)
18	Roxbury Run Village	112	Mountainside Farms
23	Delaware BOCES	114	Batavia Kill Recreation Area
25	Hunter Highlands WPC	115	Camp Oh-Neh-Tah
28	Tannersville WWTP	133	Windham (T) WWTP
30	Elka Park	134	Andes (V) WWTP
31	Village of Walton WWTP	135	Hunter (V) WWTP
33	Camp Timber Lake (Seasonal)	142	Fleischmanns (V) WWTP
35	Village of Margaretville WWTP	143	Prattsville (V) WWTP
		146	Machne Tashbar

Figure 1.12 Wastewater Treatment Plants west of the Hudson River.

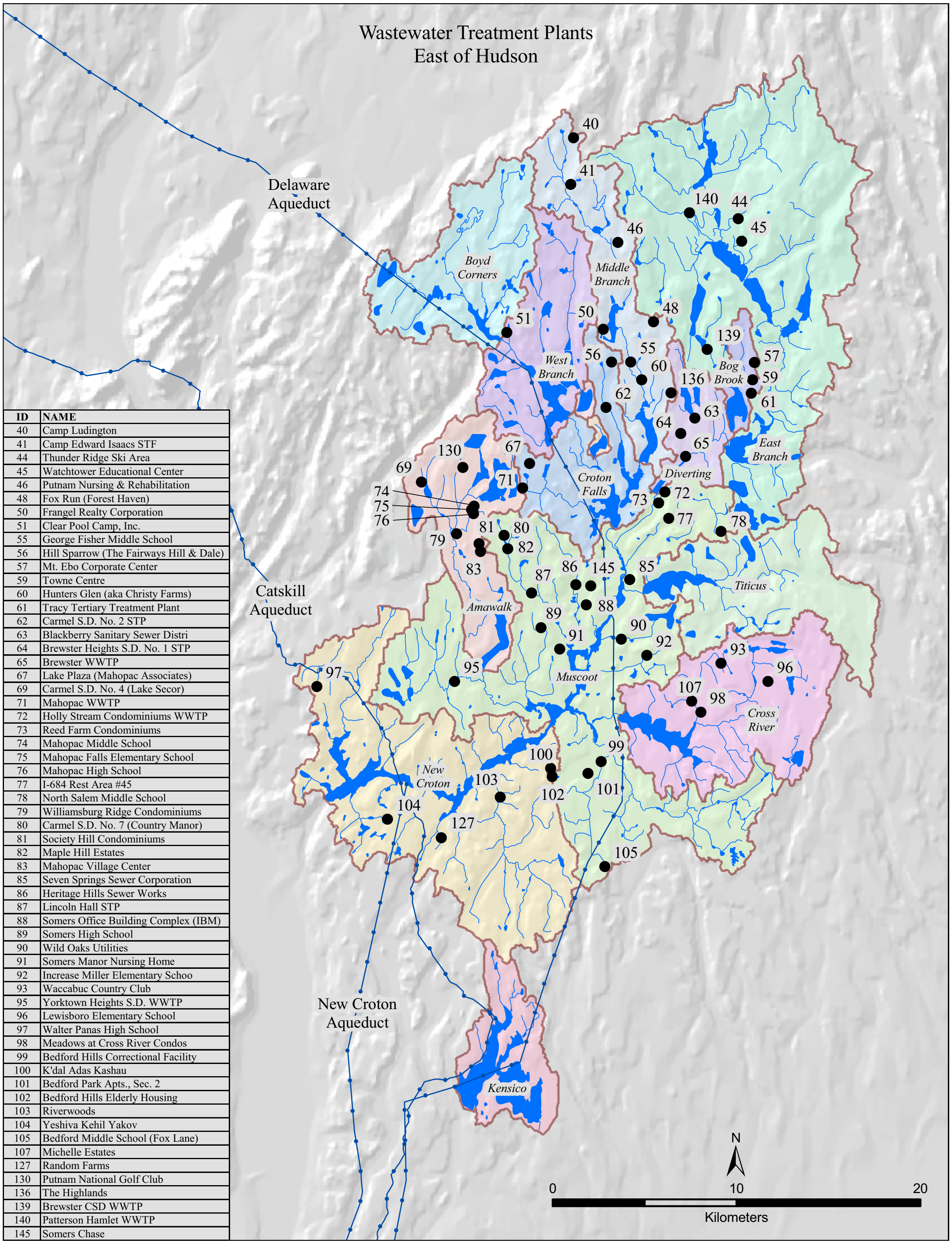


Figure 1.13 Wastewater Treatment Plants east of the Hudson River.

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.

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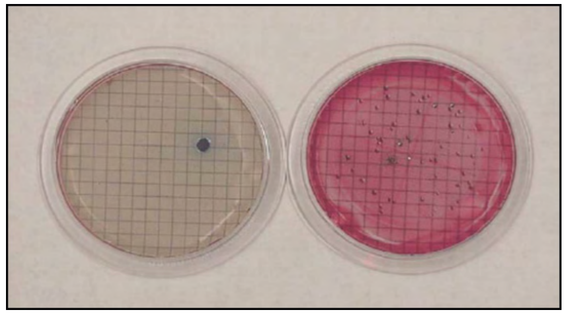
2. Regulatory Compliance Monitoring



Fecal and total coliform bacterial cultures.

This chapter is a consolidation of regulatory compliance monitoring in the New York City watershed. 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 Pollution 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, and DEP mandates. Under normal operations the sites listed in the site tables are monitored; however, under unusual conditions, bypass operations may require sampling at alternative sites. The relevant standard operating procedures (SOPs) should be reviewed to identify the most representative sampling location based on current operational configurations.

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 required filtration.

Sites

The locations to be monitored include the raw source water effluents of the three terminal reservoirs and the primary chlorinated sites of the three terminal reservoirs. These sites include the raw and chlorinated effluents of Kensico Reservoir (CATLEFF and DEL18, and CATEV and DEL19, respectively) as well as the raw and chlorinated effluents of New Croton Reservoir (CROGH and CROGHC-sampled at Site 32, respectively).

Analytes and Frequencies

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

Site Code	Analyte	Sampling Frequency	Rationale for Analyte
CATLEFF	Total coliform (or)	5d/week[1]	Required by SWTR
	Fecal coliform	5d/week[1]	Required by SWTR
	Turbidity	Every 4 hours continuous	Required by SWTR
	Flow	Continuous	Required by SWTR
DEL18	Total coliform (or)	5d/week	Required by SWTR
	Fecal coliform	5d/week[1]	Required by SWTR
	Turbidity	Every 4 hours/continuous	Required by SWTR
	Flow	Continuous	Required by SWTR
CROGH	Total coliform (or)	5d/week	Required by SWTR
	Fecal coliform	5d/week[1]	Required by SWTR
	Turbidity	Every 4 hours/continuous	Required by SWTR
	Flow	Continuous	Required by SWTR
CATEV	Temperature	1/d minimum	Required by SWTR
	pH	1/d minimum	Required by SWTR
	Free chlorine residual	1/d at peak flow	Required by SWTR
DEL19	Temperature	1/d minimum	Required by SWTR
	pH	1/d minimum	Required by SWTR
	Free chlorine residual	1/d at peak flow	Required by SWTR
CROGHC	Temperature	1/d minimum	Required by SWTR
	pH	1/d minimum	Required by SWTR
	Free chlorine residual	1/d at peak flow	Required by SWTR

[1]Actually monitored seven days per week even though only five days are required.

Data Analysis and Reporting

Data are reported as per the SWTR regulations, including monthly filtration avoidance reports to US EPA and NYSDOH, annual 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 deal with 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.

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 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).

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.

Sites

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. Systems may also use previously collected (grandfathered) data provided it meets specific requirements. NYC opted to submit grandfathered data for the first round of the LT2 and has submitted the required information to the proper regulatory parties.

Analytes and Frequencies

Currently, there are no LT2 regulatory monitoring requirements which apply to the NYC watershed until the second round of the LT2 in 2015, since NYC decided to grandfather first round data. Therefore, no additional monitoring is required beyond the requirements of the SWTR until 2015.

Data Analysis and Reporting

Since the LT2 rule does not result in additional sampling for NYC, no analysis or reporting is required until 2015.

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, including "non-transient-non-community systems" which serve at least 25 individuals. This includes a number of upstate DEP facilities at which potable water is regularly provided to at least 25 individuals.

Sites

Table 2.2: Total Coliform Rule Part 5 sample sites.

Site Code	Location	Reason for Site	# Employees
PS01	Downsville Office	TCR, SDWIS	25+
DDOK	Grahamsville Office Kitchen	TCR, SDWIS	25+
Ashokan Headworks	Ashokan Headworks	TCR, SDWIS	25+

Analytes and Frequencies

Table 2.3: USEPA and NYS required potable water analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Total Coliform/*E. coli*[1]	Quarterly (Downsville and Grahamsville)	TCR requirement
Total Coliform/*E. coli*[1]	Monthly (Ashokan)	TCR requirement
Nitrate-N	Yearly (Downsville, Grahamsville, and Ashokan)	SDWIS
Secondary Inorganic Chemicals[2]	1 per 3 yrs (Grahamsville)	SDWIS
Synthetic Organic Chemicals[2]	1 per 3 yrs (Grahamsville)	SDWIS
Primary Inorganic Chemicals[2]	Yearly (Ashokan)	SDWIS
Disinfection By-products[2]	Yearly (Ashokan)	SDWIS

[1]*E. coli* required only if total coliform is positive.

[2]Analyzed by contract lab.

Data Analysis and Reporting

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

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.
http://www.health.state.ny.us/environmental/water/drinking/part5/subpart5.htm

2.2.2 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 to at least 25 individuals. The monitoring is regulated by NYCRR Title 10, Chapter 1, part 5, Subpart 5.1 of the State Sanitary code and also under the federal Safe Drinking Water Act.

Sites

Table 2.4: DEP-required potable water sample sites.

Site Code	Location	DEP EH&S rules	#Employees
BRDAV	Brady Avenue	DEP EH&S rules	19 - 1/2 Field
FLDNOR	Carmel HQ	DEP EH&S rules	9 - mostly field
CATALUM2	Catskill Alum Plant	DEP EH&S rules	2
CATLEC	Catskill Lower Effluent Chamber	DEP EH&S rules	None
CRGAR	Cross River Garage	DEP EH&S rules	13
CROELEC	Croton Electrical Shop	DEP EH&S rules	8 - mostly field
CROFLSM	Croton Falls Maintenance	DEP EH&S rules	6 - mostly field
CLGHEP	Croton Lake Gatehouse - End Point	DEP EH&S rules	23
CROPCT	Croton Precinct	DEP EH&S rules	4
East Delaware Release Chamber	East Delaware Release Chamber	DEP EH&S rules	
East Delaware Tunnel Outlet	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
HRPS tap	Hudson River Pump Station	DEP EH&S rules	2
KENMAN	Kensico Manor	DEP EH&S rules	5
LNDMGMT	Mahopac Land Mgmt. Office	DEP EH&S rules	7 - mostly field
Neversink Intake Chamber	Neversink Intake Chamber	DEP EH&S rules	
BPB	New Beerston Precinct	DEP EH&S rules	10
DPB	New Downsville Precinct	DEP EH&S rules	12
PINEHILL STP	Pine Hill WTP	DEP EH&S rules	10
Rondout Effluent Chamber	Rondout Effluent Chamber	DEP EH&S rules	
DELSH13	Shaft 13 DA	DEP EH&S rules	None
SCHOH GH	Shandaken Tunnel Intake	DEP EH&S rules	15
TANN STP	Tannersville WTP	DEP EH&S rules	8
West Delaware Intake Chamber	West Delaware Intake Chamber	DEP EH&S rules	
West Delaware Tunnel Outlet	West Delaware Tunnel Outlet	DEP EH&S rules	

Analytes and Frequencies

Table 2.5: DEP-required potable water analytes.

Analyte	Sampling Frequency	Rationale for Analyte
Temperature	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
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 Operations. 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

2.3 Watershed Rules & Regulations

2.3.1 Phosphorus-Restricted Basin Monitoring

The New York City Watershed Rules and Regulations (WR&R) (DEP 2002) 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 conducted under Section 18-48c of Subchapter D, then the basin will be designated as phosphorus restricted. The definition and regulatory impacts of phosphorus-restricted basins is going to change in the near future with the WR&R.

The designation of a reservoir basin as phosphorus-restricted has two primary effects: 1) new or expanded wastewater treatment plants with surface discharges are prohibited in the reservoir basin, and 2) stormwater pollution prevention plans required by the Watershed Regulations must include an analysis of phosphorus runoff, before and after the land disturbance activity, and must be designed to treat the 2-year, 24-hour storm.

This regulation is currently under review and the expected time frame for promulgation of the new regulation is January 2009. This objective will be updated to reflect changes in the final regulations.

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. 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	1SS	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	3BRK	4BRK	5BRK	6BRK	7BRK	8BRK
New Croton	monthly	1CNC	2CNC	3CNC	4CNC	5CNC	6CNC		8CNC
Muscoot	monthly	1CM	2CM	4CM	6CM				
Amawalk	monthly	1CA	3CA						
Cross River	monthly	1CCR	3CCR						
Titicus	monthly	1CT	3CT						
Croton Falls	monthly	1CCF		3CCF		5CCF			
Diverting	monthly	1CD	2CD						
Middle Branch	monthly	1CMB	3CMB						
West Branch	monthly	1CWB	2CWB	3CWB	4CWB				
East Branch	monthly	1CEB							
Bog Brook	monthly	1CBB							
Boyd Corners	monthly	1CBC							
Lake Gleneida	5 samples/quarter	1CGL							
Lake Gilead	5 samples/quarter	1CGD							
Aqueducts									
Ashokan	as needed	EARCM							
Schoharie	as needed	SRR2CM							
Rondout	as needed	RDRRCM							
Neversink	as needed	NRR2CM							
Pepacton	as needed	PRR2CM							
Cannonsville	as needed	WDTO							
Kensico	as needed	CATLEFF	DEL18						
West Branch	as needed	CWB1.5	DEL10						
Croton	as needed	CROGH							

[1] Samples must be collected from each basin monthly (quarterly for controlled lakes) from May 1 to October 31. If reservoir monitoring sites are not available and the reservoir is in “reservoir mode” (in contrast to “float mode”), aqueduct sites can be used.

Analytes and Frequencies

Samples must be collected monthly from each basin, from May 1 through October 31, for the 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 interannual 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 unlikely to occur in the future. A reservoir basin designation, as phosphorus-restricted or unrestricted, may change through time based on the outcome of this annual assessment. However, a basin must have two consecutive assessments (i.e., two years in a row) that result in the new designation in order to officially change the designation.

The annual assessments are provided in the Watershed Water Quality Annual Reports (e.g., DEP 2008).

References

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

DEP. 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.
DEP. 2008. Watershed Water Quality Annual Report. Valhalla, NY. 114 p.

2.3.2 Coliform-Restricted Basin Monitoring

Coliform bacteria are used by water suppliers as potential indicators of 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. 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 bacterial cultures.

This regulation is currently under review and the expected time frame for promulgation of the new regulation is January 2009. This objective will be updated to reflect changes in the final regulations.

Background

Coliform-restricted determinations are governed by two sections of the regulations, Section 18-48(a)(1) and Section 18-48(b)(1). Section 18-48(a)(1) applies to all reservoirs and Lakes Gilead and Gleneida ("non-terminal basins") 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. Section 18-48(b)(1) applies to "terminal basins", 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. Coliform bacteria include total coliform and fecal coliform counts, which are regulated in source waters by the Safe Drinking Water Act (SDWA) at levels of 100 CFU 100 mL^{-1} and 20 CFU 100 mL^{-1}, respectively. Both are used as indicators of potential pathogen contamination. Fecal coliform bacteria are more specific in that their source is the gut of warm-blooded animals while the other coliforms comprising the total originate in water, soil, and sediments.

Sites

Most reservoir surveys have an adequate number of sites and depths to meet the minimum requirement of 5 samples per month. 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 or 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 sites.[1]		
EARCM (Ashokan)	5 days/week	20
RDRRCM (Rondout)	5 days/week	20
CWB 1.5 (West Branch)	5 days/week	20
DEL18, CATLEFF (Kensico)	7 days/week	30/site
CROGH (New Croton)	7 days/week	30
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	13
Neversink (Sites 1, 2, 4)	1 survey/month	12
Pepacton (Sites 1, 3, 4, 5, 6)	1 survey/month	16
Schoharie (Sites 1, 2, 3, 4)	1 survey/month	12
East of Hudson		
Amawalk (Sites 1, 3)	1 survey/month	5
Bog Brook (Sites 1, 3)	1 survey/month	5
Boyd Corners (Sites 1, 2, 3)	1 survey/month	6
Cross River (Sites 1, 3)	1 survey/month	6
Croton Falls (Sites 1, 3, 5)	1 survey/month	8
Diverting (Sites 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, 3)	1 survey/month	5
Muscoot (Sites 1, 2, 4, 6)	1 survey/month	7
Titicus (Sites 1, 3)	1 survey/month	5

[1]Although elevation taps may be used at management's discretion, in the event that a terminal reservoir is offline, the elevation taps will be used to obtain a representative sample.

[2]Refer to Appendix I for locations of the numbered sites

Analytes and Frequencies

Total coliform are required for the non-terminal reservoirs and controlled lakes (five samples per month), and fecal coliform are required on the terminal basins (five days per week). 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 (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. 2008. Watershed Water Quality Annual Report. Valhalla, NY. 114 p.

2.4 Croton Consent Decree

Objective

This objective addresses the requirement to monitor required sites outlined in the Croton Consent Decree (CCD) (1998) agreement for various water quality parameters.

Croton Lake Gatehouse.

Background

Since the Croton System did not meet the requirements for Filtration Avoidance, as the Catskill and Delaware systems have, DEP is required to perform mandated 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. Monitoring that takes place under this objective is specifically conducted to comply with requirements set forth in the CCD, one of which (Section VII A.5) is to continue performing all monitoring in the New Croton Watershed as per the SWTR (see Section 2.1 of this report).

2.4.1 Hydrology: Croton Consent Decree Monitoring Sites

In accordance with the Croton Consent Decree, "During the term of this Consent Decree, the City shall conduct the following sampling for coliforms… twice per month... for at least 40 sites in streams throughout the Croton watershed" (Croton Consent Decree 1998).

Table 2.8: Stream sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
COLABAUGH1	Outflow from Colabaugh Pond,Town of Cortlandt, sample collected upstream of culvert on Rt. 129, parallel to Mt. Airy Road.	To meet requirements of CCD
CORNELL1	Cornell Brook Site 1, Town of Yorktown, sample collected downstream of confluence with tributary from the south, downstream of culvert on Route 100	To meet requirements of CCD
GEDNEY3	Gedney Brook Site 3, Town of Yorktown. Park on Seven Bridges Road approximately 2/10 of a mile south of the intersection with Route 100. Collect sample downstream of the northernmost bridge, and downstream of the small tributary which feeds from the right-edge-of-water.	To meet requirements of CCD
ILLINGTON1	Illington Creek Site 1, Town of Yorktown, sample collected upstream of culvert on Croton Dam Road	To meet requirements of CCD
KITCHAWAN1	Kitchawan Site 1, Town of Yorktown, sample collected upstream of culvert on Northern Westchester Rail trail, near Route 1	To meet requirements of CCD
NCBAILEY1	New Croton Bailey Brook Site 1, Town of Yorktown, sample collected upstream of culvert on Croton Dam Road	To meet requirements of CCD
PURDY1	Purdy Brook Site 1, Town of Cortlandt, sample collected upstream of culvert on Croton Dam Road	To meet requirements of CCD
SAWMILL1	Saw Mill Brook Site 1, Town of Yorktown, sample collected upstream of culvert on Saw Mill River (Yorktown) Road, aka Route 1	To meet requirements of CCD
CATHY7	Catherine Brook site 7, Town of Yorktown. Park near DEP gate at the intersection of Catherine Street and the Catskill Aqueduct. Walk 400 feet in a west northwest direction along the aqueduct to the first stream flowing under the aqueduct. Collect sample upstream of the aqueduct.	To meet requirements of CCD
WHITE2	White Hill Brook site 2, Town of Yorktown. Collect sample on the upstream side of Rt. 129. Park at the pull-off on the right shoulder of Rt. 129 just west of the intersection with Underhill Avenue; walk northwest for about 250 feet through the woods until you reach the stream channel.	To meet requirements of CCD

Table 2.8: (Continued) Stream sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
FRENCH5	French Hill Brook site 5, Town of Yorktown. Park vehicle on the Underhill Avenue (Rt. 131) entrance ramp for the Taconic State Parkway near the culvert under the entrance ramp. Walk east approximately 150 feet upstream of the entrance ramp and collect sample	To meet requirements of CCD
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
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
LEETOWN3	Leetown Brook site 3, Town of Kent. Collect sample downstream of Ninham Road and upstream of East Boyds Lake Road (downstream of Seven Hills Lake). DEP staff gage mounted to REW side of bridge crossing Ninham Road.	To meet requirements of CCD
CROSSRVR	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

Table 2.8: (Continued) Stream sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
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
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
CROFALLSR	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
HMILL7	Hallocks Mill Brook site 7, Town of Yorktown. Collect sample upstream of culvert on Greenwood St. (upstream of Yorktown Heights SD WWTP). DEP staff gage mounted to upstream side of culvert.	To meet requirements of CCD
HMILL4	Hallocks Mill Brook site 4, Town of Somers. Collect sample downstream of culvert on Pines Bridge Road (downstream of Yorktown Heights SD WWTP). DEP staff gage mounted to rock at REW downstream of the culvert.	To meet requirements of CCD

Table 2.8: (Continued) Stream sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
PLUM2	Plum Brook site 2, Town of Somers. Collect sample upstream of the Route 100 overpass crossing the inlet of Plum Brook. Park on the southbound side of the Route 100 overpass and hike to the bottom of the overpass; walk northwest along old RR bed for approximately 500 meters to old RR bridge. Sample upstream of RR bridge by DEP staff gauge. DEP staff gage at REW	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 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
HH7	Haviland Hollow Brook site 7, Town of Patterson. Collect sample upstream of bridge crossing on Brimstone Road near intersection with Haviland Hollow Road (County Rt. 66). DEP staff gage mounted to the upstream side of the bridge abutment at the LEW.	To meet requirements of CCD
MUDTRIB1	Muddy Brook Tributary site 1, Town of Patterson. Collect sample below Covington Greens Condominiums off Rt. 311, park in condo parking lot, walk behind swimming pool down to stream. DEP staff gage located at REW mounted to a tree.	To meet requirements of CCD
BB5	Brady Brook site 5, Town of Pawling. Collect sample approximately 10 feet upstream of bridge crossing of Rt. 22 near the Dutchess/Putnam County border. DEP staff gage mounted to rock at LEW just upstream of the bridge	To meet requirements of CCD

Table 2.8: (Continued) Stream sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
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
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: Streams: Analytes and frequencies for Croton Watershed Consent Decree monitoring.

Analyte	Sampling Frequency	Rationale for Analyte
Fecal Coliform	Twice per month	Decree Requirement
Total Coliform	Twice 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. As defined in the Consent Decree, the “Croton Water Supply System” shall mean the 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 in Figure 1.9. A second survey of the month, required only on New Croton Reservoir sites described in Objective 5.2, will be performed. Samples will be collected until the terms of the CCD are satisfied.

Analytes and Frequencies

Coliform samples will be collected once each month for all reservoirs except New Croton, in which twice-monthly sampling will be conducted. 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

As per the Croton Consent Decree, Section VII A.6., coliform monitoring, "The City shall perform daily monitoring at the Croton Gatehouse keypoint location of raw water and of treated (chlorinated) water...." These sites are CROGH and CROGHC.

Table 2.10: Keypoint sites for Croton Consent Decree monitoring.

Site Code	Site Description	Reason for Site Selection
CROGH	Raw effluent of New Croton Reservoir	Decree Requirement
CROGHC/Site 32	Chlorinated effluent of New Croton Reservoir	Decree Requirement

Analytes and Frequencies

The CCD dictates that the following sites be monitored for coliforms at the specified frequencies for the term of the decree.

Table 2.11: Analytes and frequencies for keypoint monitoring for the Croton Consent Decree.

Site Code	Analyte	Sampling Frequency	Rationale for Analyte
CROGH	Total Coliform	Daily	Required by CCD
	Fecal Coliform	Daily	Required by CCD
CROGHC/Site 32	Total Coliform	Daily	Required by CCD
	Fecal Coliform	Daily	Required by CCD
	Human enteric viruses	Annually	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

Sites

Site selection for the decree was primarily driven by location and land use. Both the New Croton Reservoir effluent (CROGH) and the Muscoot Reservoir Release (MUSCOOTR) were selected due to location and importance of water quality since they are the effluent and major influent to the reservoir, respectively. Land use was also considered during site selection and led to the selection of a wastewater treatment plant (BSTP, Brewster Sewage Treatment Plant), an agricultural area (WF, Willow Farm) and an undisturbed area (HH7, Haviland Hollow Brook). The wastewater treatment plant and agricultural area were selected based on knowledge available at the time of selection that these types of land use are potential sources of human infectious pathogens, while the undisturbed location was selected as a site with no, or limited, human impact.

