New York City
Department of Environmental Protection

2006 Watershed Protection Program Summary and Assessment

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This photo of a rainbow over the Pepacton Reservoir spillway was taken by
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Acknowledgements

We dedicate this volume to Michael A. Principe, Ph.D.. His wisdom and leadership over the last 25 years helped guide development of the extensive array of watershed protection programs described in this volume. Mike started his career with NYCDEP as its first limnologist, advanced through the ranks to become the Director of the Division of Drinking Water Quality Control, and eventually became Deputy Commissioner and Director of the Bureau of Water Supply. He was responsible for building several of the Divisions within the Bureau of Water Supply, and for guiding their coordination to result in the comprehensive watershed protection program that exists today. NYCDEP's program has been the subject of extensive review by numerous organizations, such as the National Research Council, and we take pride in the fact that it is viewed as a model for the nation. Much of the success of the watershed programs is due to Mike's personal contribution of technical ability, vision, and dedication to the preservation of the City's watershed and excellent water quality, which will serve New Yorker's long into the future.

The staff carries on this mission of providing excellent water to the City. This volume consists of both a description of the implementation of the many programs referred to above, followed by an examination of their effects on water quality, over more than the last decade. A task of this magnitude has required the active participation and personal interest of several hundreds of staff members to make these programs materialize; although the staff members are too numerous to mention here, their efforts are recognized and appreciated. In particular, the Divisions of Watershed Lands and Community Planning, Wastewater Treatment Plant Upgrade Program, Drinking Water Quality Control, and the support provided by the Divisions of Management Information Systems, Management Services and Budget, and the Watershed Office of Public Affairs are acknowledged. Within these Divisions are the individual program managers, who have presented the work of their staff members in the chapters written for this volume. Program managers, authors, editors, and publishing personnel of special note include: Kerri Alderisio; Pat Ahmetaj; Andrew Bader; Tom Baudanza; Larry Beckhardt; Melissa Beristain; Erika Boetsch; Jeff Graf; Lorraine Janus, Ph.D.; Kimberlee Kane, Ph.D.; Deborah Keesler; Ed Kunsch; Nancy Levine; Laurie Machung; Gerry Marzec; Bryce McCann; Jim Mayfield; Chris Nadareski; Don Pierson, Ph.D.; Bob Ravallo; Beth Reichheld; Terry Spies; Dave Smith, Ph.D.; Ted Simroe; Anne Seeley; John Schwartz; Elliot Schneiderman, Ph.D.; Ira Stern; Dave Tobias; John Tuscanes; Mike Usai; Rich Van Dreason; David Warne; and Mark Zion. A special note of thanks to Pat Girard, whose hard work and technical wizardry helped bring all the pieces together.

Executive Summary

New York City's Watershed Protection Program for the Catskill/Delaware Systems

The New York City Department of Environmental Protection (DEP) is the City agency responsible for operating, maintaining and protecting the City's water supply and distribution system. This document, *New York City's 2006 Watershed Protection Program Summary and Assessment*, has been prepared to comply with the November 2002 Filtration Avoidance Determination (FAD).

In the early 1990s, DEP embarked on an aggressive program to protect and enhance the quality of New York City's drinking water. In 1989, the federal Surface Water Treatment Rule (SWTR) was promulgated requiring filtration of all surface water supplies. The SWTR provided for a waiver of the filtration requirement if the water supplier could meet certain objective and subjective criteria. The City was able to demonstrate that the Catskill/Delaware supply met the objective criteria: (1) the source water met the turbidity and fecal coliform standards of the SWTR, (2) there were no source-related violations of the Coliform Rule, and (3) there were no waterborne disease outbreaks in the City. The subjective criteria of the SWTR required the City to demonstrate through ownership or agreements with landowners that it could control human activities in the watershed which might have an adverse impact on the microbiological quality of the source water.

To demonstrate its eligibility for a filtration waiver, DEP advanced a program to assess and address water quality threats in the Catskill/Delaware system. This program has provided the basis for a series of waivers from the filtration requirements of the SWTR (January 1993; December 1993; January 1997; May 1997, November 2002). As outlined in the SWTR, issues of concern fall into several categories: coliform bacteria, enteric viruses, *Giardia sp.*, *Cryptosporidium sp.*, turbidity, disinfection by-products, and watershed control. DEP has developed a comprehensive program to address each of these.

Assessing the Potential Threats to the Water Supply

Over the last decade, the City has made great progress in assessing the potential sources of water contamination and has designed and implemented programs to address these sources. As part of DEP's source water monitoring program, samples are collected and tests are conducted throughout the watershed – including sites at aqueducts, reservoirs, streams, and watershed wastewater treatment plants. Each year, DEP collects more than 35,000 samples from 300 sites and performs more than 300,000 laboratory analyses. The monitoring program's fundamental goals are to help manage the system to provide the best possible water, to develop a database through which water quality trends can be identified, and to identify water quality conditions of concern to focus watershed management efforts. The City's source water monitoring program was independently evaluated in 1997, by the National Research Council. The Council found the City's program to be "informed, extensive, and of high quality for a water supply of its size." The Council also noted that "the complexity of the multiple interacting reservoir ecosystems of the NYC water supply imposes major monitoring demands to allow for effective management responses to problems. In general, NYCDEP has been performing these formidable tasks excellently." Accordingly, findings of the City's peer-reviewed source water monitoring program have reliably served as the scientific basis for the City's watershed protection program.

Based upon the information collected through its monitoring and research efforts, DEP designed a comprehensive watershed protection strategy, which focused on implementing both protective (antidegradation) and remedial (specific actions taken to reduce pollution generation from identified sources) initiatives. DEP's assessment efforts pointed to several key potential sources of pollutants: waterfowl on the reservoirs; wastewater treatment plants discharging into watershed streams; failing septic systems; the approximately 350 farms located throughout the watershed; and stormwater runoff from development. DEP has crafted a protection strategy to target those primary pollution sources and a host of secondary ones.

Implementing the Watershed Protection Program & Achievements to Date

In January 1997, the New York City Watershed Memorandum of Agreement (MOA) was signed, ushering in a new era of watershed protection and partnership with numerous watershed stakeholders. The MOA signatories include the City, the State, EPA, watershed counties, towns, and villages and certain environmental and public interest groups. This unique coalition has come together with the dual goals of protecting water quality for generations to come and preserving the economic viability of watershed communities. The MOA established the institutional framework and relationships needed to implement the range of protection programs identified as necessary by the City, the State and EPA.

In November 2002, EPA issued a FAD that builds on the decade of research conducted by the City and the programmatic framework established by the MOA. The programs covered by the 2002 FAD demonstrate the City's continued commitment to long-term watershed protection. Core programs have been ongoing with vital support from and cooperation with the City's watershed partners. DEP and its partners have concentrated on the implementation of several key watershed protection initiatives: the Watershed Agricultural Program; the acquisition of watershed lands; the enforcement of improved Watershed Regulations; and the initiation and expansion of environmental and economic partnership programs that target specific sources of pollution in the watershed. In addition, the City continued its enhanced watershed protection efforts in the Kensico reservoir basin and advanced the upgrades of non-City owned watershed wastewater treatment plants. Key watershed protection program highlights include:

Watershed Agricultural Program – In the early 1990s, the City proposed extensive regulation of farms within the watershed. The farming community expressed concern that further regulation would drive farms out of business, leaving farmlands vacant and available for development. Recognizing the mutual benefits of a healthy, environmentally conscious farming community, the City teamed with upstate partners to develop the voluntary Watershed Agricultural Program. Working through the Watershed Agricultural Council, the City funds development of farm plans and implementation of structural and non-structural best management practices. To date, more than 95% of large farms in the watershed have Whole Farm Agreements in place, 91% of the farms have commenced implementation of their Whole Farm Plans, and 68% have substantially completed implementation. To date, more than 3,600 best management practices have been installed at a cost of $25 million. In addition, the City has augmented the program with the addition of a City/federal cost-sharing effort known as the Conservation Reserve Enhancement Program (CREP). CREP pays farmers to take sensitive riparian buffer lands, adjacent to waterbodies, out of active farm use and re-establish a vegetative buffer. More than 165 miles of farm stream buffers have been enrolled in the program.

Land Acquisition – The program has just completed its ninth year and to date the City has solicited owners of more than 355,050 acres of Catskill and Delaware land. In addition, the City has resolicited owners of more than 195,000 acres in high priority purchase locations. To date, DEP has more than 70,000 acres either acquired or under purchase contract, which triples the quantity of land held for watershed protection before the program began.

Watershed Regulations – On May 1, 1997, enhanced Watershed Rules and Regulations became effective, replacing regulations that had been in place since 1953. Since the new regulations became effective, DEP staff has reviewed thousands of applications for projects that proposed one or more regulated activities, requiring numerous changes to proposed development to better protect water quality.

Environmental and Economic Partnership Programs – The City, in conjunction with its partners, has continued to implement programs that have remediated more than 2,000 failing septic systems, upgraded 30 facilities that store winter road de-icing materials, and constructed stormwater BMPs in areas with previously uncontrolled stormwater runoff.

Wastewater Treatment Plant (WWTP) Upgrades – The five City-owned WWTPs in the Catskill/Delaware watershed – which account for 40% of the WWTP flow in the west of Hudson watershed – were upgraded to tertiary treatment in the late 1990s. There are 34 non-City-owned WWTPs in the Catskill/Delaware watershed, which account for the remaining 60% of west of Hudson WWTP flow. Plants accounting for more than 96% of that flow have completed upgrades, leading to substantial localized improvements in water quality.

New Infrastructure Program – the New Infrastructure Program constructs new WWTPs in identified communities with failing or likely to fail septic systems. Two plants have been completed, four are under construction and another plant is in the design phase.

Protection of Kensico Reservoir – The City has implemented a variety of programs to ensure protection of Kensico Reservoir. Construction of 45 best management practices designed to reduce pollutants conveyed to the reservoir by stormwater run-off is complete. A turbidity curtain is maintained to protect the Catskill Upper Effluent Chamber (CUEC) and waterfowl management continues to be exceptionally effective in maintaining low levels of fecal coliform bacteria. Spill containment facilities have been constructed to prevent migration of hazardous materials through the reservoir.

Assessing the Effectiveness of New York City's Watershed Protection Program

One of the primary purposes of this report is to evaluate quantitatively how effective the watershed programs have been since 1997, and will be over the long term. The City has taken a basin-by-basin approach, evaluating each reservoir in turn to assess the status and trends in water quality. The water quality analysis presented in this document is an extension of the analysis presented in the 2001 assessment of DEP's FAD programs. Here DEP presents an analysis covering 12 years of data collection and program implementation. Long-term data is critical in the evaluation of programs that cover large geographical areas and are implemented over long periods of time, so analyses will become better as the data record becomes longer. The approach DEP has used is to evaluate water quality in terms of: status, trends, case studies, and modeling. The status of waterbodies is based on three recent years of data (i.e., 2002 through 2004) and these are compared to regulatory benchmark values. The trends are based on twelve years of data (i.e., 1993 through 2004). Five important analytes were selected, including fecal coliforms, turbidity, phosphorus, conductivity and trophic status. Case studies were done for selected monitoring sites that had sufficient proximity and sampling intensity to demonstrate program effects. Modeling was conducted to attribute program effects to programs on a watershed-wide basis. All analyses together provide a context to understand program effects.

There are a number of factors that confound straightforward analysis of the effectiveness of the watershed programs. First, the quality of water from the City's Catskill and Delaware systems has been and continues to be excellent. Most parameters of concerns are detected at very low levels, if at all. With baseline quality so good, detecting improvements will continue to be a challenge. Second, year-to-year changes in hydrology can overwhelm any long-term trends in water quality. Third, due to the size of the system and intergrative nature of the reservoirs, real long-term trends can take many years to reveal themselves.

Water Quality Summary for the Catskill System

DEP has greatly enhanced watershed protection in the Catskill System drainage basins during the course of the FAD. Most notably, the WWTPs at Hunter, Windham, Tannersville, and Grand Gorge are currently state-of-the-art tertiary treatment facilities, with 19 smaller WWTPs in the process of being upgraded or consolidated. In the Schoharie basin, phosphorus loads were reduced from more than 750 kg yr^{-1} to less than 250 kg yr^{-1}. In the Ashokan basin, the Pine Hill WWTP and four other smaller plants are being upgraded. Phosphorus loading there was reduced from 220 kg yr^{-1} to about 50 kg yr^{-1}. Case studies at Tannersville and Grand Gorge WWTPs showed that the upgrades led to significant reductions (i.e., 40% and 27% of the former values) in phosphorus concentrations in the receiving streams. A case study of the Pine Hill WWTP showed that the median TP at a stream site below the plant was reduced from 25 µg L^{-1} to 15 µg L^{-1} after the plant was upgraded. WWTP upgrades have been highly effective in achieving significant reductions in phosphorus loadings to both receiving streams and reservoirs. These WWTP upgrades will prevent rapid, cultural (man-induced) eutrophication of these reservoirs.

Changes in both animal herds and WWTP operations have contributed to significant reductions of fecal coliform concentrations in streams. Fecal coliform median values in the Bear Kill decreased to about 50% of the former value coincident with removal of a dairy herd (of 700 head).

The water quality status in all three Catskill System reservoir basins during 2002 to 2004 was very good, with all of the median values for the selected analytes (i.e., fecal coliform, turbidity, TP, conductivity, and TSI) below the benchmarks. Water quality status in the East Ashokan basin was similar to the West Ashokan basin; the primary difference between the two was lower turbidity in the East Ashokan. Schoharie, West Ashokan, and East Ashokan are all mesotrophic with progressively higher indices traveling downstream. This spatial gradient is parallel to lower turbidity medians, as water moves downstream.

Water quality temporal trends in the tributaries and reservoirs showed significant declines in phosphorus concentrations, as a reflection of both the loading reductions and meteorological conditions (i.e., flood years followed by drought.) Trends for both the West and East Ashokan basins show that although phosphorus has declined, the trophic state index shows an increase that may be related to improvements in clarity following recovery from the 1995 to 1996 flood.

Flooding due to occasional heavy rains in the Catskills remains the dominant factor controlling water quality for this system. The sequential arrangement of basins allows settling of particulate material and improvement of turbidity along the way. As turbidity decreases, trophic status may increase, so a trade-off between turbidity and algae exists. Excellent water quality prevails for the majority of time when the impacts of intermittent floods subside to background levels.

Water Quality Summary for the Delaware System

Watershed hydrology plays an extremely important role in determining water quality status and trends in the Delaware System, as in other systems. It is, therefore, crucial to note that major runoff events occurred in 1996 (event of record in many watershed areas), 1999, and 2000, and that that drought conditions were present in 2001 and 2002. This was followed by a persistent wet period (2003 and 2004). These extreme circumstances largely controlled water quality.

Since the implementation of the MOA, the DEP has made tremendous improvements in watershed protection. Wastewater treatment plants in the Delaware System, have been substantially enhanced, and have resulted in significant reductions in phosphorus loading to the watershed streams. Land acquisition and conservation easement purchases have protected more than 31,000 acres of land from potential development across the four Delaware watersheds; and the Septic System Rehabilitation and Replacement Program have remediated over 900 septic systems.

The water quality status of all four Delaware System basins is currently very good. Recent data (2002-2004) for all selected variables (i.e., phosphorus, turbidity, conductivity, fecal coliforms, and trophic state) show that median values of these constituents are well below established benchmarks.

Trend analysis shows improvements in water quality were observed throughout the Delaware System over the study period (1993-2004). Downward trends in the concentrations of phosphorus, for example, were detected in Neversink Reservoir, as well as in the outputs (diversions) from Cannonsville and Rondout reservoirs. The decrease in phosphorus concentration within Cannonsville Reservoir is particularly significant as the reductions have allowed Cannonsville to be taken off the phosphorus-restricted status list (NYC-DEP 2004).

Turbidity levels also declined over the study period in Neversink's and Cannonsville's reservoir outputs. Treatment plant upgrades, land use changes, and recovery from flooding events (1995-96) are thought to be the main factors controlling the observed decreases in phosphorus and turbidity.

Fecal coliform levels exhibited little or no change throughout the watershed reservoirs during the time period. Levels of these bacteria are generally very low (~1 CFU 100 ml^{-1}) and trends at these low levels are of no practical significance.

Water Quality Summary for the East of Hudson Catskill/Delaware System

DEP has continued to enhance watershed protection and purchase additional land in the West Branch and Kensico basins. In the West Branch basin, two large and several small stormwater remediation sites have been constructed. In the Kensico basin 45 stormwater management and erosion abatement facilities have been constructed. The Malcolm Brook Cove turbidity curtain has been repaired (2002), replaced (2003), and extended (2004) to ensure that it continues to divert stormwater away from the Catskill Effluent Chamber. The Waterfowl Management Program continues its activities on and around Kensico reservoir to reduce the population of waterbirds.

Water quality was excellent during the 2002 – 2004 analysis period in West Branch and Kensico reservoirs with median values (of the monthly reservoir-wide medians) all well below the established benchmarks for fecal coliforms, turbidity, and total phosphorus. Conductivity was relatively low in both reservoirs. Both reservoirs are mesotrophic.

For Kensico, it is important to also consider water quality at the effluent chambers (CATLEFF and DEL18) because of their significance as compliance sites for the SWTR. The water quality at these chambers largely reflects that of the reservoir's main basin. However, median values for fecal coliform and turbidity are somewhat lower than those reservoir-wide at around 1 CFU $100ml^{-1}$ and 1 NTU, respectively for both analytes, at both effluent chambers. The outputs from Kensico (at the effluent chambers CATLEFF and DEL18) showed negligible downward trends for turbidity and fecal coliform. There were very small upward trends at both sites for conductivity.

DEP's Waterfowl Management Program efforts on Kensico Reservoir continue to have a major effect on reducing the bird population on and around the reservoir resulting in low fecal coliform concentrations in the water being delivered to the City.

DEP has installed a series of Extended Detention Basins for stream stormwater pollutant load reduction to Kensico Reservoir. The facility at Malcolm Brook has considerably reduced stream storm loads for fecal coliform and turbidity (quasi-load). Peak flows have also been attenuated. A more recently installed extended detention basin (at stream N5-1), has shown similar reductions. At the Catskill Lower Effluent Chamber (CATLEFF) following storm events, the Malcolm Brook Extended Detention has been shown to have a small but statistically significant effect on peak turbidity and fecal coliform concentrations.

The Malcolm Brook Cove turbidity curtain in Kensico Reservoir has provided a small, but statistically significant, effect of the curtain on reducing peak turbidity values at CATLEFF following storm events.

Water Quality Summary for the Potential Catskill/Delaware System Basins

Water quality was generally good during the 2002 – 2004 status analysis time frame for Cross River and Croton Falls reservoirs. The fecal coliform benchmark value was not exceeded in both reservoirs and the median values were low. Croton Falls had just one turbidity value (5.1 NTU) above the benchmark 5 NTU although its median value was just 2.3 NTU, the same as that of Cross River. However, both reservoirs' median values are very close to the TP guideline value of 20 $\mu g\ L^{-1}$. Cross River Reservoir is mesotrophic, whereas Croton Falls is eutrophic. Moderate upward conductivity trends were detected for both reservoirs and small productivity increases (as Trophic State Index) were detected in both reservoirs.

It should be noted that Cross River and Croton Falls Reservoirs were added to the FAD in 2002 due to the ability to pump water from these Croton System reservoirs into the Catskill/Delaware system during times of drought. Therefore, because many of the protection programs for these basins are still in the early stages of implementation, they are unlikely to have achieved any impact on water quality thus far.

Summary of Program Effects for Cannonsville and Pepacton Estimated by Models

The effects of non-point source management, point source upgrades, and land use change on eutrophication in the Cannonsville and Pepacton Reservoirs were evaluated using DEP's Eutrophication Modeling System. Four watershed management programs were evaluated: Point Source WWTP Upgrades; the Watershed Agricultural Program; the Urban Stormwater Program; and the Septic System Rehabilitation Program. The decline in agricultural activity that occurred (independently of the agricultural management program) over the last decade was evaluated as a land use change scenario.

Land use change (decline in agriculture) and the four watershed management programs both produced substantial reductions in predicted phosphorus loading. Loading reductions due to land use change alone were ~20% for dissolved phosphorus and 30% for particulate phosphorus in Cannonsville, and ~15% for dissolved phosphorus and ~25% for particulate phosphorus in Pepacton. The combination of land use change and watershed management produced reductions of ~46% for dissolved phosphorus and 68% for particulate phosphorus in Cannonsville, and ~27% for dissolved phosphorus and ~58% for particulate phosphorus in Pepacton. Point Source WWTP upgrades and the implementation of agricultural BMPs by the Watershed Agricultural Program provided most of the loading reductions, followed by septic system remediation. Urban stormwater management provided insignificant reductions in both dissolved and particulate phosphorus, due to the small urban land use areas.

The effects of land use change, non-point BMPs, and point source management on the trophic status of the Cannonsville and Pepacton reservoirs were evaluated by driving reservoir water quality models with the different nutrient loading scenarios simulated using GWLF. For Cannonsville Reservoir, lower watershed loads due to the decline in farming that occurred over the last decade resulted in considerable reductions of 13% for in-lake growing season chlorophyll *a* and 16% for total phosphorus. Greater reductions were predicted when non-point and point source watershed management in addition to land use change were considered (38% for chlorophyll *a* and 43% for total phosphorus). The response of Pepacton Reservoir (which exhibited less eutrophication under baseline conditions) was similar, but the magnitude of the reductions was less, suggesting that eutrophic reservoirs tend to benefit proportionately more from watershed load reductions.

Examination of daily, as well as long term mean reservoir chlorophyll levels, suggests that the occurrence of extreme "bloom-like" epilimnetic chlorophyll concentrations are also affected by the differing nutrient loading scenarios, and that the implementation of the watershed management programs greatly reduced the occurrence of these extremes. Implementation of non-point BMPs was most effective at reducing the frequency of "bloom-like" concentrations of chlorophyll. This is apparently related to the effects of non-point BMPs on the magnitude and timing of storm event runoff, and the phosphorus loads associated with it.

1. Introduction

1.1 Purpose of this Report

This report has been drafted to comply with Section 5.1 of the November 2002 Filtration Avoidance Determination (FAD), which requires that the City submit a Comprehensive Water Quality/Program Evaluation Report to the United States Environmental Protection Agency (EPA) by March 31, 2006. The purpose of this report is to summarize the achievements of the programs that comprise the City's overall watershed protection program; to review water quality status and trends in the Catskill/Delaware basins; and, where possible, to demonstrate the link between program activities and changes in water quality.

The report is divided into two main sections: Chapter 2 provides short summaries of the accomplishments of each of the watershed protection programs for the past five years; and Chapters 3, 4 and 5 use monitoring results and modeling to assess current water quality and evaluate the effectiveness of some of those programs.

This document should be viewed in the context of the multitude of reports DEP has produced detailing program progress and water quality over the past five years. For specific details about the implementation of watershed protection programs, refer to the Annual Reports prepared pursuant to the FAD for the years 2001 through 2004. DEP also produces dozens of quarterly, semi-annual and annual reports on FAD programs, publishes reports on special studies and develops an annual water quality statement which gives detailed information about water quality. Finally, DEP's web site contains periodic updates on certain programs and other details.

1.2 Water Supply System

The New York City water supply system consists of three unfiltered surface water sources (the Croton, the Catskill and the Delaware) and a system of wells in Queens (the Jamaica System). The three upstate water collection systems include 19 reservoirs and three controlled lakes with a total storage capacity of approximately 550 billion gallons. They were designed and built with various interconnections to increase flexibility to meet quality and quantity goals and to mitigate the impact of localized droughts. The system supplies drinking water to almost half the population of the State of New York – over eight million people in New York City and one million people in Westchester, Putnam, Orange and Ulster Counties – plus the millions of commuters and tourists who visit the City throughout the year. Overall consumption in 2005 averaged 1.1 billion gallons a day.

The New York City Department of Environmental Protection (DEP) is the City agency with primary responsibility for overseeing the operation, maintenance and management of the water supply infrastructure and the protection of the 1,969 square mile watershed. Within DEP, the Bureau of Water Supply manages the upstate watershed and infrastructure and all drinking water quality monitoring in-City and upstate. The Bureau of Water and Sewer Operations operates the City's two main distribution reservoirs – Hillview and Jerome Park – and the drinking water distribution and sewage collection infrastructure. The Bureau of Engineering Design and Construction manages all large contracts for capital construction and maintenance of the water supply infrastructure. Other bureaus and units within DEP – including Legal Affairs, Planning & Assessment, Public Affairs, and budget, personnel and procurement staff – provide vital support services to ensure the smooth operation of the water supply. In addition, staff from the New York City Department of Health assist in certain drinking water programs and staff from the New York City Law Department provide important legal support.

The Croton watershed is located entirely east of the Hudson River in Westchester, Putnam and Dutchess Counties, with a small portion in the State of Connecticut. The oldest of the three systems, parts of the Croton system have been in service for more than 150 years. The watershed covers approximately 375 square miles. Croton's 12 reservoirs and three controlled lakes are connected primarily via open channel streams and rivers, and ultimately drain to the New Croton Reservoir in Westchester County. Approximately 10% of the City's average daily water demand is supplied by the Croton, although in times of drought the Croton system may supply significantly more water.

The City is in the process of siting, designing and constructing a water treatment plant to filter the Croton Supply. While the Croton system continues to meet all current health-based regulatory standards for a surface water supply, it does experience periodic violations of the aesthetic standards for color, taste and odor. In addition, DEP does not believe that the Croton system will be able to meet stricter disinfection by-product rules recently promulgated. The Croton water treatment is expected to resolve these concerns.

The Catskill system consists of two reservoirs – Schoharie and Ashokan – located west of the Hudson River in Ulster, Schoharie, Delaware and Greene Counties. The Catskill system was constructed in the early part of the 20th century, and Ashokan Reservoir went into service in 1915. Water leaves Schoharie Reservoir via the 18-mile Shandaken Tunnel, which empties into the Esopus Creek at Allaben and then travels 22 miles to the Ashokan Reservoir. Water leaves Ashokan via the 75-mile long Catskill Aqueduct, which travels to the Kensico Reservoir in Westchester County. The Catskill system supplies, on average, 40% of the City's daily water supply.

The Delaware system was constructed in the 1950s and 1960s, and is comprised of four reservoirs: Cannonsville, Pepacton and Neversink in the Delaware River basin, and Rondout in the Hudson River basin. The first three reservoirs supply Rondout; water then leaves Rondout and travels to West Branch Reservoir in Putnam County via the Rondout/West Branch Tunnel. Water from West Branch then flows through the Delaware Aqueduct to the Kensico Reservoir.

The Delaware system provides the remaining 50% of the City's daily demand. Because waters from the Catskill and Delaware watershed are commingled at Kensico Reservoir, they are frequently referred to as one system: the Catskill/Delaware system.

In the late 1980s, the City decided to apply for filtration avoidance for the Catskill/Delaware system under the terms of the Surface Water Treatment Rule (see "Regulatory Context", below). For the last decade, DEP and its partner agencies and organizations have developed and deployed a comprehensive watershed monitoring and protection program designed to maintain and enhance the high quality of Catskill/Delaware water. This program has been recognized internationally as a model for watershed protection and has allowed the City to secure a series of waivers from the filtration requirements of the Surface Water Treatment Rule.

1.3 Regulatory Context

The Safe Drinking Water Act (SDWA) amendments of 1986 required EPA to develop criteria under which filtration would be required for public surface water supplies. In 1989, EPA promulgated the Surface Water Treatment Rule (SWTR), which requires all public water supply systems supplied by unfiltered surface water sources to either provide filtration or meet a series of water quality, operational and watershed control criteria. These criteria are referred to as the filtration avoidance criteria.

As noted, the filtration avoidance criteria are comprised of three main areas:

- Objective Water Quality Criteria – the water supply must meet certain levels for specified constituents including coliforms, turbidity and disinfection by-products.
- Operational Criteria – a system must demonstrate compliance with certain disinfection requirements for inactivation of *Giardia* and viruses; maintain a minimum chlorine residual entering and throughout the distribution system; provide uninterrupted disinfection with redundancy; and undergo an annual on-site inspection by the primacy agency to review the condition of disinfection equipment.
- Watershed Control Criteria – a system must establish and maintain an effective watershed control program to minimize the potential for contamination of source waters by *Giardia* and viruses.

In New York State, EPA delegated primary enforcement responsibility (primacy) for the SWTR to the New York State Department of Health (DOH) for all public water supply systems in the State, except the City's Catskill/Delaware system.

1.4 Historical Context

The City first applied for a waiver for the Catskill/Delaware system from the filtration requirements of the SWTR in 1991. This first application was filed with DOH, because at the time the City and DOH believed that DOH had primacy for all systems in New York State. DOH granted a one-year filtration waiver. Subsequently, it was determined that EPA had retained primacy for the SWTR for the Catskill/Delaware systems. In mid-1992, DEP submitted a thirteen-volume application to EPA, describing in detail the City's plans for protecting the Catskill/Delaware supply. On January 19, 1993, EPA issued a conditional determination granting filtration avoidance until December 31, 1993. The waiver incorporated many elements of the program the City had described in mid-1992, and was conditioned upon the City meeting 66 deadlines for implementing studies to identify potential pollution sources, developing programs to ensure long-term protection of the watershed, and addressing existing sources of contamination in the watershed. EPA also imposed substantial reporting requirements on the City, to monitor the City's progress.

DEP submitted a second application for avoidance to EPA in September 1993. This application was based upon the knowledge gained by the City through initiation of its watershed studies and programs and laid out a long-term strategy for protecting water quality in the Catskill/Delaware system. Again, EPA determined that the City's program met the SWTR criteria for filtration avoidance, although they did express concerns about the program's ability to meet the criteria in the future. On December 30, 1993, EPA issued a second conditional determination, containing 150 conditions related primarily to enhanced watershed protection and monitoring programs. EPA also required that the City proceed with design of a filtration facility for the Catskill/Delaware supply, so that no time would be lost should EPA decide that filtration was necessary in the future.

Two critical pieces of the watershed protection program that DEP described in September 1993, and that EPA incorporated into the December 1993 Determination, were implementation of a land acquisition program and promulgation of revised watershed regulations. Primarily due to the objections of watershed residents over the impact that those programs might have on the character and economic viability of their communities, DEP was unable to move forward with implementation of those key program elements. It was against this backdrop that Governor Pataki convened a group of involved agencies and parties to try to come to an accord. The negotiations involved the City, the State, EPA, representatives of the counties, towns and residents of the watershed, and representatives from environmental groups. In November 1995, the parties reached an Agreement in Principle that set forth the framework of an agreement that would allow the City to advance its watershed protection program while protecting the economic viability of watershed communities. It took another 14 months to hammer out the details of an agreement, and in January 1997, the parties signed the MOA. The MOA supplemented the City's existing watershed protection program with approximately $350 million in additional funding for economic-environmental partnership programs with upstate communities, including a water quality investment program, a regional economic development fund and a regional advisory forum for water quality initiatives and watershed concerns. The State issued a land acquisition permit, which allows the City to purchase land in the watershed and approved a revision to the City Watershed Rules and Regulations governing certain aspects of land use in the watershed. The

City also secured a 5-year waiver from the filtration requirements for the Catskill/Delaware system. The City agreed to fund these programs, including significant funding to be used to maintain the character and economic viability of watershed communities.

In December 2001, the City submitted to EPA a rigorous, science-based assessment of Catskill/Delaware water quality and a enhanced, comprehensive long-term plan for watershed protection efforts. DEP has conducted a assessment of current water quality and the effectiveness of certain aspects of its watershed protection program. That long-term plan represented a significant enhancement to the City's watershed protection efforts and relied in part on the continued support and cooperation of the City's partners. The plan formed the basis of a revised FAD, issued by EPA in November 2002. The 2002 FAD is due to be reviewed and revised in April 2007.

1.5 Report Details

This report primarily focuses on program activities undertaken since 2002 and continuing through the end of 2005. However, since many of the programs discussed were initiated prior to 2002, there is some discussion of program activities that fall before the term of the current FAD. Indeed, the City's watershed protection efforts are best evaluated in the context of the overall program that was initiated in the early 1990s. The significant accomplishments of the City and its partners have been made possible only by the sustained commitment to watershed protection.

One of the primary purposes of this report is to evaluate quantitatively how effective the watershed programs have been since 1997, and will be over the long term. The City has taken a basin-by-basin approach, evaluating each reservoir in turn to assess the status and trends in water quality. The water quality analysis presented in this document is an extension of the analysis presented in the 2001 assessment of DEP’s FAD programs. Here DEP presents an analysis covering 12 years of data collection and program implementation. This data includes results collected through the end of 2004. Due to the time needed to process samples, and compile, review and verify data, it was not possible to incorporate any monitoring results from 2005. Long-term data is critical in the evaluation of programs that cover large geographical areas and are implemented over long periods of time, so analyses will become better as the data record becomes longer. The approach DEP has used is to evaluate water quality in terms of: status, trends, case studies, and modeling. The status of waterbodies is based on three recent years of data (i.e., 2002 through 2004) and these are compared to regulatory benchmark values. The trends are based on twelve years of data (i.e., 1993 through 2004). Five important analytes were selected, including fecal coliforms, turbidity, phosphorus, conductivity and trophic status. Case studies were done for selected monitoring sites that had sufficient proximity and sampling intensity to demonstrate program effects. Modeling was conducted to attribute program effects to programs on a watershed-wide basis. All analyses together provide a context to understand program effects.

2. Watershed Management Programs

2.1 Institutional Alliances

While DEP is responsible for the collection, monitoring, treatment and delivery of high quality water to the City, DEP relies heavily on the work of partner organizations to carry out watershed protection efforts. Numerous towns, counties, State and federal agencies, not-for-profit organizations, and private businesses have participated in and helped implement watershed protection programs. Without local input and involvement, the City's programs would not be as successful as they are today.

The Watershed Memorandum of Agreement explicitly acknowledges the importance of cooperative partnerships to the success of the City's watershed protection efforts

> "...the goals of drinking water protection and economic vitality within Watershed communities are not inconsistent and it is the intention of the parties to enter into a new era of partnership to cooperate in the development and implementation of a Watershed protection program that maintains and enhances the quality of the New York City drinking water supply system and the economic vitality and social character of the Watershed communities;"

Indeed, two of the three major sections of the MOA establish voluntary protection programs - the Protection and Partnership programs and the Land Acquisition program. These and other partnership programs arise from the recognition that the actions of private landowners – the farmers, homeowners and business people who own 70% of the land in the watershed – directly affect the quality of the City's water supply. For this reason, the City has supported strategies to encourage landowners to manage their land in a manner that will protect and improve water quality. Because of DEP's position in the watershed as a large outside municipality, however, DEP is not always the most appropriate organization to implement these programs. In addition, as a government agency, DEP's various fiscal policies can make it difficult to act quickly. For these reasons, the City has contracted with numerous municipalities and not-for-profit organizations to implement many of its watershed protection programs. These partnerships have both maximized the success of the programs and at the same time improved DEP's relations with municipalities and individuals in the watershed.

Since the last assessment of the watershed protection program in 2001, already established organizations have matured and more organizations have developed and taken hold in the NYC Watershed. The collective efforts of these organizations have greatly contributed to the implementation of the City’s efforts.

The two major organizations involved in FAD implementation - the Watershed Agricultural Council (WAC) and the Catskill Watershed Corporation (CWC) – continued to refine and enhance programming in the last five year period. Both organizations have strengthened both administratively and financially and provide excellent leadership in the watershed.

WAC completed a Strategic Plan for the organization which provided an opportunity for the Board, staff, contracting organizations and participating agencies to evaluate WAC's progress and to develop a 3 – 5 year plan for the organization. The Plan redefined WAC's mission statement, created a set of values for WAC's programs and established 10 goals to further the mission. This is a strong sign of WAC's maturation as an an environmental stewardship organization.

CWC successfully integrated new programming into its portfolio of services including Septic Maintenance, Local Planning, and Stormwater Assessment Programs. The Catskill Fund for the Future achieved an unprecedented level of economic development activity and loan servicing. The organization continued to strongly manage its finances and develop increasing administrative capabilities. It also handled many sensitive community issues with skill and diplomacy.

The period of time from 2001 and 2006 showed the continual development and prominence of County Soil and Water Conservation Districts, most notably in the area of stream management planning and restoration. The SWCD's in Delaware, Greene, Sullivan and Ulster Counties achieved a remarkable level of success in completing high quality stream management plans throughout the City's watershed. The numerous restoration projects, which ranged in size from reach scale to site scale treatments, have been recognized nationally for the application of natural channel techniques. The expertise developed at the staff level in each organization has had a marked impact on the quality of services private landowners can rely on. The stream management plans have provided a multi-stakeholder blueprint for future implementation of beneficial projects.

Beyond the efforts and participation of the Board members and staff of these organizations, private landowners throughout the watershed continue to come forward and participate in watershed protection opportunities. Whether it is by maintaining a septic system, cooperating with efforts to address an eroding streambank, selling land or a conservation easement to the City or WAC, or attending a public education program, private landowners are participating in voluntary programming in increasing numbers. This unprecedented level of participation shows that the programs are working.

All of these activities mean local expertise is being developed throughout the watershed to ensure that future land management activities are conducted in the best way possible to protect and improve water quality. While the activity and record of accomplishment is very significant, it is the local expertise, economic value of these programs, and understanding of the local benefits that will serve the New York City water supply well into the future.

2.2 Land Acquisition

During the reporting period, DEP continued to advance the Land Acquisition Program (LAP). All solicitation goals set by the FAD and MOA were met, and DEP embarked on a targeted program of resolicitation in critical areas. To date, LAP has protected more then 57,300 acres of land in the Catskill/Delaware watersheds. An additional 12,743 acres of agricultural easements have been acquired by the Watershed Agricultural Council.

2.2.1 Solicitation and Resolicitation

The entire Catskill/Delaware watershed, which includes all west of Hudson basins as well as the West Branch/Boyd Corners and Kensico basins East of Hudson, comprises 1,023,730 acres (excluding reservoirs). Of these, approximately 210,367 acres (20.5%) are owned outright by other public agencies or land trusts, and provide a strong level of protection. While there are many other properties protected by private agreements, easements, or deed restrictions, there is no comprehensive source of information on this. As of 1997, 36,047 acres (3.5%) were owned by New York City. Of the remaining 777,000 acres of privately held land, the City was required to solicit 355,050 acres during the first eight years of the Program. Acreage to be solicited was determined by estimating the eligible land (properties that meet the criteria outlined in MOA Paragraphs 63 and 67 - 70) and applying the requirements of MOA Paragraph 65, which reflects different intensities of solicitation according to the importance of each Priority Area. For example, the City was to solicit 95% of all eligible land in Priority 1A/B and 50% of all eligible land in Priority 4. As of December of 2004, the solicitation deliverable - contacting the owners of 355,505 acres - was met. As of December 31, 2005 watershed-wide solicitation and resolicitation efforts have resulted in the City securing 57,361 acres in fee simple or conservation easement, with another 12,743 acres of farm easements secured by the Watershed Agricultural Council. This represents a tripling of lands held for watershed protection as of 1997.

Before completing the formal solicitation requirement, DEP had been re-soliciting landowners in all priority areas to maximize acquisition of highly ranked properties. During the past three years, over 195,000 acres (1,700 landowners) were re-contacted (see Table 2.1). Almost 5% of re-contacted landowners have already signed contracts, representing 6,830 acres (3% of acres). As a part of re-solicitation, DEP has identified 444 properties (over 32,000 acres) of previously solicited land that has been conveyed to new ownership. Contacting these new owners has resulted in an additional 577 acres in signed contracts, bringing the sum of land protected through resolicitation efforts to 7,407 acres since January 2003, or about 46% of all lands signed during this period. There are also over 43,000 acres that have been (or are being) appraised and others yet to be appraised, all of which will contribute to success rates.

Table 2.1. Re-solicitation results, 2003 through 2005.

Category	Total Re-Solicited Count	Total Re-Solicited Acres	Interested (1) Count	Interested (1) Acres	% Interested (3)	Appraised Count	Appraised Acres	% Appraised (3)	Under Contract (2) Count	Under Contract (2) Acres	% Contract (3)
Same Owner *(Previously)*	449	53,119	231	33,165	62%	195	27,550	52%	55	4,453	8%
Offer Refused (Previously)	175	28,572	64	10,346	36%	24	3,219	11%	8	1,108	4%
Not Interested (Previously)	1,073	113,622	131	28,056	25%	66	8,612	8%	20	1,269	1%
No Response											
Sub-Total – Same Owners	1,697	195,313	426	71,567	37%	285	39,381	20%	83	6,830	3%
New Owners	444	32,971	103	7,868	24%	60	4,190	13%	13	577	2%
Totals	2,141	228,284	529	79,435	35%	345	43,571	19%	96	7,407	3%

Source: *Land Acquisition Tracking System (LATS) December, 2005*

Notes:

(1) Interested column includes responders to City Letters or Calls, as well as Landowner Call-Ins. In the case of City-initiated contacts, multiple attempts may have been made.

(2) Under Contract column includes Signed Contracts, as well as Offer Accepted and Contract to Seller, and may be Fee Simple or CE.

(3) Percentage of Total Acres in Category.

Supplementary Funds

DEP has consulted with EPA regarding the potential use of the supplementary $50 million. In 2004, it was decided to allocate $7 million of the fund to the Farm Easement Program managed by the Watershed Agricultural Council (see below). The remaining $43 million continues to be the subject of planning and discussion, and is expected to be addressed in 2006 and beyond.

2.2.2 Basin Status Reports

Schoharie

The Schoharie basin contains 200,911 acres, excluding the reservoir (“basin land area”), and all land within has been categorized as either Priority 3 or 4. As of 1997, DEP owned 1,044 acres of reservoir buffer land, or 0.5% of basin land area, with another 37,902 acres (18.9%) protected by non-City entities[1]. Since 1997 the City has protected 10,508 acres in fee or easement, and WAC has secured 768 acres under easement. This newly acquired land represents 5.6% of

1. Information on land protected by non-City entities is derived from County tax data and/or other non-verified independent sources.

the basin and a 1,000% increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 50,222 acres, or 25.0% of the basin. Figure 2.1 illustrates lands protected by program area for each of the Catskill/Delaware basins. Figure 2.2 shows lands within the Schoharie basin that have been protected.

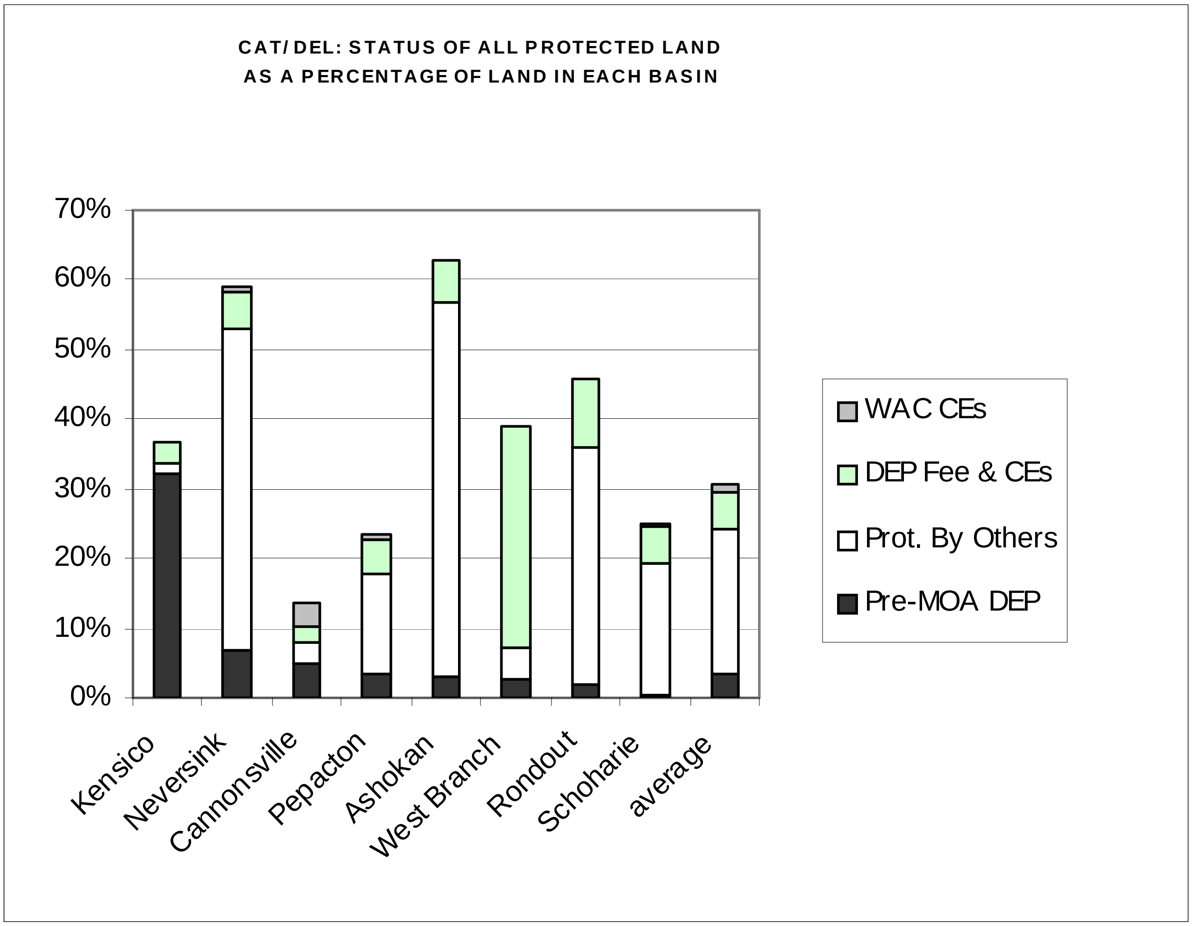

Figure 2.1 Protected lands by basin.

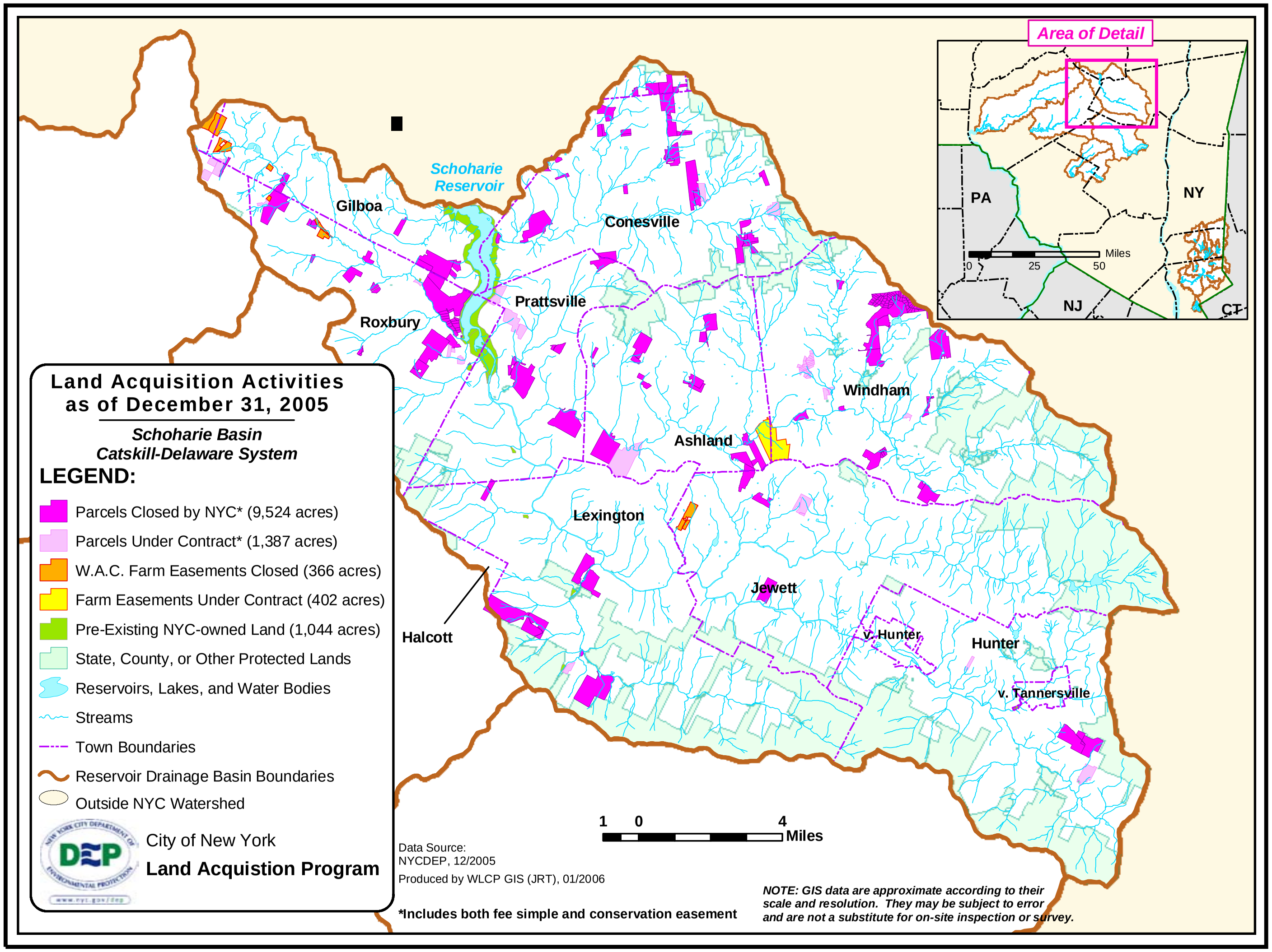

Figure 2.2 Land Acquisition activities in the Schoharie basin as of December 31, 2005.

Ashokan

The Ashokan basin land area is 155,344 acres, all categorized as either Priority 1 or 2. As of 1997, DEP owned 4,854 acres of reservoir buffer land, or 3.1% of the basin, with another 83,242 acres (53.6%) protected by non-City entities. Since that time DEP has protected 9,707 acres in fee or easement. This land represents 6.2% of the basin land area and a 200% increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 97,803 acres, or 63.0% of basin land area. Figure 2.3 illustrates lands protected by program area.

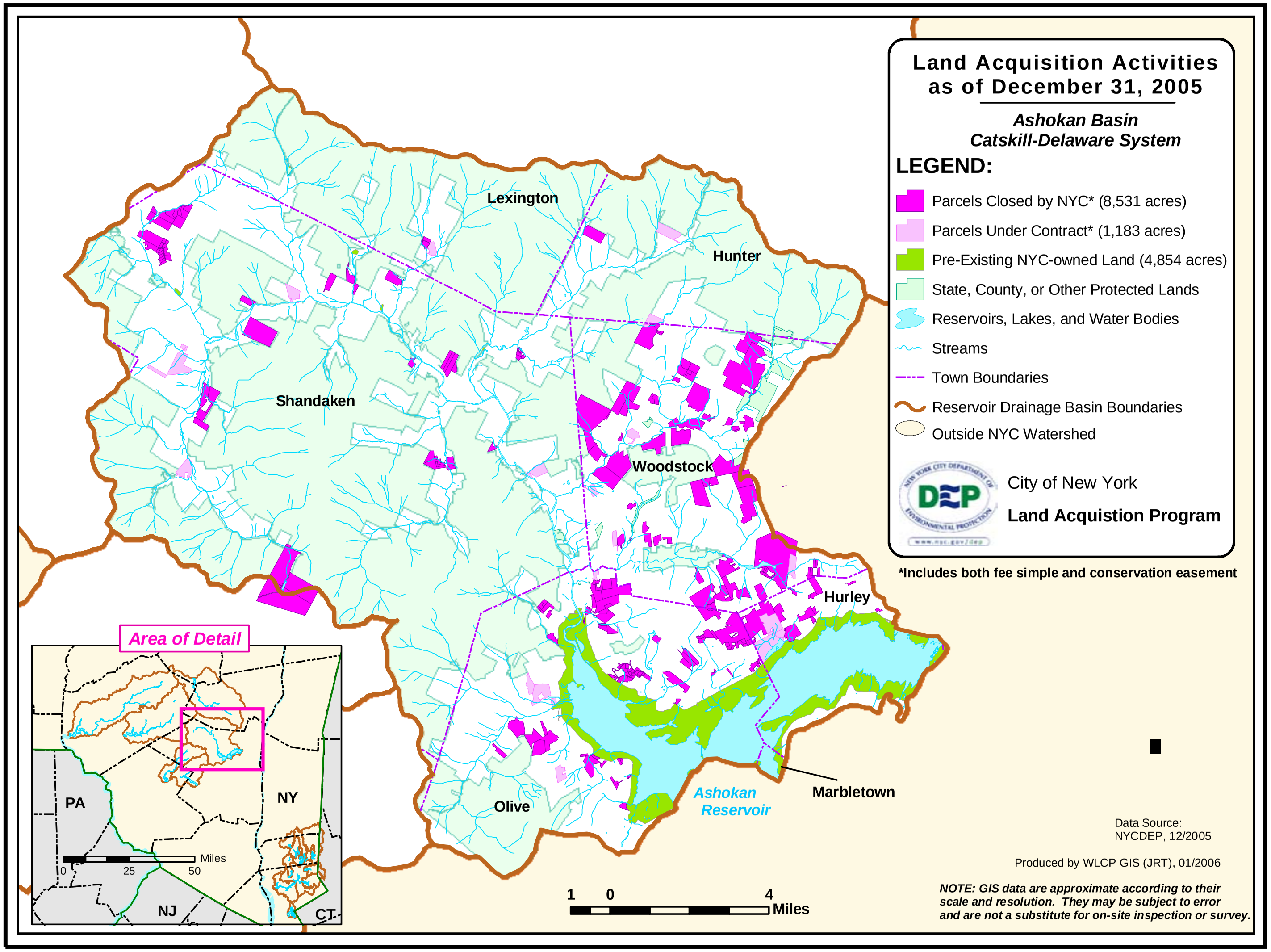

Figure 2.3 Land Acquisition activities in the Ashokan basin as of December 31, 2005.