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
MUSCOOTR	Muscoot Reservoir Release	Major influent to New Croton Reservoir
BSTP	Brewster Sewage Treatment Plant final effluent	Sewage treatment plant effluent, potential human infectious pollutant source
WF	Willow Farm	Agricultural, potential human infectious pollutant source
HH7	Haviland Hollow Brook	Forested, minor human disturbance
CROFALLSR	Croton Falls Reservoir Release	Can be pumped into system for consumption
CROSSRVR	Cross River Reservoir Release	Can be pumped into system for consumption

Analytes and Frequencies

The CCD 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: Analytes and frequencies for pathogen monitoring for the CCD.

Site Code	Analyte[1]	Sampling Frequency	Rationale for Analyte
CROGH (or alternate)	*Giardia*	Weekly	Required by CCD
	Cryptosporidium	Weekly	Required by CCD
	Human enteric viruses	Weekly	Required by CCD
BSTP	*Giardia*	Monthly	Required by CCD
	Cryptosporidium	Monthly	Required by CCD
	Human enteric viruses	Bi-Monthly	Required by CCD
	Chlorine residual	Bi-Monthly with virus sample	Required to determine if dechlorination is needed
WF	*Giardia*	Monthly	Required by CCD
	Cryptosporidium	Monthly	Required by CCD
	Human enteric viruses	Annually	Required by CCD
HH7	*Giardia*	Monthly	Required by CCD
	Cryptosporidium	Monthly	Required by CCD
	Human enteric viruses	Annually	Required by CCD
MUSCOOTR	*Giardia*	Monthly	Required by CCD
	Cryptosporidium	Monthly	Required by CCD
	Human enteric viruses	Annually	Required by CCD
CROFALLSR	*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
CROSSRVR	*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 CCD.

Sites, Analytes, and Frequencies

Sites include all WWTPs in the Croton watershed. Sites are required to be monitored twice monthly as per the requirements stated in their SPDES permits, which are issued and available through the Department of Environmental Conservation.

Table 2.14: East of Hudson CCD Waste Water Treatment Plant sites.

Location/ WWTP Plant	Reason for Selection
Bedford Hills Correctional Facility	required by CCD
Bedford Hills Elderly Housing	required by CCD
Bedford Middle School	required by CCD
Bedford Park Apartments	required by CCD
Thunder Ridge Ski Area	required by CCD
Blackberry Hill	required by CCD
Brewster Heights	required by CCD
Brewster Schools	required by CCD
Brewster STP	required by CCD
Camp Edward Isaacs	required by CCD
Camp Ludington	required by CCD
Carmel STP	required by CCD
Clear Pool Camp	required by CCD
Country Manor	required by CCD
Fox Run	required by CCD
Frangel	required by CCD
George Fischer Middle School	required by CCD
Heritage Hills	required by CCD
Highlands	required by CCD
Holly Stream	required by CCD
Hunters Glen	required by CCD
IBM Somers	required by CCD
Increase Miller Elementary School	required by CCD

Table 2.14: (Continued) East of Hudson CCD Waste Water Treatment Plant sites.

Location/ WWTP Plant	Reason for Selection
K'dal Adas Kashau	required by CCD
Putnam Nursing Home	required by CCD
Lake Plaza	required by CCD
Lake Secor	required by CCD
Lewisboro Elementary School	required by CCD
Lincoln Hall	required by CCD
Mahopac Falls Elementary School	required by CCD
Mahopac High School	required by CCD
Mahopac Middle School	required by CCD
Mahopac STP	required by CCD
Mahopac Village Center	required by CCD
Maple Hill Estates STP	required by CCD
Michelle Estates	required by CCD
Mount Ebo	required by CCD
North Salem Middle School	required by CCD
Patterson Hamlet	required by CCD
Putnam Country Club	required by CCD
Random Farms	required by CCD
Reed Farm	required by CCD
Rest Area I-684	required by CCD
Riverwood	required by CCD
Society Hill	required by CCD
Somers Chase	required by CCD
Somers High School	required by CCD
Somers Manor Nursing Home	required by CCD
Hill Sparrow	required by CCD
The Meadows At Cross River	required by CCD
Towne Centre Southeast	required by CCD
Tracy Tertiary Treatment Plant	required by CCD
Waccabuc Country Club	required by CCD
Walter Panas High School	required by CCD
Watchtower Society	required by CCD
Seven Springs	required by CCD
Wild Oaks	required by CCD
Williamsburg Ridge	required by CCD

Table 2.14: (Continued) East of Hudson CCD Waste Water Treatment Plant sites.

Location/ WWTP Plant	Reason for Selection
Yeshiva Kehil Yakov	required by CCD
Yorktown STP	required by CCD

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

Location/ WWTP Plant	Analytes (vary by SPDES)	Frequency
Bedford Hills Correctional Facility	same as SPDES permit	2/mo
Bedford Hills Elderly Housing	same as SPDES permit	2/mo
Bedford Middle School	same as SPDES permit	2/mo
Bedford Park Apartments	same as SPDES permit	2/mo
Thunder Ridge Ski Area	same as SPDES permit	2/mo
Blackberry Hill	same as SPDES permit	2/mo
Brewster Heights	same as SPDES permit	2/mo
Brewster Schools	same as SPDES permit	2/mo
Brewster STP	same as SPDES permit	2/mo
Camp Edward Isaacs	same as SPDES permit	2/mo
Camp Ludington	same as SPDES permit	2/mo
Carmel STP	same as SPDES permit	2/mo
Clear Pool Camp	same as SPDES permit	2/mo
Country Manor	same as SPDES permit	2/mo
Fox Run	same as SPDES permit	2/mo
Frangel	same as SPDES permit	2/mo
George Fischer Middle School	same as SPDES permit	2/mo
Heritage Hills	same as SPDES permit	2/mo
Highlands	same as SPDES permit	2/mo
Holly Stream	same as SPDES permit	2/mo
Hunters Glen	same as SPDES permit	2/mo
IBM Somers	same as SPDES permit	2/mo
Increase Miller Elementary School	same as SPDES permit	2/mo
K'dal Adas Kashau	same as SPDES permit	2/mo
Kent Nursing Home	same as SPDES permit	2/mo
Lake Plaza	same as SPDES permit	2/mo

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

Location/ WWTP Plant	Analytes (vary by SPDES)	Frequency
Lake Secor	same as SPDES permit	2/mo
Lewisboro Elementary School	same as SPDES permit	2/mo
Lincoln Hall	same as SPDES permit	2/mo
Mahopac Falls Elementary School	same as SPDES permit	2/mo
Mahopac High School	same as SPDES permit	2/mo
Mahopac Middle School	same as SPDES permit	2/mo
Mahopac STP	same as SPDES permit	4/mo
Mahopac Village Center	same as SPDES permit	2/mo
Maple Hill Estates STP	same as SPDES permit	2/mo
Michelle Estates	same as SPDES permit	2/mo
Mount Ebo	same as SPDES permit	2/mo
North Salem Middle School	same as SPDES permit	2/mo
Patterson Hamlet	same as SPDES permit	2/mo
Putnam Country Club	same as SPDES permit	2/mo
Random Farms	same as SPDES permit	2/mo
Reed Farm	same as SPDES permit	2/mo
Rest Area I-684	same as SPDES permit	2/mo
Riverwood	same as SPDES permit	2/mo
Society Hill	same as SPDES permit	2/mo
Somers Chase	same as SPDES permit	2/mo
Somers High School	same as SPDES permit	2/mo
Somers Manor Nursing Home	same as SPDES permit	2/mo
Hill Sparrow	same as SPDES permit	2/mo
The Meadows At Cross River	same as SPDES permit	2/mo
Towne Centre Southeast	same as SPDES permit	2/mo
Tracy Tertiary Treatment Plant	same as SPDES permit	2/mo
Waccabuc Country Club	same as SPDES permit	2/mo
Walter Panas High School	same as SPDES permit	2/mo
Watchtower Society	same as SPDES permit	2/mo
Seven Springs	same as SPDES permit	2/mo
Wild Oaks	same as SPDES permit	2/mo
Williamsburg Ridge	same as SPDES permit	2/mo
Yeshiva Kehil Yakov	same as SPDES permit	2/mo
Yorktown STP	same as SPDES permit	2/mo

References

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

2.5 Administrative Orders

2.5.1 DEL19 Administrative Order: Monitoring for Mercury, Lead, and PCBs

Objective

This objective addresses the requirement to monitor Delaware Aqueduct keypoint DEL19 for specific water quality parameters as specified by Administrative Order on Consent (AO).

Background

As part of the AO, which addresses remediation of mercury, lead, and PCB contamination at Delaware Aqueduct shafts 9, 10, 17, and 18, "Respondent [NYC] shall continue routine monitoring of the water supply for mercury, PCBs and lead that includes weekly monitoring for mercury and monthly monitoring for PCBs and lead. All monitoring shall be performed at the sampling point within Shaft 19."

Sites

Table 2.16: DEL19 administrative order sampling site.

Site Code	Site Description	Reason for Site Selection
DEL19	DEL19 sample tap	AO Requirement

Analytes and Frequencies

Table 2.17: Administrative Order DEL19 analytes and frequency of monitoring.

Analyte	Sampling Frequency	Rationale for Analyte
Hg	Weekly	AO Requirement
Pb	Monthly	AO Requirement
PCB	Monthly	AO Requirement

Data Analysis and Reporting

In accordance with the AO, sampling results will be reported to USEPA Region II as follows: "Respondent [NYC] shall include all information regarding the implementation of this activity in its quarterly reporting to the Region [and to NYSDOH].... In addition, in the event respondent detects mercury, PCBs, or lead in an amount greater than 50% of the applicable Maximum Contaminant Level under the Safe Drinking Water Act, as a result of the monitoring required above, respondent shall notify the Region and the NYSDOH as soon as possible after respondent receives the monitoring results with the detection, but in no case later than the close of the next business day."

References

Administrative Order on Consent, Docket No. RCRA-02-2000-7303, USEPA Region II. The City of New York, respondent.

2.5.2 CRO9 Administrative Order: Monitoring for Chlorine Residual

Objective

This objective addresses the requirement to monitor the leak at the New Croton Aqueduct Shaft 9 for total chlorine residual as specified by Administrative Order on Consent (AO).

Background

As part of the AO, which addresses, in part, two discharges of chlorinated water into the Pocantico River from New Croton Aqueduct Shaft 9 in 2002, DEP must test for total chlorine residual at the three sites listed below, monthly, unless a monthly total chlorine residual result exceeds 0.09 ppm, in which case monitoring will be increased to weekly. DEP is required to sample only when the New Croton Aqueduct is in service and chlorinated water is being sent through the Aqueduct, and shall continue testing until the Aqueduct is taken out of service, chlorinated water is no longer being sent through the Aqueduct, and two consecutive samples show no detections of total chlorine residual.

Sites

Table 2.18: CRO9 administrative order sampling sites.

Site Code	Site Description	Reason for Site Selection
CRO9 Discharge	"Blowoff" outside CRO9 building	AO Requirement
Welkers Brook/CRO9 (NCA Combined Flow)	Downstream of CRO9 building	AO Requirement
Pocantico River	Downstream of CRO9 building	AO Requirement

Analytes and Frequencies

Table 2.19: CRO9 administrative order analyte and frequency of monitoring.

Analyte	Sampling Frequency	Rationale for Analyte
Total chlorine residual	Monthly	AO requirement

Data Analysis and Reporting

The DEP Kensico Laboratory sends results to Eastern Operations, which reports the data to the NYSDEC Water Engineer at Tarrytown. NYSDEC is also notified if a total chlorine residual result exceeds 0.09 ppm.

References

Administrative Order on Consent. File No. R3-20030127-12. State of New York Department of Environmental Conservation. New York City Department of Environmental Protection, Respondent.

2.5.3 Hillview Administrative Order

The Hillview Administrative Order is concerned with the requirement to cover Hillview Reservoir. The Order also includes additional water quality protection projects, including installation of a back-up turbidity curtain in Kensico Reservoir at Malcolm Brook, addition of a UV disinfection system at the Carmel 2 WWTP, and creation of a robotic water quality monitoring network. For further details regarding robotic monitoring refer to Objective 4.2.

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)

Objective

This objective addresses the requirement to monitor New York City-owned Waste Water Treatment Plant (WWTP) effluents 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 59 non-City owned WWTPs and 1 City-owned WWTP that are monitored by DEP east of the Hudson River. There are 24 non-City-owned WWTPs and 6 City-owned WWTPs that are monitored by DEP west 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 FAD (WOH plants – Chapter 3) and the CCD (EOH plants – Chapter 2) and not due to a compliance SPDES requirement.

Sites

Table 2.20: WWTP SPDES sites and reasons for selection.

Location/ WWTP Plant	Reason for Selection
WOH/Grahamsville	SPDES permit requirement
WOH/Margaretville	SPDES permit requirement
WOH/Tannersville	SPDES permit requirement
WOH/Grand Gorge	SPDES permit requirement
WOH/Pine Hill	SPDES permit requirement
WOH/Port Jervis NY	SPDES permit requirement
EOH/Mahopac	SPDES permit requirement

Analytes and Frequencies

Table 2.21: Analytes and frequencies for the WWTP SPDES objective.

Location/ WWTP Plant	Analytes	Frequency
WOH/Grahamsville	As required by SPDES permit	As required by SPDES permit
WOH/Margaretville	As required by SPDES permit	As required by SPDES permit
WOH/Tannersville	As required by SPDES permit	As required by SPDES permit
WOH/Grand Gorge	As required by SPDES permit	As required by SPDES permit
WOH/Pine Hill	As required by SPDES permit	As required by SPDES permit
WOH/Port Jervis NY	As required by SPDES permit	As required by SPDES permit
EOH/Mahopac	As required by SPDES permit	As required by SPDES permit

Data Analysis and Reporting

Water quality data are provided to the BWS Facilities Compliance staff for inclusion in WWTP inspection reports. City-owned WWTP data are included in the Discharge Monitoring Reports provided to NYSDEC.

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.

From June-October, Tunnel outlet turbidity is required to be no more than 15 NTU above the turbidity in Esopus Creek upstream of the Tunnel outlet. For November-May, this requirement is a maximum of 20 NTU above the Esopus Creek level. This 20 NTU limit is in place as an interim requirement. Final permit requirements will be in place upon the completion of turbidity reduction measures. The final permit requirement reduces the 20 NTU difference to 15 NTU for the November-May period. 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°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. Limnological sites are based on the necessity to obtain an accurate measure of cold water storage volume in Schoharie Reservoir in June.

Table 2.22: Sites for Shandaken Tunnel Outlet SPDES permit.

Site Code	Site Description	Reason for Site Selection
Water Quality Directorate		
SRR2CM	Outlet of Shandaken Tunnel	As specified by permit
AEAP	Esopus Creek – above confluence of Shandaken Tunnel Outlet	As specified by permit
3SS	Schoharie Reservoir limnology site	Cold Water Storage Estimation
Operations Directorate		
SRR2CM	Outlet of Shandaken Tunnel	As specified by permit
AEAP	Esopus Creek – above confluence of Shandaken Tunnel Outlet	As specified by permit
USGS		
01362230	Shandaken Tunnel Outlet	As specified by permit
01362200	Esopus Creek at Allaben	As specified by permit

Analytes and Frequencies

Analytes and frequencies are based on the requirements of the SPDES permit.

Table 2.23: Analytes and frequencies for Shandaken Tunnel Outlet SPDES permit.

Analyte	Sampling Frequency	Site(s)	Rationale for Analyte
Water Quality Directorate			
Turbidity	Daily (M-F) Weekly	SRR2CM AEAP	Used for QA/QC of automated equipment
Total Phosphorus	Weekly	SRR2CM	Required by permit
Total Settleable Solids	Weekly	SRR2CM	Required by permit
Total Suspended Solids	Weekly	SRR2CM	Required by permit
Temperature	Annually, within 7 days of June 15	3SS[1]	Calculation of cold water storage

Table 2.23: (Continued) Analytes and frequencies for Shandaken Tunnel Outlet SPDES permit.

Analyte	Sampling Frequency	Site(s)	Rationale for Analyte
Operations Directorate			
Turbidity	Continuous[2]	SRR2CM AEAP	Required by permit
Temperature	Continuous	SRR2CM	Required by permit
USGS			
Flow	Continuous	01362230 01362200	Required by permit

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

[2] Back-up sampling by ISCO autosampler is available.

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. The primary purpose of the permit is to allow for alum treatment. Normally alum treatment is not required. However, 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. Alum treatment has only been used on 9 occasions, for about 7% of the time, over the last 20 years. Monitoring requirements for the permit differ based on whether or not alum is being used.

During the most recent alum treatment event (Oct. 13, 2005–May 24, 2006) DEP implemented enhanced monitoring in addition to the requirements of the SPDES permit. This enhanced monitoring is detailed on pages 15-16 of the Alum Post-Treatment Report (DEP 2006). This enhanced treatment 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

Table 2.24: Sites for CATIC SPDES permit.

Site Code	Site Description	Reason for Site Selection
CATALUM	Catskill Aqueduct Alum Plant	As specified by permit
5BRK	Kensico Reservoir limnology site	As specified by permit

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 2.25: 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
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. The enhanced monitoring for the most recent alum event is described on pages 15-16 of the Alum Post-Treatment Report (DEP 2006).

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 as required by the permit.

References

DEP 2006. Alum Post-Treatment Report Water Quality and System Operations Catskill Water Supply, October 13, 2005 - May 24, 2006, Volume I. Bureau of Water Supply, Division of Drinking Water Quality Control, Kingston, NY.

2.6.4 Del 9, Del 17

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 operational 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

Table 2.26: SPDES permits monitoring and reporting.

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

Analytes and Frequencies

Table 2.27: Delaware Aqueduct (DEL9 and DEL17) SPDES analytes and frequency of monitoring.

Analyte	Sampling Frequency	Rationale for Analyte
Flow	Daily	Regulatory requirement
Chlorine (Total Residual)[1]	Daily	Regulatory requirement
Dissolved Oxygen[2]	Daily	Regulatory requirement

[1] Chlorine is only monitored during chlorination events.

[2] Dissolved oxygen is continuous by EWRM; Water Quality Ops only performs back-up sampling.

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 Sump Monitoring

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 sump 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 2.28: Sump monitoring sites.

Site Code	Site Description	Reason for Site Selection
Shokan – Outfall 005	Shokan – Outfall 005 – LGC plant	Per SPDES permit
EDTO – Hydro – Outfall 001	EDTO – Hydro – Outfall 001 – Ground-water sump	Per SPDES permit

Analytes and Frequencies

Sump monitoring analytes and frequencies are listed in Table 2.26.

Table 2.29: Sump monitoring analytes and frequencies.

Site	Analyte	Sampling Frequency	Rationale for Analyte
Shokan BNL 005 LGC	Total chlorine residual, temperature, flow, pH, TSS, settleable solids	During backwash (approximately quarterly)	Per SPDES permit
EDTO Bypass 01A	pH	Annually	Per SPDES permit
EDTO Hydro 001	pH	Annually	Per SPDES permit

Data Analysis and Reporting

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

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 2007 Filtration Avoidance Determination (FAD) that must be met to protect public health. 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 2006). Watershed monitoring is addressed in Section 5.1 of the 2007 FAD, which states that "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 DEP's watershed management program and that it can be used to evaluate the effectiveness of programs established under the FAD and MOA." The periodic reassessment of the City's monitoring program is in fact reflected in this updated monitoring plan and thus the WWQMP is itself a specific FAD deliverable (due October 31, 2008).

The FAD further states that: "The data generated through the City's monitoring program, in conjunction with other defensible scientific findings, is to be used to conduct the City's periodic assessment of the effectiveness of the watershed protection program." Therefore DEP's water quality monitoring data also serve to evaluate watershed programs in DEP's periodic Watershed Protection Summary and Assessment report.

The 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 Program (DEP 2006) and the milestones therein. The goals of this program over the next five years include:

- Provide an up-to-date, objective-based monitoring plan for the routine watershed water quality monitoring programs, including keypoints, streams, reservoirs, and pathogens.
- Provide routine water quality results for keypoint, stream, reservoir, and pathogen programs to assess compliance and provide comparisons with established benchmarks. Describe ongoing research activities.
- Provide mid-term results from routine watershed (e.g., stream and WWTP) pathogen monitoring.
- 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.

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.

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) being used by DEP's Stream Management Program to address the turbidity and suspended sediment problems observed in Catskill Mountain streams. Turbidity and suspended sediment are one of the challenging water quality issues facing DEP, and evaluating the effectiveness of methods intended to reduce them is important. In addition, a component of this study is mandated by the 2007 FAD, which states: "The City will also implement a special monitoring study on the Batavia Kill (at the Conine site) to evaluate whether water quality improvements can be quantified for this restoration project."

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 recommendations.

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 the Batavia Kill delivers a significant quantity of suspended sediment and turbid water to Schoharie Creek, the main inflow to Schoharie Reservoir. Major sediment source areas were identified upstream and downstream of Red Falls on the Batavia Kill, including the Conine property, located just downstream of Red Falls. The Greene County Soil and Water Conservation District, through a contract with DEP, designed and implemented

BMPs to reduce the sediment and turbidity originating in the Red Falls area. 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.

In addition to the Conine site, DEP will also establish monitoring at two other Stream Management Program BMP sites, Stony Clove in the Ashokan watershed, and the West Kill in the Schoharie watershed. These streams will also be sampled above and below a restoration project before and after its implementation. The Stony Clove BMP will be evaluated using all the analytes set forth in Table 3.2, as well as on the basis of its macroinvertebrate community, while the West Kill BMP will be evaluated solely on the basis of its macroinvertebrate community. For more details on the use of biomonitoring protocols to assess BMP effectiveness, see Section 3.7.1.

Sites

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

Site Code	Site Description	Reason for Site Selection
S10-RF	Batavia Kill immediately upstream of Red Falls, between the Red Falls and Conine BMP zones.	Upstream of the Conine BMP zone
S10	Batavia Kill downstream of BMP. Samples collected just upstream of the Rt. 23A bridge, near the confluence of Batavia Kill and Schoharie Creek.	Downstream of BMP
SBB	Brandau Brook, a small tributary that enters the Batavia Kill immediately below Red Falls, between S10-RF and S10.	May contribute turbidity and TSS load to BMP area
SCL-A	Stony Clove upstream of the BMP zone. (The location of this site may change based on the exact location of the BMP zone.)	Upstream of the Stony Clove BMP zone
SCL-B	Stony Clove downstream of the BMP zone. (The location of this site may change based on the exact location of the BMP zone.)	Downstream of BMP
258	West Kill upstream of Long Road BMP	Upstream of Long Road BMP zone
259	West Kill at lower end of Long Road BMP	Downstream of Long Road 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[1] + Storm Events	To assess BMP effectiveness in reducing turbidity and suspended solids
Turbidity	Monthly [1]+ Storm Events	To assess BMP effectiveness in reducing turbidity and suspended solids
Flow (USGS and WQD)[2]	Continuous	Needed to assist with above assessments
pH	Annually	Needed to assist with biomonitoring assessment
Specific conductivity	Annually	Needed to assist with biomonitoring assessment
Temperature	Annually	Needed to assist with biomonitoring assessment
Dissolved oxygen	Annually	Needed to assist with biomonitoring assessment

[1]Stony Clove sites only.

[2]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 each 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. (Previous sampling has shown this to be the case for the Conine area.) If the BMPs are effective, this ratio will decrease. The more effective the BMPs, the closer to one the ratio will become.

For analysis of biomonitoring data, see Section 3.7.1.

Per the 2007 FAD, a final report by the Stream Management Program on the Conine project is due December 31, 2012. The results from this monitoring will also be reported in the FAD Program Summary and Assessment.

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 Long-Term Watershed Protection Program (DEP 2006) 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 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 2002) 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 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 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 sites of the locations.

Table 3.3: Stream water quality status sites.

Site Code	Site Description	Reason for Site Selection
E10I	Bushkill	Inflow to reservoir. Used to assess status with regard to WR&R.
E16I	Esopus Creek at Coldbrook	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
E5	Esopus Creek at Allaben	Data are used in WQD Annual Report.