Neversink

The Neversink basin land area contains 57,424 acres, all categorized as Priority 4 with the exception of 0.2% in Priority 1A. As of 1997, DEP owned 3,990 acres of reservoir buffer land, or 6.9% of the basin, with another 26,394 acres (46.0%) protected by non-City entities. Since that time DEP has protected 3,069 acres in fee or easement, and WAC has secured 508 acres under easement. This land represents 6.2% of the basin land area and a 90% increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 33,961 acres, or 59.1% of basin land area. Figure 2.4 illustrates lands protected by program area.

Rondout

The Rondout basin land area contains 59,008 acres, all categorized as Priority 1A or 1B. As of 1997, DEP owned 1,063 acres of reservoir buffer land, or 1.8 % of the basin, with another 20,049 acres (34%) protected by non-City entities. Since that time DEP has protected 5,801 acres in fee or easement. This land represents 9.8% of the basin land area and more than a five-fold increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 26,913 acres, or 45.6 % of the basin land area. Figure 2.4 illustrates lands protected by program area.

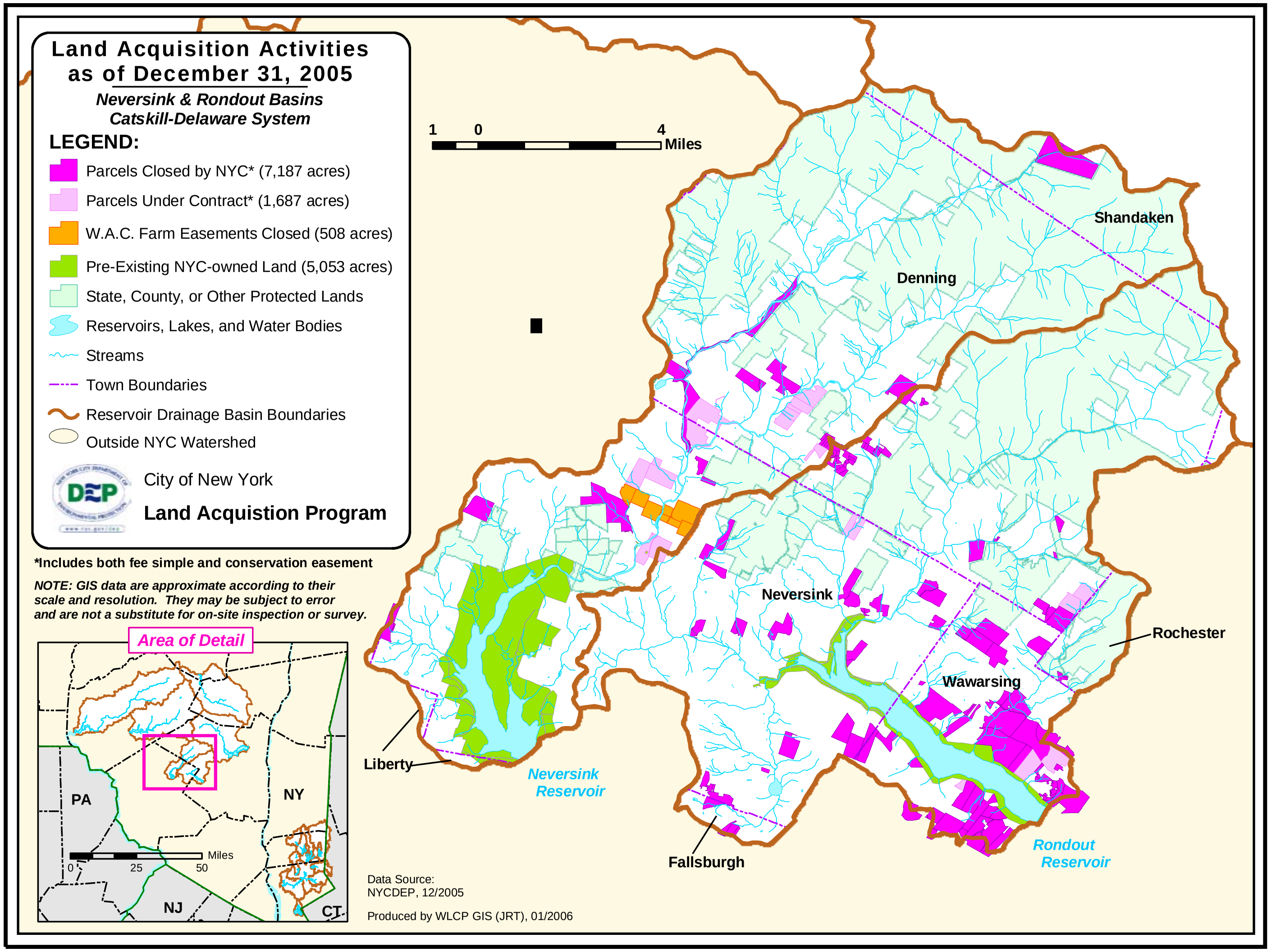

Figure 2.4 Land Acquisition activities in the Neversink and Rondout basins as of December 31, 2005.

Pepacton

The Pepacton basin land area contains 232,297 acres, categorized variously as Priority 1, 3 and 4. As of 1997, DEP owned 7,734 acres of reservoir buffer land, or 3.3% of the basin land area, with another 33,773 acres (14.5%) protected by non-City entities. Since that time DEP has protected 11,156 acres in fee or easement, and WAC has secured 1,486 acres under easement. This land represents 5.4% of the basin land area and an increase of over 150% in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 54,149 acres, or 23.3 % of the basin land area. Figure 2.5 illustrates lands protected by program area.

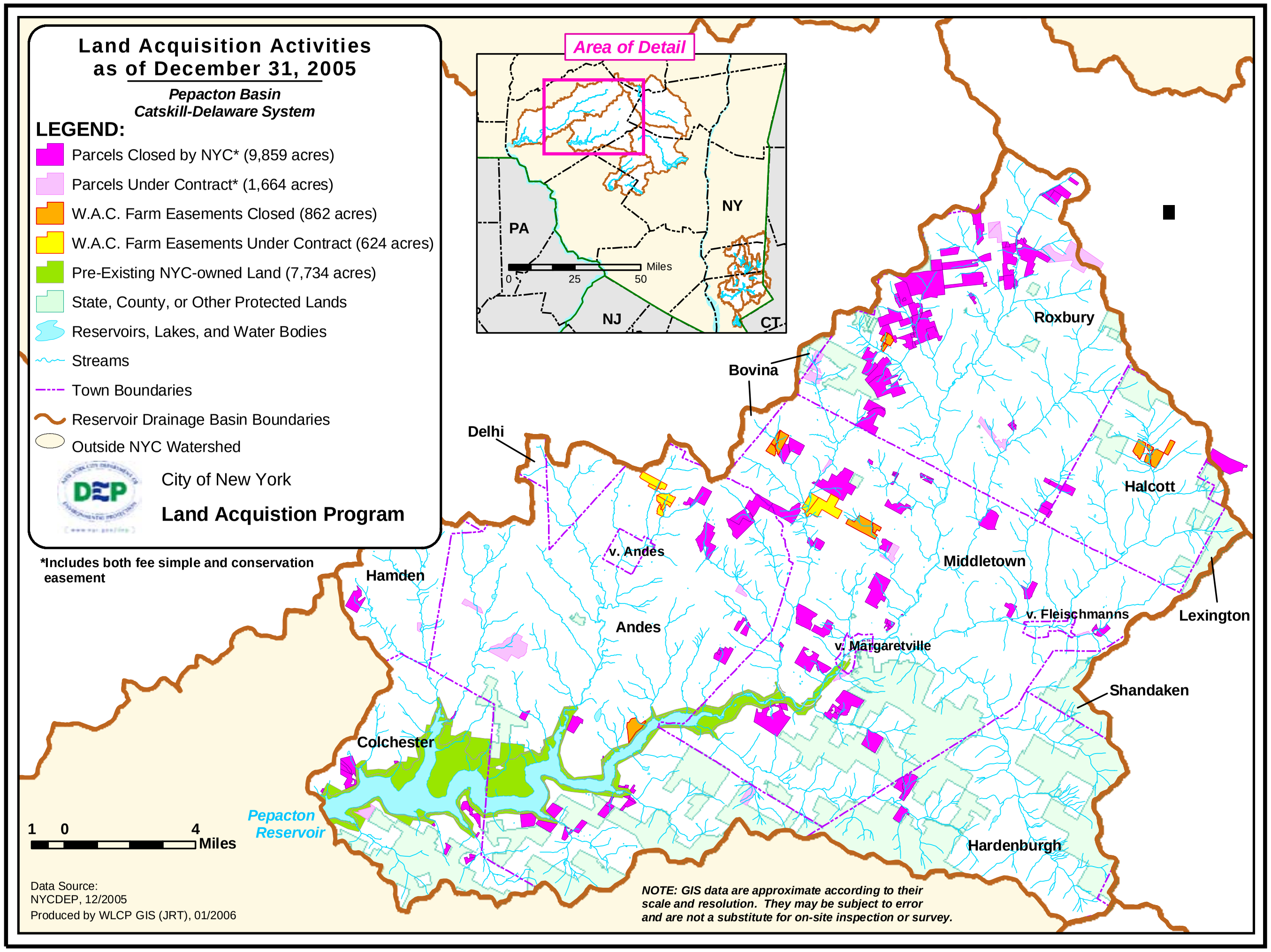

Figure 2.5 Land Acquisition activities in the Pepacton basin as of December 31, 2005.

Cannonsville

The Cannonsville basin land area contains 286,512 acres, categorized variously as Priority 1, 3 and 4. As of 1997, DEP owned 14,625 acres of reservoir buffer land, or 5.1% of the basin, with another 7,733 acres (2.7%) protected by non-City entities. Since that time DEP has protected 6,829 acres in fee or easement, and WAC has secured 9,981 acres under easement. This land represents 5.9% of the basin land area and an increase of over 100% in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 39,168 acres, or 13.7 % of the basin land area. Figure 2.6 illustrates lands protected by program area.

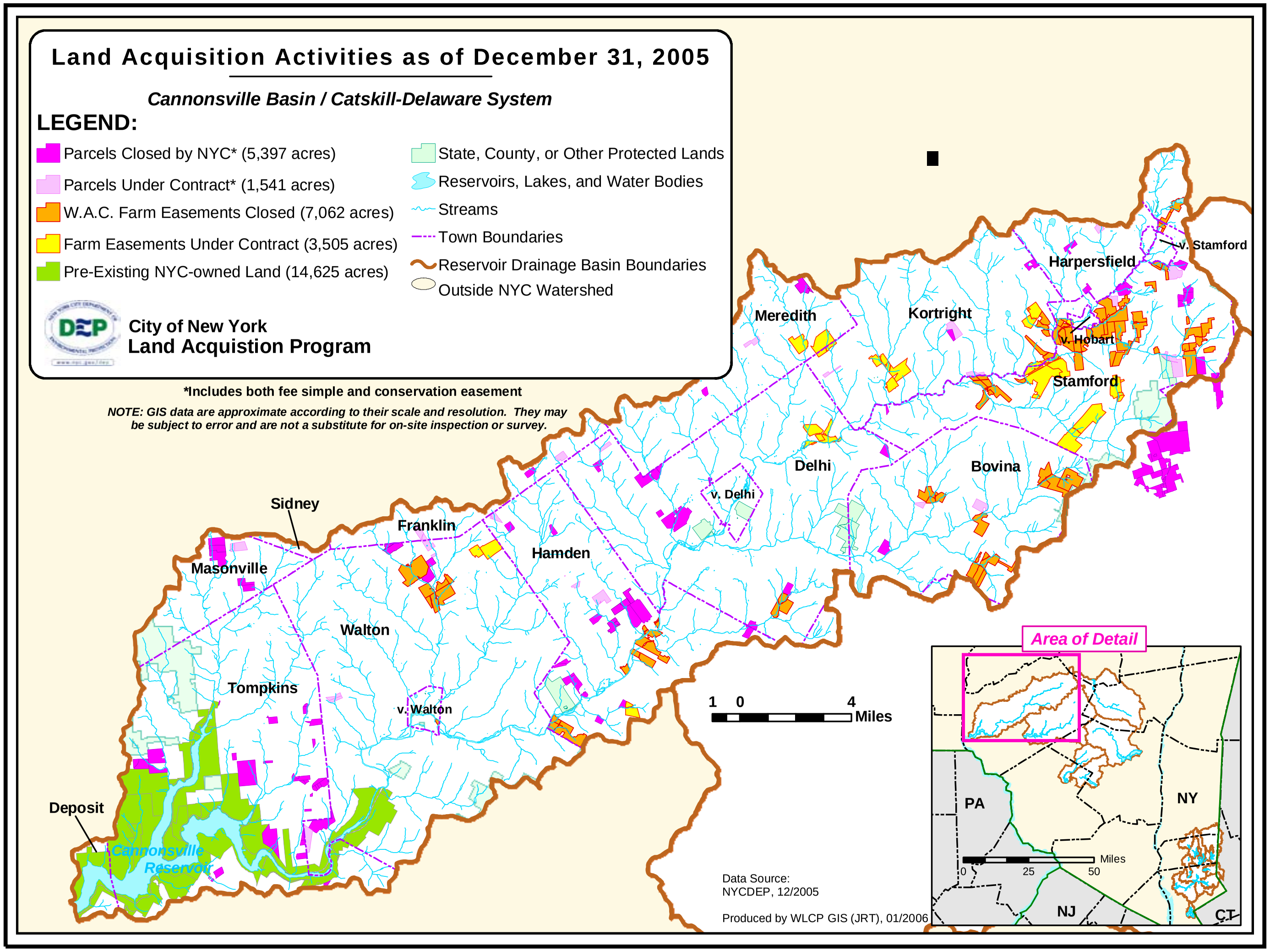

Figure 2.6 Land Acquisition activities in the Cannonsville Basin as of December 31, 2005.

West Branch / Boyd Corners

The West Branch and Boyd Corners basin land areas contain 25,830 acres, all categorized as Priority 1A or 1B. As of 1997, DEP owned 680 acres of reservoir buffer land, or 2.6 % of the basin land area, with another 1,170 acres (4.5%) protected by non-City entities. Since that time DEP has protected 8,239 acres in fee or easement. This land represents 31.9% of the basin land area and a twelve-fold increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 10,089 acres, or 39.1 % of the basin land area. Figure 2.7 illustrates lands protected by program area.

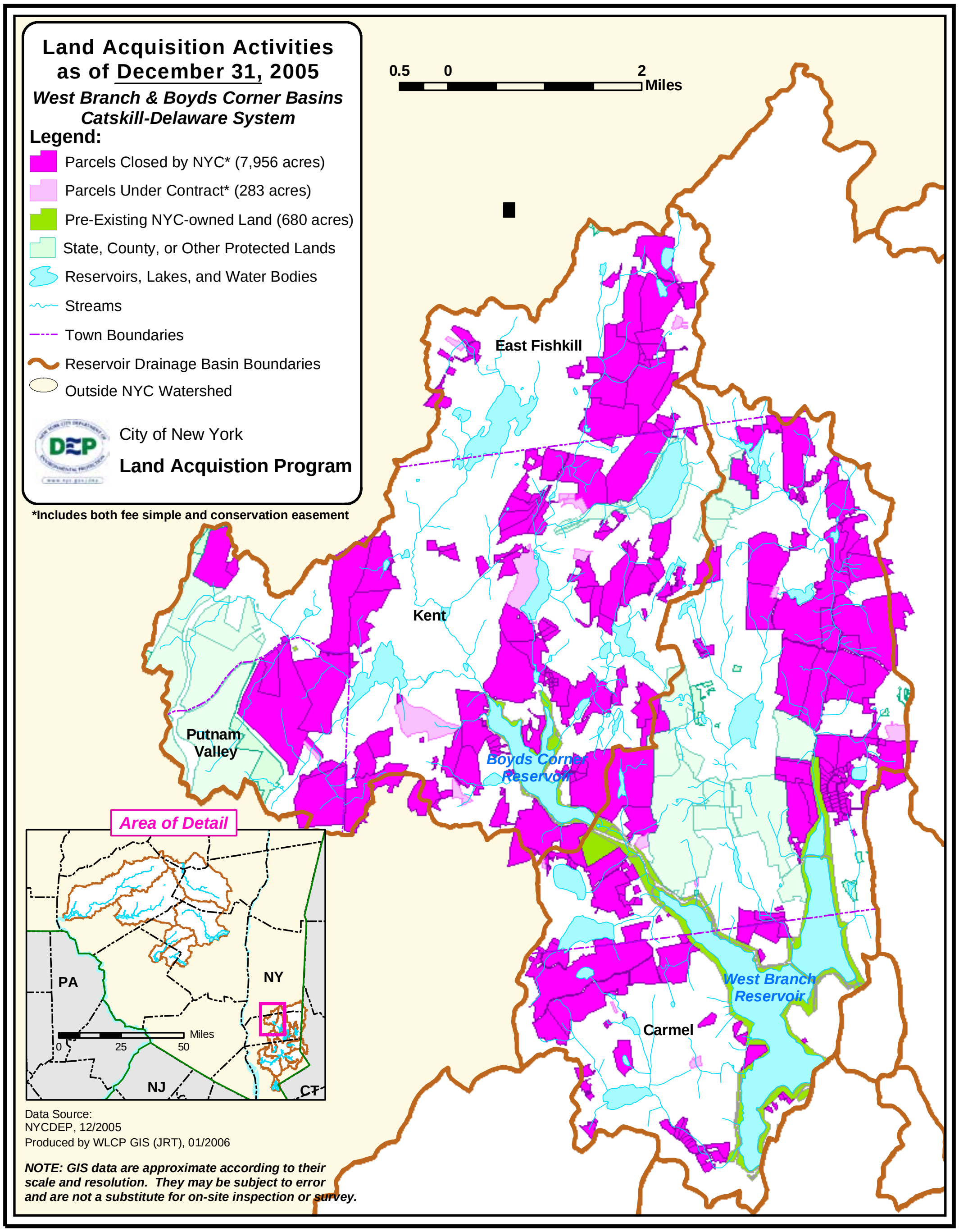

Figure 2.7 Land Acquisition activities in the West Branch and Boyd Corners basins as of December 31, 2005.

Kensico

The Kensico basin land area contains 6,406 acres, all categorized as Priority 1A or 1B. As of 1997, DEP owned 2,057 acres of reservoir buffer land, or 32.1 % of the basin land area, and another 104 acres (1.6%) were protected by non-City entities. Since that time DEP has protected 195 acres in fee or easement, representing 3.0% of the basin and bringing total land under City control to 35.2% of the basin land area. Total land protected by City and non-City entities is 2,356 acres, or 36.8% of the basin land area. Figure 2.8 illustrates lands protected by DEP.

DEP has made, and continues to make, considerable efforts to acquire land in the Kensico. In addition to spending $16 million to date to acquire 195 acres, including roughly 30% of vacant land in Priority 1A, LAP has pursued several other important properties. We have appraised and offered to pay over $9 million for an 8-acre commercial tract, and $1.7 million for a vacant building lot (properties not yet under contract). We recently paid a premium for a 3-acre property because it contains a residence, but believe its location is vital to DEP ownership and control. The very limited number of landowners and vacant parcels (fewer than 30) presents a challenge, so we are working in partnership with several towns and non-profit organizations to pursue other properties of importance, and will continue such efforts to maximize acquisitions in Kensico.

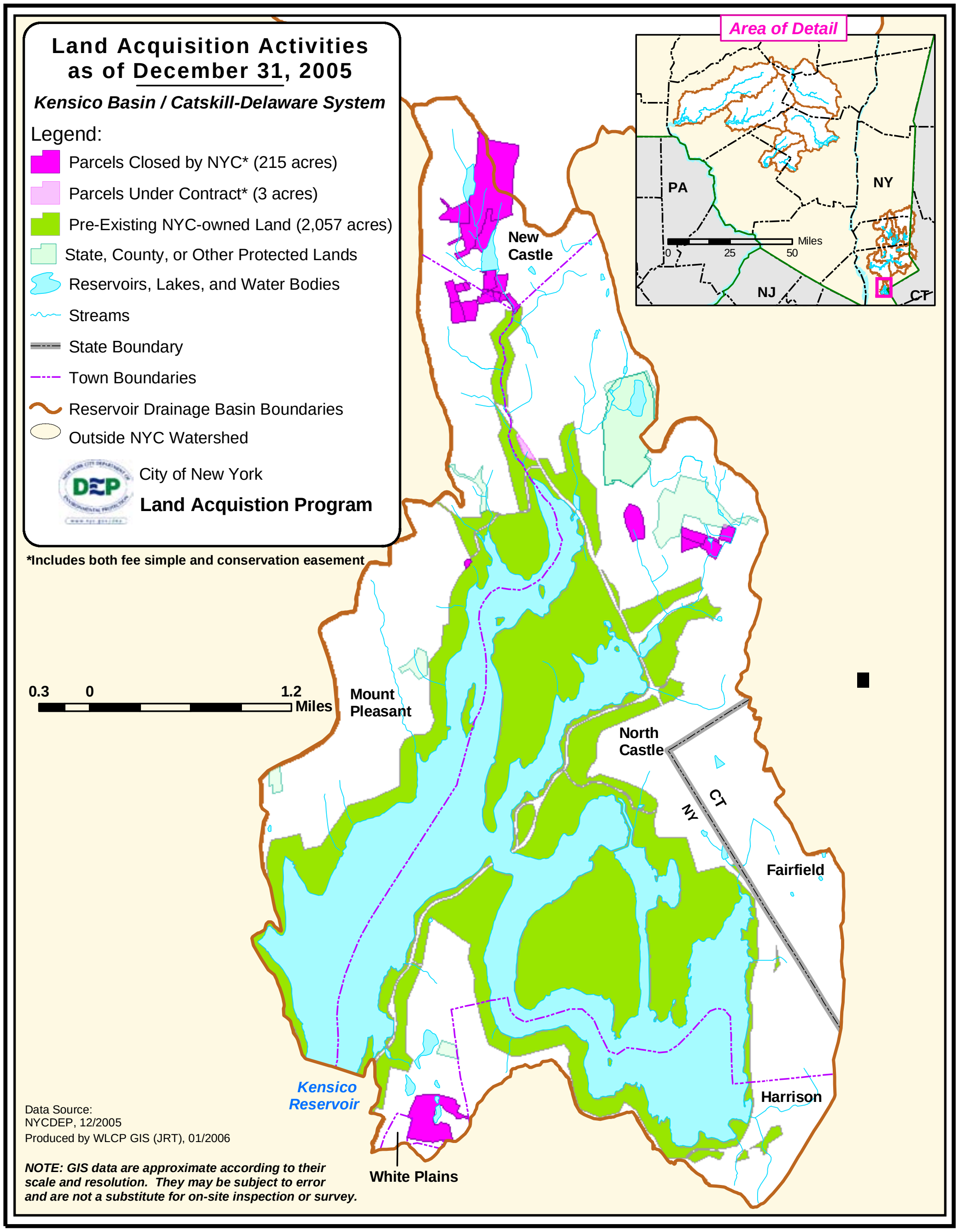

Figure 2.8 Land Acquisition activities in the Kensico basin as of December 31, 2005.

Cross River

The Cross River basin is part of the Croton system and the basin land area contains 18,294 acres, categorized as Priority A. As of 1997, DEP owned 536 acres of reservoir buffer land, or 2.9% of the basin land area, with another 4,063 acres (22.2%) protected by non-City entities. Since that time DEP has secured 90 acres under contract (conservation easement). This land represents 0.5% of the basin and a 17% increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities in the Cross River basin is 4,689 acres, or 25.6 % of the basin land area. Figure 2.9 illustrates protected land in the basin.

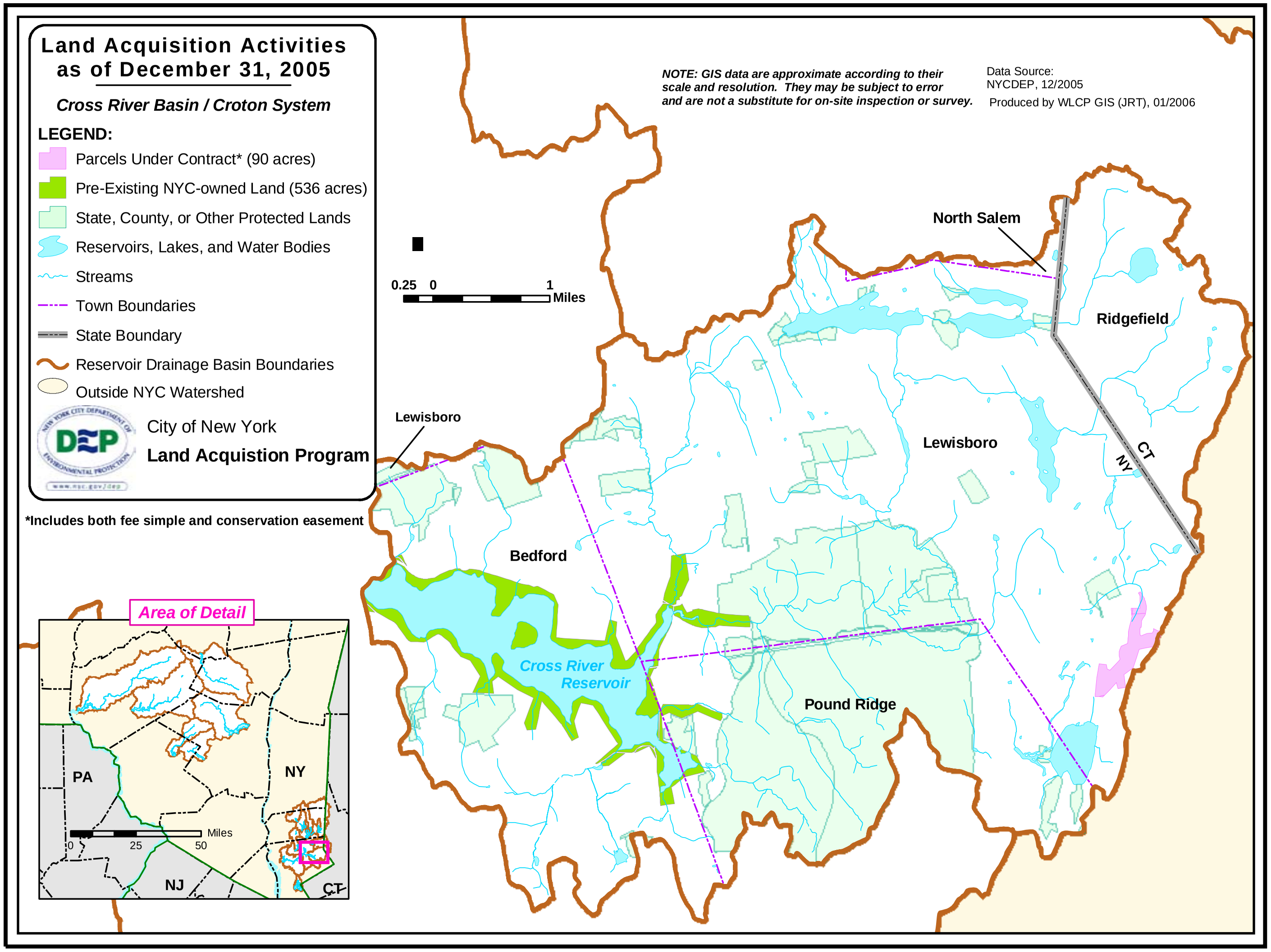

Figure 2.9 Land Acquisition activities in the Cross River basin as of December 31, 2005.