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

Site Code	Site Description	Reason for Site Selection
SRR2CM	Diversion from Schoharie Reservoir	Data are used in WQD Annual Report.
S5I	Schoharie Creek at Prattsville	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
S6I	Bear Kill at Hardenburgh Falls	Inflow to reservoir. Used to assess status with regard to WR&R.
S7I	Manor Kill	Inflow to reservoir. Used to assess status with regard to WR&R.
P-13	Tremper Kill above Pepacton Reservoir	Data are used in the FAD Mid-Term Evaluation Report.
P-21	Platte Kill at Dunraven	Inflow to reservoir. Used to assess status with regard to WR&R.
P-60	Mill Brook near Dunraven	Inflow to reservoir. Used to assess status with regard to WR&R.
P-7	Terry Clove above Pepacton Reservoir	Inflow to reservoir. Used to assess status with regard to WR&R.
P-8	Fall Clove above Pepacton Reservoir	Inflow to reservoir. Used to assess status with regard to WR&R.
PMSB	East Branch Delaware River at Margaretville	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
NCG	Neversink River near Claryville	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
NK4	Aden Brook above Neversink Reservoir	Inflow to reservoir. Used to assess status with regard to WR&R.
NK6	Kramer Brook above Neversink Reservoir	Inflow to reservoir. Used to assess status with regard to WR&R.
RD1	Sugarloaf Brook at Lowes Corners	Inflow to reservoir. Used to assess status with regard to WR&R.
RD4	Sawkill Brook near Yagerville	Inflow to reservoir. Used to assess status with regard to WR&R.
RDOA	Rondout Creek near Lowes Corners	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
RGA	Chestnut Creek above Grahamsville STP	Data are used in the FAD Mid-Term Evaluation Report.

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

Site Code	Site Description	Reason for Site Selection
RGB	Chestnut Creek below Grahamsville STP	Inflow to reservoir. Used to assess status with regard to WR&R.
C-7	Trout Creek above Cannonsville Reservoir	Data are used in the FAD Mid-Term Evaluation Report.
C-8	Loomis Brook above Cannonsville Reservoir	Data are used in the FAD Mid-Term Evaluation Report.
WDBN	West Branch Delaware River at Beerston Bridge	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
BOYDR	West Branch Croton River below dam near Kent Cliffs (Boyd Corners outflow)	Inflow to reservoir. Data are used in WQD Annual Report.
CROFALLSR	West Branch Croton River near Croton Falls (Croton Falls outflow)	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
CROSS2	Cross River near Cross River	Inflow to reservoir. Data are used in WQD Annual Report.
CROSSRVR	Cross River at Katonah (Cross River outflow)	Data are used in WQD Annual Report to assess status and are also used in the FAD Mid-Term Evaluation Report.
GYPSYTRL1	Gypsy Trail Brook	Inflow to reservoir.
HORSEPD12	Horse Pound Brook	Inflow to reservoir.
LONGPD1	Long Pond outflow	Inflow to reservoir.
MIKE2	Michael's Brook	Inflow to reservoir.
WESTBR7	West Branch Croton River at Richardsville. Input to CBC.	Inflow to reservoir. Data are used in WQD Annual Report.
WESTBRR	West Branch Croton River near Carmel (West Branch outflow)	Data are used in WQD Annual Report.

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).
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

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. 2006. 2006 Long-Term Watershed Protection Program. Valhalla, NY. 66 p.

DEP. 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.

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 and controlled lake. 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 waterbody.

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 is required by the 2007 FAD (USEPA 2007). These requirements were met by the Watershed Protection Summary and Assessment reports in 2001 (DEP 2001) and 2006 (DEP 2006). The 2007 FAD requires continued analysis of status, with a report to be issued in 2011.

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 2002), 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	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[1]	3RR					
East of Hudson								
Kensico	1.1BRK	2BRK	3BRK	4BRK	5BRK	6BRK	7BRK	8BRK
Cross River	1CCR		3CCR					
Croton Falls	1CCF		3CCF		5CCF			
West Branch	1CWB	2CWB	3CWB	4CWB				
Boyd Corners	1CBC	2CBC[2]	3CBC[2]					

[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, 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. 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 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
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^5_4	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[5]	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
Nitrogen	Monthly (Apr.–Nov.)	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.

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

Analyte	Sampling Frequency[1]	Rationale for Analyte
NH_x-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
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
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

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

Analyte	Sampling Frequency[1]	Rationale for Analyte
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, and alkalinity. 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, 4
	West Branch	1, 4
	Boyd Corners	1
	Croton Falls	1, 3
	Cross River	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 2007 FAD. The next report is due in 2011.

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.

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.

USEPA. 2007. New York City Filtration Avoidance Determination. U.S. Environmental Protection Agency. New York, NY. 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 2006) states that one of the goals of DEP's Watershed Monitoring Program is to collect routine water quality data for keypoint, stream, reservoir, and pathogen 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)
WDTO	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent)

Table 3.8: (Continued) Keypoint water quality sites.

Site Code	Site Description
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent
SRR2CM	Portal (Shandaken Tunnel Outlet into Esopus Creek), continuous monitoring
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 downtake, influent to Kensico Reservoir.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL18	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 forebay.
CATLEFF	Catskill Aqueduct, lower effluent chamber, untreated Kensico Reservoir effluent.
CROGH	Raw (untreated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Laboratory at level 213.

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	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	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Temperature	M	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

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

Analyte	Sampling Frequency[1]	Rationale for Analyte
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
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).
TP	M	Pool of dissolved and particulate P
Chlorophyll *a*	M[2]	
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

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

Analyte	Sampling Frequency[1]	Rationale for Analyte

[1]Samples to be collected only when aqueduct is operational.

[2]April-November only.

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. 2006. 2006 Long-Term Watershed Protection Program. Valhalla, NY. 66 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

Biological sampling of stream benthic communities was first undertaken in 1994, using protocols developed by the NYS Stream Biomonitoring Unit (NYSDEC 2002, 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.

Benthic macroinvertebrate sampling.

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	Years 1 and 5
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 4
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
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 1
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
150	Unnamed tributary to Croton Falls Reservoir	Examination of impacts to benthic macroinvertebrate community from land use changes; inflow to reservoir	Year 3
155	Whippoorwill Creek	Inflow to reservoir; assess impacts to benthic macroinvertebrate community of stream stabilization project; rare taxa present;	Years 1 and 5
203	Butternut Creek	Inflow to reservoir	Year 4
207	East Kill at SEK	Mainstem tributary; presence of nearby water quality sampling site	Year 5
210	Bear Kill below Grand Gorge WWTP	Examination of impacts to benthic macroinvertebrate community from pollution sources; inflow to reservoir	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]
213	Esopus Creek at E16I	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes	Year 4
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 4
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 4
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 5
224	Birch Creek near E3	Examination of impacts to benthic macroinvertebrate community from pollution sources or land use changes	Year 4
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

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]
243	Little Beaver Kill near LBK	Mainstem tributary; rare taxa present	Year 4
246	Bush Kill at E10I	Inflow to reservoir; presence of nearby water quality sampling site	Year 4
251	Sugarloaf Brook at SSHG	Examination of impacts to benthic macroinvertebrate community in Schoharie Creek from pollution sources and land use changes	Year 5
252	Bushnellville Creek at BNV	Mainstem tributary; presence of nearby water quality sampling site	Year 4
253	Mink Hollow	Headwater reference site	Year 4
255	Esopus Creek above BK	Examination of impacts to benthic macroinvertebrate community in Esopus Creek from pollution sources and land use changes	Year 4
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 4
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 4
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 1
310	Rondout Creek at RDOA	Inflow to reservoir; presence of nearby water quality sampling site	Year 3
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

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]
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 3
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 3
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
335	Sawkill Brook at RD4	Inflow to reservoir; presence of nearby water quality sampling site	Year 3
339	Third Brook	Examination of impacts to benthic macroinvertebrate community from pollution sources; mainstem tributary	Year 1
340	Beers Brook	Mainstem tributary	Year 1
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
346	Little Delaware River upstream of CLDG	Mainstem tributary; presence of nearby water quality sampling site	Year 1

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]
347	Sugarloaf Brook at RD1	Tributary to Rondout Creek; presence of nearby water quality sampling site	Year 3

[1]Status sites are sampled on a 5-year rotating basis. Year 1 = 2009, Year 2 = 2010, Year 3 = 2011, Year 4 = 2012, Year 5 = 2013.

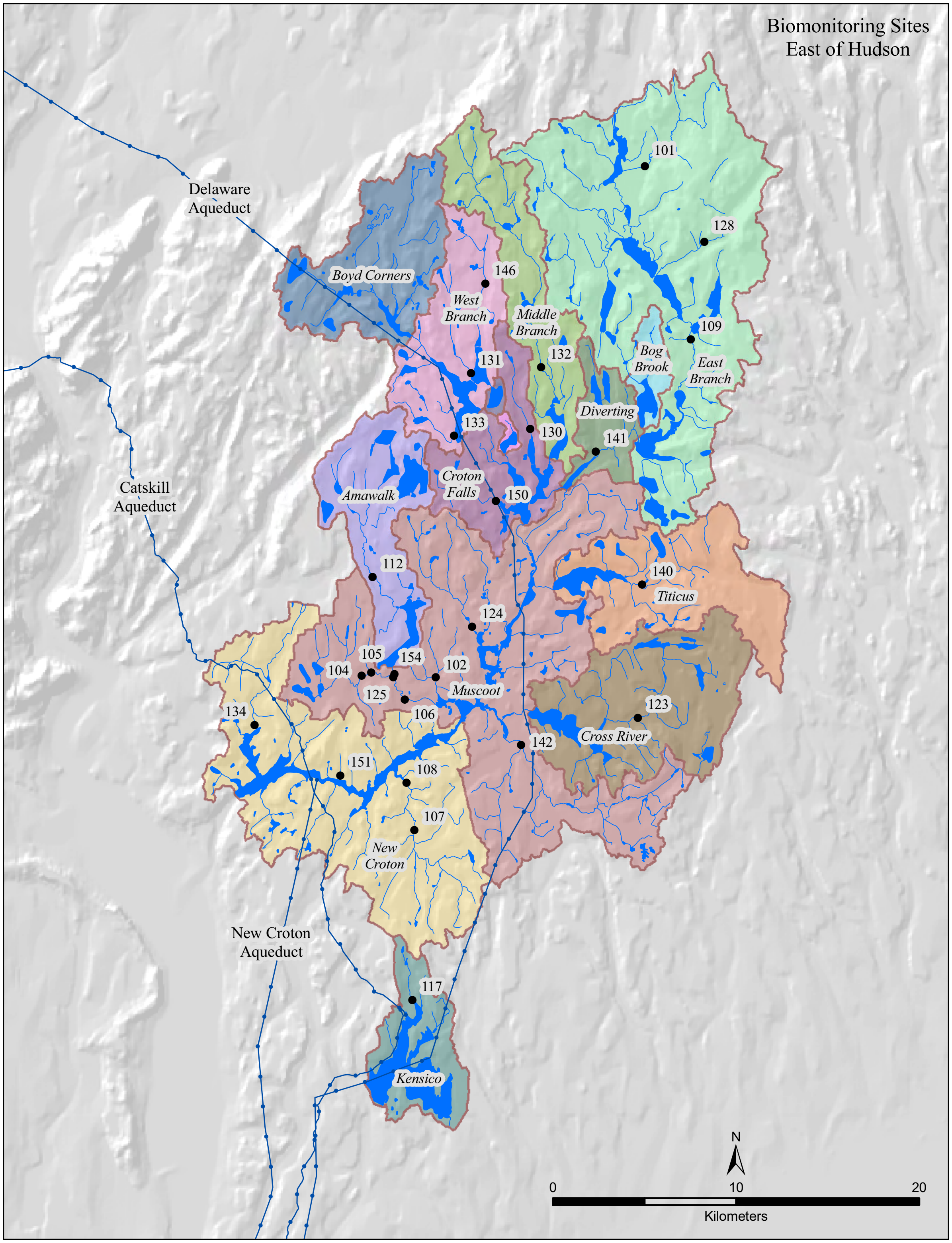


Figure 3.1 Biomonitoring sites, East of Hudson.

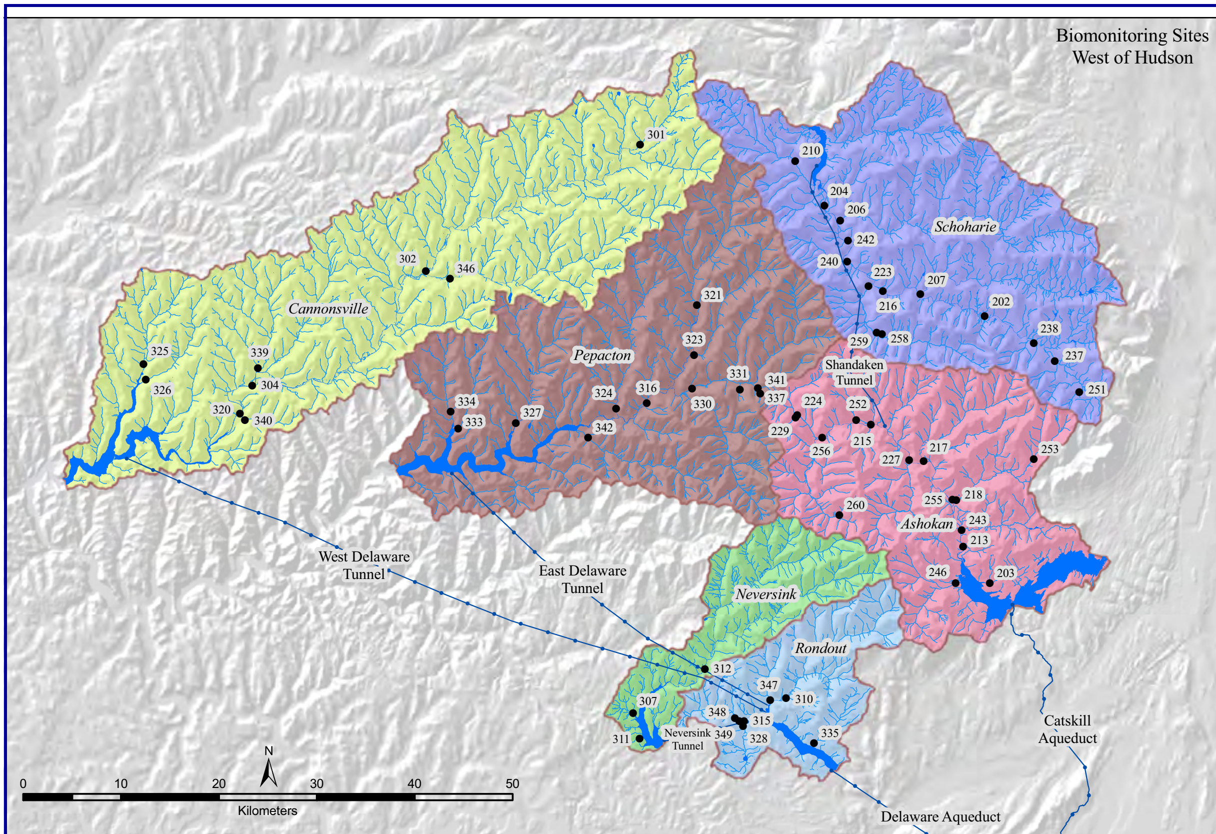


Figure 3.2 Biomonitoring sites, West of Hudson.

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); and the Hilsenhoff Biotic Index (a measure of organic pollution)), 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 overlaps with routine stream sampling, whose list of required analytes includes those specified here.

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

Analyte	Sampling frequency	Rationale for analyte
pH	Annually	Analyte has been found to be significantly correlated with biomonitoring metrics
Dissolved oxygen	Annually	Analyte has been found to be significantly correlated with biomonitoring metrics
Temperature	Annually	Analyte has been found to be significantly correlated with biomonitoring metrics
Specific Conductivity	Annually	Analyte has been found to be significantly correlated with biomonitoring metrics

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 [Department of Environmental Conservation]. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. Albany, NY. 116 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 Program (DEP 2006) 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, 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

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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.
SRR2	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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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 as required by the 2007 FAD.

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.
CROFALLSR	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.
CROSSRVR	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).
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.

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.

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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) and 2006 (DEP 2006). The 2007 Filtration Avoidance Determination requires continued analysis of trends with a report to be issued in 2011.

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 as required by the 2007 FAD.

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[1]	3RR					
East of Hudson								
Kensico	1.1BRK	2BRK	3BRK	4BRK	5BRK	6BRK	7BRK	8BRK
Cross River	1CCR		3CCR					
Croton Falls	1CCF		3CCF		5CCF			
West Branch	1CWB	2CWB	3CWB	4CWB				
Boyd Corners	1CBC	2CBC[2]	3CBC[2]					
Aqueducts								
Ashokan	EARCM							
Schoharie	SRR2CM							
Rondout	RDRRCM							
Neversink	NRR2CM							
Pepacton	PRR2CM							
Cannonsville	WDTO							
Kensico	DEL17	DEL18	CATALUM	CATLEFF				
West Branch	DEL9	DEL10						

[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.

Table 3.15: List of analytes for reservoir trend objective as required by the 2007 FAD.

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
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[3]	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[4]	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[4]	End product of acid deposition, source of S^{-2} during anoxia
Dissolved Na[4]	Major component of road salt
Dissolved Ca[4]	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity[4]	A measurement of acid neutralizing capacity, buffering capacity, needed for chemical treatment activities

Table 3.15: (Continued) List of analytes for reservoir trend objective as required by the 2007 FAD.

Analytes	Reason for Inclusion
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*[5]	Useful in assessing primary productivity and trophic state
Phytoplankton[5]	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards
Nitrogen	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	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
Phosphorus	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)	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

Table 3.15: (Continued) List of analytes for reservoir trend objective as required by the 2007 FAD.

Analytes	Reason for Inclusion
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]Dissolved oxygen is not collected at aqueducts.

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

[5]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 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 laboratory changes, such as equipment, filters, and analytical methods must, be discussed with the appropriate supervisors well in advance to discuss the possible ramifications. If a change is necessary, there should be a method overlap, preferably for one year, at the most representative sites in each reservoir (Newell and Morrison 1993).

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. The first report was issued in 2001 (DEP 2001) and the second in March 2006 (DEP 2006). The next report is due in 2011.

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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 Program (DEP 2006) 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 (i.e., water entering aqueducts) 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 as required by the 2007 FAD.

Site Code	Site Description
RDRRCM	Rondout Reservoir effluent
NRR2CM	Neversink Tunnel Outlet (Neversink Reservoir effluent)
PRR2CM	East Delaware Tunnel Outlet (Pepacton Reservoir effluent)
WDTO	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent)
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent
SRR2CM	Portal (Shandaken Tunnel outlet into Esopus Creek), continuous monitoring
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 downtake, influent to Kensico Reservoir.
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.
DEL18	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir. Sampled at Shaft 18 forebay.
CATLEFF	Catskill Aqueduct, lower effluent chamber, untreated Kensico Reservoir effluent.
CROGH	Raw (untreated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Laboratory at level 213.

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	M	Early alert to potential contravention of NYS health standard (SDWA)
pH	M	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	Measured surrogate for total inorganic ions. Will be used to estimate total dissolved solids.
Temperature	M	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 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

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

Analyte	Sampling Frequency[1]	Rationale for Analyte
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).
TP	M	Pool of dissolved and particulate P
Chlorophyll *a*	M[2]	Estimate of biomass, eutrophication indicator
Total Coliform and Fecal Coliform	M	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard
Total Phytoplankton/ 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.

M = Monthly.

Q = Quarterly (February, May, August, 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.

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.

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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 (DEP 2005, 2006, 2007). No trends in the condition of stream benthic communities have been observed thus far.

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

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
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
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

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
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); and the Hilsenhoff Biotic Index (a measure of organic pollution)). 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 overlaps with routine stream sampling, whose list of required analytes includes those specified here.

Sites are sampled annually, as per the NYSDEC protocols employed by DEP (NYSDEC 2002). 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

Long-term trends in the condition of the macroinvertebrate communities of watershed streams are presented in the Watershed Protection Program Summary and Assessment report, which is produced every five years and is a FAD requirement. An upward or downward trend is deemed to have occurred when a site assesses at a higher or lower category of impairment for at least three consecutive years.

References

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DEP. 2006. Watershed Water Quality Annual Report. Valhalla, NY. 138 p.

DEP. 2007. Watershed Water Quality Annual Report. Valhalla, NY. 130 p.

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3.3 Kensico Surveillance

Objective

The surveillance of Kensico Reservoir is a primary requirement of the 2007 FAD under Section 4.10 “Kensico Water Quality Control Program”. This program requires an annual report that includes discussion of monitoring data and other information. 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 is the primary terminal reservoir in the NYC water supply system and, during normal operations, approximately 90% of the City’s drinking water is conveyed through this reservoir. Regarding Kensico Reservoir, the 2007 FAD states, “protection of this reservoir is critically important to maintaining filtration avoidance for the City” and requires “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 requires that DEP submit a Kensico Programs Annual Report, which includes a presentation, discussion, and analysis of monitoring data (e.g., keypoint, reservoir, stream, BMPs).

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

An evaluation of 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. A comparison of weekly, monthly, and bi-monthly sample intervals from the Malcolm Brook dataset indicated that the weekly and monthly sample means for *Cryptosporidium* were comparable (within the same order of magnitude), whereas bi-monthly sample averages were different. This suggests that bimonthly sampling frequency is not sufficient to capture a representative annual mean *Cryptosporidium* concentration and is too infrequent to capture seasonality or trends.

Sites

Locations for stream sampling at Kensico Reservoir include all eight perennial streams that flow into Kensico: Malcolm Brook, N5-1, N-12, 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	Perennial tributary to terminal reservoir
E9	Discharge of stream E9	Perennial tributary to terminal reservoir
E10	Discharge of stream E10	Perennial tributary to terminal reservoir
E11	Discharge of stream E11	Perennial tributary to terminal reservoir
MB-1	Discharge of Malcolm Brook, below West Lake Drive attenuation basin (BMP)	Perennial tributary to terminal reservoir
N12	Discharge of stream N12	Perennial tributary to terminal reservoir
N5-1	Discharge of stream N5, below BMP	Perennial tributary to terminal reservoir
WHIP	Discharge of Whippoorwill Creek	Perennial tributary to terminal reservoir

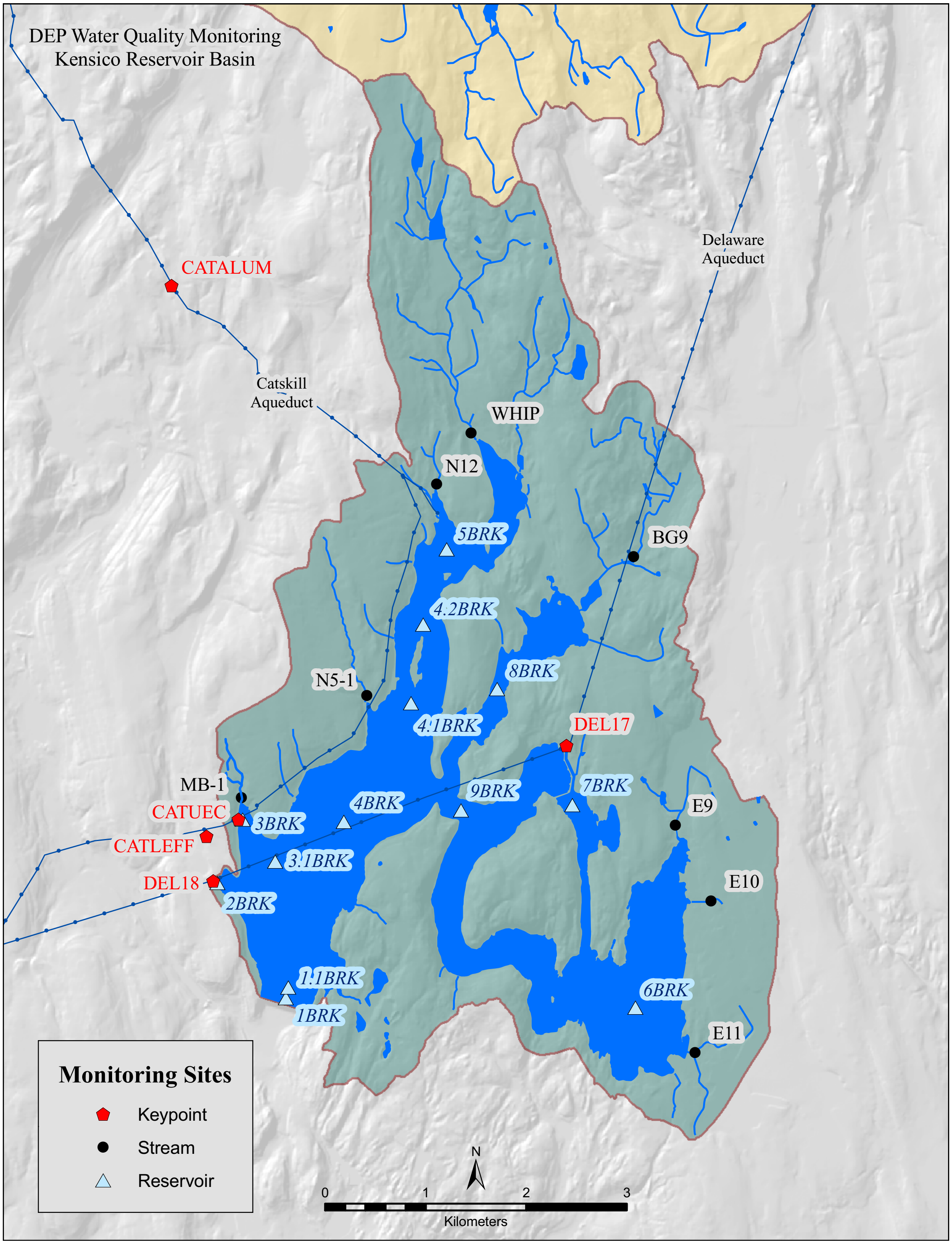


Figure 3.3 Water quality monitoring in the Kensico Reservoir basin.

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 would 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.

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

Analyte	Sampling Frequency	Rationale for Analyte
Dissolved Chloride	Monthly	Major component of road salt, indicator of septic system failures.
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•50 L^{-1}	Monthly	Early warning surveillance
Giardia cysts•50 L^{-1}	Monthly	Early warning 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.

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 and the mid-term report on watershed surveillance. 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

USEPA. 2007. New York City Filtration Avoidance Determination.

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 twice monthly by DEP.

Sites

West of Hudson WWTP sites required for monitoring under the 2007 FAD (Section 6.2) are listed in Table 3.21 and shown in Figure 3.11. Grab samples are collected twice monthly from each facility and analyzed for all SPDES parameters. Where applicable, DEP also analyzes composite samples on an annual basis for all SPDES parameters.

Table 3.21: West of Hudson WWTP sites required for monitoring under the 2007 FAD.

Location/ WWTP	Reason for Selection
ANDES	FAD requirement
BATAVIA KILL RECREATION AREA	FAD requirement
CAMP L'MAN A'CHAI	FAD requirement
CAMP OH-NEH-TAH	FAD requirement
CAMP OORAH	FAD requirement
CAMP TIMBERLAKE	FAD requirement
CRYSTAL POND	FAD requirement
DELHI	FAD requirement
ELKA PARK	FAD requirement
FLEISCHMANNS	FAD requirement
GRAHAMSVILLE	FAD requirement
GRAND GORGE	FAD requirement
HOBART	FAD requirement
HUNTER HIGHLANDS	FAD requirement
HUNTER WWTP	FAD requirement
MACHNE TASHBAR	FAD requirement
MARGARETVILLE	FAD requirement
MOUNTAIN VIEW	FAD requirement
MOUNTAINSIDE FARMS	FAD requirement
OLIVE WOODS	FAD requirement
ONTEORA CENTRAL SCHOOL	FAD requirement
PINE HILL	FAD requirement
PRATTSVILLE	FAD requirement
ROXBURY RUN	FAD requirement

Table 3.21: (Continued) West of Hudson WWTP sites required for monitoring under the 2007 FAD.

Location/ WWTP	Reason for Selection
STAMFORD	FAD requirement
TANNERSVILLE	FAD requirement
WALTON	FAD requirement
WEST DELAWARE BOCES	FAD requirement
WINDHAM WWTP	FAD requirement
Non-contact cooling water discharges[1]	
DMV INTERNATIONAL	
KRAFT COOLING WATER	
MORNINGSTAR ULTRA DAIRY	

[1]Although monitoring of these industrial non-contact cooling water discharges is not explicitly required by the FAD, DEP believes they are important, and therefore routinely monitors them for temperature, phosphorus, pH, CBOD, turbidity, and at Kraft, also for TSS.

Table 3.22: West of Hudson WWTP analytes and frequencies for FAD monitoring.

Location/ WWTP	Analytes (vary by SPDES)	Frequency[1]
ANDES	Same as SPDES permit	2/month, 1/yr.
BATAVIA KILL RECREATION AREA	Same as SPDES permit	2/month, 1/yr.
CAMP L'MAN A'CHAI	Same as SPDES permit	2/month, 1/yr.
CAMP OH-NEH-TAH	Same as SPDES permit	2/month, 1/yr.
CAMP OORAH	Same as SPDES permit	2/month, 1/yr.
CAMP TIMBERLAKE	Same as SPDES permit	2/month, 1/yr.
CRYSTAL POND	Same as SPDES permit	2/month, 1/yr.
DELHI	Same as SPDES permit	2/month, 1/yr.
ELKA PARK	Same as SPDES permit	2/month, 1/yr.
FLEISCHMANNS	Same as SPDES permit	2/month, 1/yr.
GRAHAMSVILLE	Same as SPDES permit	1/month
GRAND GORGE	Same as SPDES permit	2/month
HOBART	Same as SPDES permit	2/month, 1/yr.
HUNTER HIGHLANDS	Same as SPDES permit	2/month, 1/yr.
HUNTER WWTP	Same as SPDES permit	2/month, 1/yr.
MACHNE TASHBAR	Same as SPDES permit	2/month, 1/yr.
MARGARETVILLE	Same as SPDES permit	2/month
MOUNTAIN VIEW	Same as SPDES permit	2/month, 1/yr.
MOUNTAINSIDE FARMS	Same as SPDES permit	2/month, 1/yr.

Table 3.22: (Continued) West of Hudson WWTP analytes and frequencies for FAD monitoring.

Location/ WWTP	Analytes (vary by SPDES)	Frequency[1]
OLIVE WOODS	Same as SPDES permit	2/month, 1/yr.
ONTEORA CENTRAL SCHOOL	Same as SPDES permit	2/month, 1/yr.
PINE HILL	Same as SPDES permit	2/month, 1/yr.
PRATTSVILLE	Same as SPDES permit	2/month, 1/yr.
ROXBURY RUN	Same as SPDES permit	2/month, 1/yr.
STAMFORD	Same as SPDES permit	2/month, 1/yr.
TANNERSVILLE	Same as SPDES permit	2/month
WALTON	Same as SPDES permit	2/month, 1/yr.
WEST DELAWARE BOCES	Same as SPDES permit	2/month, 1/yr.
WINDHAM WWTP	Same as SPDES permit	2/month, 1/yr.
Non-contact cooling water discharges[2]		
DMV INTERNATIONAL		Quarterly
KRAFT COOLING WATER		Quarterly
MORNINGSTAR ULTRA DAIRY		Quarterly

[1] 1/yr is a composite sample collected once each year. All other samples are grab samples.

[2] Although monitoring of these industrial non-contact cooling water discharges is not explicitly required by the FAD, DEP believes they are important, and therefore routinely monitors them for temperature, phosphorus, pH, CBOD, turbidity, and at Kraft, also for TSS.

Data Analysis and Reporting

Sample results are reported quarterly to USEPA in accordance with FAD Section 6.2, *Sample Monitoring of NYC-owned and non-City-owned WWTPs discharging in the CAT/DEL watershed.* 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.

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 for *Giardia*, *Cryptosporidium*, and, at CATALUM and DEL17 only, 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

The NYC water supply consists of 19 reservoirs and three controlled lakes, six of which are west of the Hudson River (WOH). These WOH reservoirs contribute 90% (or greater) of the water delivered to NYC for municipal use, making them an integral part of the water supply system. All water delivered to NYC must be fit for human consumption, so it is vital that pathogen occurrence is monitored at these major reservoir keypoint locations to provide information and guide possible changes to the delivery process of high quality source water to downstream reservoirs.

The aqueduct intake keypoints at each of the WOH reservoirs provide excellent monitoring sites for assessment of water quality destined for 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 3.23: 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
CATLEFF	Catskill Aqueduct—Lower Effluent Chamber	Terminal reservoir outflow
DEL17	Delaware Aqueduct—Shaft 17 influent to Kensico Reservoir	Terminal reservoir input
DEL18	Delaware Aqueduct—Shaft 18 effluent from Kensico Reservoir	Terminal reservoir outflow
SRR2CM	Schoharie Reservoir—effluent at Shandaken Tunnel Outlet, Shandaken, NY	Upstate reservoir diversion
RDRRCM	Rondout Reservoir effluent at Rondout Effluent Chamber, Napanoch, NY	Upstate reservoir diversion
NRR2CM	Neversink Reservoir effluent, Grahamsville, NY	Upstate reservoir diversion
PRR2CM	Pepacton Reservoir effluent at East Delaware Tunnel Outlet	Upstate reservoir diversion
WDTO	Cannonsville Reservoir effluent at West Delaware Tunnel Outlet	Upstate reservoir diversion

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

Analyte	Frequency	Rationale for Analyte
Cryptosporidium oocysts•50 L^{-1}	Monthly[1]	Surveillance and trends
Giardia cysts•50 L^{-1}	Monthly[1]	Surveillance and trends
HEV[2]	Weekly	Surveillance and trends
Flow (cfs)	Continuous[1] (10 minute data)	Required to estimate loading
Weather (general conditions)	Monthly[1]	Supporting data to explain possible protozoan results
Sample volume	Monthly[1]	For determination of (oo)cyst concentration
Turbidity	Continuous[1] (10 minute data)	Recovery potential/interference
pH	Monthly[1]	Required by ICR Method (HEV)
Water temperature	Monthly[1]	Measured to ensure QA/QC
Pressure differential on sample filter	Monthly[1]	Recovery potential/interference
Flow for filtered sample	Monthly[1]	USEPA method requirement

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

Sampling for protozoa at these sites should be conducted for a period of five years, after which an evaluation of the program shall be conducted.

Data Analysis and Reporting

Reporting will be done on a semi-annual basis in accordance with the FAD (USEPA 2007), and included as part of the Watershed Water Quality Annual Report and the mid-term FAD report on watershed surveillance. 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

USEPA. New York City Filtration Avoidance Determination. 2007.

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 increased or decreased, as resources allow, if there is suspicion of newly identified 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. Previously, 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 sites are evenly distributed to represent four sites in the Catskill and four sites in the Delaware watersheds. The sample locations include, but are not limited to, the sites listed in Table 3.25. Other sites can be incorporated into the sampling plan as resources allow, if there is suspicion of a new potential pathogen source, or an upstream point source. Each site and a description of its approximate location is listed in Table 3.26.

Table 3.25: Stream sites and their basic statistics identified from 84 previous indicator sites as having relatively greater protozoan levels.

Aqueduct System	Site Code	*Cryptosporidium* oocysts·50 L^{-1}	*Giardia* cysts·50 L^{-1}	N	Max *Cryptosporidium* oocysts·50 L^{-1}	Max *Giardia* cysts·50 L^{-1}
Catskill	ABCG	4.17	44.55	14	36	303
	S4	0.73	48.66	75	7	249
	S5I	0.84	52.29	71	11	351
	S7I	0.85	225.92	11	5	1118
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
	PMSB	0.96	21.04	68	7	115

Table 3.26: 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
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
PMSB	East Branch Delaware River, taken 140 feet downstream of the Margaretville Wastewater Treatment Plant outfall.	Identified as site for further monitoring
ABCG	Birch Creek, at Big Indian, sample taken at bridge next to Peekamoose (formerly Jake Moon) Restaurant, downstream of USGS gauge.	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 1623HV (USEPA) or updated method if applicable. Further, additional associated supporting parameters will be included as part of the sampling plan (Table 3.27). All appropriate QA/QC requirements as outlined by DEP will be satisfied as part of this sampling effort.

Table 3.27: Analytes and frequencies for each selected stream indicator site.

Analyte	Reason for Inclusion	Frequency
Giardia cysts	Pathogen of interest	monthly
Cryptosporidium oocysts	Pathogen of interest	monthly
Weather (general conditions)	Supporting data to explain possible protozoan results	monthly
Sample volume	Required for calculating concentration	monthly
pH	Method effects	monthly
Turbidity	Matrix recovery effects	monthly
Water temperature	Required by method	monthly
Pressure differential on sample filter	Matrix recovery effects	monthly
Flowthrough filter	Required by method	monthly
Flow at sampling location	Required for loading estimates	monthly

Data Analysis and Reporting

Reporting will be done on a semi-annual basis in accordance with the 2007 FAD. The data will be included in the semi-annual and annual FAD reports as well as in the Watershed Water Quality Annual Report. 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 and Virus 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 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 this future plan for monitoring.

Sites

As with the previous FAD 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 3.28). 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 3.28: 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 as well as Human Enteric Viruses. *Giardia* and *Cryptosporidium* (oo)cyst samples will be analyzed using Method 1623HV (USEPA) or updated method if applicable. Human Enteric Virus samples will be analyzed using the ICR method (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 3.29). All appropriate QA/QC requirements as outlined by DEP will be satisfied as part of this sampling effort.

Table 3.29: Analytes and frequencies for the pathogen and human enteric virus monitoring performed at WWTPs.

Analyte	Reason for Inclusion	Frequency
Giardia cysts	Pathogen of interest	quarterly
Cryptosporidium oocysts	Pathogen of interest	quarterly
Human enteric viruses	Pathogen of interest	quarterly
Weather (general conditions)	Supporting data to explain possible protozoan results	quarterly
Sample volume	Required for calculating concentration	quarterly
pH	Method 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
Chlorine residual	Needed to determine if dechlorination is needed	quarterly

Data Analysis and Reporting

Reporting will be done on a semi-annual basis in accordance with the 2007 FAD. Results will be reported in the Annual Water Quality report as well as the annual and semi-annual 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 is an ongoing FAD mandate and is addressed in Section 4.1 of the 2007 FAD.

The program was developed through the efforts of DEP, the USEPA, and the New York State Department of Health. The rationale for the program is as follows:

- DEP monitors waterbird populations on the NYC reservoir system to identify potential effects from fecal pollution from birds. An environmentally sensitive bird mitigation program has been developed and continues to be implemented to eliminate birds and prevent fecal coliform bacteria elevations which could threaten water quality.
- Without a robust and effective program to monitor and disperse these wildlife populations, New York City would potentially risk failing to comply with the SWTR due to high fecal coliform bacteria concentrations from waterfowl. Failure of the SWTR compliance could possibly affect the health of millions of NYC drinking water consumers. This would force DEP to construct a multi-billion dollar filtration plant. DEP will implement the USEPA-mandated Waterfowl Management Program Expansion (Nov. 2002 FAD) through this plan. Specifically, by controlling waterfowl and therefore fecal coliform inputs more effectively, lower chlorine dosages may be possible, which in turn could lower, to some extent, the disinfection by-product concentration in distribution.
- The Waterfowl Management Plan will assess the level of waterbird activity and the potential for negative effects on water quality in the NYC water supply.

Background

This program has been deemed highly effective for NYC water quality improvements since the early 1990s. Due to the nature of the program, which involves often unpredictable behavioral changes in bird populations, DEP will continue this program indefinitely. The time period of this study was determined through preliminary surveys conducted by DEP staff prior to initiating bird mitigation actions. The preliminary bird surveys identified both the spatial and temporal distributions and species richness and evenness of the waterbirds inhabiting the reservoirs. All reference to the development of the Waterfowl Management Program can be found in previous FAD annual reports on the program dating from 1993 up through 2008.

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 subsequently compared with data collected 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). Each NYC reservoir was divided into distinct Bird Zones which correspond to reservoir limnology sampling locations and water effluent locations. Each reservoir Bird Zone can be monitored for waterbirds from established shoreline locations and from motorboats. The goal of waterbird sampling is the ability to count and speciate all waterbirds present during the time of the survey for both diurnal and nocturnal counts.

Analytes

This objective strives to quantify the presence of waterbirds through enumeration and speciation. Fecal coliform bacteria are measured through other DEP objectives and these are mathematically related to the presence of waterbirds.

Sampling Frequency

Sampling frequency is based on waterbird population dynamics including migration and wintering movements throughout the reservoir system. Seasonal population fluctuations are important and often determine the increase or decrease in sampling frequency.

In general the sampling frequency is fixed as species influx in populations often occurs at predictable times annually. For instance, Canada Geese populations often begin the onslaught of autumnal migration southward into the NYC reservoir region in mid-September. At times, storm events may increase or decrease certain waterbird species depending on the prevailing winds associated with and during migration movements. For instance, coastal storm events in the Northeast may push more species that generally migrate along the coast further inland to the NYC reservoirs as temporary stopovers.

The Waterfowl Management Program sampling frequency intensifies from late summer through early spring annually when migration and over-wintering of many species occurs. During the late spring and early summer period there are fewer routine surveys conducted as the emphasis changes to identifying local breeding populations of geese, cormorants, swans, and ducks.

Data Analysis and Reporting

There are two references to the data analysis protocols. The first is an SOP developed by the DEP contractor (HDR, P.C.), titled “Waterfowl Management Program WMP-08 Standard Operating Procedures”. This document briefly identifies the procedure for data collection, data entry, and quality control.

All waterbird data are compared to fecal coliform bacteria data. Bird counts at specific Bird Zones are charted against fecal coliform bacteria levels recorded at limnology sampling locations. Total reservoir bird counts are also compared to reservoir effluent samples for fecal coliform bacteria. Monthly data reports are issued internally.

The annual FAD report is submitted to the USEPA and the New York State Department of Health. The report is listed as FAD 4.1 Waterfowl Management Program. The FAD report for the Waterfowl Management Program reports on the previous year's activities regarding species population monitoring and includes all mitigative actions to reduce waterbird populations and improve water quality. The report is due annually on July 31.

3.7 Stream Management Program

3.7.1 Biological Monitoring of Stream Restoration Projects

Objective

This objective seeks to evaluate the effectiveness of stream restoration projects mandated by the 2007 FAD (USEPA 2007) by assessing the benthic macroinvertebrate communities upstream and downstream of the affected reach.

Background

Both the 2002 and 2007 FADs (USEPA 2002, 2007) required DEP to construct projects to restore unstable stream reaches; construction of these projects is expected to improve stream habitat by decreasing streambank erosion. Biological monitoring uses protocols developed by the New York State Stream Biomonitoring Unit to assess the level of impairment to the benthic communities found in these streams and to determine the extent to which their condition improves following installation of the BMPs. Healthy benthic communities are essential to best uses of the streams, including the delivery of drinking water and support of a unique cold water fishery.

Sites

Generally, two sites are established to monitor each project, an upstream control site and a site located within or slightly below the affected reach (in the latter case, close enough to capture the effects of the disturbance). At present, only one stream reach is being sampled (Table 3.30 and Figure 3.2), but new projects (including Stony Clove (see Section 3.1)) may be added in the future. Future monitoring will be submitted in the year of implementation as an addendum to the WWQMP.

Table 3.30: Sites for biological monitoring of stream restoration projects. Analyses are performed by a contract laboratory.

Site Code	Site Description	Reason for Site Selection
258	West Kill upstream of Long Road BMP	Evaluation of BMP effectiveness
259	West Kill at lower end of Long Road BMP	Evaluation of BMP effectiveness

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); and the Hilsenhoff Biotic Index (a measure of organic pollution)). 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 3.31 provide context for interpreting the invertebrate data.

Table 3.31: Analytes for assessment of biological water quality status.

Analyte	Sampling frequency	Rationale for analyte
pH	Annually	Analyte is significantly correlated with biomonitoring metrics
Dissolved Oxygen	Annually	Analyte is significantly correlated with biomonitoring metrics
Temperature	Annually	Analyte is significantly correlated with biomonitoring metrics
Specific Conductivity	Annually	Analyte is significantly correlated with biomonitoring metrics

For each project, one year of pre-construction sampling will be performed, followed by two years of post-construction sampling (more if there is evidence that the post-construction community has not yet stabilized). Pre-construction sampling was performed at the West Kill BMP in 2008. Project construction is expected to conclude in September 2009.

Sites are sampled annually, as per NYSDEC protocols (NYSDEC 2002). While those protocols provide for sampling anytime between July and September, DEP biomonitoring samples have historically been collected in September in Catskill and Delaware.

Data Analysis and Reporting

The data from benthic samples will be used to calculate metrics which categorize habitat condition. An improvement in assessment category at the downstream site will be considered an indication that the restoration project has been effective. If both the upstream and downstream sites initially assess as non-impaired, a similarity measure will be used to determine the degree of similarity between the two sites; if the pre-construction similarity is less than 50%, an increase to greater than 50% will be considered an indication that the restoration project has been effective in improving the habitat for the growth and reproduction of the benthic community. If a satisfactory control site is unavailable (i.e., significant impairments exist upstream of the restoration reach), comparisons will be made to a non-impaired site with similar habitat features in a stream from the same or a nearby watershed.

Results will be reported in the Watershed Water Quality Annual Report and in the Watershed Protection Program Summary and Assessment report, which is produced every five years. Both documents are 2007 FAD requirements.

References

NYSDEC [Department of Environmental Conservation]. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. Albany, NY. 116 p.

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

USEPA [United States Environmental Protection Agency] Region 2. 2002. New York City Filtration Avoidance Determination. http://www.epa.gov/region2/water/nycshed/2002finalfad.pdf. 70 p.

USEPA [United States Environmental Protection Agency] Region 2. 2007. New York City Filtration Avoidance Determination. http://www.epa.gov/r02earth/water/nycshed/2007finalfad.pdf. 96 p.

3.8 Conversion of Septic to Sewer Evaluation

Objective

The objective of this plan is to determine the water quality effects of providing new or improved WWTP service to areas that are now on septic systems. The current FAD (USEPA 2007) lists three types of improvements that will be undertaken within the next five years: 1) the septic and sewer program, 2) the new infrastructure program, and 3) the community wastewater management program. Each of these programs has the potential to improve water quality in the receiving waters and needs to be evaluated to determine the benefits.

Background

There are three sections of the FAD that pertain to the septic system conversions as listed above. The three programs are designed to address the issue of septic systems located in a relatively dense pattern adjacent to receiving waters. In some cases, this may be a lake or pond, or more commonly, a stream. Septic systems typically require a certain amount of space to effectively treat wastewater. In hamlets or subdivisions where density may constrain the capacity of septic systems, water quality in adjacent receiving waters may suffer degradation.

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 small streams or lakes 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. Another WOH project (Bloomville) will monitor an area where individual septic systems for homes will be replaced with a community septic system. Streams in these three areas will be monitored for water quality improvements following the removal of individual septic systems from the immediate watershed area. East of Hudson, the homes in the community around Peach Lake are currently served by individual septic systems. A new WWTP will be built to serve the community. Although this site is not within the Catskill/Delaware basins, it was chosen as an excellent research site with a high likelihood of demonstrating water quality improvements of septic conversion due to its headwater location with few other influences on water quality. Sites will be assessed for accessibility and other potential sampling constraints. Table 3.32 provides a list of potential sites that will be evaluated.

Table 3.32: Potential sites for evaluation of conversion from septic systems to sewers.

Site	Reason for Site Selection	Tributary	Number of Sites
West of Hudson			
Bloomville A/B	New community septic	West Branch Delaware River	2
Margaretville A/B	Sewer extension	East Branch Delaware River	2
Hunter A/B	Sewer extension	Schoharie Creek	2
East of Hudson			
Peach Lake	New WWTP	Peach Lake	1

Note: If field logistics prove to be difficult, other locations may be selected. A/B represents above and below the proposed site improvement.

Analytes and Frequencies

The variables of interest for this objective are those that are typically indicative of septic contamination. They include fecal coliform, total phosphorus, total nitrogen, ammonia, chloride, nitrate, and dissolved organic carbon. Additional routine variables include temperature, dissolved oxygen, pH, and field specific conductivity. This suite of analytes will be compared between the upstream and downstream sites to determine the existing impacts. For lake sites, these analytes, along with chlorophyll *a*, will be compared on a temporal basis to determine existing conditions and the effect of septic conversion after construction.

Fecal coliform are indicative of contamination from warm-blooded animals. Total phosphorus, total nitrogen, and ammonia are nutrients found in wastewater and their concentrations are dependent upon the degree of treatment. Chloride is present in wastewater in relatively high concentrations and, because of its conservative nature, serves as a good tracer for faulty septic systems. The difference between an upstream site and a downstream site can be used to indicate the relative contribution from septic systems along a reach of the stream. Lysimeter levels of chloride before and after conversion are also good indicators of the relative contribution to groundwater and subsequent levels in nearby streams. Chlorophyll *a* will be used to evaluate trophic status on the lakes.

To capture the effect of these improvements on water quality, samples will have to be collected for at least two years before and two years after completion of the projects. Stream sites will be sampled on a monthly basis. Lake or outlet samples will also be collected on a monthly basis. If outlet sites are not practical, lake sampling at the deepest site will have to be established and the practical frequency determined.

Data Analysis and Reporting

Data analysis will include both temporal plots and nonparametric statistics. Upstream and downstream sites will be plotted through time for easy visual assessment of differences. Wilcoxon rank sum will be used to compare the upstream/downstream sites and also for before and after construction periods on the downstream sites. Lake sites will also be plotted and the Wilcoxon test will be used to assist in determining differences before and after construction. Raw chlorophyll *a* data will be used for the Wilcoxon assessment and the trophic status index (TSI) will be calculated according to Carlson (1977) and plotted for the duration of the study.

Since the timeline for each project is different, the reports should be produced as each project and its associated sampling are completed, rather than waiting for all projects to be completed. Upon completion of the two-year post-construction sampling of a project, the data will be analyzed and reported. The data and results for the overall objective will be included in the 2011 interim FAD progress report.

References

Carlson, R. E. (1977). “A trophic state index for lakes.” Limnol. Oceanogr. 22: 361-369.