2.2.3 Basin Status Summary

As of 1997, DEP owned and controlled 3.5% of watershed lands (not including reservoirs). Since 1997, an additional 5.4% has been secured by DEP and 1.2% by WAC; therefore, including pre-MOA land, DEP now controls 10.2% of land. Tax map data and other sources indicate that at least another 20.5% is owned and controlled by non-City (non-WAC) public agencies and land trusts, bringing total protected land to over 30% of the watershed, up from about 23% ten years ago. Through DEP's land acquisition efforts to date, therefore, there has been almost a tripling of City-controlled land in the watershed, or a 27% increase in all protected lands (regardless of owner) since 1997.

2.2.4 Farm Easements

The Farm Easement Program is an integral component of the DEP's Land Acquisition Program, and has served to protect about 60 farms to date (see Table 2.2), principally in the Cannonsville basin. The Watershed Agricultural Council (WAC) has been under contract to acquire farm easements since 1999, using City funds and with the City holding third-party enforcement rights and reversionary interests. During those six years WAC has acquired over 12,000 acres in easements at a cost of roughly $12 million; this represents 18% of all lands protected to date at a price of about 10% of total costs. The protection afforded by the WAC Easement Program is vital because farms are, by and large, more sensitive to development impacts than non-farm properties, as they generally have a higher proportion of streams, stream buffers, road frontage, cleared land and views (proxies for development interests), and moderate slopes. The Farm Easement Program has been deemed a successful initiative and in 2004 the City appropriated an additional $7 million to the program.

Table 2.2. WAC farm easements by basin.

Reservoir Basin	# of Parcels	Total Acres	Average Lot Size (acres)	Value
Cannonsville	47	9,981	212	$9,039,465
Neversink	1	508	508	$279,677
Pepacton	8	1,486	186	$1,676,413
Schoharie	6	768	128	$1,032,028
Report Totals	**62**	**12,743**	**206**	**$12,027,582**

Case Studies

Any measure of success of DEP's Land Acquisition Program should rest in large part on how likely it is that properties acquired would have been eventually developed. If DEP has acquired properties that are largely undevelopable, it would have failed to mitigate significant pollution problems in the future. If DEP acquired properties that generally would have been otherwise developed, it would have succeeded in strengthening the protection of its water supply from likely pollution problems. While it is virtually impossible to know with certainty how any undeveloped property might have been developed, a review of case studies can be instructive.

Lakepointe Woods / Town of Carmel / Putnam County / West Branch Basin / Priority 1A

This property consists of 509 acres in the highest priority area of West Branch, part of the Delaware supply system (see Figure 2.10), and is located within a few thousand feet of the intake on the Reservoir. The property can be reached from New York City in under an hour and has road frontage on two opposing sides, and an abandoned town road bisecting the property length-wise; these excellent access features provided a strong basis for subdivision, but the market was poor for such a venture even through the late 1990s. In the early 1990s the property was owned by the Federal Deposit Insurance Corporation (FDIC), having been foreclosed on from a prior owner. DEP had sought to acquire from FDIC in 1993, but FDIC decided to convey to a private buyer in the early 1990s. Preliminary plans had been drawn up by that owner for development of about 200 residential lots. The City recognized the importance of this property early on and commissioned several appraisals (in 1993, 1998, and 1999). After extended and difficult negotiations, the seller did accept a fair market appraised value and signed a purchase contract in March 2000. DEP closed on the property in 2001.

Since 2001, the real estate market has risen considerably. At this writing, the range for desirable building lots in this neighborhood is $200,000 - $350,000. The price paid by the City for Lakepointe Woods was roughly $28,000 per building lot, assuming 200 units. There is a very high probability that if the property had not been acquired by the City, it would now be substantially built at something close to the proposed intensity, with miles of paved roads, lawns, and septic fields in very close proximity to one of the most important intakes in the City supply. .

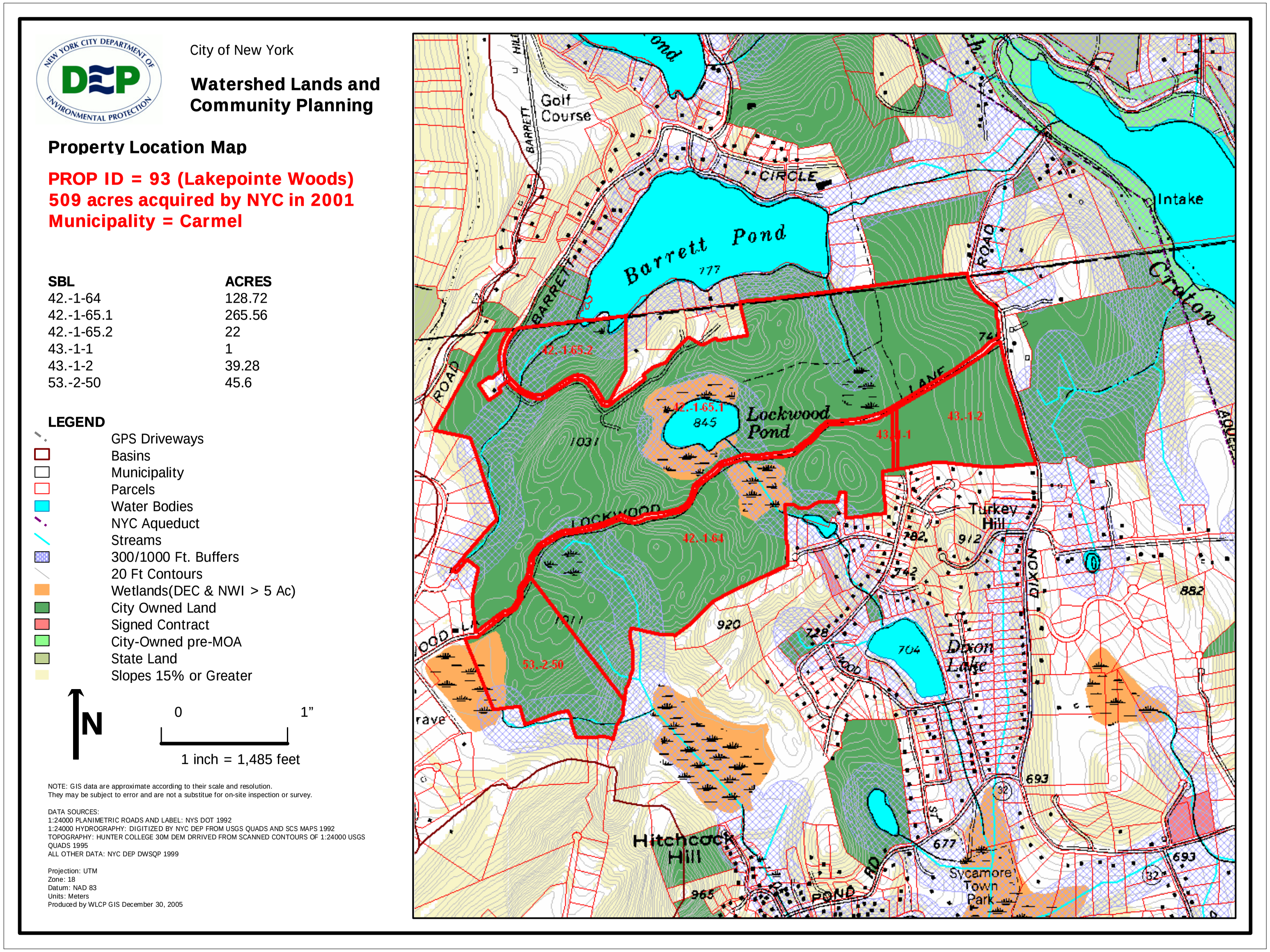

Figure 2.10 Case study 1: Lakepointe Woods in Carmel, Putnam County, West Branch Priority 1A.

The Meadows / Town of Kent / Putnam County / West Branch Basin / Priority 1B

This property consists of 248 acres in the priority area 1B of West Branch, part of the Delaware supply system (see Figure 2.11). Ownership of this property and others had been pieced together between 1961 and 1988 by an investment firm, whose preliminary plans called for approximately 186 single family residences and 360 townhouses. Following difficult negotiations, the seller signed a purchase contract in April 1998. DEP closed on the property in late 1998.

Since 1998, the real estate market has risen considerably. At this writing, the range for desirable building lots in this neighborhood is $200,000 - $350,000. The price paid by DEP for the Meadows was roughly $6,227 per residential unit, assuming 546 units. There is a very high probability that if the property had not been acquired by the City, it would have been substantially developed at something close to the proposed intensity (a density of 2 units per acre), along with miles of paved roads, lawns, and a sewage treatment plant. Note high density developments to the east and northwest of the site.

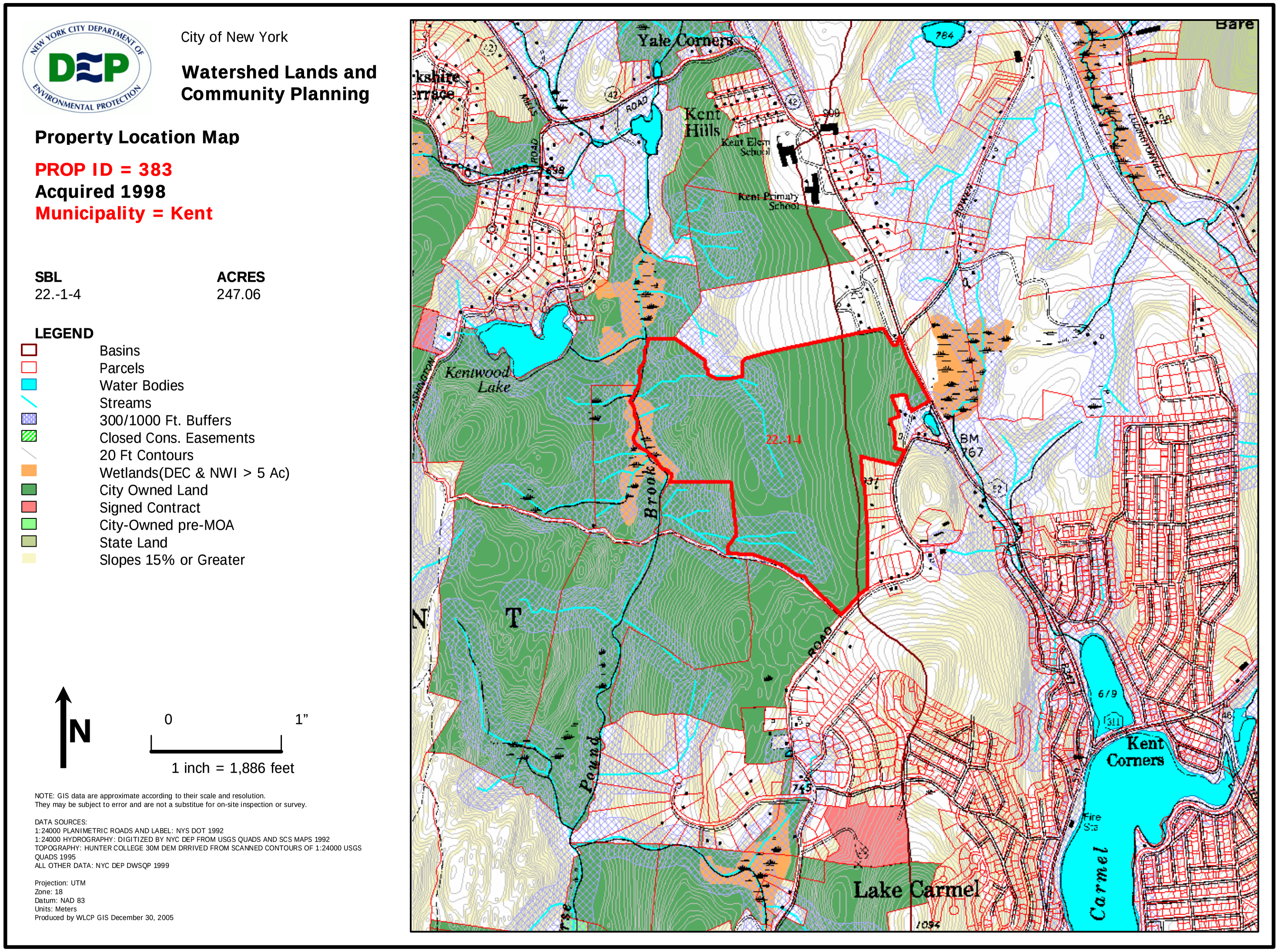

Figure 2.11 Case study 2: The Meadows in Kent, Putnam County, West Branch Priority 1B.

PIN 377 / Town of Wawarsing / Ulster County / Rondout Basin / Priority 1A

This property is 349 acres (see Figure 2.12) and includes a full mile of Trout Creek (both banks), and substantial road frontage (2/3 of a mile along both sides of Sholam Road and 1/5 of a mile on Yeagerville Road). The property is forested and includes gently rolling hills with easy access to Routes 55 and 209, and is relatively near population centers such as Ellenville, Liberty and Monticello. The property abuts five other parcels recently acquired by DEP, and is part of a larger contiguous block of dozens of properties totaling over 6,600 acres, including the original 3,500 acres of reservoirs and associated buffer land.

Priority 1A in Rondout has been a very fertile zone overall for DEP's land acquisition efforts, with 3,145 acres secured since 1997. As mentioned previously, the real estate market has risen considerably during this time, resulting in many subdivisions and developments being approved throughout the watershed and including this area. At this writing, the approximate range for single (1 – 15 acre) building lots in this area is $25,000 – $100,000. DEP acquired this property in early 2004 at a cost of $556,000. A review of subdivision and development in the area (for example, a 75-acre property in the Town of Neversink was recently subdivided into 11 lots, with several already sold at about $75,000 each) suggests that City acquisition has potentially prevented a large amount of additional development in this critical area by securing this property.

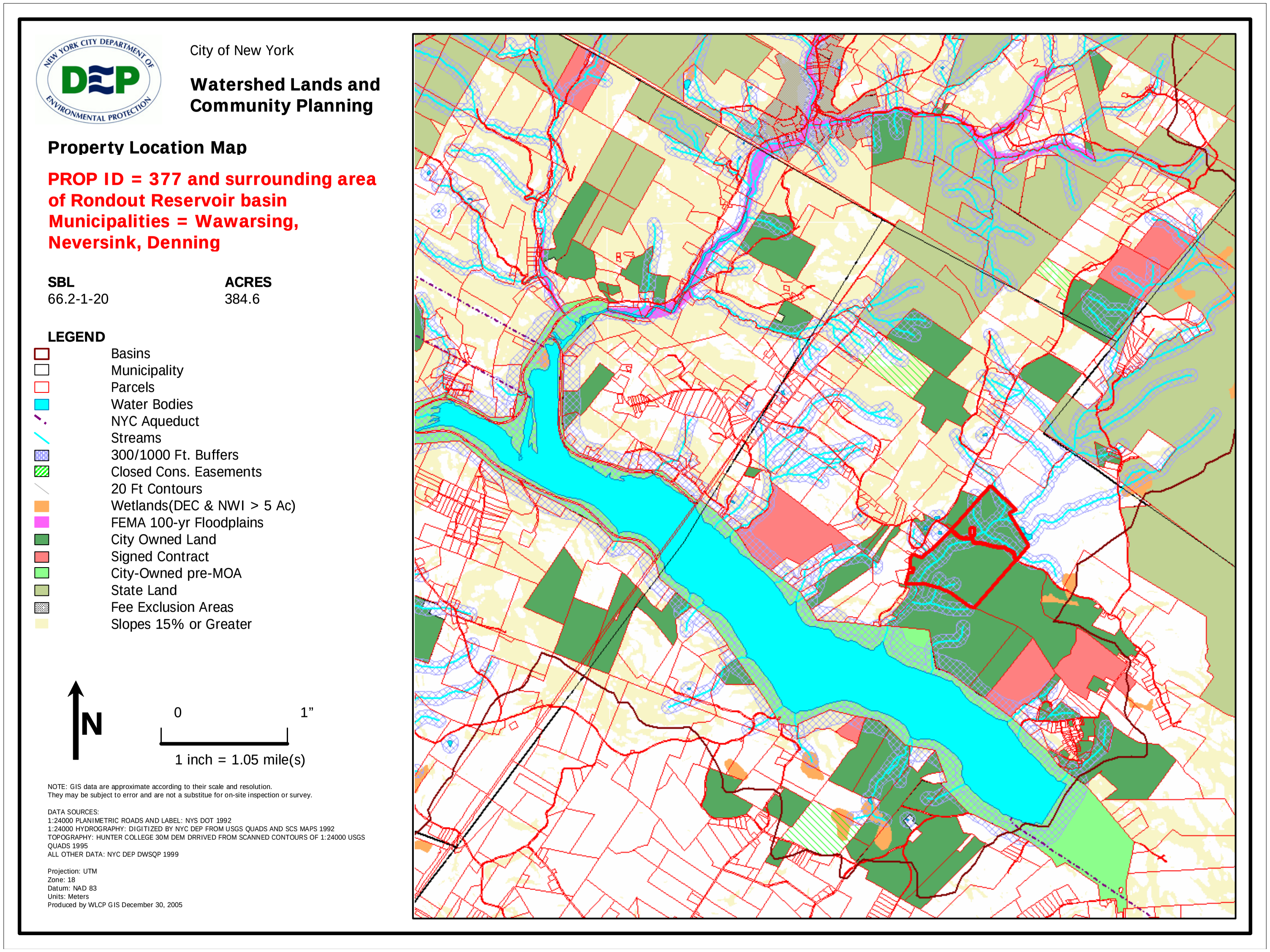

Figure 2.12 Case study 3: PIN 377 in Wawarsing, Ulster County, Rondout Priority 1A.

2.3 Watershed Agricultural Program

The Watershed Agricultural Program (WAP) has operated since 1992 as a comprehensive effort to develop and implement pollution prevention plans on 85% of the commercial farms in the City's Catskill/Delaware watershed. The program is a voluntary partnership between the City and farmers in the watershed to manage nonpoint sources of agricultural pollution, with particular emphasis on waterborne pathogens, nutrients and sediment. In addition, the program incorporates to the extent possible the economic and business concerns of each farm into the development of its Whole Farm Plan in order to fully establish the principles and goals of pollution prevention into the farm operation.

Funded primarily by DEP, the Program is administered by the not-for-profit Watershed Agricultural Council (WAC), whose board consists of farmers, agri-business representatives, forest landowners and the DEP Commissioner. Over time, the City and WAC have been able to leverage generous financial support from other sources to enhance the Program, particularly the US Department of Agriculture, EPA, and Army Corps of Engineers. Local, State, and federal agricultural assistance agencies provide planning, technical, educational, engineering, scientific and administrative support for the program under sub contractual agreements with the Council.

WAP strives to maintain and protect the existing high quality of the water supply system from agricultural nonpoint source pollution through the planning and implementation of Best Management Practices (BMPs) on farms. When appropriate, the Program uses traditional BMPs that are proven to protect and enhance source water quality, and, if necessary, to employ and evaluate innovative BMPs to increase the number of alternatives available to farmers to address "non-traditional" agricultural water pollution concerns, especially waterborne pathogens. More than $25 million has been spent on implementation of BMPs on over 275 farms since 1992.

The goal of the Watershed Agricultural Program is to obtain overwhelming farmer/landowner participation and cooperation in a program to identify and address non-point sources of water pollution from farms. This kind of collaboration between DEP and watershed farmers/landowners is essential for long-term watershed protection and filtration avoidance in a watershed in which most land is privately owned. The success of the Watershed Agricultural Program is therefore primarily linked to the high rate (over 90%) of participation by commercial farmers.

The high rate of farmer participation and cooperation in the Watershed Agricultural Program ensures two things. Foremost, through its relationship with the WAC, DEP has been able to provide farmers with the technical and financial resources to develop and implement pollution prevention plans for their operations: close to 250 of the largest landowners in the watershed have been empowered to serve as active managers and stewards of the landscape for water quality purposes as part of their day to day operations. Second, the institutional relationships between DEP, WAC and the watershed farm community have provided a mechanism to respond quickly and effectively to pollution issues on individual farms as they arise.

2.3.1 Whole Farm Planning and Implementation

Table 2.3 below describes the progress of WAP in meeting its various FAD milestones.

Table 2.3. The progress of the Watershed Agricultural Program in meeting FAD milestones.

Task	Farms	Sub-Farms	Total Farms	FAD Goal 12/31/05
Original Farm Sign-ups	329	41	370	Monitor
Estimated Number of Watershed Farms	262	41	303	
Current Eligible Sign-ups*	249	41	290	Monitor
WFP Implementation Agreements	247	41	288	All Participating Farms
WFPs Commenced Implementation				
Active	162	30	192	All Participating Farms
Under Revision	37	9	46	
Inactive	36	2	38	
Inactive Prior to Implementation	7	0	7	
Total	242	41	283	
WFPs Substantially Implemented				
Active	103	11	114	
Under Revision	37	9	46	
Inactive	44	2	46	
Total	184	22	206	257
WFP Annual Follow-up	144	26	170	219

*Note: 81 farms that have signed up are no longer eligible for the program due to a change in the farm operation (i.e. farm is out-of-business, all animals were sold etc.)

Currently, there are 288 farms (including 41 "sub-farms") with Whole Farm Plan agreements, representing 95.0% of commercial farms in the watershed. This includes four farms that had a plan approved in 2005. Two of these newly planned farms originally signed up under the small farm program, but due to an expansion of their operations they are now considered large farms. There are two other farms that have signed up but still do not have a plan. One of these farms has been unable to come to agreement on a final plan and the other farm plan will be brought to the Council for Whole Farm Plan approval in early 2006. Another new farm plan was to be presented in 2006, but the producer who leased the farm has moved off the farm and the farm is now inactive.

There are currently 290 (including 41 sub-farms) commercial farms signed up for the program out of a possible 303 farms. This represents 95.4% participation rate. The FAD goal is to have 85% participation.

Commenced Implementation

The goal for 2005 was to have 288 (or all participating) farms to have commenced implementation. The number achieved to date is 276 farms (plus there are 7 farms that went out of business before any implementation occurred). This leaves three newly approved Whole Farm Plans that have no documented implementation and two plans that will require plan revisions due to changes in ownership and changes in the operation. The three new plans have implementation scheduled for 2006 and the two other plans will be revised in 2006.

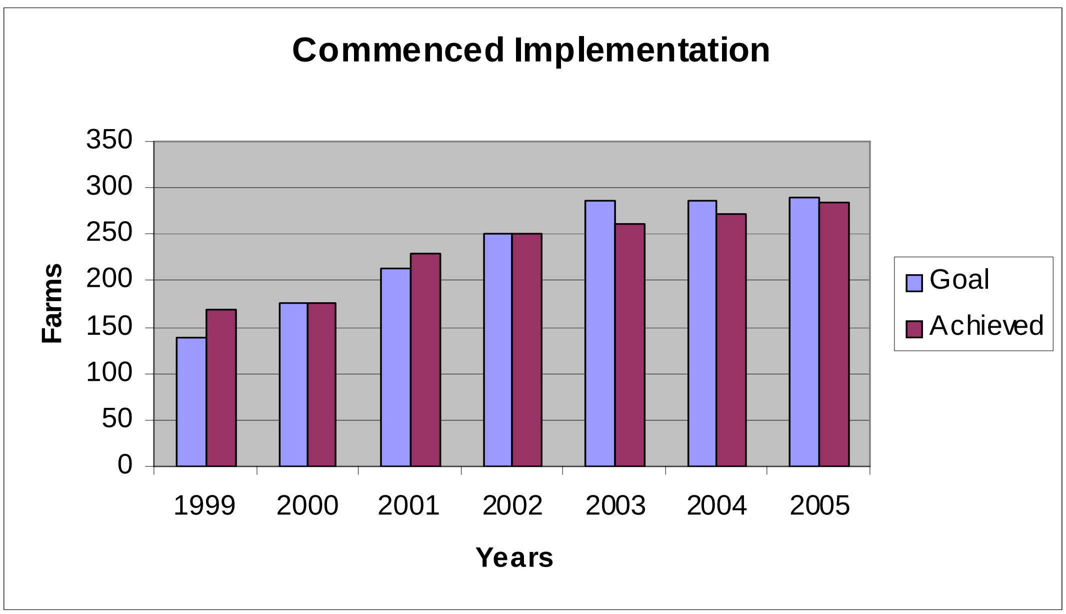

Figure 2.13 Farms that have commenced implementation of WFPs.

Farms Substantially Implemented

There are now 206 farms substantially implemented (27 added in 2005). In addition there are 7 more farms that are substantially implemented based upon work that was finalized in January. There are also 5 other farms that no longer have livestock and the remaining pollutant issues have been addressed when the animals were removed from the farm. Although the goal for this year was not met again, WAC has been able to maintain a good rate of BMP implementation and maintained steady progress towards meeting this milestone.

Table 2.4 summarizes BMPs that have been implemented to date.