USEPA [United States Environmental Protection Agency] Region 2. 2007. New York City Filtration Avoidance Determination. http://www.epa.gov/r02earth/water/nycshed/2007finalfad.pdf. 96 p.

3.9 Stormwater Program

3.9.1 Stormwater Retrofit

Objective

The goal of this monitoring will be to demonstrate the effectiveness of stormwater programs in removing pollutants from stormwater, and thus providing a water quality benefit to the impacted surface waters.

Background

As part of its long-term program (DEP 2006), DEP has agreed to enhance its stormwater programs in a number of ways. These include working with the Catskill Watershed Corporation (CWC) to explore ways to expand the effectiveness of its Stormwater Retrofit Program, and working with NYSDEC to explore ways to better coordinate stormwater enforcement activities in the City's watersheds. The 2007 FAD also states that DEP will continue funding the installation of stormwater BMPs; community-wide stormwater infrastructure assessment and planning; and the installation of stormwater BMPs throughout the West of Hudson watershed. DEP was awarded two grants—a Water Resources Development Act (WRDA) grant for the construction of two wetland extended detention basins, and a Safe Drinking Water Act (SDWA) grant for the associated monitoring stations—that will allow DEP to assess how well these facilities reduce TP, TDP, TSS, and DOC loads in stormwater.

Sites

When candidate programs are identified, sites will be selected based on their ability to isolate and detect impacts from the stormwater program, as well as their accessibility and other potential sampling constraints. At this time, no sites have been selected. DEP expects candidate sites to become available once new stormwater control structures have been built.

Analytes and Frequencies

Analytes will be selected based on the design criteria of the selected stormwater program, but will likely include TSS, turbidity, and nutrients. Due to the nature of the program, storm event sampling will be required.

Data Analysis and Reporting

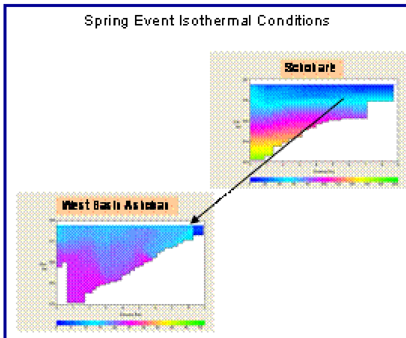
DEP will analyze results from the sampling program and prepare a report describing the program, and the effectiveness of the stormwater program in removing pollutants from stormwater.

References

DEP. 2006. 2006 Long-Term Watershed Protection Program. Valhalla, NY. 66 p.

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

4. Modeling



Thermal conditions in reservoirs govern flow pathways.

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).

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 current 2007 FAD, Section 5.2 (USEPA 2007). Specific FAD requirements related to this objective include:

- "Continue model improvements based on ongoing data analyses and research results"
- "Continue model testing as additional data from DEP's ongoing monitoring programs becomes available"
- "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", due 3/31/2011.

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:

Flow and water quality quantification are essential for modeling.

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. Proposed new monitoring sites to support sediment model development (retrofitting of existing USGS flow gage stations for automated turbidity monitoring)
E. Support watershed hydrologic model development
F. Ongoing NYSDEC monitoring to support watershed nutrient model development, including FAD requirement for 2011 FAD Program Assessment
G. Proposed new NYSDEC monitoring to support watershed nutrient model development, including FAD requirement for 2011 FAD Program Assessment
H. Water temperature monitoring only, for reservoir model development and applications

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

In addition to existing sites, new automated monitoring Robohut sites are planned for major tributaries of Esopus Creek and Rondout Creek, to support development of sediment models. These will be established by retrofitting existing USGS flow gage stations, maintained by USGS or UFI, and will require periodic water quality sampling by WQD for automated equipment calibration and for establishing TSS/turbidity relationships. DEP proposes that in the future site PMG be sampled under a contract with NYSDEC, in an arrangement similar to that for WDBN at Beerston.

Table 4.1: Stream water quality monitoring for modeling sites.

Site Code	Site Description	Reason for Site Selection
Existing WQD-Provided Data Sites		
E10I	Bush Kill below Maltby Hollow Brook at Shokan	H
E16I	Esopus Creek at Coldbrook	A, B, C
P-13	Tremper Kill near Andes	H
P-60	Mill Brook near Dunraven	H
P-7	Terry Clove above Pepacton Reservoir	H
NK4	Aden Brook (aka Nauvoo Brook) near Aden	H
NCG	Neversink River near Claryville	H

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

Site Code	Site Description	Reason for Site Selection
RD4	Sawkill Brook (aka Trout Creek) near Sholam	H
RDOA	Rondout Creek near Lowes Corners	A, B, D, H
RGB	Chestnut Creek at Grahamsville	H
S5I	Schoharie Creek at Prattsville	A, B, C
S6I	Bear Kill near Prattsville	H
S7I	Manor Kill at West Conesville near Gilboa	H
C-7	Trout Creek, near Trout Creek	H
Existing Contractor-Provided Data Sites: NYSDEC		
NYSDEC–Beerston	NYSDEC - West Branch Delaware River at Beerston	B, F
Proposed Contractor-Provided Data Site: NYSDEC		
PMG	East Branch Delaware River at Margaretville	B, G
Existing WQD-Provided Data Sites: Robohuts		
E16ICM	Robohut at E16I	A,B, C
S5ICM	Robohut at S5I	A,B, C
AEAP	Robohut at AEAP	C
SRR2CM	Robohut at SRR2CM	A,B, C
New WQD-Provided Data Sites: Robohuts Funding Approved		
Near RDOA	Robohut at Rondout Creek—exact location to be determined	C, D
Proposed WQD-Provided Data Sites: Robohuts to Support Turbidity Modeling Project		
ASCHGCM	Robohut at Hollow Tree Brook at Lanesville	D
SCLCM	Robohut at Stony Clove near Phoenicia	D
LBKCM	Robohut at Little Beaver Kill at Beechford near Mt. Tremper	D
ABCGCM	Robohut at Birch Creek at Big Indian (E15)	D
WDLCM	Robohut at Woodland Creek above mouth at Phoenicia	D

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, E
01362230	Diversion from Schoharie Reservoir (SRR2CM or SRR1CM)	A, B, C, E
01362342	Hollow Tree Brook at Lanesville (ASCHG)	D, E
01362380	Stony Clove near Phoenicia (SCL)	D, E
001362497	Little Beaver Kill at Beechford near Mt. Tremper	D, E
01362500	Esopus Creek at Coldbrook	A, B, C, E

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

Site Code	Site Description	Reason for Site Selection
01363382	Bush Kill below Maltby Hollow Brook at Shokan (E10I)	A, B, E
013621955	Birch Creek at Big Indian (E15)	D, E
136230002	Woodland Creek above mouth at Phoenicia	D, E
01349700	East Kill near Jewett Center	E
01349711	West Kill Below Hunter Brook near Spruceton	E
01349810	West Kill near West Kill	E
01349950	Batavia Kill at Red Falls near Prattsville	E
01350000	Schoharie Creek at Prattsville (S5I)	A, B, C, E
01350035	Bear Kill near Prattsville (S6I)	A, B, E
01350080	Manor Kill at West Conesville near Gilboa (S7I)	A, B, E
01350101	Schoharie outflow, stream (dam spill + release)	A, B, E
01413398	Bush Kill near Arkville	E
01413408	Dry Brook at Arkville	E
01413500	East Branch Delaware River at Margaretville (PMG)	B, G, E
01414000	Platte Kill at Dunraven (P-21)	B, E
01414500	Mill Brook near Dunraven (P-60)	B, E
01415000	Tremper Kill near Andes (P-13)	B, E
01417000	East Branch Delaware River at Downsville (Pepacton outflow) (PDB)	B, E
01434017	East Branch Neversink River near Claryville	E
01434021	West Branch Neversink River at Winnisook Lake near Frost Valley	E
01434025	Biscuit Brook above Pigeon Brook at Frost Valley	E
01434092	Shelter Creek below Dry Creek near Frost Valley	E
01434498	West Branch Neversink at Claryville	E
1435000	Neversink River near Claryville (NCG)	B, E
1436000	Neversink River at Neversink (Neversink outflow) (NB)	B, E
0143400680	East Branch Neversink River northeast of Denning	E
01365000	Rondout Creek near Lowes Corners (RDOA)	A, B, D, E
01365500	Chestnut Creek at Grahamsville (RGB)	B, E
01421618	Town Brook southeast of Hobart (CTNBG)	F, E
01421900	West Branch Delaware River upstream from Delhi	E
01422500	Little Delaware River near Delhi	E
01423000	West Branch Delaware River at Walton	B, F, E
1425000	West Branch Delaware River at Stilesville (Cannonsville outflow) (CNB)	B, E
0142400103	Trout Creek, near Trout Creek	B, E

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 TP, TDP, SRP, TDN, NOx, NHx, DOC, Si sampled during storms and in inter-storm periods. Two sites are chosen for this in Table 4.1. The first (Beerston) has been monitored under contract by NYSDEC since 1992. The second (PMG) will be added in the near future (contract under development). By monitoring these two sites, DEP will have a record of the nutrients loads entering Cannonsville and Pepacton Reservoirs, the two WOH reservoirs most susceptible to eutrophication, and the two reservoir watersheds most important for nutrient model development. At both sites, a sampling protocol will be used which will allow accurate estimates of total nutrient load. As all work will be done under contract it will require no DEP laboratory or field group resources. Flow monitoring is according to USGS flow gage protocol.

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

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

Site Code	Analytes	Sampling Frequency	Rationale for Analyte
Existing WQD-Provided Data: Routine grab sampling			
E10I	Temperature	routine	H
P-13	Temperature	routine	H
P-60	Temperature	routine	H
P-7	Temperature	routine	H
NK4	Temperature	routine	H
NCG	Temperature	routine	H
RD4	Temperature	routine	H

Table 4.3: (Continued) Analytes and frequencies for stream monitoring for modeling.

Site Code	Analytes	Sampling Frequency	Rationale for Analyte
RDOA	Temperature	routine	H
RGB	Temperature	routine	H
S6I	Temperature	routine	H
S7I	Temperature	routine	H
C-7	Temperature	routine	H
Existing WQD-Provided Data: WQ Sampling to Support Existing Robohuts			
E16I Robohut	TSS, turbidity	routine and selected storms	A, B, C
S5I Robohut	TSS, turbidity	routine and selected storms	A, B, C
SRR2CM Robohut	TSS, turbidity	routine and selected storms	C
AEAP Robohut	TSS, turbidity	routine and selected storms	C
Existing WQD-Provided Data: Automated Sampling at Robohuts			
E16I Robohut	Flow, temperature, turbidity, conductivity	continuous	A, B, C
S5I Robohut	Flow, temperature, turbidity, conductivity	continuous	A, B, C
Existing Data-From Operations Division: Automated Sampling at Robohuts			
SRR2CM Robohut	Flow, temperature, turbidity, conductivity	continuous	A, B, C
AEAP Robohut	Flow, temperature, turbidity, conductivity	continuous	C
Existing Contractor-Provided Data: NYSDEC			
NYSDEC - West Branch Delaware River at Beerston	Chlorophyll, N series, P series, DO, temperature, turbidity, SC, TSS	routine and storms	B, F
Existing WQD-Provided Data or New Contractor-Provided Data: NYSDEC			
PMG (proposed)	Chlorophyll, N series, P series, DO, temperature, turbidity, SC, TSS	routine and storms	B, G
Existing Contractor-Provided Data: USGS			
USGS gage stations	flow	instantaneous	A, B, C, D, E
New WQD-Provided Data: WQ Sampling to Support New Robohuts			
RDOA	TSS, turbidity	routine and selected storms	D
New Contractor-Provided Data: Automated Sampling at robohuts Maintained by UFI			
RDOA	Flow, temperature, turbidity, conductivity	continuous	D

Table 4.3: (Continued) Analytes and frequencies for stream monitoring for modeling.

Site Code	Analytes	Sampling Frequency	Rationale for Analyte
WQD-Provided Data: WQ Sampling to Support Proposed Robohuts			
ASCHGCM	TSS, turbidity	routine and selected storms	D
SCLCM	TSS, turbidity	routine and selected storms	D
ABKHGCM	TSS, turbidity	routine and selected storms	D
LBKCM	TSS, turbidity	routine and selected storms	D
ABCGCM	TSS, turbidity	routine and selected storms	D
WDLCM	TSS, turbidity	routine and selected storms	D
Proposed Contractor-Provided Data: Automated Sampling at Robohuts Maintained by USGS or UFI			
ASCHGCM	Flow, temperature, turbidity, conductivity	continuous	D
SCLCM	Flow, temperature, turbidity, conductivity	continuous	D
LBKCM	Flow, temperature, turbidity, conductivity	continuous	D
ABCGCM	Flow, temperature, turbidity, conductivity	continuous	D
WDLCM	Flow, temperature, turbidity, conductivity	continuous	D

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

USEPA 2007. New York City Filtration Avoidance Determination. July 2007

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 FAD evaluation reports (DEP 2001, 2006), 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 2011.
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

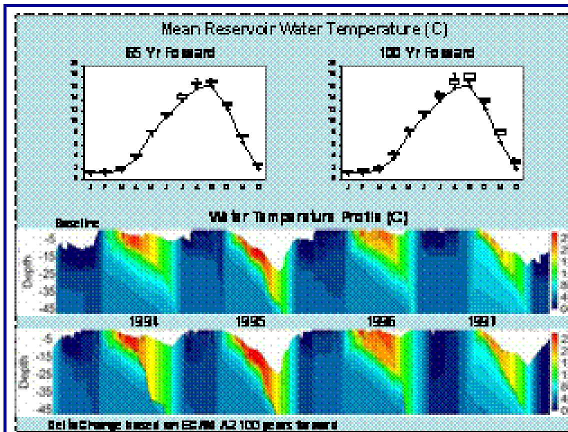
Continued testing and updating of DEP reservoir models is a FAD requirement as specified in the 2007 FAD, Section 5.2 (USEPA 2007).

- "Continue model improvements based on ongoing data analyses and research results"
- "Continue model testing as additional data from DEP's ongoing monitoring programs becomes available"
- "Continue testing and improvements to 1-D reservoir eutrophication models (including Phytoplankton Functional Group Model Application to Cannonsville Reservoir)"

Furthermore, the 2007 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 2011. 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. DEP will be acquiring seven reservoir monitoring buoys as a result of a project slated to start in January 2009. The placement of these buoys as described in Table 4.4 may change depending on final site selection criteria.

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

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Table 4.4: Sites for support of reservoir modeling.

Site Code	Site Number[1]	Reason for Site Selection
Existing WQD-Provided Data Sites: Routine Reservoir Monitoring		
EAW(Ashokan West Basin)	1, 2, 3	A, B
EAE (Ashokan East Basin)	4, 5, 6	A, B
SS (Schoharie)	1, 1.5, 2, 3, 4	A, B
NN (Neversink)	1, 2, 3, 4	B
RR (Rondout)	1, 2, 3	B
EDP (Pepacton)	1, 2, 3, 4, 5, 6	B
WDC (Cannonsville)	1, 2, 3, 4, 5, 6	B
BRK (Kensico)	1, 2, 3, 4, 5, 6, 7, 8	A, B
CWB (West Branch)	1, 2, 3, 4	A, B
Existing WQD-Provided Data Sites: 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, 3, 4, 5	A, B
CWB (West Branch)	1, 2, 3	A, B
Existing WQD-Provided Data Sites: Turbidity Event-Based Reservoir Monitoring		
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
CWB (West Branch)	1,2,3	A
BRK (Kensico)[2]	1, 2, 3, 3.1, 4, 4.1, 4.2, 5	A
New Contractor-Provided Data Sites: Automated Reservoir Monitoring Buoys UFI[3]		
EAW(Ashokan West Basin)	1.4, 3	A, B
EAE (Ashokan East Basin)	4	A, B
SS (Schoharie)	3	A, B
RR (Rondout)	1	A, B
BRK (Kensico)	2, 3, 4.1	A, B

[1]See Appendix I for locations of sites as numbered above.

[2]Samples to be collected at listed sites where possible.

[3]Final site selection may change.

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 requested for all routine in-reservoir monitoring analyses are the same as that being suggested for surveillance 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 being carried out to meet other objectives, and collection of these data does not require additional resources.

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

Site	Analyte	Sampling Frequency	Rationale for Analyte[1]
Existing WQD-Provided Data: Routine Grab Sampling			
All routine reservoir monitoring sites[2] (Table 4.4)	TDN, Total P, TDP, SRP, NOX, NH3, TN, Si[3], DOC, DO, chlorophyll[4], phytoplankton counts, Secchi depth	Monthly	Eutrophication model development and testing
	TSS, temperature	Monthly	Turbidity and eutrophication model testing and development
	Turbidity	Monthly	Turbidity model development and testing. Initial conditions for turbidity model
Existing WQD-Provided Data Sites: 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

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

Site	Analyte	Sampling Frequency	Rationale for Analyte[1]
Existing WQD-Provided Data: Parameters Derived from In Situ Measurements Concurrent with Routine Grab Sample Collection			
All routine reservoir monitoring sites (Table 4.4)	Temperature, dissolved oxygen, conductivity, depth	Monthly	Testing and development. Initial conditions (all reservoir models)
	PAR – light extinction coefficient[5]	Monthly	Driving data for eutrophication and turbidity model
Existing WQD-Provided Data: Turbidity Event-Based Sampling			
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
New Contractor-Provided Data: Parameters Derived from Automated Buoy Measurements			
All reservoir monitoring buoys (Table 4.4)	Temperature, turbidity, conductivity, depth	3-4 times per day; 1 meter or less vertical resolution	Testing and development. Initial conditions (all reservoir models)

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

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

[5]Light extinction is measured at dam sites only, at 1-m intervals.

[6]Beam attenuation coefficient is measured when possible.

4.3 Monitoring of Reservoir Operations and Aqueducts

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*
Existing WQD-Provided Data Sites: Routine Grab Sampling		
SRR1CM	Schoharie outflow	A, B
SRR2CM	Shandaken Tunnel outflow	A, B
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
WDTO	Cannonsville Tunnel inflow to Rondout Reservoir	A, B
RDRRCM	Delaware Aqueduct withdrawal from Rondout Reservoir	A, B
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
DEL18	Delaware Aqueduct outflow from Kensico Reservoir	A
CATALUM	Catskill alum plant (inflow)	A

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

Site Code	Site Description	Reason for Site Selection*
CATLEFF	Catskill Aqueduct outflow from Kensico Reservoir	A
RB	Rondout Reservoir Release	B
NB	Neversink Reservoir Release	B
PDB	Pepacton Reservoir Release	B
CNB	Cannonsville Reservoir Release	B
Existing Operations Division-Provided Data Sites: Automated Monitoring		
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 outflow	A, B
SRR2CM	Shandaken Tunnel outflow	A, B
WDTO	Cannonsville Tunnel inflow to Rondout Reservoir	A, B
CATALUM	Catskill Aqueduct alum plant (inflow)	A
CATLEC	Catskill Aqueduct outflow from Kensico Reservoir	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
DEL18	Delaware Aqueduct outflow from Kensico Reservoir	A

*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.

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

Site	Analyte	Sampling Frequency	Rationale for Analyte
Existing WQD-Provided Data: Routine Grab Sampling			
All aqueduct keypoint sites (Table 4.6)	Turbidity	Daily[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[3]	Testing and development. Initial conditions (all reservoir models)
Major aqueduct inputs, outputs, and controlled releases to reservoirs[4]: SRR2CM, EARCM, NRR2CM, PRR2CM, WDTO, RDRRCM, DEL9, DEL10, RB, NB, PDB, CNB	Total P, TDP, SRP, NO_X, NH_3, TN, DOC, chlorophyll, temperature, conductivity, turbidity, TDN, pH, DO	Monthly	Eutrophication model testing and development
Existing Data From Operations Division: Automated Sampling			
Automated monitoring sites (Table 4.6)	Temperature, conductivity, turbidity, and flow, from either PCRM or SCADA system	Daily or hourly	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] There is no eutrophication model for Kensico Reservoir.

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 should be supplied in a daily summary report defining all of the information listed in Table 4.8 below.

Table 4.8: Monitoring of reservoir operations to support reservoir modeling.

Site	Measurement	Frequency	Reason for Site Selection*
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
	Waste 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	
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	

Table 4.8: (Continued) Monitoring of reservoir operations to support reservoir modeling.

Site	Measurement	Frequency	Reason for Site Selection*
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 Del 18	Daily	A,B
	Depth of withdrawal CATLEFF	Daily	
	Water elevation	Daily	
	Reservoir operation mode	Daily	

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.

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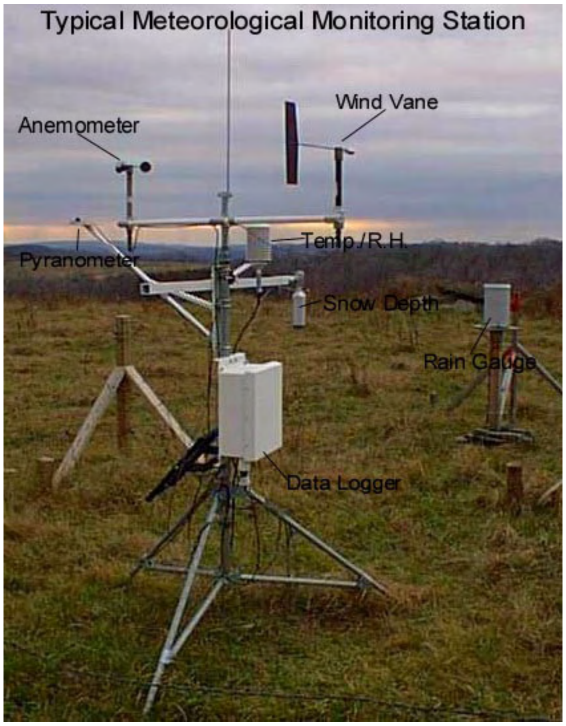
4.4 Meteorological Monitoring Support for Modeling



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.

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
CSM039	Prattsville Airport near Prattsville	Watershed models
CSM040	Batavia Kill near Ashland	Watershed models
DCM074	Cannonsville Dam	Reservoir and watershed models
DCM076	Tymeson Farm on Dunk Hill Road near Walton	Watershed models
DCM077	Eklund Farm near Delhi	Watershed models
DCM080	Snyder Farm near Delhi	Watershed models
DCM081	Meile Farm near Bovina	Watershed models
DRM181	Merriman (Rondout) Dam	Reservoir and watershed models
DRM184	Breath Hill near Peekamoose	Watershed models
DRM190	Red Hill near Denning (DEP property)	Watershed models
DPM110	Pepacton Dam near Downsville	Reservoir and watershed models
DPM111	Hillriegel Farm on Mill Brook near Margaretville	Watershed models

Table 4.9: (Continued) Operations Directorate meteorological stations.

Site Code	Site Description	Reason for Site Selection
DPM113	Oquago Retreat Center at Perch Lake near Andes	Watershed models
DPM118	DEP property near New Kingston	Watershed models
DNM146	Neversink Dam	Reservoir and watershed models
DNM147	Big Bend Club on Hunter Road near Claryville	Watershed models
DNM148	Winnisook Club at Winnisook Lake near Frost Valley	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

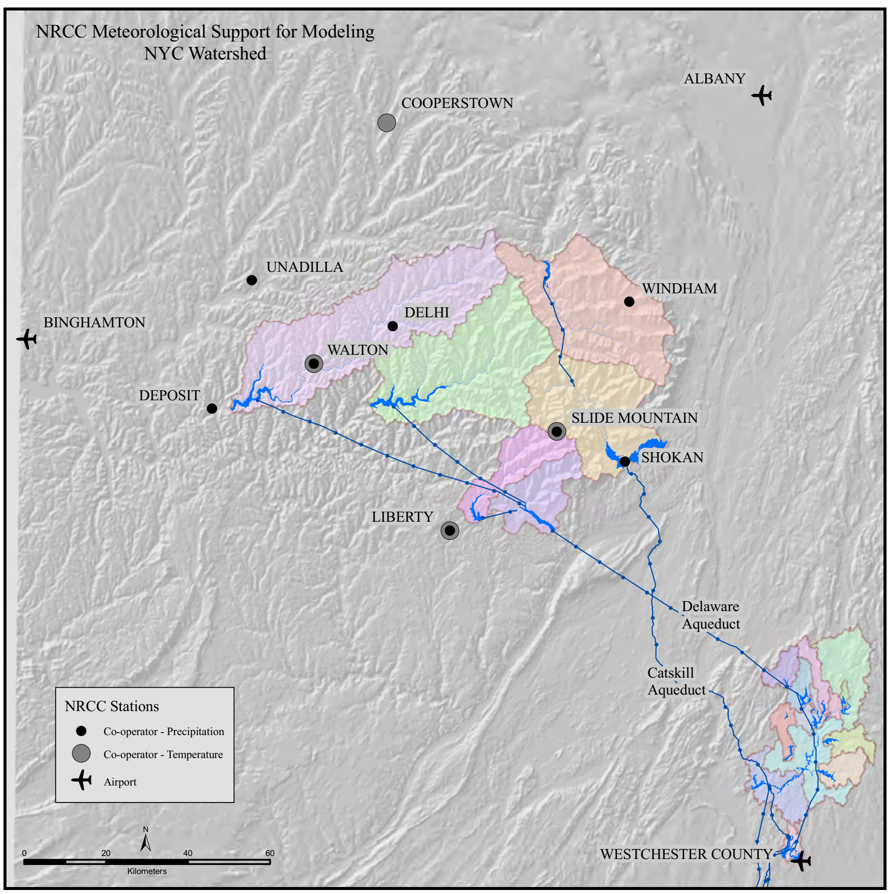


Figure 4.1 NRCC meteorological support for modeling, New York City watershed.

Table 4.10: Operations Directorate snow survey sites.

Site Code	Site Description	Reason for Site Selection
A-3	Lanesville	SWE calculation
A-4	Bushnellville	SWE calculation
A-5	Highmount	SWE calculation
A-6	Winnisook Lake	SWE calculation
A-12	Ohayo Mountain Road	SWE calculation
A-13	Lake Hill	SWE calculation
A-14	Fox Hollow Road	SWE calculation
A-15	Woodland Valley	SWE calculation
A-16	Kanape Brook Trailhead	SWE calculation
A-17	Route 28A at McMillan Road	SWE calculation
S-1	Route 42 and Spruceton Road	SWE calculation
S-2	Lexington	SWE calculation
S-3	Route 30 and Ferris Hill Road	SWE calculation
S-4	West Conesville	SWE calculation
S-5	Prattsville	SWE calculation
S-6	Batavia Kill near Ashland	SWE calculation
S-7	Route 10 and Case Road	SWE calculation
S-8	Windham	SWE calculation
S-9	East Jewett	SWE calculation
S-10	Elka Park	SWE calculation
S-11	DEP WWTP, Allen Lane and Route 23A	SWE calculation
C-1	Near Cannonsville Dam	SWE calculation
C-5	Trout Creek Road near Mormon Hollow Road	SWE calculation
C-11	Beerston	SWE calculation
C-12	2.6 miles northwest of Walton	SWE calculation
C-14	Bear Spring Mountain State Campground	SWE calculation
C-15	Hawleys	SWE calculation
C-17	Fraser	SWE calculation
C-18	Lee Hollow Road	SWE calculation
C-19	4 miles north of Delhi	SWE calculation
C-20	Bloomville	SWE calculation
C-22	Town Brook Road	SWE calculation
C-23	Whisky Hollow Road and Odell Lake Road	SWE calculation
C-25	Stamford	SWE calculation
P-2	Huntley Hollow/Skip Way Road	SWE calculation
P-8	Fall Clove Road	SWE calculation
P-9	Holiday Brook Road	SWE calculation
P-16	New Kingston	SWE calculation
P-18	Weaver Hollow Road and New Kingston Road	SWE calculation

Table 4.10: (Continued) Operations Directorate snow survey sites.

Site Code	Site Description	Reason for Site Selection
P-19	County Route 49 at Balsam Lake Trailhead	SWE calculation
P-21	Mill Brook Road	SWE calculation
P-22	John Burroughs Memorial Picnic Area	SWE calculation
P-30	Brock Mountain	SWE calculation
P-32	Swart Road and Margaretville Mountain Road	SWE calculation
P-34	New Kingston Mountain Road	SWE calculation
P-35	Elk Creek Road	SWE calculation
P-36	Cross Mountain Road	SWE calculation
P-37	Weaver Hollow Road	SWE calculation
N-2	Aden Road	SWE calculation
N-4	Husson Road	SWE calculation
N-6	Aden Hill Road near St. John’s Brook	SWE calculation
N-8	Aden Hill Road and Smith Road	SWE calculation
N-10	Woodard Road	SWE calculation
N-11	Frost Valley Road near County Route 19	SWE calculation
N-13	Denning Road	SWE calculation
N-14A	Blue Hill Road	SWE calculation
N-15	Denning Road and Strauss Road	SWE calculation
N-16	Round Pond Road and Wild Meadow Road	SWE calculation
N-17	Red Hill Knolls Road	SWE calculation
N-18	Frost Valley Road near High Falls Brook	SWE calculation
N-20	Frost Valley Road near Winnisook	SWE calculation
N-30	Wild Meadow Road	SWE calculation
N-32	Red Hill Road	SWE calculation
R-1	Sherman Road and Spook Hollow Road	SWE calculation
R-3	Route 55 near Sherman Road	SWE calculation
R-4	Yagerville Road and Greenville Road	SWE calculation
R-5	Route 42 and Thunder Hill Road	SWE calculation
R-6	Yagerville Road and Greeenville Road	SWE calculation
R-7	South Hill Road	SWE calculation
R-8	Route 55A	SWE calculation
R-9	Route 55 and Smith Lane	SWE calculation
R-11	Cummings Road near Wyman Hill Road	SWE calculation
R-13	Moore Hill Road near Bungalow Road	SWE calculation
R-15	Sugarloaf Road near Red Hill Road	SWE calculation
R-16	Peekamoose Road near Bear Hole Brook	SWE calculation
R-18	Peekamoose Road near Peekamoose Notch	SWE calculation

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
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

Table 4.18: (Continued) Analytes and frequencies for NRCC airport stations.

Analyte	Sampling Frequency	Rationale for Analyte
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.

Secchi depth transparency is a routine limnological measurement.

The first objective of this chapter is focused on "keypoint" monitoring for management and operational decisions. The keypoint 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. These data are supplemented by reservoir water quality data (the second objective), which provide higher spatial resolution of water quality. This is 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 trace metals, volatile organic compounds, and pesticides. The fifth objective is devoted to tracking potential water quality impacts from a major development project in the Catskills. This should provide insight into how development of the landscape can affect water quality. A 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. 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 2012. 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 Keypoint Monitoring for Operations Support

Objective

The primary objective of the keypoint 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 (shutdown, bypass, or float operations) and selective withdrawal (changing intake elevations), and occasionally, during extreme conditions, blending (Catskill-Croton blend) and treatment (alum). Keypoint 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 enter two aqueducts and 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 also has its own watershed, which supplies just 2% or less of the total water volume entering the reservoir.

The possible operational permutations to get water down to the City result in the need to monitor several sites across the NYC drinking water system. These are summarized in Table 5.1.

Table 5.1: Site descriptions for operations support keypoint monitoring.

Site Code	Site Description	Reason for Site Selection
RDRRCM	Rondout Reservoir Effluent taken from the continuous monitoring equipment.	operational decisions
RR1–RR4	Rondout Reservoir Elevation Taps 1–4, taken in the upper level of the Rondout Effluent Chamber.	operational decisions
NRR2CM	Neversink Tunnel Outlet continuous monitoring tap, located on the north side of the upstream butterfly valve.	operational decisions
NR1–NR4	Neversink Reservoir Elevation Taps 1–4, taken in Valve Chamber B at the Neversink Release Chamber.	operational decisions
PRR2CM	East Delaware (Pepacton) Tunnel Outlet continuous monitoring tap, located on the last bypass valve into the hydroelectric plant on Route 55A.	operational decisions
PR1–PR4	Pepacton Reservoir Elevation Taps 1–4, taken in the pump room of the East Delaware Intake Chamber.	operational decisions
WDTO	West Delaware Tunnel Outlet (Cannonsville Reservoir effluent), taken at the tunnel outlet on Route 55A.	operational decisions
CR1–CR3	Cannonsville Reservoir Elevation Tap 1–3, taken from tap located in the pump room of the West Delaware Intake Chamber.	operational decisions
EARCM	Ashokan Reservoir, continuous monitoring—raw effluent	operational decisions
ES, EM, EB	Ashokan Reservoir, East Basin - surface (S), middle (M), bottom (B) - collected out gatehouse window.	operational decisions
WS, WM, WB	Ashokan Reservoir, West Basin - surface (S), middle (M), bottom (B) - collected out gatehouse window.	operational decisions
E16I	Esopus Creek, at Boiceville from bridge, below gaging station.	operational decisions
SRR2CM	Portal (Shandaken tunnel outlet into Esopus Creek), continuous monitoring, located in shed on upstream side of Rt. 28	operational decisions

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

Site Code	Site Description	Reason for Site Selection
SRR1CM	Schoharie Reservoir—tap in gatehouse for continuous monitoring	operational decisions
CATALUM	Catskill Aqueduct raw water taken at the alum plant above Kensico Reservoir.	operational decisions
CATLEFF	Catskill Aqueduct, lower effluent chamber, untreated Kensico Reservoir effluent.	operational decisions
CATEV	Catskill Aqueduct treated supply. Sample tap located at the Eastview Water Quality Monitoring Station.	operational decisions
DEL17	Delaware Aqueduct, sampled at Shaft 17 downtake, influent to Kensico Reservoir.	operational decisions
DEL18	Delaware Aqueduct, untreated sample pump effluent from Kensico Reservoir.	operational decisions
DEL19	Delaware Aqueduct treated supply. Sample tap located at Shaft 19	operational decisions
DEL9	Delaware Aqueduct sampled at Shaft 9, influent to or bypass above West Branch Reservoir.	operational decisions
DEL10	Delaware Aqueduct sampled at Shaft 10, effluent of or bypass below West Branch Reservoir.	operational decisions
CWB1.5	West Branch Reservoir sampled at shed on the balcony of Delaware Aqueduct Shaft 10.	operational decisions
CROGH	Raw (untreated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Laboratory at level 213.	operational decisions
CROGHC	Chlorinated (treated) effluent from Croton Reservoir selective withdrawal blend. Sample tap located in Croton Gate House Lab at level 210.	operational decisions
CRO9	Croton Aqueduct treated supply. Sample tap located at NCA Shaft 9 Water Quality Monitoring Station.	operational decisions
CROGH1CM	Croton Reservoir raw blended water as the aqueduct enters Croton Lake Gate House effluent from Gate House No.1. Sample tap is located in CLGH at elevation 128.	operational decisions
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.	operational decisions

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

Site Code	Site Description	Reason for Site Selection
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.	operational decisions
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.	operational decisions
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.	operational decisions
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.	operational decisions

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 keypoint sites for operations monitoring.

Analyte	Sampling Frequency	Site Codes	Rationale for Inclusion
Temperature, Color, Scent, pH, Specific Conductivity, Turbidity	5D	RDRRCM, NRR2CM, PRR2CM, WDTO, EARCM, SRR2CM, CAT-ALUM, DEL17, CWB1.5	Operational decisions
	5D/7D	CRO9	
	7D	CATLEFF, CATEV, DEL18, DEL19, CROGH, CROGHC	
	W/5D	CROGH1CM	
	W	RR1–RR4, NR1–NR4, PR1– PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, SRR1CM, DEL9, DEL10, CRO1B, CRO1T, CRO143, CRO163, CRO183	
Temperature, Turbidity only	W	E16i	
Chlorine Residual	7D	CATEV, DEL18, DEL19, CROGHC	Operational decisions
	5D/7D	CRO9	
T Coli/F Coli	W	RR1–RR4, NR1–NR4, PR1– PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, SRR1CM, DEL9, DEL10, CRO1B, CRO1T	Operational decisions
	W/D	CROGH1CM, CRO143, CRO163, CRO183	
	4D	RDRRCM, NRR2CM, PRR2CM, WDTO, EARCM, SRR2CM	
	5D	CATALUM, DEL17, CWB1.5	
	7D	CATLEFF, CATEV, DEL18, DEL19, CROGH, CROGHC	
	5D/7D	CRO9	
T. Coli non-sheen	W	CATEV, DEL19, CROGHC, CRO9	
Giardia/Cryptosporidium	W	CATALUM, CATLEFF, DEL17, DEL18, CROGH	Operational decisions
	M	RDRRCM, NRR2CM, PRR2CM, WDTO, SRR2CM	

Table 5.2: (Continued) Analytes, frequencies, and corresponding keypoint sites for operations monitoring.

Analyte	Sampling Frequency	Site Codes	Rationale for Inclusion
HPC	W	CATEV, DEL19, DEL9, DEL10, CWB1.5, CROGHC, CRO9	Supplemental Water Quality Information
Total/Genus Phytoplankton	W	RR1–RR4, NR1–NR4, PR1–PR4, CR1–CR3, ES, EM, EB, WS, WM, WB, SRR1CM, CATALUM, DEL17, DEL9, DEL10, CWB1.5, CROGH1CM, CRO1B, CRO1T, CRO143, CRO163, CRO183	Supplemental Water Quality Information
	3D	RDRRCM, NRR2CM, PRR2CM, WDTO, EARCM, SRR2CM, CATLEFF, DEL18, CROGH	

3D = 3 days/week
4D = 4 days/week
5D = 5 days/week
7D = 7 days/week
5D/7D = 5 days/week if Croton is off-line, 7 days/week if Croton is on-line.
W = weekly
W/D or W/5D = routinely weekly, but daily or 5D if active intake
M = Monthly
CROGH daily monitoring requirement met at optimal sampling location when Croton is off-line

Data Analysis and Reporting

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

5.2 Reservoir 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.

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.

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

Reservoir	Sites					
Catskill						
Ashokan	1EA	1.4EA[1]	2EA	3EA	3.2EA[2]	4EA
Schoharie	2SS	3SS				
Delaware						
Rondout	1RR	2RR	3RR			
Neversink	1NN	2NN	3NN			
Pepacton	3EDP	4EDP	5EDP			
Cannonsville	3WDC	4WDC	5WDC			
East of Hudson						
Kensico	1.1BRK	2BRK	3BRK	4BRK	5BRK	
New Croton	1CNC	3CNC	4CNC			
West Branch	1CWB	2CWB	3CWB			

[1]Temperature and turbidity only.

[2]Turbidity only. Site 3 Hydrolab readings are used as a surrogate for Site 3.2 to avoid Hydrolab problems. Phytoplankton analyses will only be conducted during the full reservoir survey of the month on the 3-meter sample at all sites and at all sampling depths at intake sites.

Analytes and Frequencies

The analytes selected are those that are commonly used for determining drinking water quality. They include turbidity, specific conductivity, color, temperature, pH, dissolved oxygen, scent, total coliform, fecal coliform, and phytoplankton (total count, dominant genus 1 and count, dominant genus 2 and count). Total Fe and total Mn are analyzed as needed for operation of the Croton supply. Iron and manganese are included because they impart taste and color to the finished water. Dissolved oxygen is included because of the impact of low oxygen concentrations on Fe and Mn concentrations. The rationale for all the other analytes can be found in Table 5.2.

Terminal reservoirs (Kensico, New Croton, West Branch, Rondout, and Ashokan) will be collected twice a month. One survey is an Operations support survey, while the other is described under status and trends objectives (Sections 3.2.2 and 5.8 (status), and 5.2.6 and 5.11 (trends)). This schedule will provide management with more frequent data needed for these important reservoirs. All other reservoirs listed above will be sampled once per month. Of course if conditions change, additional sampling may be required by management. All samples are to be collected from March through December if weather conditions permit.

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.

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 Non-Routine Contaminants (i.e., Pesticides, VOCs, Trace and Other Metals, and Algal Toxins)

Objective

The purpose of this objective is to keep apprised of potential and emergent contaminants in the NYC water supply system. Select sites will be sampled to evaluate existing conditions by comparison with current standards where applicable. 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 will be applied to selected contaminants in this section.

Background

Reservoirs represent a collective summary of water quality conditions in the watershed. Contaminants from the watershed can either pass through the reservoir, precipitate or settle to the sediments or in some cases, bioaccumulate in the food web. Contaminants (e.g., metals) may also become available when low oxygen causes reduced species to solubilize (Stumm and Morgan 1996).

The keypoints are important for ensuring that reservoir water meets applicable standards before entering the distribution system**.** To keep apprised of existing conditions, selected contaminants and sites are monitored and compared with current standards. For emerging contaminants, literature results will be reviewed and a monitoring plan proposed as standards are developed. A monitoring plan will also be developed for algal toxins as part of this objective.

Sites

These keypoint sites have been part of DEP's long-established monitoring program. The West of Hudson sites provide information on the status of upstream reservoirs while the East of Hudson sites provide information on water entering and leaving terminal reservoirs. Table 5.4 provides a list of the sites for monitoring pesticides, volatile organic hydrocarbons (VOC) and semi-volatile organic hydrocarbons (SVOC). Table 5.5 provides a list for the trace metal monitoring sites.

Table 5.4: Keypoints for pesticides, VOC and SVOC monitoring.

Site Code	Site Description	Reason for Site Selection
East of Hudson		
CATLEFF	Catskill Lower Effluent Chamber	Catskill intake on Kensico
CROGH	Croton Gate House	Croton Aqueduct intake
DEL10	Delaware Shaft 10	Delaware intake on West Branch
DEL18	Delaware Shaft 18	Delaware intake on Kensico
West of Hudson		
EARCM	Ashokan Intake	Represents Ashokan water
NRR2CM	Neversink Intake	Represents Neversink water
PRR2CM	Pepacton Intake	Represents Pepacton water
SRR2CM	Schoharie Intake monitoring site	Schoharie water entering Esopus
RDRRCM	Rondout Intake	Represents Rondout water
WDTO	West Delaware Tunnel Outlet	Represents Cannonsville water

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.

Table 5.5: Keypoint sampling sites for trace and other metal occurrence monitoring.

Reservoir Basin	Site(s)
Catskill	
Ashokan	EARCM
Schoharie	SRR2CM
Delaware	
Cannonsville	WDTO
Pepacton	PRR2CM
Neversink	NRR2CM
Rondout	RDRRCM
East of Hudson	
Kensico	CATALUM, CATLEFF, CATEV, DEL17, DEL18, DEL19
Croton[1]	CROGH, CROGH1CM[2], CROGHC, CRO9
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 analytes and frequency for pesticides, SVOC, and VOC monitoring is provided in Table 5.6.

Table 5.6: Pesticides, VOC, and SVOC monitoring—analytes and frequency of monitoring. Analyses are performed by a contract laboratory.

Analyte	Sampling Frequency	Rationale for Analyte
USEPA Method 524.2 (VOC)	Yearly	Synoptic survey
USEPA Method 525.2 (SVOC and pesticides)	Yearly	Synoptic survey

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, Ni, Pb, Sb, Se, Tl and Zn.

Samples are to be collected during the months of February, May, August, and November. CROGH and other Croton sites may be sampled for Fe and Mn at a higher frequency on an as-needed basis. In the event that the data suggest that there are unusual results, additional sampling may be requested.

As monitoring plans are developed for algal toxins and other emerging contaminants, new analytes will be considered for addition to this objective.

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 ($\mu g\ L^{-1}$)	Secondary Standard ($\mu g\ L^{-1}$)
Ag		100
Al		50-200
As	10	
Ba	2000	
Be	4	
Cd	5	
Cr	100	

Table 5.7: (Continued) USEPA National Primary and Secondary Drinking Water Quality Standards.

Analyte	Primary Standard (μg L^{-1})	Secondary Standard (μg L^{-1})
Cu	1300	1000
Fe		300
Hg	2	
Mn		50
Pb	15	
Sb	6	
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

References

Stumm, W. and J. J. Morgan. 1996. Aquatic Chemistry: Chemical Equilibria and Rates in Natural Waters. 3rd ed. Wiley-Interscience, New York.

5.5 Special Surveillance Projects

5.5.1 Crossroads Ventures Project

Objective

This program is a continuation of the Phase II sampling program of a four phase program designed to investigate surface water quality issues associated with the construction and operation of the proposed new resort on Belleayre Mountain, referred to as Crossroads Ventures ("CRV").

Background

Belleayre Mountain lies on the watershed divide between the Pepacton and Ashokan Reservoir basins. The proposed new resort will be built on the border of Ulster and Delaware Counties in the Towns of Shandaken and Middletown. The project includes two hotels, 259 lodging units, a conference center, spa, and organic golf course. The land is adjacent to the state-owned Belleayre Mountain Ski Center and will feature ski-in/ski-out recreational opportunities. The majority of the construction for this project will occur on the Pepacton side of the divide.

DEP anticipates that possible impacts to ambient water quality from this development may include increased turbidity during construction, and increased nutrient and pesticide concentrations in local streams as a result of fertilizers and pesticides that may be required to maintain the golf courses and other landscaping.

The CRV proposal has not yet completed State Environmental Quality Review (SEQR) and construction plans are not finalized; therefore, this program must remain flexible to respond to shifts in location of the construction activity. Also, Phase III monitoring will occur once construction begins, and would include storm event monitoring. Upon the completion of construction, Phase IV monitoring would commence for monitoring for post-development changes in water quality.

Sites

Table 5.9 provides the sites that will be monitored for this study.

Table 5.9: Crossroads Ventures Project monitoring sites.

Site Code	Site Description	Reason for Site Selection.
BELLEGIG	Giggle Hollow	Control Site
BELLE5	Unnamed trib. near Wild Acres Hotel	Located in Project Area
BELLETOD	Trib. near Todd Mtn. Road	Control Site

Analytes and Frequencies

Table 5.10 provides the analytes that will be monitored for this study.

Table 5.10: Analytes that will be monitored for the Crossroads Ventures Project.

Analyte	Sampling Frequency	Rationale for Analyte
Flow (WQD)[1]	Continuous	Required for flow adjustment and load determination.
Temperature	Monthly	Important in the regulation of biotic community structure and function, and critical in regulating the chemical composition of water.
NH_x-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.
TP	Monthly	Pool of dissolved and particulate P
TSS	Monthly	Interferes with disinfecting processes, mechanism of pathogen transport. Included as a system specific characteristic in the NYC Watershed Rules and Regulations.
Turbidity	Monthly	Related to a site's suspended solids concentration and water clarity, NYSDEC Water Quality Regulation/Part 703 narrative standard.
Fecal Coliform	Monthly	Indicator of potential pathogen contamination, NYSDEC Water Quality Regulation/Part 703 water quality standard.
Macroinvertebrates	Annually	Will assist with assessment of project's impact.

[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 that have been previously collected were used to calculate export coefficients for tributaries on Belleayre Mountain to assist in modeling the impacts of the proposed development on water quality. The data collected in Phase II will be summarized and used to refine the Phase III sampling that will occur once construction commences. The water quality data collected prior to the start of construction will be also compared to data gathered during and after the construction phases of the project in order to assess the project's impact, or lack thereof, on ambient water quality.

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 April through November, 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 frequency of monitoring, however, is different for the East of Hudson reservoirs than the West of Hudson reservoirs, due to the increased potential for infestation in the East of Hudson reservoirs, although the methods used are the same.

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. These reservoirs are monitored on a monthly basis beginning April and ending during the month of November. Additional sampling, however, occurs on a bi-weekly basis (twice per month) during the months of July, August, and September in these East of Hudson reservoirs.

The West of Hudson Reservoirs sampled include: Ashokan, Schoharie, Rondout, Neversink, Pepacton, and Cannonsville. The reservoirs are monitored in June, August, and October of each year.

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 and pump sampling (veliger) sites.

Table 5.11: NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method	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

Table 5.11: (Continued) NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method	Reason for Selection
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	S,P	Impact area
A-2	Ashokan	West Gate House	BV,P	Impact area
A-3	Ashokan	West Gate House	S	Impact area
S-1	Schoharie	Chamber Deck-Left	S	Impact area
S-2	Schoharie	Chamber Deck-Center	BV	Impact area
S-3	Schoharie	Chamber Deck-Right	S	Impact area
S-4	Schoharie	Boat Ramp Area	P	Likely area of introduction
S-5	Schoharie	Gate 22 Area	P	Impact area
	Cannonsville	2 WDC, DEP Launch	P	WQD sampling site
C-2	Cannonsville	3 WDC, Dry Brook launch	P	WQD sampling site
C-3	Cannonsville	5 WDC, Chamberlain Brook launch[1]	P	WQD sampling site
P-1	Pepacton	1 EDP, Dam Area	P	WQD sampling site
P-2	Pepacton	3 EDP Rt. 30 Fishing Access	P	WQD sampling site
R-1	Rondout	1 RR Dam Area	P	WQD sampling site
R-2	Rondout	3 RR,,, Monument Area	P	WQD sampling site
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

Table 5.11: (Continued) NYCDEP zebra mussel monitoring locations and methods. Analytical services are contractor-provided.

Sampling Site	Reservoir	Location	Sampling Method	Reason for Selection
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				
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
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]This site may be removed following completion of the recreational boating pilot project.

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 June, August, and October from each West of Hudson reservoir. Two integrated pump samples (0-5m) are collected monthly (April–November) from each East of Hudson reservoir and twice 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, in general they have water quality parameters that would more likely support zebra mussel populations. They are located near unregulated water bodies that have water quality that could support zebra mussel populations, and they are close to the Hudson River, where zebra mussels are present.