Table 2.4. BMPs implemented on large and small farms 1992 – 2005.

NRCS/WAC Code #	Best Management Practice Name	Number of BMPs
193/749	Waste Field Storage/Manure Pile Area	20
312	Waste Management System	19
313	Waste Storage Structure	56
314	Brush Management	16
327	Conservation Cover	7
328	Conservation Crop Rotation	99
329	Conservation Tillage	2
340	Cover & Green Manure Crop	11
342	Critical Area planting	12
362	Diversion	85
382	Fencing	346
391	Riparian Forest Buffer	67
393(a)	Milk House Waste System	59
411	Grasses & Legumes in Rotation	7
412	Grassed Waterways	9
447	Silage Leachate Management	2
468	Lined Waterway	20
500	Obstruction Removal	11
510	Pasture & Hayland Planting	25
512	Pasture & Hayland Management	33
528a	Prescribed Grazing	48
558	Roof Runoff Management	30
560	Access Road	101
561	Heavy Use Area protection	83
574/516/378	Spring Development/Pipeline/Pond	228
575	Animal Trails & Walkways	147
580	Streambank Protection	15
585	Contour Stripcropping	4
586	Field Stripcropping	20
587	Structure for Water Control	17
590	Nutrient Management	503
595/702	Pesticide Management/Agri-Chemical Mixing Facility	27
606	Subsurface Drain	86

Table 2.4. BMPs implemented on large and small farms 1992 – 2005.

NRCS/WAC Code #	Best Management Practice Name	Number of BMPs
612	Tree/Shrub Establishment/Natural Regeneration	199
614	Trough or Tank	54
620	Underground Outlet	23
633	Waste Utilization	322
634	Waste Transfer System	21
707/3010	Barnyard Water Management System/Roofed Barnyard	183
748	Record Keeping	282
3100	Calf Hosing Structure	31
3120	Calf Hutches/Kennel	12
3130	Barn Ventilation	11
3400	Manure Spreading and other Equipment	235
3510	Farm Dump Cleanup	3
3600	Pesticide Handling Facility	2
5002	Bridge Replacement	2
	Total No. of Best Management Practices	**3652**
	Total Cost	**$25,112,397**

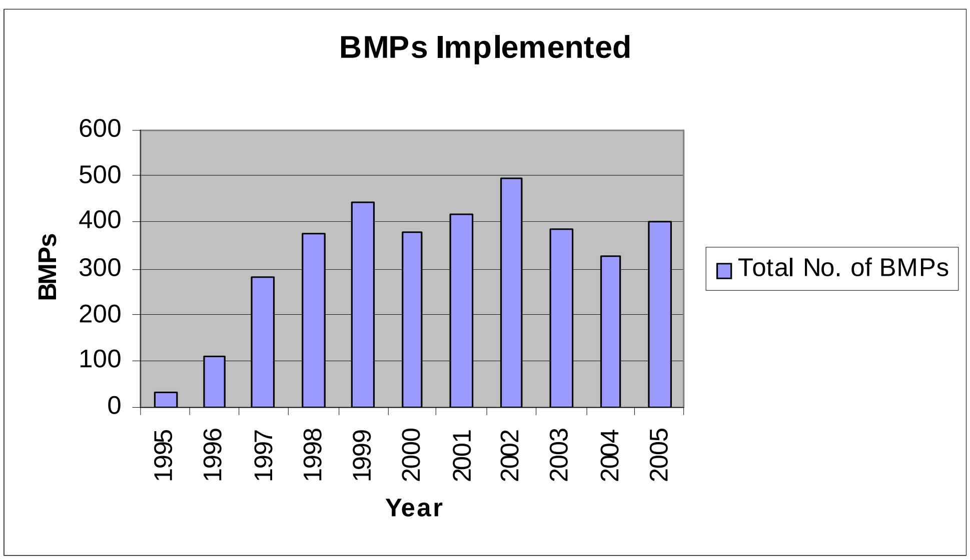

Figure 2.14 Number of farm BMPs implemented.

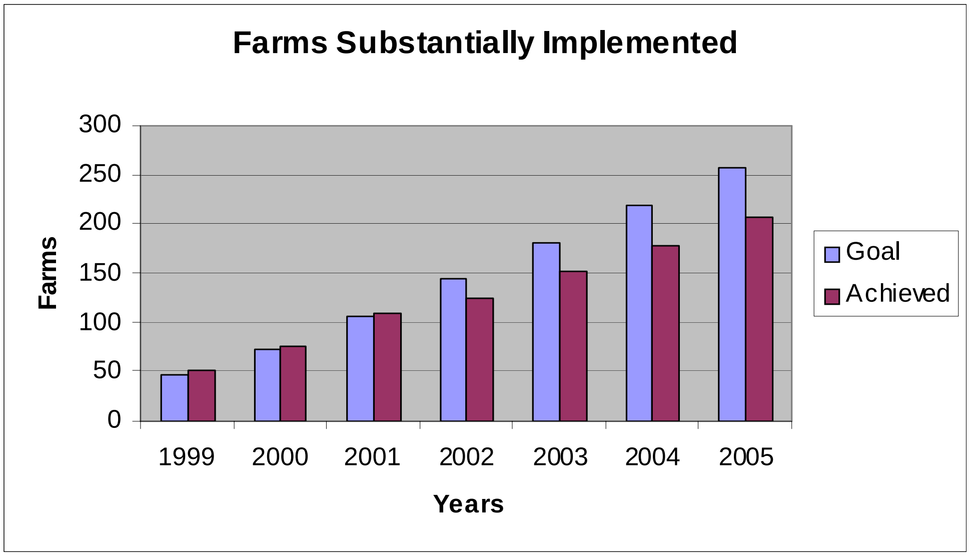

Figure 2.15 Farms that have substantially implemented WFPs.

Annual Status Reviews (ASR)

The FAD goal is to conduct an ASR on all farms that were listed as substantially implemented in 2004 (179). In 2005, WAC completed an ASR on 170 farms. Upon review of the 170 ASRs, DEP identified 46 farms that were substantially implemented in 2004, but did not have an ASR. Nineteen of these farms are currently listed as inactive, but an ASR should be conducted to verify that farm is still inactive. There appears to have been a misunderstanding by WAP staff as to which farms needed an ASR. DEP has requested that WAC ensure that an ASR is completed on these farms by no later than March 30, 2006. WAC will also provide all appropriate staff with a list of farms that will need an ASR in 2006.

2.3.2 Conservation Reserve Enhancement Program (CREP)

The CREP completed its seventh full year in September 2005. The program is extremely popular with watershed farmers and more than 150 farmers and landowners have expressed interest in participating. As of November 2005, 1,797 acres of riparian forest buffers have been planned; 143 contracts have been signed; and a total of 1,697 acres of riparian land, the equivalent of 165 miles of stream miles, protected by riparian forest buffers. USDA has committed in these 143 contracts more than $5.0 million in rental and incentive payments and another $2.2 million for 50% of the cost of installing conservation practices associated with the buffers. DEP pays the cost for the technical assistance to implement the program and the remaining 50% of the cost of conservation practices.

The most frequently used conservation practices for establishing riparian buffers are fencing to exclude animals from buffers and streams; alternative watering systems to provide drinking water to animals once they no longer able to drink from the stream; and tree and shrub planting. CREP has installed close to 100 miles of stream fencing to exclude more than 9,000 head of livestock (including dairy, beef, horses, sheep, etc.) from streams and rivers. A research study conducted by a Penn State Graduate Student in 2003[1] has reported that recent efforts to exclude cattle from streams as part of the CREP were estimated to have already reduced in-stream deposition of livestock fecal phosphorus by 32%.

2.3.3 Nutrient Management Planning

The Nutrient Management Team is working with farmers and the whole farm planning teams to ensure that all livestock farms with approved Whole Farm Plans have an updated nutrient management plan (NMP). NMPs are updated every three years as is recommended by the Natural Resources Conservation Service (NRCS). This requires new soil tests when the plans are updated. Currently, 90% of the active participating livestock farms have an updated NMP.

These nutrients management plans contain a significant amount of historical data regarding nutrient level changes that have occurred on farms since the beginning of the program in 1992. WAC's Nutrient Management Team is collaborating with Delaware County SWCD and Cornell University Staff to organize all this data, which is in many different formats (hard copy and digital), into a comprehensive database that can be used to measure and forecast changes in nutrient soil levels across many farms at once.

WAC has also offered financial incentives to farmers in the Cannonsville basin who provide documentation that they have properly implemented their nutrient management plan. Farmers receive a nutrient management credit ($10/acre in their NMP) that can be used to reimburse farmers for certain nutrient management expenses (i.e., manure spreaders, pumps, custom spreading etc.).

Farms with manure storages that are required by their NMP to spread manure more than two miles from the farmstead are eligible to receive additional financial incentives through the "Enhanced Nutrient Management Credit Program". This program was designed to encourage the use of custom spreading instead of purchasing and maintaining large manure transportation BMPs.

2.3.4 Small Farms Program

In October 2000, WAC initiated a process to inventory small farms (those earning less than $10,000 per year) using the New York State Agricultural Environmental Management (AEM) Guide. There have been 224 Tier I surveys submitted to WAC and the Small Farm Team has completed Tier II Environmental Reviews on 141 small farm operations. In addition 41 whole

1. James, Erin et. al., Phosphorus Contributions From Pastured Dairy Cattle to Streams, 2003

farm plans have been approved covering more than 6,000 acres. To date 345 BMPs have been implemented on 31 small farms and 11 of these farms have had all pollution issues addressed. The program has a goal of developing 10 new whole farm plans per year with farm selection based upon those farms with the greatest water quality concerns.

2.3.5 Conservation Security Program

The Conservation Security Program (CSP) was authorized by the federal Farm Security and Rural Investment Act of 2002. CSP is a voluntary program that provides financial and technical assistance to producers who advance the conservation and improvement of soil, water, air, energy, plant and animal life, and other conservation purposes on private working lands. Such lands include cropland and improved pasture, as well as forested land and other non-cropped areas that are an incidental part of the agriculture operation.

CSP supports ongoing land and water stewardship by providing financial and technical assistance for producers to maintain and enhance resources. The purpose of CSP is to:

- Identify and reward those farmers and ranchers meeting the very highest standards of conservation and environmental management on their operations;
- Create powerful incentives for other producers to meet those same standards of conservation performance on their operations; and
- Provide public benefits for generations to come.

CSP goes beyond the past approach of repairing on-farm conservation problems. Instead, CSP offers rewards to those who have been good stewards of the soil and water resources on their working agricultural land. It also offers incentives for those who wish to exceed the minimum levels of resource protection and enhance the natural resources on the land they manage. The program is available in designated watersheds, which USDA selects annually, based upon funds allocated by Congress. In federal FY 2006, the *East Branch Delaware Watershed* was selected. WAC will provide assistance to watershed farmers and will encourage them to participate in this program. DEP and WAC anticipate that all WAC participating farmers will be eligible to enroll in CSP in the next few years. CSP will be an excellent financial incentive to encourage farmers to continue implementing and maintaining their WFPs.

2.4 Stream Management Program

The primary goal of the DEP SMP is to preserve and/or restore achievable levels of stream system stability and ecological integrity by facilitating the long-term stewardship of streams and floodplains. Many pervasive problems experienced by watershed communities – erosion at public and private properties and infrastructure, habitat degradation, and reach-scale water quality degradation – are linked to the physical condition of those streams. Further, actions taken by individuals or agencies can positively or negatively impact those same processes. Since all stream work is regulated by NYSDEC, permits granted weigh heavily on the outcome of all of this stream work. Management decisions in this mountainous, glacially influenced, and predominantly privately-owned landscape are especially sensitive, calling for a voluntary program to focus outreach, training, planning and demonstration on the appropriate management of stream corridors.

A more detailed account of the history and mission of the SMP is available in the Five Year Plan (Appendix K, 2001 Watershed Protection Program Summary, Assessment and Long Term Plan). More recently, in April 2004 the SMP worked with its Advisory Board to evaluate program effectiveness in the context of five programmatic goals. This biennial report will be updated again in April 2006. For a most complete assessment of the accomplishments and challenges of the SMP, please refer to this upcoming document.

Since 2002, the SMP and its partners completed six Stream Management Plans addressing 33% of the west of Hudson watershed and remain on schedule to complete three additional stream management plans bringing the area addressed to 65% by 2007. See Figure 2.16.

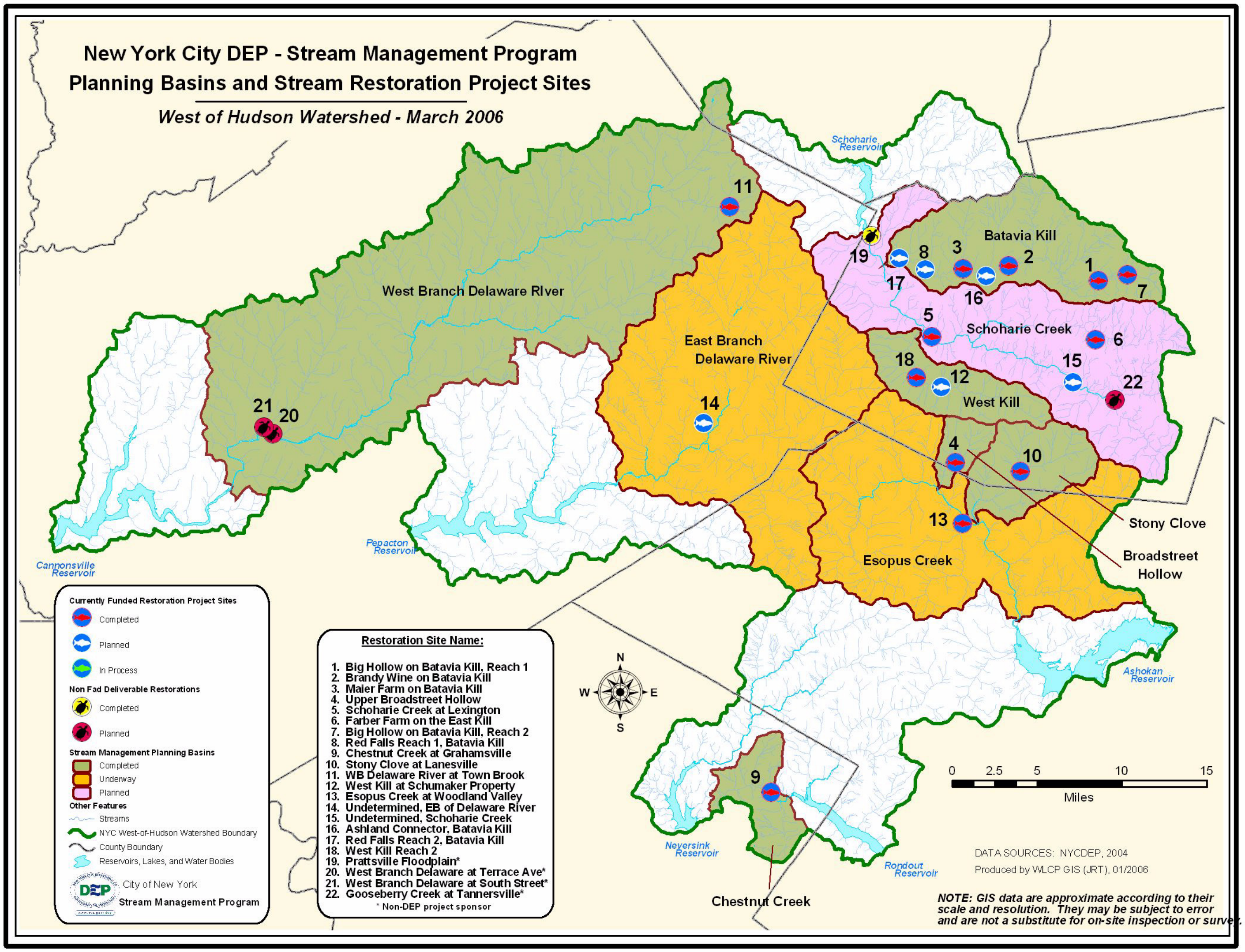

Figure 2.16 Stream Management Program planning basins and stream restoration project sites - March 2006.

Further, SMP realized its goal of establishing a diverse network of restoration demonstration projects by completing assessment, design and construction of six projects as of December 2005. SMP has completed 12 projects since 1996, and expects to complete an additional five projects before December 2007.

Most importantly, a strong network of stream management professionals has been established in the west of Hudson watershed, linked together by a series of contracts that are enabling the development of stream management plans, state of the art restoration techniques to solve complex and chronic stream related problems, and education programs to promote greater stream stewardship by watershed residents.

2.4.1 Partnership and Education

Through partnerships and educational efforts, the SMP is building a constituency of stream stewards ranging from agency resource managers to local highway superintendents to riparian landowners, college students and schoolchildren. DEP and our project partners have supported partnership and education through participation at public presentations and workshops, sponsorship of a stream education program for area schools, production and distribution of educational pamphlets and newsletters, participation/coordination of local and regional groups and coordination of Project Advisory Committees (PACs) to develop stream management plans.

Partnerships

SMPs principal partners have been the Soil and Water Conservation Districts (SWCDs) in stream assessment, planning and the design and construction of restoration projects. SMP's network of partners includes Cornell Cooperative Extension of Ulster County and Delaware County Planning Department. The SMP's Advisory Board worked with SMP and its partners to provide direction on management planning, assessment, restoration and riparian management, effectively keeping all connected to advances in relevant science and watershed management. Through the stream management planning process, SMP and these partners have effectively engaged the involvement of NYSDOT, NYSDEC, NYS Emergency Management Office, recreational groups and local leaders to craft stream management plans.

Local, Regional Meetings and Conferences

In addition to the numerous PAC meetings held to support the stream management planning process, SMP delivered sixteen major presentations and hosted or sponsored ten workshops (Table 2.5). The presentations and workshops provided an important opportunity to present DEP's approach as a model for multi-objective stream management to professionals and landowners locally and across the country, to obtain constructive input that helped refine DEP's methods and to promote future collaboration with appropriate stakeholders.

Table 2.5. Selected workshops and presentations of the SMP, 2002 through 2005.

Workshop/Presentation Title	Type
Habitat and Fisheries to multiple Trout Unlimited Chapters.	Presentation
Japanese knotweed biology and management.	Presentation
Esopus Creek assessments and status.	Presentation
Introduction to stream management planning process and stream restoration projects to newly elected Town of Shandaken officials.	Presentation
Habitat & Hydrologic Modification Working Group, Troy and Phoenicia, NY.	Presentation
6th Annual Conference on Watershed Protection and 2nd Annual New York City Watershed Science and Technical Conference, New York, NY.	Presentation
Environmental Restoration within the Hudson River Basin: From Planning to Practice, Hudson, NY.	Presentation
Maryland Stream Symposium, Baltimore, MD.	Presentation
USGS, Stream Restoration Workshop, Urbana, IL.	Presentation
Mid-Atlantic Highlands Stream Restoration, Cacapon State Park, WV.	Presentation
Integrated Restoration of Riverine Wetlands, Streams, Riparian Areas and Floodplains in Watershed Contexts, Amherst, MA.	Presentation
NYS Wetlands Forum, Syracuse and Saratoga, 2002 and 2003.	Presentation
Watershed Management for Water Supply Systems (AWRA).	Presentation
Stream, floodplain and wetland restoration: Improving effectiveness through watershed and source water protection programs, Bear Mountain, NY.	Presentation
Riparian Buffers workshops.	Workshop
Two Saturday public meetings to describe the SMP and take people on tours of demo projects.	Workshop
Symposium on Reconciliation Ecology.	Workshop
Streamside Landscaping for Bank Stabilization and Ecosystem Enhancement.	Workshop
What a Small, Mostly Rural Watershed Association Can Do.	Workshop
Stream Assessment and Restoration Activities: a comparison of activities on the West Branch of the Delaware River with geomorphic projects on agricultural lands in Pennsylvania.	Workshop
Ecological Restoration: Design of Native Vegetation for Water Quality In Floodplains, Riparian Zones and Waterways.	Workshop
Effectiveness of watershed management activities on turbidity and suspended sediment levels in the Schoharie and Ashokan basins.	Workshop
Regional Knotweed Manager's Initiative.	Workshop

Education and Training

DEP, in collaboration with the Green County SWCD, developed a watershed-specific education and outreach strategy targeting highway departments, riparian landowners and municipal leaders and planners within the Batavia Kill and Schoharie watersheds. Fourteen educational publications were distributed to over 2,600 streamside households, and at various other venues. Several workshops were organized to provide property owners with tools to better manage their riparian land. DEP continued to advocate for the formation of, and support the activities of, watershed landowner associations. DEP project staff worked closely with the public, coordinating and leading hikes, creating a Japanese knotweed management project to study and demonstrate various invasive plant control techniques, and participate in local community events such as stream clean-ups and community celebrations.

The Catskill Stream and Watershed Education Program, taught by the Catskill Center for Conservation and Development delivered watershed lesson plans to over 500 students within 30 classes from eight schools. Exchange programs with students from the watershed community and City schools assisted in planting over 4,500 shrubs and willow fascines at streamside properties.

Training a cadre of stream professionals supported both planning and outreach. In addition to the staff hired by DEP and the County partners, the stream management program maximized efficiency by training and utilizing 15 AmeriCorps members and 54 Watershed Conservation Corps members, many of whom remained active in watershed work with DEP, a Soil and Water Conservation District, or the Watershed Agricultural Council upon completion of their service.

2.4.2 Stream Management Plans

Stream Management Plans are an effective tool to catalyze and coordinate long-term management and stewardship of streams and stream corridors in the watershed. The Stream Management Program and its project partners have met all FAD requirements with respect to the completion of stream management plans for priority sub-basins. This includes the preparation of plans for the Batavia Kill, Broadstreet Hollow, Chestnut Creek, Stony Clove Creek, the West Kill and the West Branch of the Delaware River (see Figure 2.16). The planning process has been successfully extended to new watersheds including Esopus Creek and the East Branch of the Delaware River, and new partners have joined with DEP in accomplishing this goal. To date, the SMP and its partners have created plans for 32.9% of the west of Hudson watersheds, are currently working to develop plans on an addition 22.9% of the west of Hudson watersheds and will have created plans for almost 65% of the west of Hudson watersheds by the end of 2007.

One of the goals of the SMP is to work with local agencies that have a credible and effective reputation with each community and familiarity with its resources. The knowledge and understanding of stream systems garnered by these agencies during the plan development process stays in the community and is put into action. To that end, these plans are developed through contracts between the SMP and various local partners. Previously the principal partners were the SWCDs of Delaware, Greene, Sullivan and Ulster Counties. Under its contracts to date, DEP has employed and trained over 27 full or part-time professionals working with the stream management program for county governments.

SMP has recently expanded its network of partners. In 2004, DEP entered into a contract with in Cornell Cooperative Extension of Ulster County. Under this same project, DEP also contracted with US Army Engineer Research Development Center – Environmental Laboratory (ERDC-EL) out of Vicksburg, MS to lead the watershed/stream geomorphic assessment on the Esopus. As part of the East Branch of the Delaware River SMP contract, Delaware County SWCD has formally joined with Delaware County Planning Department for the first time to launch a more comprehensive public outreach effort and extend the protection message to local planning boards.

Each stream management plan contains a comprehensive set of recommendations to address stream management issues at both watershed and reach scales. These recommendations typically call for improving and coordinating stream stewardship education and outreach initiatives, riparian and floodplain management programs, stream stability restoration approaches, as well as fish habitat enhancement and recreational opportunities.

SMP views these plans and their recommendations as critical guidance documents for protecting water quality while also fulfilling community stakeholder interests. SMP and its partners focused on developing an understanding of river process and the explaining this process through stream management plans. SMP continues to strengthen its relationships with local and State officials and support progressive local management activities, such as the coordinated emergency flood response, the adoption of hazard mitigation plans, and revision of floodplain maps. SMP has expanded its relationship with the Catskill Watershed Corporation in an effort to support local community adoption and implementation of management plans. A continued emphasis on education, outreach and community organization will also be an integral part of any implementation strategy.

2.4.3 Stream Restoration Demonstration Projects

The 2002 FAD requires that 12 stream restoration demonstration projects be constructed. These projects demonstrate the use of natural channel design and bioengineering techniques in stream channel and stream bank stabilization projects. Figure 2.16. depicts the location of each project, and the text below summarizes project status and construction costs. The reported cost excludes all staff time costs (design, construction management and inspection, partial bioengineering, and monitoring), engineering certification and consulting fees for assessments. To date, a little over $2.6 million dollars has been spent on construction/maintenance. Further detail on each project is available in its project summary report prepared following its completion.

In addition to working on these restoration projects, SMP provided technical assistance to numerous non-DEP-sponsored projects. Specific examples, described in detail in the semi-annual reports, include Schoharie Creek floodplain restoration at Prattsville; design support for streambank stabilization projects on the West Branch Delaware River at Terrace Avenue and South Street in Walton; and Gooseberry Creek bike path streambank stabilization; Herrick Hollow stream restoration at the Richardson Hill Road landfill.

Chestnut Creek Town Hall Demonstration Site, Chestnut Creek

This project was selected to address streambank instability, enhance infiltration of parking lot runoff, remove invasive species (*Rosa multiflora*) and a non-functioning dry hydrant, and to establish a diverse, native vegetated riparian buffer at the Neversink Town Hall. Paid for by DEP and the Watershed Agricultural Council, Sullivan County SWCD completed the construction in 2003. The project has withstood several bankfull or higher flows. Project monitoring of vegetation vigor and permanent cross-sections have shown that despite the high flows, minimal repair was required - usually just replanting of vegetation. The Town Hall location is a popular site for visitors and special events, and as such has provided excellent demonstration opportunities. Information pamphlets describing the project, the plants used and warning of the dangers of the invasive Japanese knotweed are available at the site. Small, sturdy plant markers label the plants for those interested. Community groups and classes have visited the site to learn more about the project. The Town will assume maintenance responsibilities in fall 2006. The final construction cost for this project is $19,864.

Lanesville Stream Restoration Demonstration Project, Stony Clove

The Stony Clove was identified in a storm-sampling study DEP as a major contributor of suspended sediment to the Esopus Creek, and the Lanesville site was identified at that time as one of two major sources within the Stony Clove. The unstable reach contained extensive exposures of lacustrine clay over its length and was undermining a clay-rich sixty-foot high stream terrace. Greene County SWCD reconstructed a 1,700 foot long channel to new dimensions designed to effectively convey sediment; installed four large rock cross-vanes and six deflecting rock vanes; and extensively revegetated the banks and floodplain, including 3,200 linear feet of willow fascines, 1,500 live willow posts, and 4,000 potted trees and shrubs. Record-setting high flows in 2003 and 2004 prevented project completion. The first-time use of a passive dewatering pipeline enabled completion in 2005. As of December 2005, the project had already experienced several bankfull flows, and appeared to be functioning as designed. The final construction cost for this project is $344,368.