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. These artificial substrates and bridal veils are pulled once per month (in the East of Hudson Reservoirs) and in June, August, and October (in the West of Hudson reservoirs) for analysis and replaced at that time. The first set of plates for the West of Hudson reservoirs is set in April, along with the first set of plates set in the East of Hudson reservoirs. (Note: Artificial substrates and bridal veils are set offshore in the Catskill and Delaware Systems. DEP personnel will set and retrieve the offshore substrates and bridal veils for the four Delaware reservoirs. Substrate and bridal veil samplers in the Croton and Catskill Systems are set offshore and are set and retrieved by the contractor. The boat and boat operator are provided by DEP. Water clarity and water temperature are measured at each sampling location on a monthly basis as part of the scheduled 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 Monitoring Effects of Cannonsville Recreational Boating Pilot Project

Objective

Recreational boating activities will be allowed on Cannonsville Reservoir from Memorial Day to Columbus Day for the next three years. Under this objective, DEP will assess the impacts to the reservoir from this new, unprecedented activity.

Background

Recreational boating has not previously been allowed on Cannonsville Reservoir, and the possibility exists that it may introduce zebra mussels into the reservoir and/or impact water quality. DEP already samples Cannonsville Reservoir for zebra mussels and water quality; under this program, that sampling will be expanded to enhance DEP's ability to detect impacts from these boating activities.

Sites

Sampling for zebra mussels will be performed at Cannonsville sites 1-5WDC. Although monitoring in areas where a high frequency of boating activity is expected (e.g., in the vicinity of a boat launch) is currently performed elsewhere in the reservoir, it has not until now been performed in the part of the reservoir where site 5WDC is located. The new sampling site near the boat launch at Chamberlain Brook will fill this gap. Water quality sampling will be performed at Cannonsville sites 1-6WDC. At sites 1WDC and 3-6WDC, water quality sampling for the required analytes (see below) is already being performed under other monitoring objectives. Water quality sampling at site 2WDC has been added for this objective due to the existence of a long-term historical record at the site.

Sampling methods are presented in Table 5.11. Pump samples will be collected by the contractor; all other zebra mussel monitoring (substrates, bridal veil), as well as water quality monitoring, will be performed by DEP personnel.

Analytes and Frequencies

Samples for both zebra mussels and water quality will be collected monthly from May-October. Water quality samples will be collected at three depths at each site. The analytes are pH, temperature, dissolved oxygen, specific conductance, color, turbidity, TN, TP, total coliform, and fecal coliform.

Data Analysis and Reporting

WWQSR will perform a preliminary assessment of the effects of the boating program on water quality in 2010 and 2011. The results will also be reported in the Watershed Water Quality Annual Report following each year of the study.

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 2002), 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 5.12.

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 5.12: 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 at Brewster (East Branch outflow)	Data are used in WQD Annual Report
DIVERTR	East Branch Croton River near Croton Falls (Diverting outflow)	Data are used in WQD Annual Report

Table 5.12: (Continued) Sampling sites for Croton streams (non-FAD watersheds) status objective.

Site Code	Site Description	Reason for Site Selection
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 5.13. 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 5.13: 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

Table 5.13: (Continued) List of analytes for Croton streams (non-FAD watersheds) status objective.

Analyte	Sampling Frequency	Rationale For Analyte
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.
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 5.13, 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, 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.

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 2002), 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 5.14. 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 5.14: 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	1CA	3CA					
Titicus	1CT	3CT					
Diverting	1CD	2CD					
Middle Branch	1CMB	3CMB					
East Branch	1CEB	3CEB[1]					
Bog Brook	1CBB	3CBB[1]					
Kirk Lake	1CKL						
Lake Gleneida	1CGL						
Lake Gilead	1CGD						

[1]These sites only get sampled for fecal coliform.

Analytes and Frequencies

A list of analytes and reasons for their inclusion are provided in Table 5.15. 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 5.15: List of analytes for Croton reservoirs (non-FAD reservoirs) 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
Conductivity	Monthly (Apr.–Nov.)	Measured surrogate for total inorganic ions

Table 5.15: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status objective.

Analyte	Sampling Frequency[1]	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[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/Part703 water quality standard
Dissolved Chloride[4]	May, August, November	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[4]	May, August, November	End product of acid deposition, source of S^{-2} during anoxia
Dissolved K[4]	May, August, November	Na/K ratio used to determine and characterize hydrologic flow path
Dissolved Mg[4]	May, August, November	Ca/Mg ratio used to determine and characterize hydrologic flow path
Dissolved Na[4]	May, August, November	Major component of road salt
Dissolved Ca[4]	May, August, November	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity[4]	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[5]	Monthly (Apr.–Nov.)	Useful in assessing primary productivity and trophic state
Phytoplankton[5]	Monthly (Apr.–Nov.)	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards

Table 5.15: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status objective.

Analyte	Sampling Frequency[1]	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
Total Storage	Daily	Explanatory variable used to assist in interpretation of water quality variables

Table 5.15: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) status objective.

Analyte	Sampling Frequency[1]	Rationale for Analyte
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. The three controlled lakes (Gilead, Gleneida, and Kirk), however, will only be sampled in May, August, and October.

[2]Photic depth to be measured at dam sites only, at 1-m intervals.

[3]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.

[4]Filtered: Ca, Na, K, Mg, Cl, SO_4, and alkalinity. Samples collected in May, August, and November for Sites 1 and 3 on Croton Falls Reservoir, and at Site 1 on all other Croton System reservoirs and controlled lakes.

[5]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, 2002. Rules and Regulations for the Protection from Contamination, Degradation, and Pollution of the New York City Water Supply. Valhalla, NY. 132 p.

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 2002, 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 5.16 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 benthos?
- 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 5.16: 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 1
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	Years 1 and 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 4
107	Kisco River at Rte. 133, Mt. Kisco	Monitoring site for Kisco River in Mt. Kisco	Year 3
108	Kisco River at KISCO3	Inflow to reservoir	Year 5
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 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 2
140	Titicus River upstream of June Road crossing	Inflow to reservoir	Year 3

Table 5.16: (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]
141	Tonetta Brook	Examination of impacts to benthic macroinvertebrate community from pollution sources	Year 3
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 5
154	Muscoot River upstream of confluence with Hallocks Mill Brook	Monitor impact to benthic macroinvertebrate community of upgrade to wastewater treatment plant	Year 1

[1]Status sites are sampled on a 5-year rotating basis. Year 1 = 2009, Year 2 = 2010, Year 3 = 2011, Year 4 = 2012, Year 5 = 2013.

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); and the Hilsenhoff Biotic Index (a measure of organic pollution)). 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 5.11 (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 overlaps with routine stream sampling, whose list of required analytes includes those specified here.

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 [Department of Environmental Conservation]. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. Albany, NY. 116 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 5.17. 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. One site, Holly, was selected to evaluate impacts from development. 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.

Table 5.17: 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.
PLUM2	Plum Brook	Downstream monitoring site of Plum Brook above Muscoot 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.

Table 5.17: (Continued) Sampling sites for Croton streams (non-FAD watersheds) trends objective.

Site Code	Site Description	Reason for Site Selection
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.
HOLLY	Holly Stream at confluence with Diverting Release	To determine impacts from development (Meadows at Deans Corner).
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 5.18 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 5.18: 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.
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.

Table 5.18: (Continued) List of analytes for Croton streams (non-FAD watersheds) trends objective.

Analyte	Sampling Frequency	Rationale for Analyte
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

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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 5.19 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 5.19: 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	1CA	3CA					
Titicus	1CT	3CT					
Diverting	1CD	2CD					
Middle Branch	1CMB	3CMB					
East Branch	1CEB	3CEB[1]					
Bog Brook	1CBB	3CBB[1]					
Kirk Lake	1CKL						
Lake Gleneida	1CGL						
Lake Gilead	1CGD						

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

Analytes and Frequencies

A list of analytes and reasons for their inclusion are provided in Table 5.20. 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, conductivity, temperature, and dissolved oxygen) will be collected through the water column. The time interval between monthly surveys shall be consistent.

Table 5.20: List of analytes for Croton reservoirs (non-FAD reservoirs) trends 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

Table 5.20: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) trends objective.

Analyte	Sampling Frequency[1]	Rationale for Analyte
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 Chloride[4]	May, August, November	Major component of road salt, indicator of septic system failures and other anthropogenic sources
Dissolved SO_4[4]	May, August, November	End product of acid deposition, source of S^{-2} during anoxia
Dissolved Na[4]	May, August, November	Major component of road salt
Dissolved Ca[4]	May, August, November	Essential mineral for zebra mussels, Ca depletions observed in forested catchments, Ca/Na ratio used to determine anthropogenic impacts
Alkalinity[4]	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[5]	Monthly (Apr.–Nov.)	Useful in assessing primary productivity and trophic state
Phytoplankton[5]	Monthly (Apr.–Nov.)	Indicators of nutrient enrichment, useful in predicting taste and odor problems, and to manage for compliance with WQD standards

Table 5.20: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) trends objective.

Analyte	Sampling Frequency[1]	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 5.20: (Continued) List of analytes for Croton reservoirs (non-FAD reservoirs) trends objective.

Analyte	Sampling Frequency[1]	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]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.

[2]Photic depth to be measured at dam sites only, at 1-m intervals.

[3]TSS analyzed monthly at dam and intake sites for New Croton Reservoir. TSS to be analyzed quarterly at dam sites for EOH reservoirs and controlled lakes.

[4]Filtered: Ca, Na, K, Mg, Cl, SO_4, and alkalinity. Samples collected in May, August, and November for Sites 1 and 3 on Croton Falls Reservoir, and at Site 1on all other EOH reservoirs and controlled lakes.

[5]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

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.

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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. No trends in the condition of stream benthic communities have been observed thus far.

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); and the Hilsenhoff Biotic Index (a measure of organic pollution)). 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 5.11. No additional sampling effort is required to collect these field analytes because in most cases collection overlaps with routine stream sampling, whose list of required analytes includes those specified here.

Sites are sampled annually, as per the NYSDEC protocols employed by DEP (NYSDEC 2002). 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

Long-term trends in the condition of the macroinvertebrate communities of watershed streams is presented in the Watershed Protection Program Summary and Assessment Report, which is produced every five years and is a FAD requirement. An upward or downward trend is deemed to have occurred when a site assesses at a higher or lower category of impairment for at least three consecutive years.

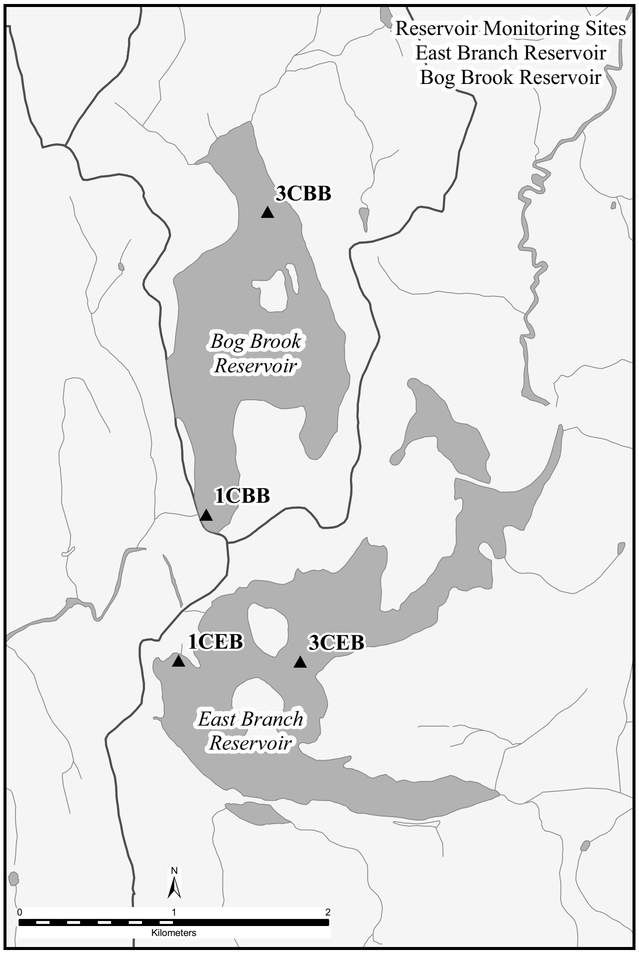
References

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

NYSDEC [Department of Environmental Conservation]. 2002. Quality Assurance Work Plan for Biological Stream Monitoring in New York State. Albany, NY. 116 p.

Appendix I - Limnological Sampling Site Maps

(All sites are displayed. Sites required for specific objectives are listed in the text.)



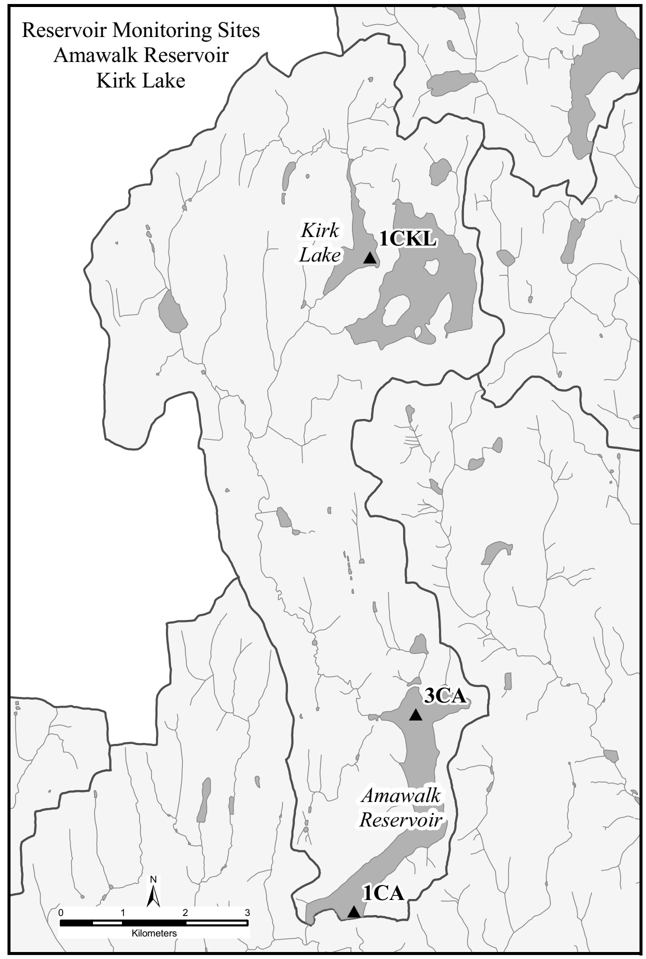


Figure A.1 Reservoir monitoring sites - East Branch Reservoir - Bog Brook Reservoir.

Figure A.2 Reservoir monitoring sites - Amawalk Reservoir - Kirk Lake.

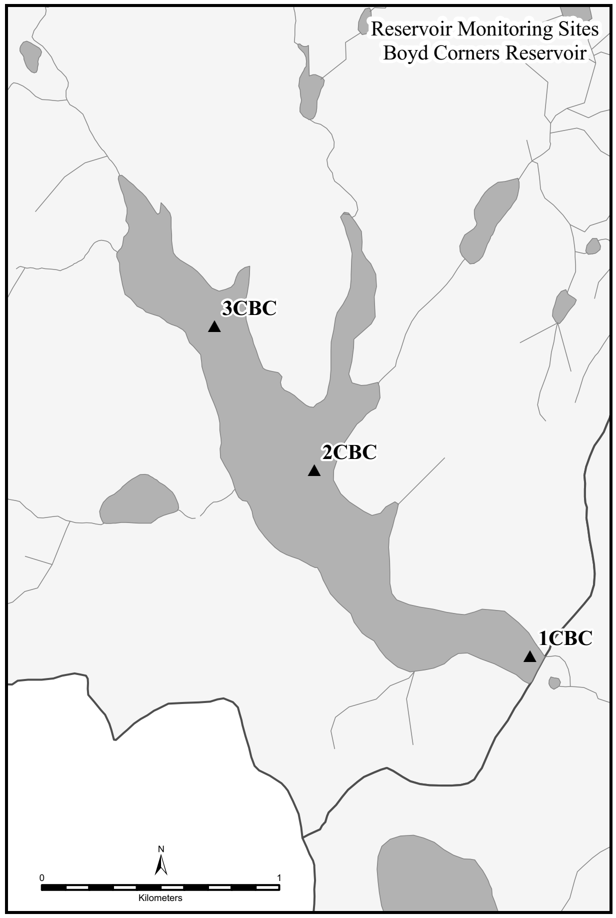


Figure A.3 Reservoir monitoring sites - Boyd Corners Reservoir.

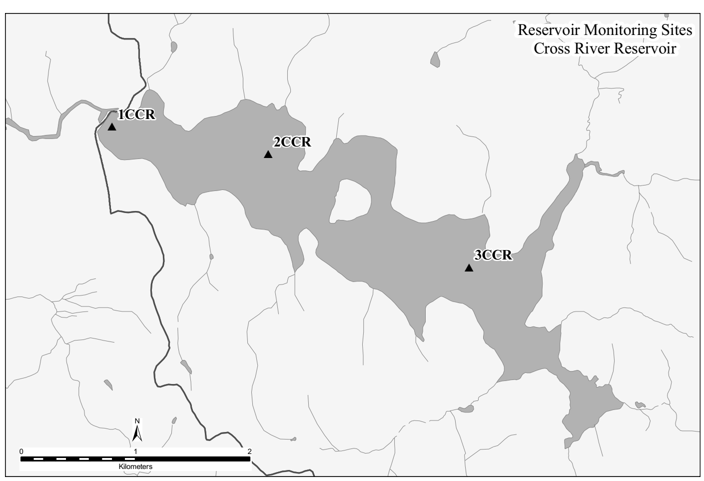


Figure A.4 Reservoir monitoring sites - Cross River Reservoir.

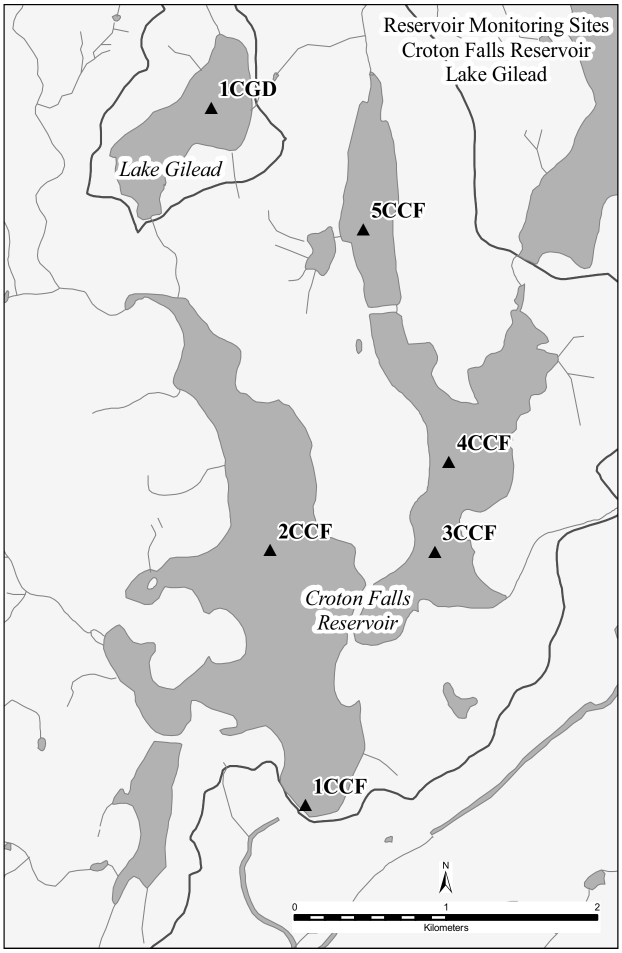


Figure A.5 Reservoir monitoring sites - Croton Falls Reservoir - Lake Gilead.

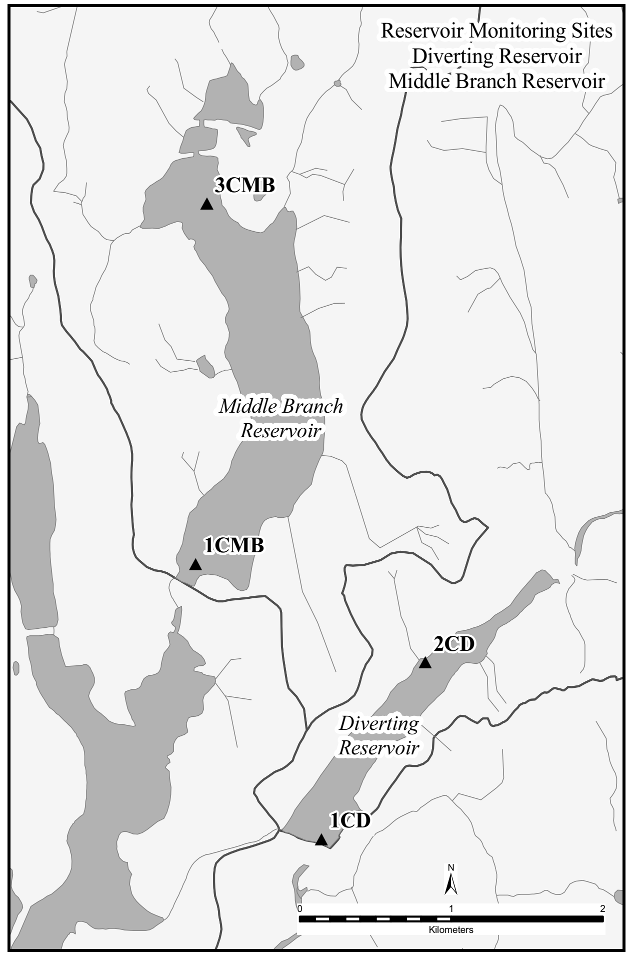


Figure A.6 Reservoir monitoring sites - Diverting Reservoir - Middle Branch Reservoir.

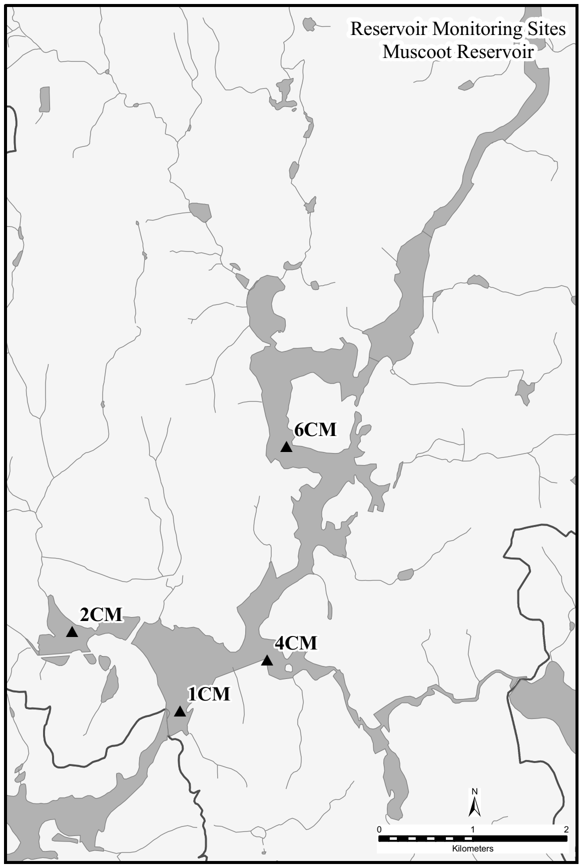


Figure A.7 Reservoir monitoring sites - Muscoot Reservoir.

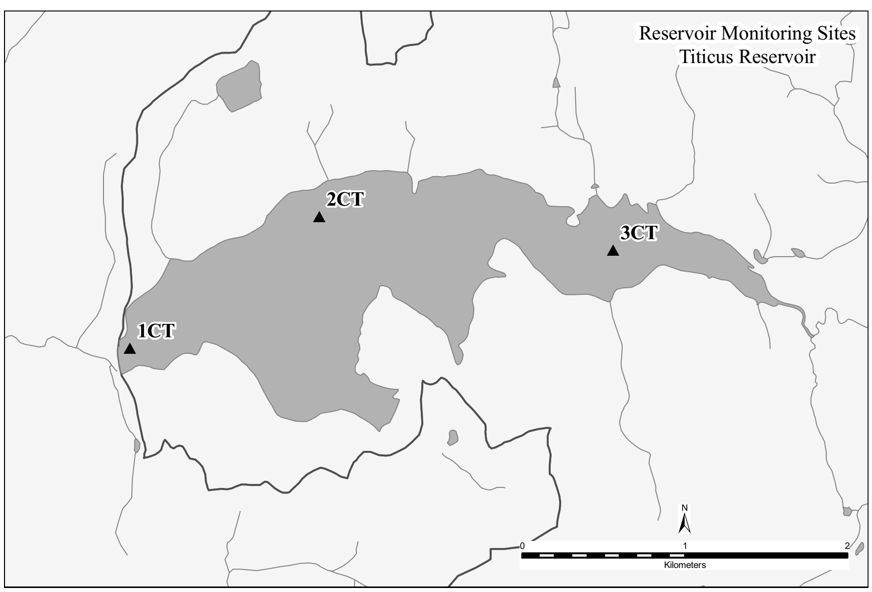


Figure A.8 Reservoir monitoring sites - Titicus Reservoir.

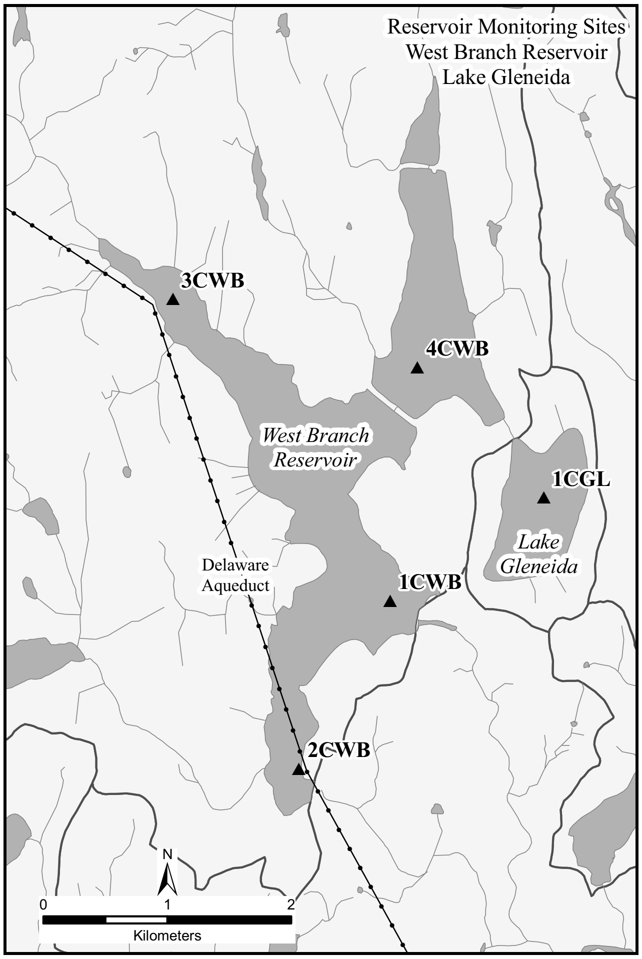


Figure A.9 Reservoir monitoring sites - West Branch Reservoir - Lake Gleneida.

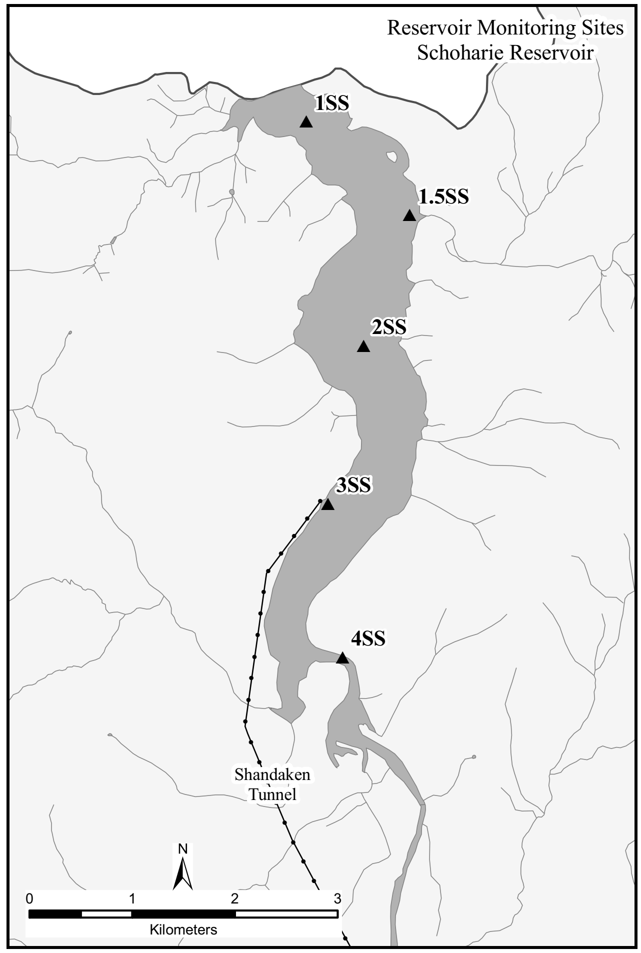


Figure A.10 Reservoir monitoring sites - Schoharie Reservoir.

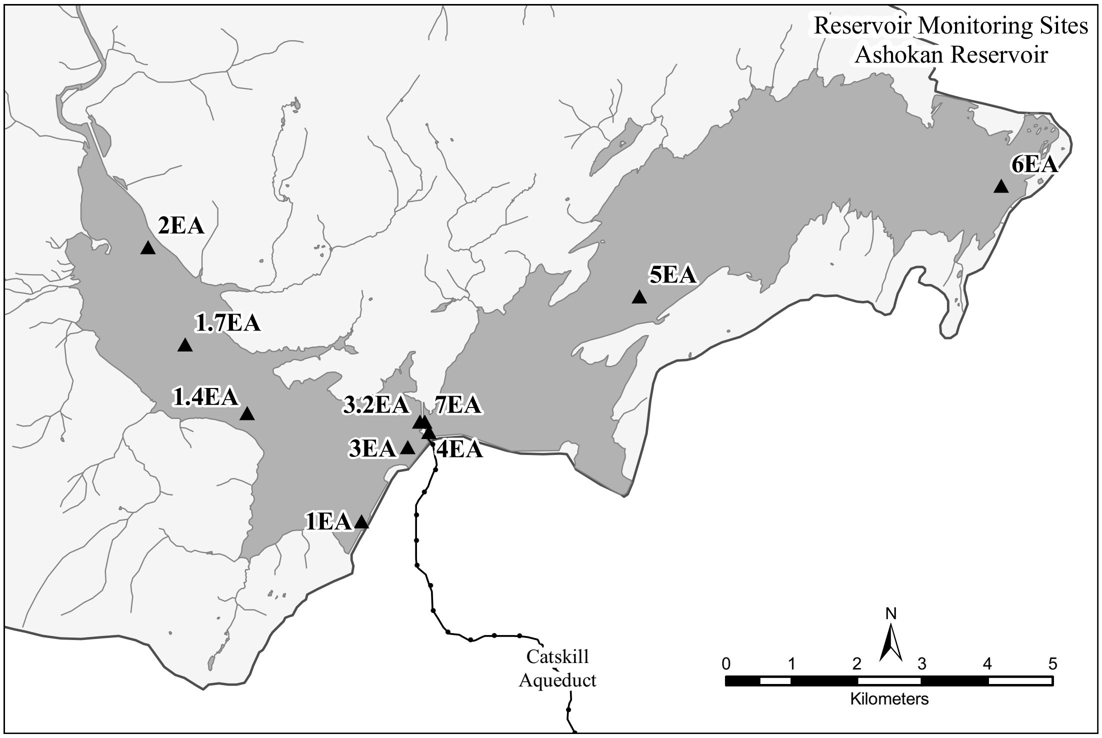


Figure A.11 Reservoir monitoring sites - Ashokan Reservoir.

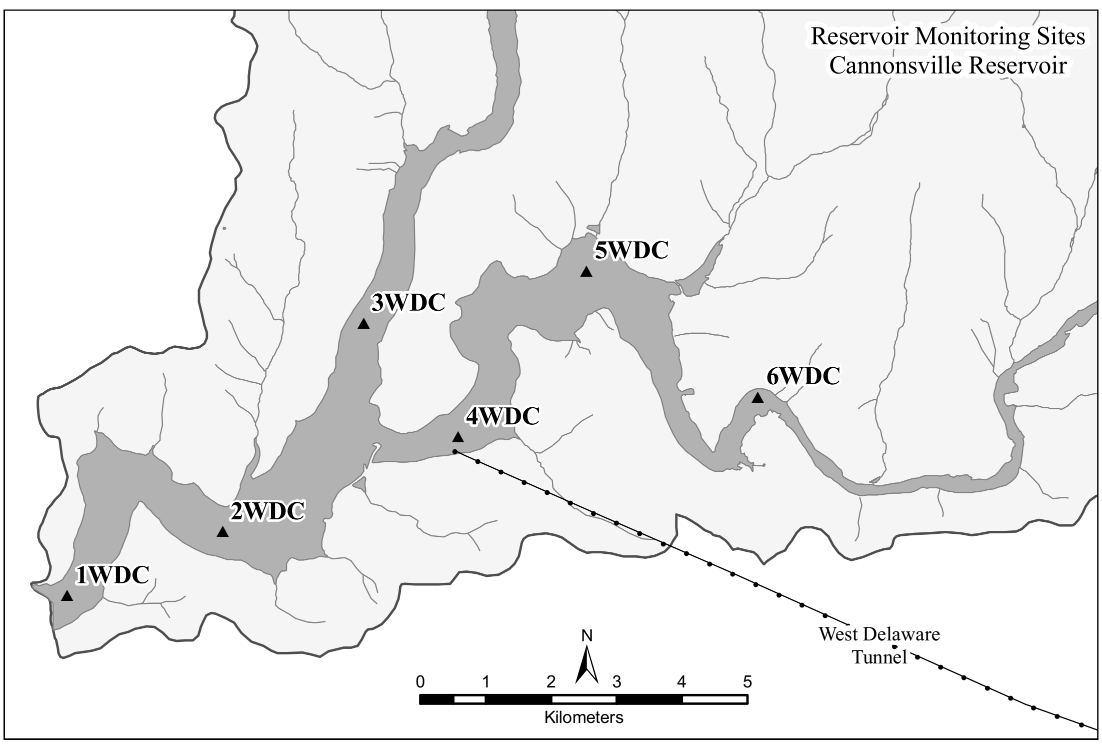


Figure A.12 Reservoir monitoring sites - Cannonsville Reservoir.

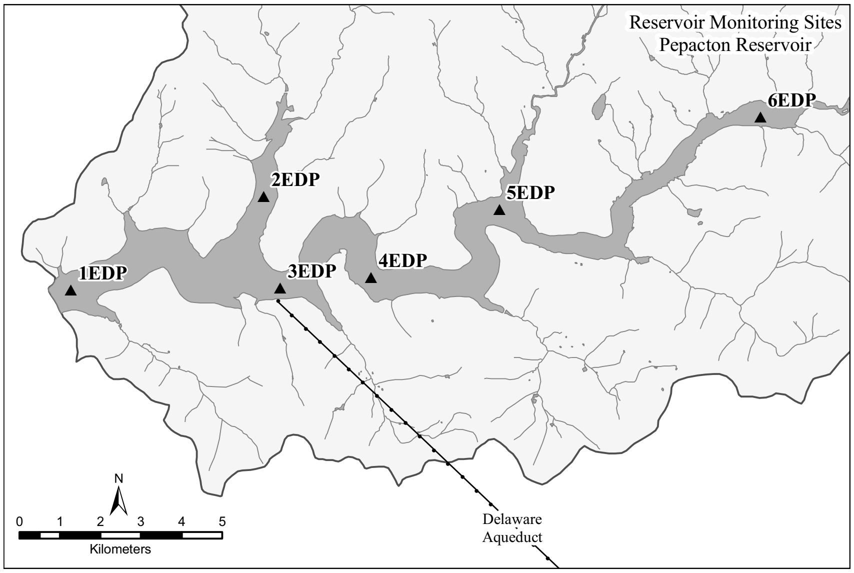


Figure A.13 Reservoir monitoring sites - Pepacton Reservoir.

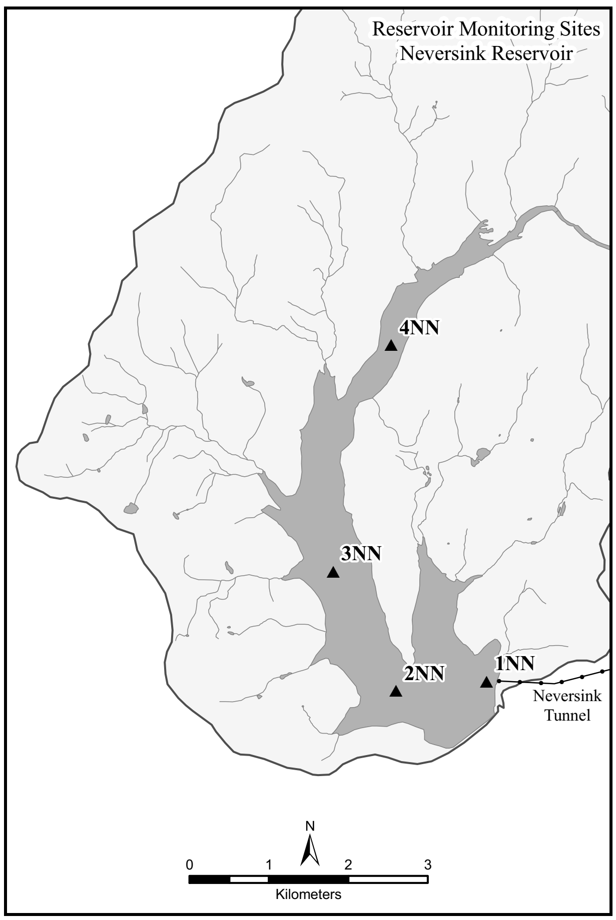


Figure A.14 Reservoir monitoring sites - Neversink Reservoir.

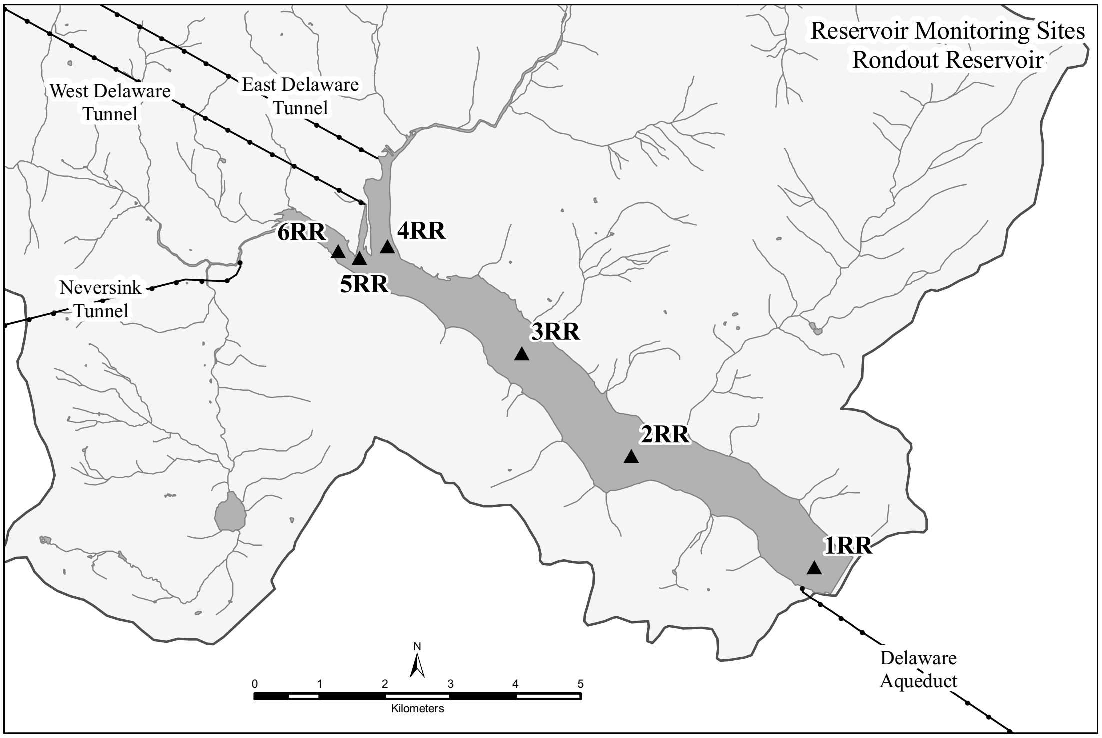


Figure A.15 Reservoir monitoring sites - Rondout Reservoir.

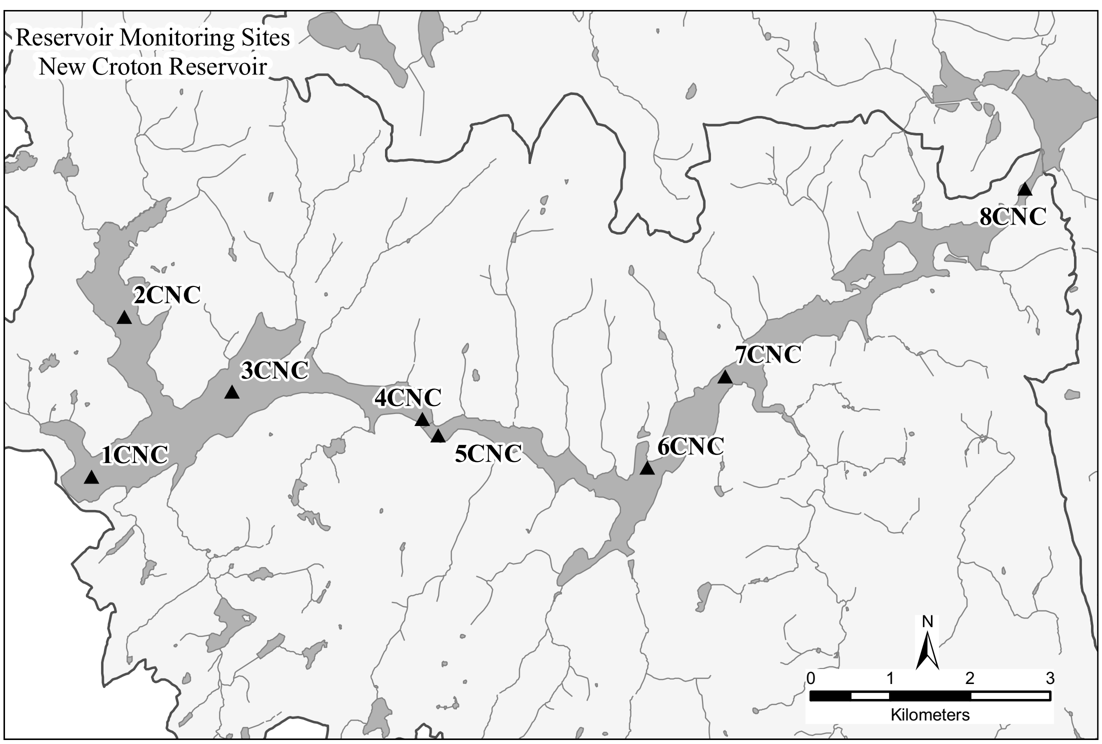


Figure A.16 Reservoir monitoring sites - New Croton Reservoir.

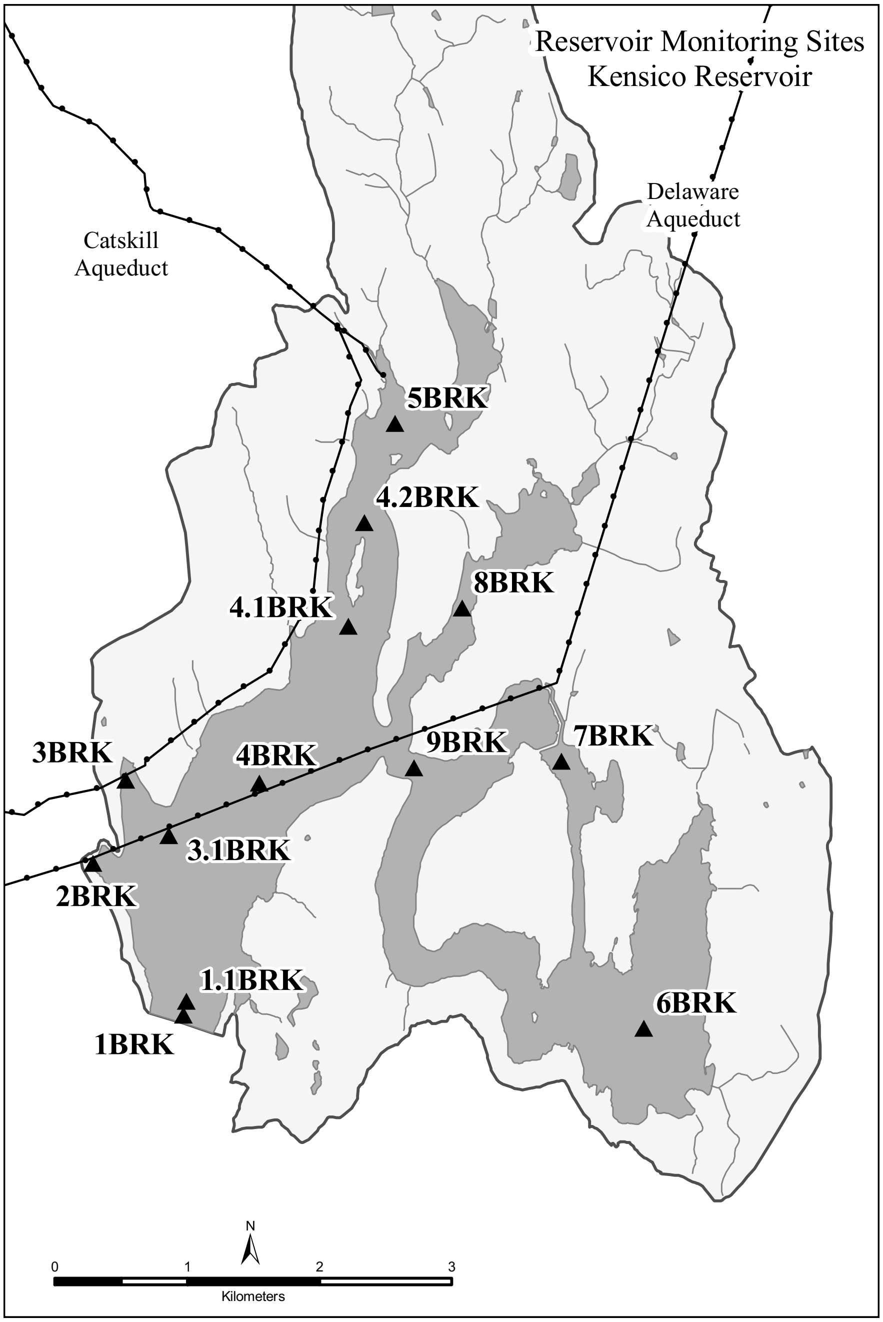


Figure A.17 Reservoir monitoring sites - Kensico Reservoir.

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 $3 \leq Zth \leq Zmax-4$ 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 $3 \leq Zth \leq Zmax-4$ and $Zth \leq Zmax/2$ (**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 $3 \leq Zth \leq Zmax-4$ 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

Watershed Water Quality Monitoring Plan - ADDENDUM
Document Control No. [AOP 3461.DOC]

Summary:

This document describes the procedure for making changes, edits, additions or subtractions to the 2008 Watershed Water Quality Monitoring Plan (WWQMP). The WWQMP was submitted to the USEPA on October 31, 2008 as a FAD requirement. 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 2008 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 WWQSR & WQO 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 Supervisor of Publications and Reporting (P. Girard), with copies to:
   a. Director (S. Schindler)
   b. Chiefs (L. Janus & L. Emery)
   c. Deputy Chiefs (A. Bader, C. Cutietta-Olson, J. Broderick)
   d. Section Chiefs (J. Mayfield, D. Pierson, K. Alderisio, K. Lewis, B. Richardson, D. Borchert, R. Aquino)
   e. Field Operations Program Directors/Assistant Directors (K. Moore, P. Brown, K. Gabel)
   f. Laboratory Operations Directors (M. Rodden, L. Loos, D. Robinson, L. Blancero)
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 (P. Girard) 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.

References:

NYCDEP 2008. 2009 Watershed Water Quality Monitoring Plan.

WWQMP Changes; 20__ Addendum (indicate current year)

Program: ______________________
Program Supervisor:_____________________
WWQMP Objective affected:__________________

Description of specific change: (include # of sites, samples, analytes, frequency, etc.)
____
____
____

Justification for change: (answer 'why' the changes should be made)
____
____
____

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 (S. Schindler) (yes/no) _______________
b. Watershed Division Chiefs:
WWQSR (L. Janus)(yes/no) _______________
WWQO (L. Emery)(yes/no) _______________

Appendix IX - Benchmarks as listed in the Watershed Rules and Regulations for Reservoirs, Controlled Lakes, and Streams

Appendix Table 1: Reservoir and controlled lake benchmarks as listed in the Watershed Rules and Regulations.

Analyte	Croton System		Catskill/Delaware System		
	Annual Mean	Single Sample Maximum	Annual Mean	Single Sample Maximum	Basis
Alkalinity (mg L^{-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 as listed in the Watershed Rules and Regulations.

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

Appendix Table 2: (Continued) Stream water quality status benchmarks as listed in the Watershed Rules and Regulations.

Analyte	Croton System		Catskill/Delaware System (including Kensico)	
	Annual Mean	Single Sample Maximum	Annual Mean	Single Sample Maximum
Organic Nitrogen	0.5	1.5	0.5	1.5
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