Big Hollow Restoration Project, Batavia Kill

Greene County SWCD and DEP chose the Big Hollow Restoration Project, located in the headwaters of the Batavia Kill in the Town of Windham, to address instability associated with excessive lateral and vertical erosion in areas containing extensive glacial lacustrine and lodgement till exposures. Funded by DEP and NYSDEC, construction of the 5,310-foot . reach commenced in 2001 in a two-phase plan; both phases were completed by 2002 as scheduled. The restoration project incorporated the use of channel realignment, in-stream structures (60 rock vanes, 12 cross vanes and root wads), bioengineering (5,800 feet of live fascines and 5,200 feet of brush layering), clay removal and creation of two ponds to supply fill material for re-connecting the constructed channel to its floodplain. Monitoring includes: as-built surveys completed post-construction, including 26 permanent cross-sections completed by Greene County SWCD and fish sampling completed by United States Geological Survey (USGS). This site is one of three in the BMP Study, discussed in Section 2.4.4 of this report.

The Big Hollow project incurred serious damage as a result of the April 2, 2005 flood event. Three meander bends were cut off as a head cut moved through the reach and rock key-ways holding the planform geometry were flanked. Greene County SWCD and DEP implemented a first set of repairs in September 2005. Additional repairs may be planned following Greene County SWCD completion of modeling the designed project condition compared to the as-built condition to better understand possible failure mechanisms and determine if additional repair to major project aspects is necessary. The combined construction and maintenance cost to date is $758,140.

Red Falls Restoration Project, Batavia Kill

Red Falls was targeted by DEP as a significant contributor to turbidity in the Batavia Kill in the mid 1990s. Originally scheduled for completion by December 31, 2004, the project was first postponed to allow Greene County SWCD to focus on the West Kill and Stony Clove projects that were postponed due to weather delays. The project has now been postponed indefinitely for a number of reasons. DEP is awaiting decision to sell by a major landowner within the reach and has requested that Greene County SWCD cease assessment activities until further notice. Concerns were also raised in fall 2005 about the geo-technical stability of an area possibly experiencing a high hill slope failure. Greene County SWCD was cautioned by their licensing engineer against proceeding with the conceptual design until more information is gathered about the failure. To pull the channel away from the slope would mean encroaching upon an area that is eligible for the National Register of Historic Sites. This may result in a more traditional hard revetment or a channelization of the stream, not a natural channel design achieving multiple objectives as advocated by DEP. It also adds considerably to the project cost and complexity. At this time DEP is considering program objectives and weighing associated risks in order to make an informed decision about the future of this project.

Ashland Connector Restoration Project, Batavia Kill

Upon completion of the Batavia Kill assessment, this reach was ranked as one of the top three sites needing restoration. This 3,600 foot project was selected by GCSWCD and DEP to address severe erosion and to connect previously built projects at the Maier Farm and Brandywine reaches. As it is scheduled for completion by December 2006, appropriate assessments and landowner outreach are in full swing. The archeological assessment is complete and unremarkable. The site contains no known geo-technical failures. After Greene County SWCD completes a flood analysis with the proposed design, DEP will evaluate the project's effect on the development potential of the reach. SMP recognizes that it may not be in the City's interest to use public money to improve the development potential of watershed lands.

Conine Restoration Project, Batavia Kill

This reach was ranked among the top three sites in need of restoration by GCSWCD upon completion of their Batavia Kill assessment. Just downstream of the Red Falls project site, Conine was selected to address severe erosion, clay and lodgement till exposures and large slope failures. Originally scheduled for completion by December 2006, DEP has postponed the project until an undetermined date. The archeological assessment is complete and unremarkable. Due to the slope failures present, a geo-technical investigation was initiated in December 2005. A report recommending further investigation, slope stabilization or no action is expected in May 2006, at the earliest. Upon receipt of the report, the project partners will evaluate future action.

Post Farm Restoration Demonstration Project, Town Brook, West Branch Delaware River

This project was selected by Greene County SWCD to address a geomorphic problem of channel incision and lateral migration of a headwater stream in an agricultural setting. The Whole Farm Plan for the Post Farm called for expansion of the riparian buffer under CREP and installation of a permanent cattle stream crossing through a reach where cattle pressures had destabilized the stream. The project would improve water quality by facilitating nutrient management on the farm and reducing bank and bed erosion in the channel. Design and construction was managed by the District and funded by NYS Department of Agriculture and Markets (75%) and DEP (25%). The final construction cost is $225,897.

The project, completed in 2004, has controlled erosion and attempted to establish a stable planform through the use of 13 rock vanes and cross vanes. The floodplain elevation was adjusted to allow higher than bankfull flows to access their floodplain, which was then vegetated. As built, the change in drop at several of the cross vanes was found to be excessive and these vanes were later notched to correct this condition to facilitate fish passage. Fish passage remains a concern at the project and the District has monitored the site with the assistance of the USGS. Two of the project's structures experienced minor damage in the April 2005 flood event, but the integrity of the project was not threatened.

Shoemaker Road Stream Restoration Project, West Kill

This project included stabilization of a 3,100-foot stream reach on the West Kill along Greene County Route 6 in the Town of Lexington, and was completed in 2005. Addressing severe incision into lacustrine clay, construction began in July 2003, but was delayed by high flows in 2003 and 2004. By October 2004, 75% of the project had been completed. The April 2, 2005 flood event necessitated extensive repairs and re-bioengineering over approximately 65% of the project length.

Greene County SWCD modified the channel to reconnect it to its floodplain, excavated 10,600 cubic yards of clay from the streambed over the entire project length, and installed 10 cross-vanes and nine rock deflecting vanes to hold the elevation and planform geometry. Further, the District employed the innovative and experimental use of a sediment screen on site to sort the excavated channel material for targeted use in the restoration: coarse material for the channel bed, medium for the banks and fines for the floodplain. The goal is to improve channel bed and bank stability during the initial flushing flows, and to improve soil structure (and vegetative growth) on the floodplain. The District has attempted to revegetate this site extensively, planting some 2,800 feet of live willow fascines, 750 live willow posts and 3,500 potted plants. The final construction cost is $657,065.

Esopus Creek Stream Restoration Demonstration Project

The Esopus Creek project was constructed in 2003 at the confluence of Woodland Valley Creek. This ~1,000-foot. reach of stream had historically been unstable, the bifurcated channel shifting back and forth between the railroad on the south and a terrace on the north. An active shift of the main channel toward the north into the glacial till terrace undermined the steep stream bank causing excessive erosion and threatening water quality by potentially exposing septic systems and contributing to turbidity from the silts and clay in the till. Several project partners worked together to develop a design, secure funding, manage the construction and conduct follow-up monitoring. To date approximately $850,000 has been spent on all aspects of the project. DEP has provided approximately 50% of the funding and the US Army Corp provided the other 50% with the support of NYSDEC through Water Resources Development Act (WRDA) funding. The Ulster County SWCD coordinated the effort, and the NRCS provided substantial in-kind engineering and construction support. The project design included excavation of a new channel, four diverting rock vanes, two cross vanes, rip rap revetment and bioengineering. Importantly, the use of a VRSS — vegetation reinforced slope stabilization system — was piloted for use in the watershed at this site. Thus far it has proven to be a very successful bioengineering technique for steep slopes.

The April 2, 2005 flood caused some damage to the project. The estimated flow through the project site was approximately 30,000-35,000 cfs – an order of magnitude above the design bankfull flow and estimated to be over a 50-year return interval event. As part of the ongoing commitment to project monitoring and maintenance, a flood damage assessment was completed by Ulster County SWCD and FIScH Engineering in spring 2005. Maintenance repair work to the damaged riprap was completed and several hundred new bare-root trees were replanted in spring/summer 2005. Repairs to the eroded bank below Woodland Valley Creek are planned for summer 2006. The combined construction and maintenance cost to date is $604,834.

2.4.4 Stream Process Research

The long-term strategy of the research and data development efforts of the SMP is summarized in Section 6.4.5 and Appendix K of DEP's 2001 Long-Term Watershed Protection Program. In 1996, following reactive regional response to flooding, the SMP initiated a multi-year effort to develop and distribute regional stream morphology databases to support stream management decisions, stream restoration design, and program and project evaluation. This effort is composed of the following set of coordinated data development projects:

- Development of Catskill Mountain Regional Curves of Bankfull Discharge and Associated Hydraulic Geometry
- Reference Reach Design and Fluvial Process Database Development
- Monitoring Effectiveness of Stream Restoration Projects
- Erosion and Scour Monitoring

The status of each project is summarized in the following text. Further detail is available in previously submitted SMP reports.

For all projects, USGS was contracted to perform comprehensive and detailed hydrologic components. Remainder of field data collection, analysis, interpretation and reporting work was completed by DEP staff, and through agreement with Ulster County Community College for annual student intern teams.

Development of Catskill Mountain Regional Curves of Bankfull Discharge and Associated Hydraulic Geometry

Relationships developed through this study are used to help identify and confirm field indicators of bankfull stage. This is a necessary first step in any geomorphic stream assessment. SMP, our partners and outside agencies, on request, use regional curves in watershed assessments, project design review, site visits, restoration project design and monitoring.

Regional curve data collection, analysis, interpretation and reporting were completed in 2005. There were minor delays due primarily to weather constraints. A single gage site on the initial list remains unmeasured, anticipated to be completed summer 2006, with revision of the curves to be completed by fall 2006.

Reference Reach Design and Fluvial Process Database Development

Knowledge and understanding of stable stream morphology (shape) and function (sediment transport and stream flow) enables managers to re-engineer unstable stream reaches to look and function like their stable counterparts in similar valley settings. Documenting both physical and biological form and function will provide a valuable set of templates for Catskill regional stream stability restoration designs and assessments. This database will also provide the start of an understanding of sediment transport and hydraulic characteristics for stable streams for comparison with unstable streams and project sites. Study of fish population dynamics, associated aquatic habitat, detailed morphology and sediment transport measurements enable better understanding of variability we can expect in stable stream settings.

The Reference Reach Design Geometry and Fluvial Process Study final report is due in 2007. Interim reporting with initial data analysis and findings was completed in 2005. Although the USGS paper is in draft format, initial analysis and conclusions regarding habitat conditions and fish population studies confirm that reference reaches appear to maintain relatively low variability and high function, suggesting a level of "stability" in these reaches year to year.

Monitoring Effectiveness of Stream Restoration Projects

A primary component of the stream management planning process in each priority subbasin is construction of a stream restoration project to demonstrate and evaluate effectiveness of Natural Channel Design (NCD) concepts. To gather pertinent data to support the effective application of this method, SMP set out to compare project reaches with those of "stable" reference reaches and "unstable" non-treated control reaches to evaluate selected aspects of project performance. Evaluation includes analysis and comparison of post-construction adjustment of fish population, geomorphic stability and aquatic habitat.

This spatially complex study design has required an intensive data collection effort. Locating stable reference reaches has proven problematic; so, reference reaches used in BMP comparisons have largely been limited to a biological reference. These biological reference reaches demonstrate reference fishery and habitat conditions but do not necessarily represent a geomorphic stable reference match for the project site. Unstable, untreated control reaches have been easier to find. Each project site also has an unstable control for comparison. A total of five construction projects with unstable and stable control and reference reaches have been monitored and analyzed throughout the last four years (total of 15 sites).

This project will provide an interim report in 2007. Data collection and analysis are ongoing. Interim reporting has been provided in part through Batavia Kill Post-April Flood Reports and USGS papers documenting preliminary results of fish and habitat data related to restoration and control sites. Although USGS papers are in draft form, initial analysis and conclusions are presented. Findings indicate that biological integrity of resident fish communities in Catskill Mountain stream reaches can be improved by NCD restorations.

Erosion and Scour Monitoring

This project is not a separate project as originally scoped in 2001. As an alternative and at the advice of its Advisory Board, the SMP scaled the study back to a monitoring effort at five of the reference reaches and three treatment and three associated control reaches.

DEP is currently installing/monitoring scour chains at three project reaches, associated unstable control reaches and at five reference reaches to begin to compute bed scour and fill dynamics post-construction. This project is currently scoped to provide detailed interim reporting with data analysis and interpretation in 2006.

Data Management and Distribution

DEP, with support from PAR Government Technologies under SDWA funding, is creating a unified database for the storage, maintenance and distribution of regional stream morphology data collected by the SMP and its program partners. The Stream Data Management Project is integrating data collected during the stream assessments, stream morphology surveys and restoration BMP evaluation survey efforts.

PAR has designed a geodatabase for use in ArcGIS as well as a set of software tools for loading field survey data into the geodatabase. Additional tools have been created to help organize, analyze and provide reports of the data. DEP has begun loading data into the geodatabase, preparing instructional documents for users and introducing program partners in Greene and Delaware Counties on its use.

The project will enable stream managers to readily access their information from a single, secure repository and conduct spatial and temporal analysis of the data. Additional benefits of the project include the standardization of data management practices amongst the partners and further development of data collection protocols.

CASE STUDY

Effects of the Stream Management Projects on the Fish Communities of the Batavia Kill and Broadstreet Hollow: USGS Monitoring Study

Stream restoration efforts to increase stream bank stability in impaired streams commonly involve straightening, widening and hardening of stream banks and beds. While habitat and species diversity in impaired stream reaches are generally lower than in unimpaired streams, few studies have documented the effects of restoration on stream fish communities. This study seeks to document the effects stream restoration has on fish community structure and species assemblages.

In 1997, the New York City Department of Environmental Protection (NYCDEP) implemented a program strategy to improve stream stability by designing stream improvement projects using natural-channel design techniques (NCD) where stable reference reach geomorphology is used as a template for designing and repairing an impaired/problem reach. As part of this program, the

U.S. Geological Survey (USGS), in conjunction with DEP and the Greene County Soil and Water Conservation District, began a coordinated effort to assess fish community response to NCD restorations in Catskill Mountain Streams. To evaluate the NCD restoration effects on stream fish communities, pre-restoration electrofishing surveys were conducted in 1999-2001 and post-treatment surveys were conducted in 2002–2003 in paired treatment and reference reaches in the Batavia Kill (Schoharie basin) and Broadstreet Hollow (Ashokan basin). Fish community effects were assessed primarily through before-after-control-impact (BACI) analysis to standardize changes in community characteristics at the restored (treatment) reaches to normal year-to-year changes observed at unaltered reference reaches. Fish community density (total number of fish m^{-2}), community fish biomass (total grams fish m^{-2}), community richness (mean number of fish species present) and community equitability (relative abundance) were estimated for the treatment and reference reaches.

There was no statistically significant change in community density (total number of fish m^{-2}) between the treated and reference reaches in the Batavia Kill: there was a decrease of 0.9 fish m^{-2} ($p = 0.40$)—Figure 2.17A. At Broadstreet Hollow there was a statistically significant increase in community density of 0.9 fish m^{-2} ($p = 0.067$; significant at $\alpha = 0.10$)—Figure 2.17B. Although total density was predicted to decrease after restoration (i.e., numerous small minnows would be replaced by fewer large trout), normal year-to-year variation in fish assemblages at paired reaches, combined with interannual variability in other factors may have prevented detecting expected shifts. High density estimates in the Batavia Kill prior to restoration are partially attributed to dry weather conditions (2001 drought) resulting in a significantly smaller stream.

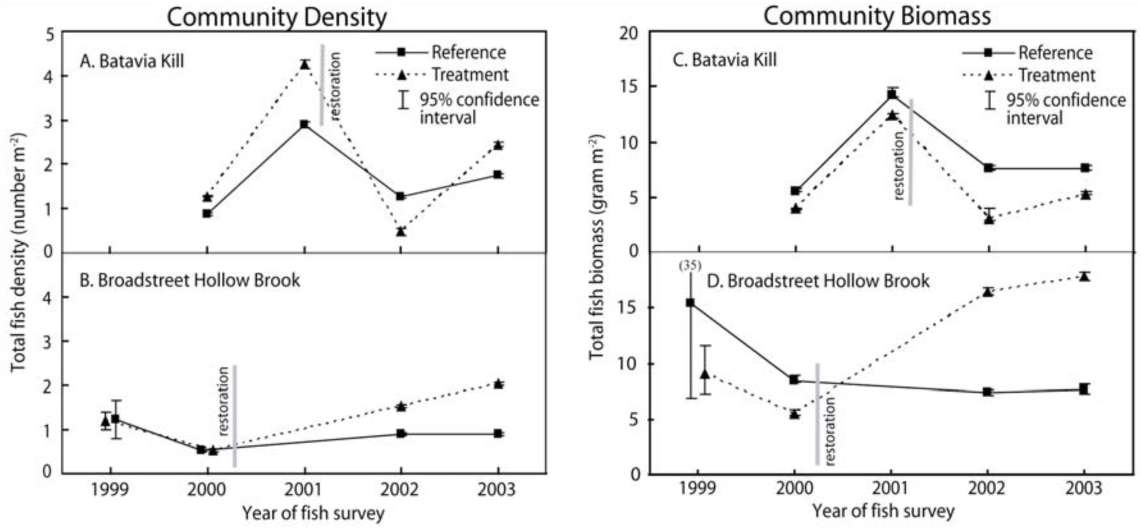

Figure 2.17 Total fish community density and biomass and 95% confidence intervals at paired treatment and reference reaches in two study streams before and after restoration.

Community biomass estimates (total grams of fish m^{-2}) increased significantly at Broadstreet Hollow treatment reach by 14.3 g m^{-2} (p = 0.02), yet showed a non-significant decrease at the Batavia Kill treatment reach (1.7 g m^{-2} (p = 0.27)) following restoration (see Figure 2.17C, 2.17D). Though restoration strongly affected community biomass at Broadstreet Hollow, interannual variation in fish biomass at all study reaches suggest other environmental factors also contribute to observed fluctuations and may explain the observed decrease at Batavia Kill.

Community richness (the mean number of fish species present) was different for the two study streams (see Figures 2.18A, 2.18B). Net richness increased significantly by 5 species (p = 0.02) in the Batavia Kill treatment reach yet no new species were added at the Broadstreet Hollow treatment reach following respective restorations (Figures 2.18A, 2.18B).

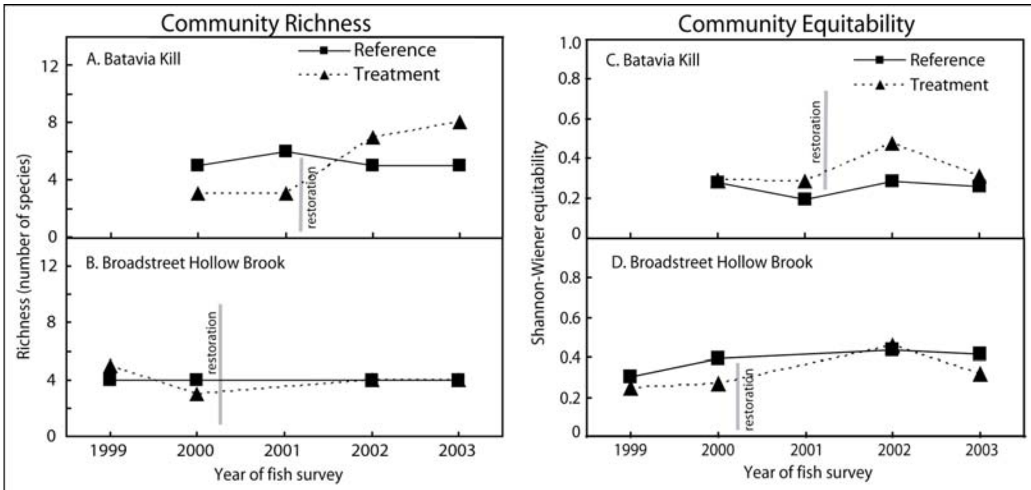

Figure 2.18 Total fish community richness (number of species) and species equitability (Shannon-Wiener diversity) at paired treatment and reference reaches in two study streams before and after restoration.

Measures of community equitability or evenness (relative abundance) give an indication of community structure and integrity (resilience). There was no apparent change in equitability based on species numbers at either treatment reach (see Figure 2.18C, 2.18D), however, equitability based on species biomass did appear to increased consistently in the Batavia Kill treatment reaches following restoration (see Figure 2.19A). The results suggest that the few opportunistic or tolerant species that can exist in the degraded reaches before restoration were not replaced significantly by less tolerant species after restoration. The fish species assemblage was not any more balanced.

Interannual variation in stream conditions and other environmental factors prevent making conclusions on restoration effects on fish density and biomass. However, changes in the fish community and trophic structure resulting from restoration can be detected by looking at changes in biomass equitability and species richness. Though the NCD restorations did not alter the numeric balance of fish species, they influenced the distribution of species biomass within the restored reaches. Community structure and thus integrity improved in the previously degraded reaches. Biomass and proportion of top predators (trout) increased after restoration and decreased for prey species.

The fish communities that were established in restored reaches generally resembled the natural, evenly balanced fish communities in corresponding reference reaches. The NCD helped resurrect a more diverse, resilient and well-structured fish community and the fish communities and populations generally benefit from NCD restorations in the stream reaches studied.

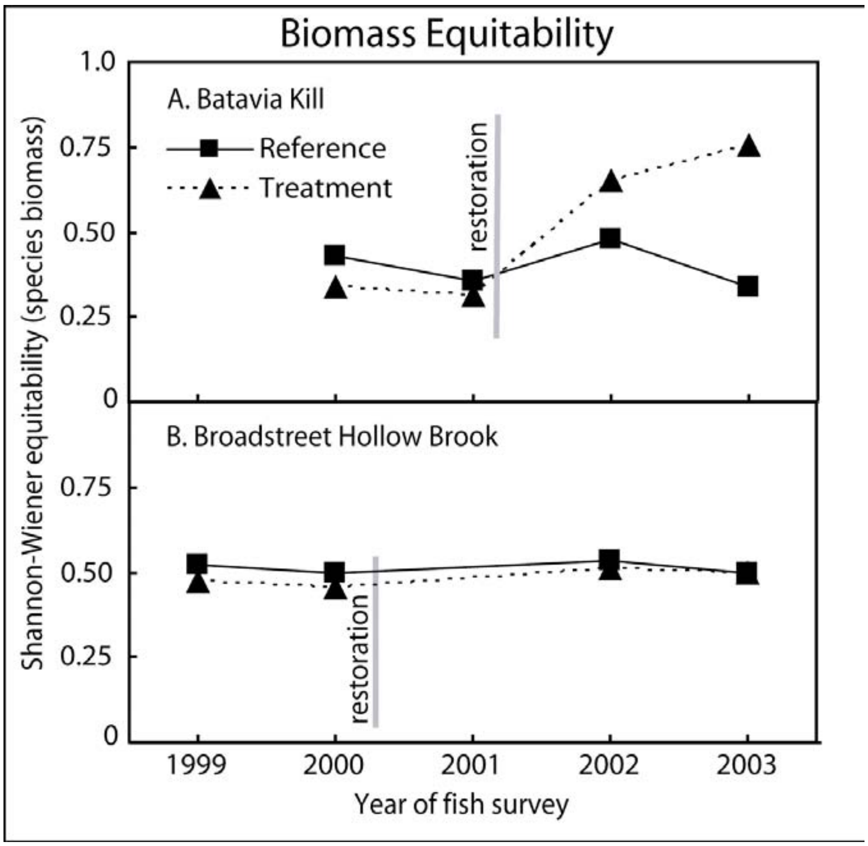

Figure 2.19 Biomass equitability (Shannon-Wiener) for fish communities at paired treatment and reference reaches in two study streams before and after restoration.

2.5 Environmental Infrastructure Programs

2.5.1 WWTP Regulatory & SPDES Upgrade Program

As part of the 1997 MOA, the City agreed to fund the eligible costs of designing, permitting and constructing upgrades of all non-City-owned wastewater treatment plants (WWTPs) in the watershed. For the purposes of this program, "Upgrades" mean equipment and methods of operation that are required solely by the City's Watershed Rules and Regulations (WR&R), and not by federal or State law. The City further agreed to pay the annual costs of operation and maintenance of the upgraded facilities.

The task of coordinating these complex projects with 37 different west of Hudson owners (the total includes one facility located in the West Branch basin east of Hudson) and an additional 69 east of Hudson owners in the watershed is an enormous one. Virtually all of the WWTP owners are restaurateurs, hoteliers, camp operators, homeowners' associations, school administrators, managers of recreational facilities and the like – not professional WWTP operators or construction specialists. DEP has proceeded diligently with this vast undertaking and provided step-by-step guidance on a host of legal, engineering, contracting and regulatory issues.

To assist in implementation of the upgrades, DEP contracted with the New York State Environmental Facilities Corporation (EFC) to assist with the administration of the program. EFC's technical expertise and long history of assisting in wastewater infrastructure projects throughout the State made it the perfect partner for the Upgrade Program. DEP entered into a contract with EFC that identifies a wide range of tasks to be performed by EFC to ensure achievement of the upgrades at the various WWTPs. The tasks include, but are not limited to, various program start-up tasks, contracting with each WWTP owner, technical assistance to each WWTP owner, change order administration, construction oversight at each WWTP, funds management (including invoice review and reconciliation) and project management assistance and fiscal reporting to DEP.

The upgrade of WWTPs is divided into two distinct programs: Regulatory Upgrades and SPDES Upgrades (west of Hudson only). Although two separate programs, the Upgrade Agreement between the EFC and the WWTP owner encompasses both programs.

The Regulatory Upgrade Program is designed to assist each WWTP in meeting the requirements of the WR&R and provides for the design and installation of highly advanced state of the art treatment of WWTP effluent. Treatment technologies required by the Regulatory Upgrade Program and funded by DEP include, but are not limited to, phosphorus removal, sand filtration, back up power, back up disinfection, microfiltration (or DEP-approved equivalent), flow metering and alarm telemetering.

The SPDES Upgrade Program is designed to assist WWTPs in achieving and maintaining compliance with the current SPDES permit. Equipment that is unreliable or reaching the end of its useful life is eligible for replacement under this program. $4,600,000 is available for funding under this program. A separate portion of this program dedicates an additional $400,000 to Infiltration and Inflow (I/I) projects.

Over the past five years of the Wastewater Treatment Plant Regulatory Upgrade Program remarkable progress has been made toward achieving the goals of the program. In fact, efforts of the WOH projects are drawing to a close. By the end of the reporting period 25 of the 37 WOH WWTP Upgrade projects have been completed, either through construction of an on site upgrade or through connection or pending connection to another tertiary WWTP (see Table 2.6). These facilities account for more than 96 percent of the SPDES permitted flow from non-City-owned

WWTPs west of Hudson. Four other projects have solicited and received construction bids, with construction anticipated to begin in the spring of 2006. Eight projects are still in the design stage. Three of these projects were added late in the program, one as recently as 2005, and are in the early stages of design. The other five have had delays in finalizing the designs either due to: extensive subsurface investigations; a need to redesign due to originally designing around the CBUDSF technology which DEP has determined is not suitable for low flow WWTPs; or being considered for a regional WWTP project. These five are nearing completion of their designs.

Table 2.6. WWTP Upgrade Program status.

	Drainage Basin	Permit Flow MGD	Status
Catskill District			
Bataviakill Recreation Area	Schoharie	0.0050	Design
Black Bear Enterprises (a.k.a. Mountainside Inn)	Ashokan	0.0031	Completed
Camp Timberlake	Ashokan	0.0340	Completed
Camp Loyaltown	Schoharie	0.0210	Completed
Camp Oh Neh Tah	Schoharie	0.0075	Design
Colonel's Chair Estates	Schoharie	0.0300	Completed
Crystal Pond	Schoharie	0.0360	Design
Elka Park	Schoharie	0.0100	Design
Forester Motor Lodge	Schoharie	0.0039	Completed
Frog House Restaurant	Schoharie	0.0018	Design
Golden Acres	Schoharie	0.0092	Completed
Harriman Lodge	Schoharie	0.0200	Completed
Hunter Highlands	Schoharie	0.0400	Completed
Latvian Church Camp	Schoharie	0.0070	Completed
Liftside	Schoharie	0.0810	Completed
Mountainview Estates (#001)	Schoharie	0.0070	Construction Bids Received
Mountainview Estates (#002)	Schoharie	0.0060	Construction Bids Received
Olive Woods (a.k.a. Woodstock Percussion/Rotron)	Ashokan	0.0127	Design
Onteora Jr./Sr. High School	Ashokan	0.0270	Design
Rondevoo Restaurant	Schoharie	0.0010	Completed
Thompson House, Inc.	Schoharie	0.0050	Completed
Whistle Tree Development	Schoharie	0.0125	Construction Bids Received
Windham Mountain (a.k.a. Snowtime/Ski America/Ski Windham)	Schoharie	0.1200	Completed

Table 2.6. WWTP Upgrade Program status.

	Drainage Basin	Permit Flow MGD	Status
Delaware District			
Camp Nubar	Pepacton	0.0125	Construction Bids Received
Camp L'man Achai	Pepacton	0.0075	Completed
Delaware Boces	Cannonsville	0.0100	Completed
Delhi (Village Of)	Cannonsville	0.5150	Completed
Hobart (Village Of)	Cannonsville	0.1600	Completed
Regis Hotel	Pepacton	0.0096	Completed
Roxbury Run Village	Pepacton	0.0350	Completed
Seva Institute (#002 And #003)	Cannonsville	0.0078	Design
South Kortright Center For Boys/Allen Residential	Cannonsville	0.0200	Completed
Stamford (Village Of)	Cannonsville	0.5000	Completed
Ultradairy/Morningstar	Cannonsville	0.2000	Completed
Walton (Village Of)	Cannonsville	1.1700	Completed
Worcester Creameries/Msf Dairy	Pepacton	0.0360	Completed
East of Hudson			
Clear Pool Camp, Inc.	West Branch	0.0200	Completed

In addition to completing construction on a number of projects, the Upgrade Program also paid for the first year of Start-Up and Performance Testing for 21 of the projects. The rest of the projects were not eligible for Start-Up and Performance Testing payments as they had converted to a subsurface disposal system as their upgrade. Over $2.3 million was disbursed through the Regulatory Upgrade Program for this first year of start-up.

2.5.2 Septic System Rehabilitation & Replacement Program

Section 124 of the MOA established the $13.6 million Septic System Rehabilitation & Replacement Program to provide for pump-outs and inspections of septic systems serving single- or two-family residences in the west of Hudson watershed, to upgrade substandard systems and to rehabilitate or replace systems that are failing or reasonably likely to fail in the near future. The Catskill Watershed Corporation (CWC) administers the Septic Program. As part of its 2002 Filtration Avoidance Determination commitment, DEP provided an additional $15 million in funding (over the initial 1997 infusion of $13.6M) for the Septic Program.

Prior to 1997, DEP's method of detecting and facilitating the remediation of failing septic systems relied on follow-through by watershed inspectors of identified or reported septic system failures. Such efforts depended on "drive-by" detections, neighbor complaints or on self-reporting. The Septic Program has proved to be a far more effective mechanism for detecting and remediating failing septic systems. Through December 2005, approximately 2,128 west of Hudson septic failures have been identified and remediated under the CWC Septic Program

CWC Septic Program Rules in effect reflect an inspection and remediation program deployed in a prioritized fashion according to potential impact to the City's water supply system. Initially targeted were 60-day travel time areas, followed by areas within defined limiting distances from streams (i.e., within 50 feet, 100 feet, 300 feet etc.). Under the Program, CWC solicits its homeowner interest within priority areas and conducts inspections to determine whether or not systems are functioning properly. A system found to be failing as a result of the inspection is eligible to receive CWC funding. Program elements include:

- Phased implementation based upon priority criteria;
- Cost-share (40%) for non-primary residents;
- Remediation process managed by homeowner, eligible costs reimbursed;
- Design and construction payments based upon CWC Schedule of Values;
- CWC staff presence on-site to provide input into repair/replacements; and
- DEP regulatory oversight of repairs.

In 2000, CWC began implementing the inspection and remediation program within the Priority 1A area (sub-basins within 60-day travel time to distribution that are near intakes). Solicitation letters were ultimately sent out to over 500 homeowners in the Priority 1A area.

During 2001, CWC staff continued to inspect and identify failures in the Priority 1A area. Early in 2002, CWC expanded the program to the Priority 1B area (sub-basins within 60-day travel time to distribution that are not near intakes) by mailing solicitations to nearly 1,300 additional homeowners. During 2002, CWC conducted public meetings in Walton, Neversink and Olive to explain the priority area program and its eligibility requirements to homeowners. Also during 2002, CWC began to locate septic systems installations by Global Positioning System (GPS) technology. From program inception through the end of 2002, CWC had paid for the remediation of over 1,500 septic systems.

In 2003, the CWC septic system inspection and remediation program expanded outside the 60-day travel time areas to address septic systems located within 50 feet of a watercourse or within 500 feet of a reservoir or reservoir stem (Priority 3 area). Solicitation letters were sent to approximately 1,700 homeowners in this area. Through 2003, over 1,800 septic system remediations had been paid for by CWC.

In 2004, the CWC Septic Program expanded again – this time to homeowners with septic systems located within 100 feet of a watercourse. Approximately 1,300 letters were sent out in November 2004 to homeowners in the Priority 4 area (identified as lots located between 50 feet and 100 feet of a watercourse). An unusually wet construction season slowed the rate of septic system remediations in 2004. Through year's end, CWC had paid for a total of 1,925 septic system remediations since program inception.

CWC continued to implement the inspection and remediation program in the various priority areas during 2005, although the primary focus was in the Priority 4 area. Through December 2005, a total of 3,134 homeowners had participated in the Septic Program and CWC had paid for a total of 2,128 septic system remediations since program inception.

The Septic System Rehabilitation and Replacement Program has been successful in eliminating pollution from a large number of failing septic systems, most of which are located along streams and in 60-day travel time areas. Figures 2.20 through 2.24 show the distribution of septic system remediations by reservoir basin. In the future, the Septic Program will continue to be implemented in prioritized fashion based upon potential impact to the City's water supply system.

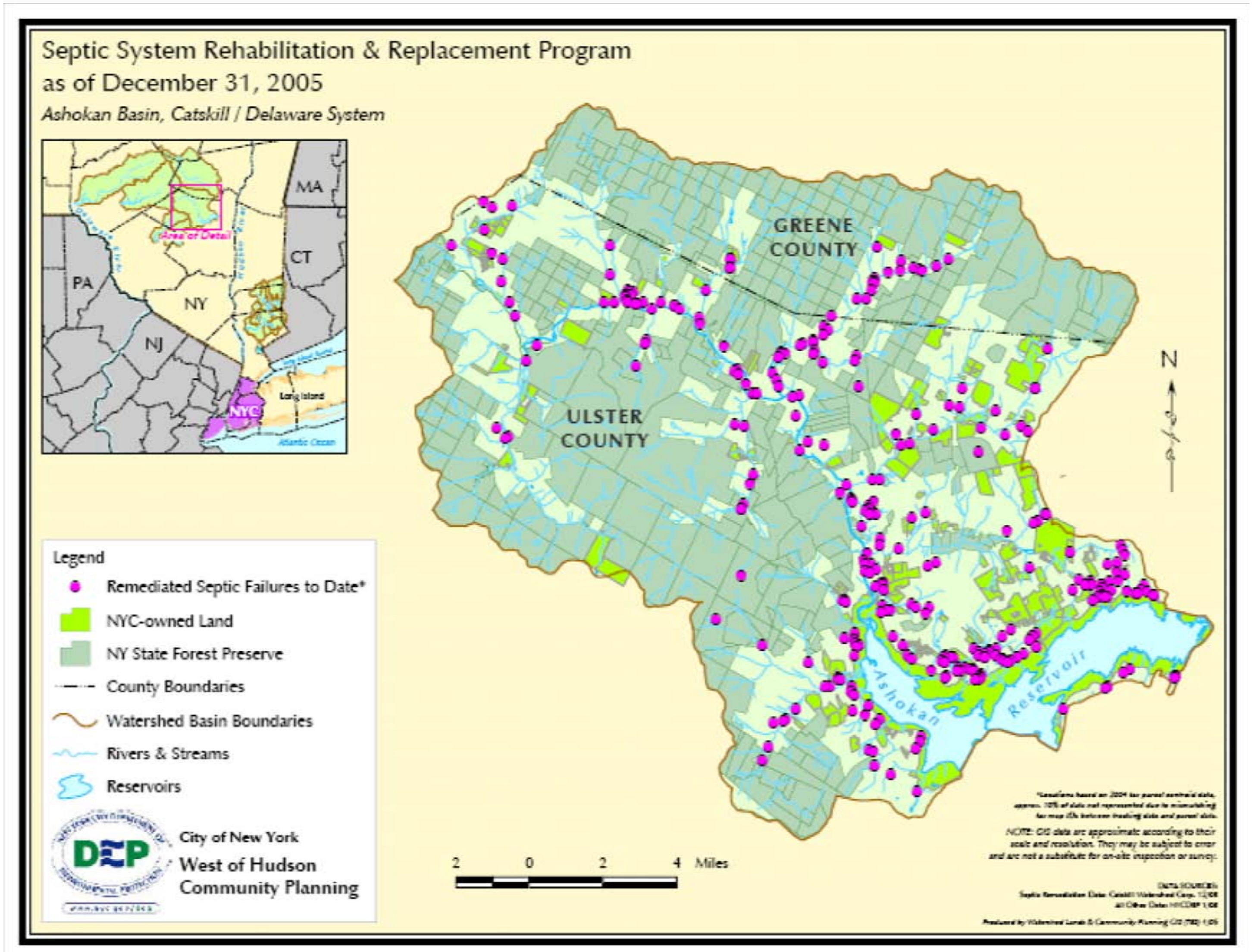

Figure 2.20 Septic System Rehabilitation and Replacement Program as of December 31, 2005 - Ashokan basin, Catskill/Delaware system.

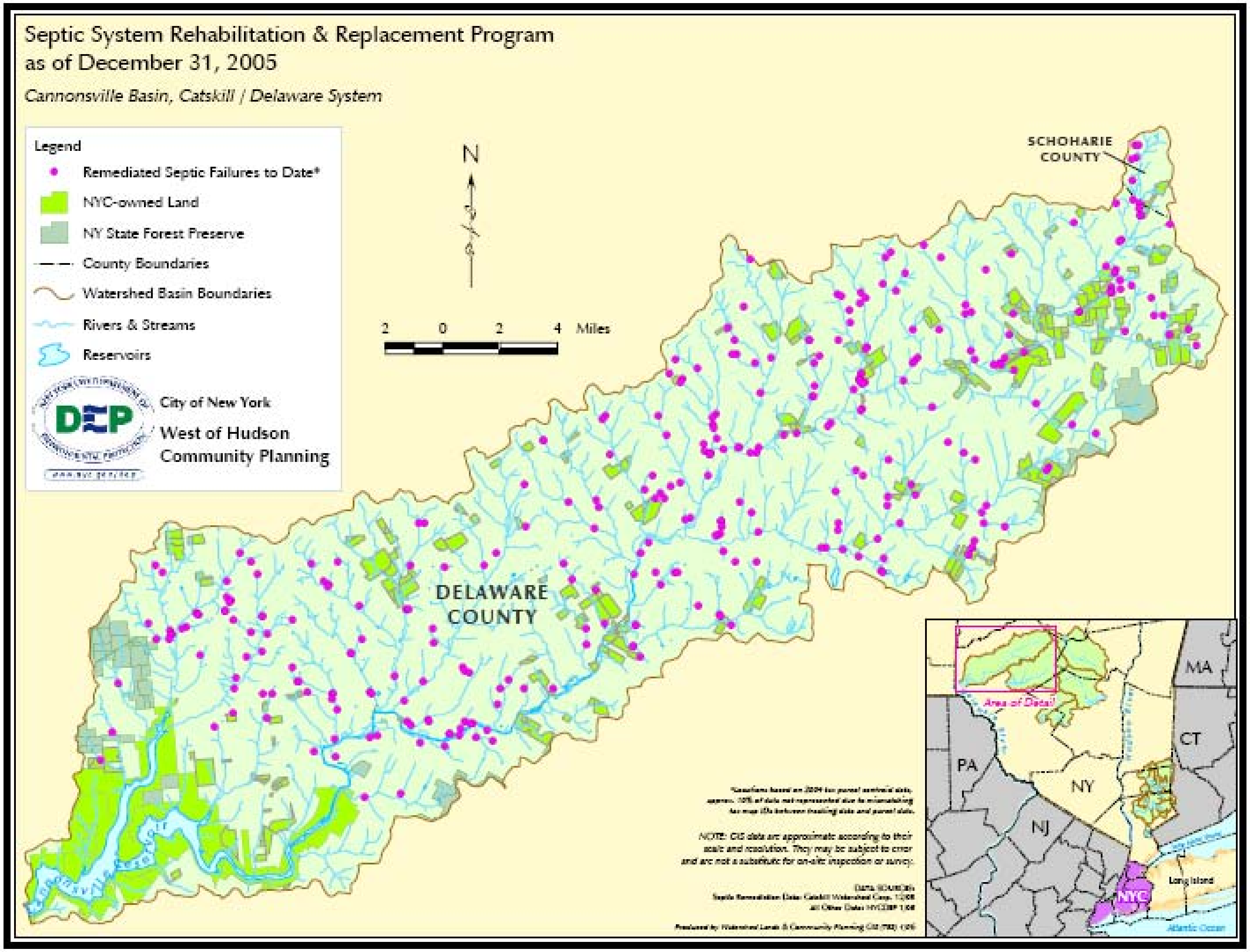

Figure 2.21 Septic System Rehabilitation and Replacement Program as of December 31, 2005 - Cannonsville basin, Catskill/Delaware system.

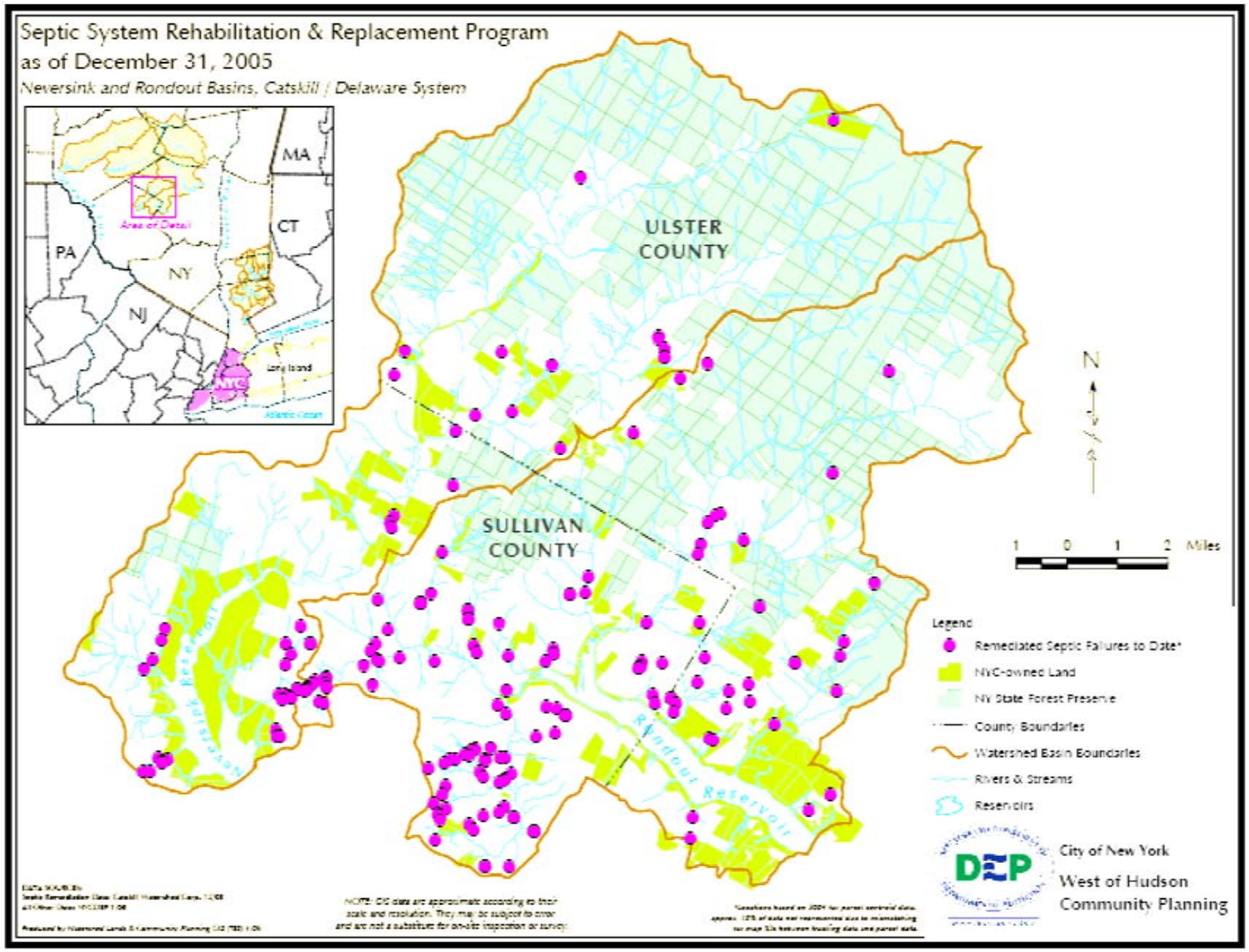

Figure 2.22 Septic System Rehabilitation and Replacement Program as of December 31, 2005 - Neversink and Rondout basins, Catskill/Delaware system.

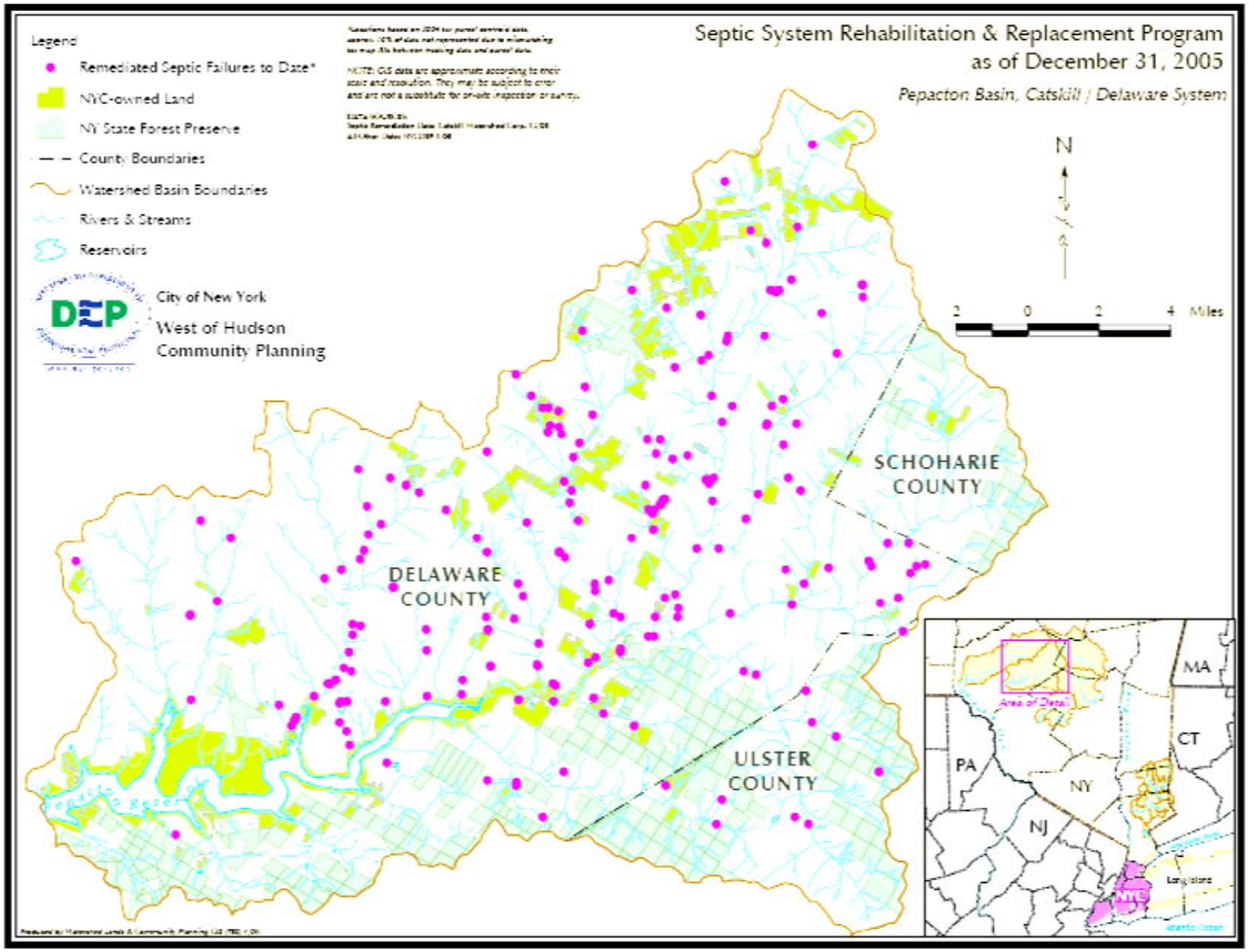

Figure 2.23 Septic System Rehabilitation and Replacement Program as of December 31, 2005 - Pepacton basin, Catskill/Delaware system.

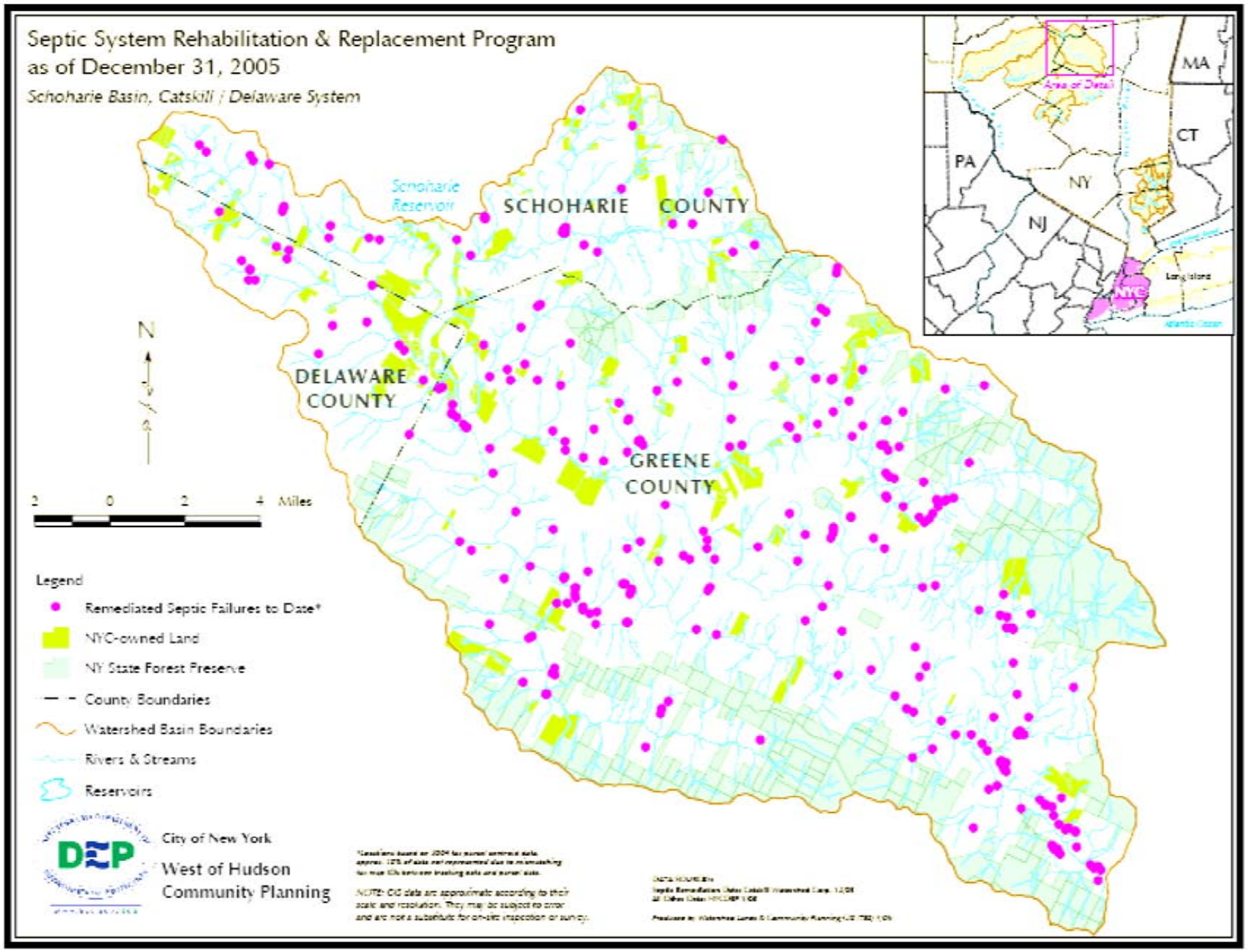

Figure 2.24 Septic System Rehabilitation and Replacement Program as of December 31, 2005 - Schoharie basin, Catskill/Delaware system.

2.5.3 New Sewage Treatment Infrastructure Program

The New Sewage Treatment Infrastructure Program is described in Paragraph 122 of the MOA. The New Sewage Treatment Infrastructure Program was funded at $75,000,000. As part of DEP's 2002 FAD commitment, $12,150,000 was added to the New Infrastructure Program to allow block grant allocations to be awarded to Identified Communities 6 & 7.

The New Sewage Treatment Infrastructure Program funds the study, design and construction of new wastewater projects in seven communities: Andes, Roxbury, Hunter, Windham, Fleischmanns, Phoenicia, and Prattsville. After extensive studies at each of the top seven communities, allocations of "block-grants" to complete design and construction, based upon highly scrutinized cost estimations, were agreed upon.

Table 2.7 shows the design flows and agreed upon block grants for wastewater projects in Identified Communities 1-7.

Table 2.7. Design flows and block grants for wastewater projects in identified communities 1-7.

Municipality	Maximum Permitted Flow*	Block Grant Award	Total Contract Award**
1. Hunter	338,400 gpd	$15,300,000	$19,241,000
2. Fleischmanns	10,000 gpd	$11,505,986	$11,505,986
3. Windham	373,800 gpd	$20,000,000	$23,120,000
4. Andes	62,000 gpd	$6,250,000	$6,250,000
5. Roxbury	100,000 gpd***	$8,550,000	$8,550,000
6. Phoenicia	185,000 gpd	$11,159,000	$11,159,000
7. Prattsville	86,000 gpd	$8,238,137	$8,238,137

* Includes flow from WWTPs being decommissioned

** Includes Consolidation Increments for connection of Tie-in Facilities

*** Roxbury Maximum Permitted Flow includes possible future flow from Hubbell Corners

The top five communities signed design/construction contracts with EFC in 2001. Design/construction contracts were signed with EFC by Prattsville in January 2004, and by Phoenicia in March 2005. Project summaries for each community follow:

<u>Hunter</u> – WWTP project – 95% construction complete. The WWTP also treats flow from the following decommissioned facilities: Colonel's Chair, Forester Motor Lodge, Camp Loyaltown, Liftside and Whistletree for a total SPDES permitted flow of 338,400 gpd. The service area includes approximately 300 homes with septic systems and approximately 70 businesses. Plans at the 65% and 90% design levels were submitted in 2002. In April 2003, DEP issued Design

Approval on the WWTP and the Route 23-A collection system. Design approval for the sewers for the village streets was issued in September 2004. Construction on the WWTP, sewers and remote pump stations occurred during 2003, 2004, and 2005, and is substantially complete. Lateral connections have begun. Some punch list items related to the WWTP remain to be completed.

Fleischmanns – WWTP project – 50% construction complete. The WWTP service area encompasses approximately 160 homes and 130 commercial structures. The SPDES permitted flow is 160,000 gpd. Design approval for the WWTP and collection system was issued in November 2004. Construction on the WWTP and collection system commenced during 2005 and is expected to be completed in 2006.

Windham – WWTP project – 95% construction complete. The SPDES permitted flow for the WWTP is 373,800 gpd, which includes 126,800 gpd in flow from three decommissioned wastewater facilities - Ski Windham, Thompson House and Frog House. The service area includes more than 520 dwelling units and approximately 80 non-residential properties. Design approval for the WWTP was issued in May 2003 and for the Route 23-A collection system in July 2003. Construction commenced in 2003 and continued in 2004 and 2005. Construction on the WWTP was completed in June 2005. Design approval for the local roads sewer collection system was issued in August 2005. Construction of the sewer collection systems was completed by the end of 2005 and lateral connections will occur in 2006.

Andes – WWTP Project – 100% construction complete. The WWTP has a maximum permitted flow of 62,000 gpd. The wastewater service area encompasses the core of the village and several adjacent properties. There are 144 parcels in the service area, 23 of which are non-residential. Design approval for the WWTP was issued in November 2002 and for the collection system in January 2003. Construction commenced in 2003 and continued in 2004. The WWTP and sewerage system was completed in August 2004. Lateral connections began in 2004 and were completed in 2005. A project close-out letter was issued on August 31, 2005.

Roxbury – Force Main Project – 100% construction complete. The hamlet of Roxbury sewer collection system is connected to New York City's Grand Gorge WWTP via force main. The maximum permitted flow is 100,000 gpd. The service area includes approximately 246 dwelling units, 32 commercial use units, 8 non-residential/non-commercial establishments, and the Roxbury Central School. Design approval was issued in December 2002 and construction commenced in 2003. Force main and collection system construction was completed in 2004 and lateral connections occurred during 2005.

Phoenicia – WWTP Project – 50% design complete. The maximum permitted design flow for the Hamlet of Phoenicia WWTP is 185,000 gpd. The service area includes approximately 393 dwelling units, which account for approximately two-thirds of the projected wastewater flow. The 35% design submittal was received in September 2005. Design is expected to be completed in 2006 and construction by 2008.

Prattsville – WWTP Project – 15% construction complete. The SPDES permitted flow for the WWTP in the Hamlet of Prattsville is 86,000 gpd. The service area encompasses approximately 235 dwelling units and 43 non-residential units. The WWTP and collection system designs were approved in June 2005. Construction commenced in 2005 and is scheduled to be completed by 2007.

Overall, the New Sewage Treatment Infrastructure Program is providing centralized wastewater solutions in seven communities, eliminating the potential threat to water quality posed by failing septic systems. Although a voluntary program, all seven communities where centralized wastewater treatment was deemed to be the appropriate solution have elected to participate. By the end of 2005, wastewater projects in four of the seven communities were complete or substantially complete. The remaining three projects will be completed over the course of the next several years.

2.5.4 Sewer Extension Program

Paragraph 123 of the MOA provides up to $10,000,000 for the design and construction of sewer extensions to service areas of City-owned wastewater treatment plants in the west of Hudson watershed. City-owned wastewater treatment plants in the watershed where sewer extensions are planned include: Grahamsville, Margaretville, Pine Hill, Tannersville and Grand Gorge.

The purpose of the Sewer Extension Program is to protect the quality of the City’s water supply by connecting existing residences and businesses to the sewer system in areas where on-site septic systems are either failing or are likely to fail. DEP reviewed, evaluated and selected proposed sewer extensions for funding by:

- developing construction cost estimates of all the proposed extensions;
- conducting field inspections of all the proposed extensions;
- meeting with DEP inspectors and regulatory staff to learn of areas where septic systems have failed; and
- prioritizing the proposed extensions using an evaluation matrix based on factors that affect water quality, including but not limited to the distance of septic systems from water bodies, whether any properties along the areas proposed for extensions had failing septic systems, and whether any of the areas proposed for funding are within the 60-day travel time.

Based on the prioritization of extensions that resulted from using the matrix, and after consulting further with local officials from the involved communities and with CWC, DEP selected extensions for funding in December 1998. Ultimately, 14 areas were selected to receive Program funding for the design and construction of extensions. These areas were listed in the New York City's 2001 Watershed Protection Program Summary, Assessment and Long-term Plan.

In June 2002, the Town of Shandaken (Pine Hill WWTP) opted out of the program. In May 2005 the Town initiated discussions with DEP concerning its interest to once again participate in the program. The Town officially indicated its interest in September 2005 in re-entering the program. Upon contract signing, the Town plans to contract out for design and then construction.

During the past four years DEP and the involved communities have made significant strides in advancing the Program. All of the eligible communities with the exception of the Town of Shandaken have signed agreements with the DEP to implement the program.

The following provides a synopsis of the status of the Program in each of the involved communities.

Town of Hunter (Tannersville WWTP)

The Town of Hunter signed an Agreement with the City which commenced on January 16, 2001. The Town Board thereafter adopted a new Sewer Use Law which took effect on July 16, 2002. The Town is one of two communities that opted to manage the design and construction of its planned sewer extensions.

The Town substantially completed construction of the planned extensions in the fall of 2005. Residents and business owners who will be connected are in the process of making their house connections and deactivating their on/site septic systems. The only construction activities that remain are completing “punch list” items. These activities are anticipated to be completed in spring 2006.

Altogether, the extensions will connect approximately 110 homes/businesses that have been using on-site sewage disposal systems.

Figure 2.25 illustrates the location of the five sewer extensions in the Town.

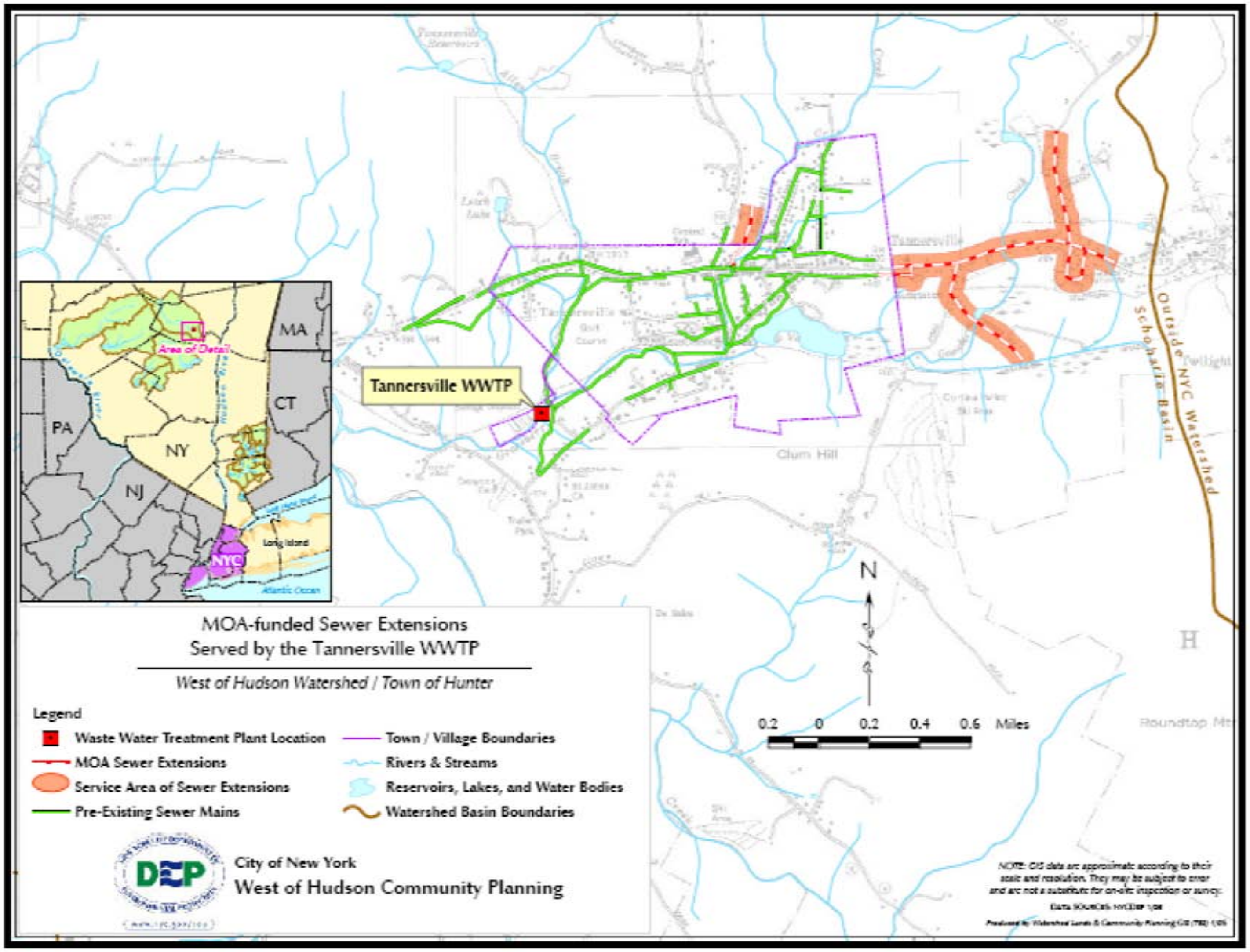

Figure 2.25 MOA-funded sewer extensions served by the Tannersville Wastewater Treatment Plant.

Town of Roxbury (Grand Gorge WWTP)

The Town of Roxbury signed an agreement with the City which commenced on September 10, 2002. The Town Board subsequently adopted a new Sewer Use Law which took effect on March 19, 2003 and was later revised on May 3, 2004.

In February 2005, DEP (which is managing the design and construction of the extension) finalized the design plans for the extension planned along NYS Rt. 23 just west of Grand Gorge. In January 2006 DEP expects to conclude the bid process for the construction of the extension by awarding a contract to the low bidder. Construction of the extension and associated laterals is expected to commence in spring 2006 and is expected to be completed by the end of the 2006 construction season.

This extension will serve approximately 20 residences which have been using on-site sewage disposal systems.

The Figure 2.26 illustrates the location of this extension.

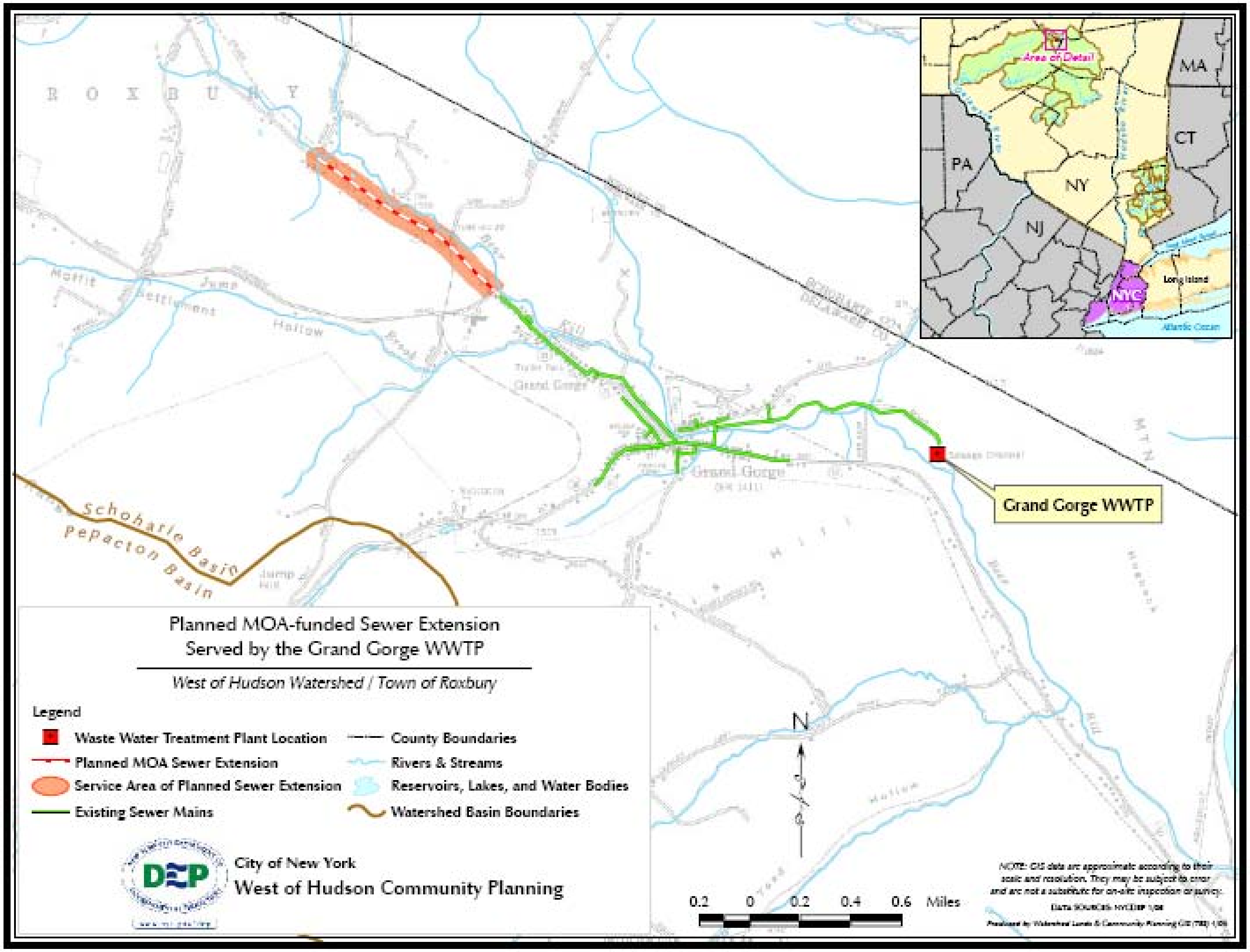

Figure 2.26 MOA-funded sewer extensions served by the Grand Gorge Wastewater Treatment Plant.

Town of Neversink (Grahamsville WWTP)

The Town of Neversink signed an Agreement with DEP which commenced on May 3, 2004.

During the past year, the Town (which opted to manage the design and construction of the extensions) has been engaged in design activities associated with its planned extensions. These activities include but are not limited to preparing Preliminary Plans and Specifications, complying with SEQR, and conducting Phase I Environmental Site Assessments. The only activities that remain prior to finalizing the design plans include obtaining applicable permits, finalizing the alignments of the extensions. Construction is anticipated to commence either late in the 2006 construction season or in spring 2007. Construction of the extensions and associated laterals should be completed by the end of the 2007 construction season.

All-told, these extensions will involve approximately 120 connections of homes currently on on-site sewage disposal systems.

Figure 2.27 illustrates the location of the four planned sewer extensions.

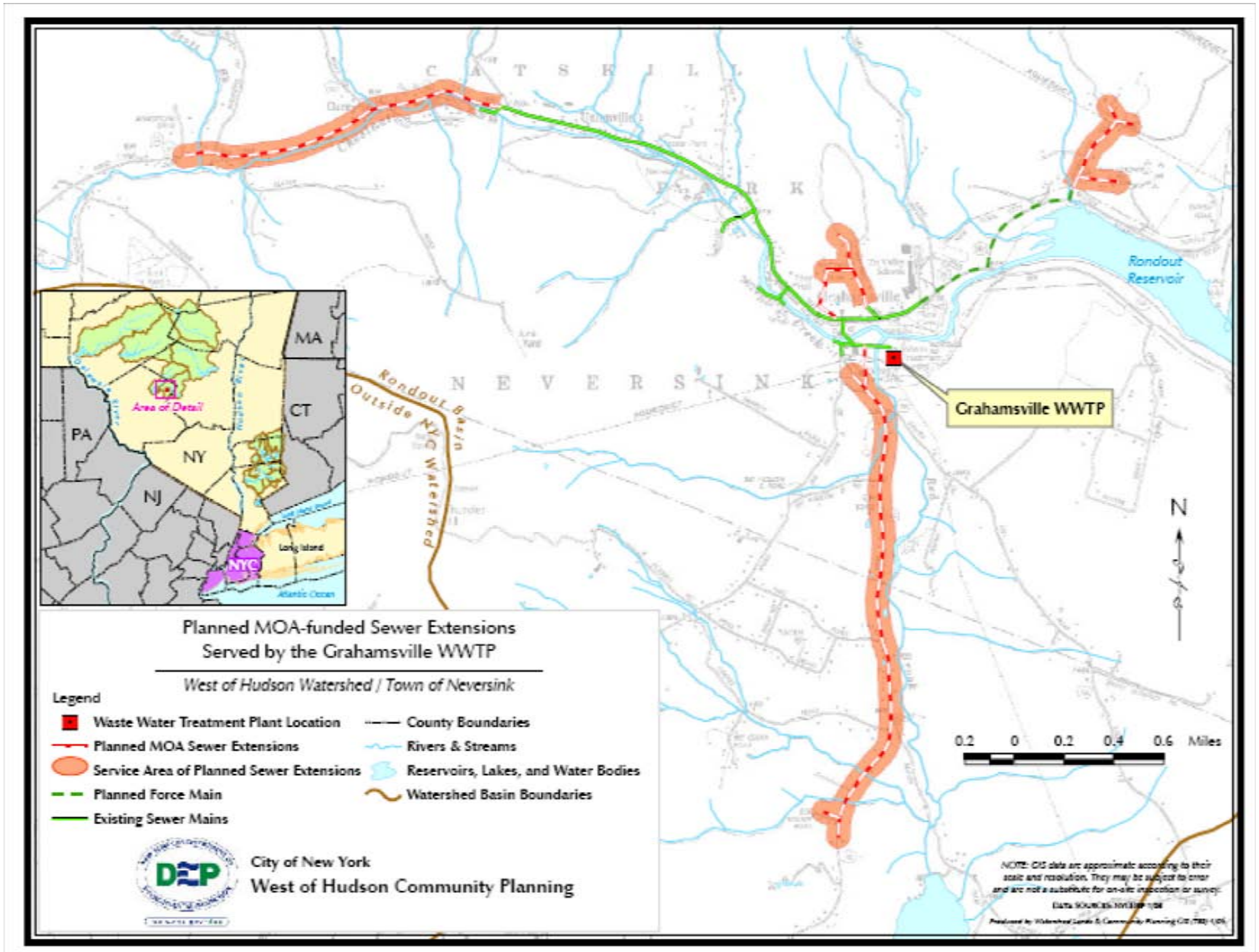

Figure 2.27 MOA-funded sewer extensions served by the Grahamsville Wastewater Treatment Plant.

Village of Margaretville/Town of Middletown (Margaretville WWTP)

The Village of Margaretville and Town of Middletown signed a joint Agreement with DEP which took effect on September 21, 2005.

DEP (which is managing the design and construction of the extensions) has already undertaken preliminary planning and design activities for the planned extensions. Once the Village and Town obtain easements for properties through which portions of sewer mains are planned outside of right-of-way areas, DEP will resume and finalize design plans for the extensions. Activities that need to be undertaken before the design plans can be finalized include complying with SEQR, obtaining all applicable permits, preparing project specifications and finalizing the proposed alignments of the planned extensions. It is expected that construction will commence in 2007 and be completed by the end of the 2007 construction season.

Approximately 65 homes that previously used on-site sewage disposal systems will be connected to the sewer system.

Figure 2.28 illustrates the location of the three planned sewer extensions.

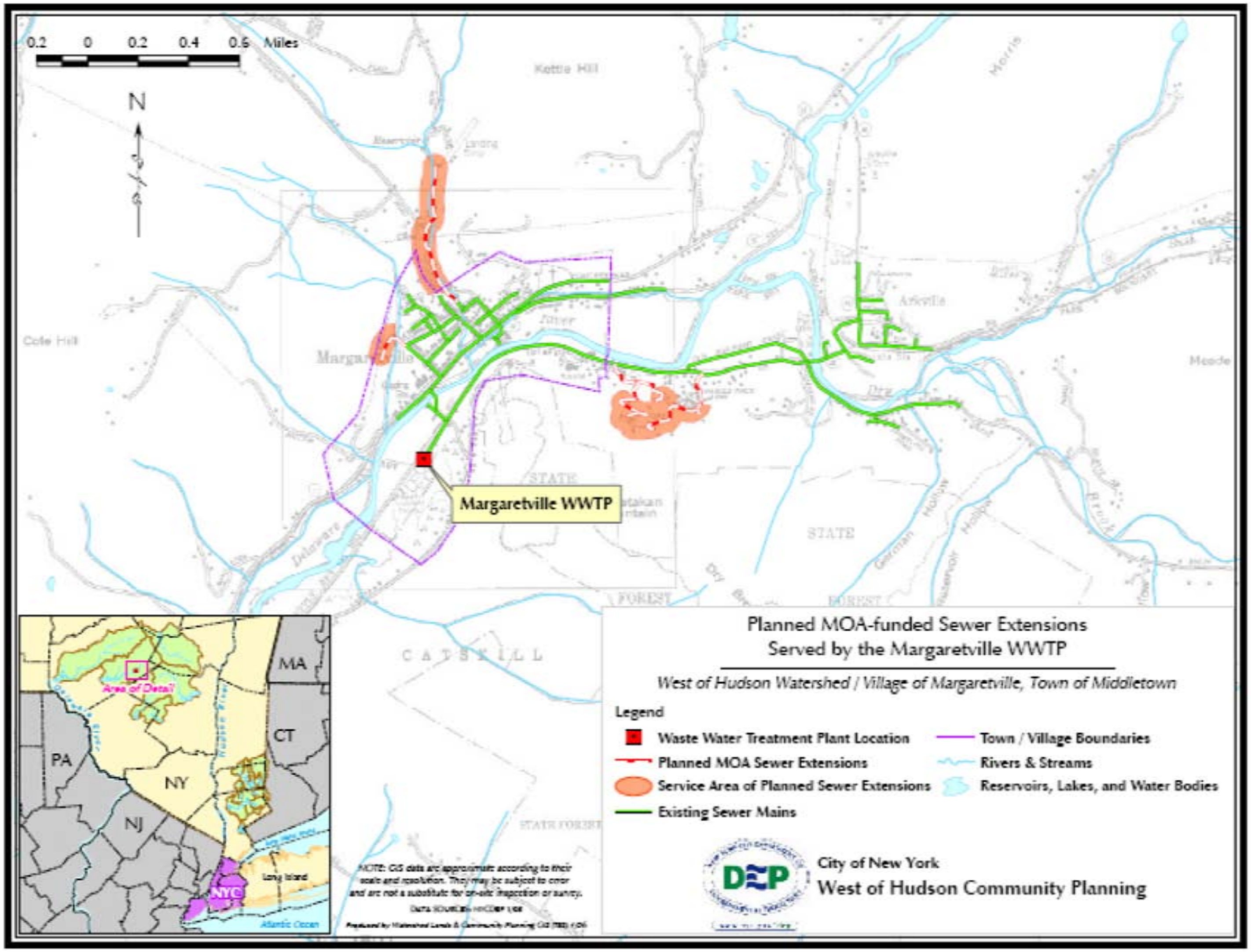

Figure 2.28 MOA-funded sewer extensions served by the Margaretville Wastewater Treatment Plant.

Table 2.8. List of extensions selected by DEP for funding.

Proposed Extensions	WWTP	# of Septics	Town
NYS Rt. 55 W to Armstrong Dr.	Grahamsville	32	Neversink
County Rt. 25	Tannersville	23	Hunter
NYS Rt. 23 W	Grand Gorge	19	Roxbury
Hastings Dr./Hastings Ct.	Grahamsville	22	Neversink
NYS Rt. 23A/Cabbage Patch Rd./ Schoonmaker Rd.	Tannersville	53	Hunter
NYS Rt. 23 A (600 Linear Feet)	Tannersville	8	Hunter
NYS Rt. 42 S to Bob Walker Rd.	Grahamsville	45	Neversink
Harold Finch Rd.	Margaretville	45	Middletown
Bull Run Rd.	Margaretville	15	Middletown
Academy St.	Margaretville	5	Middletown
Terns Rd.	Tannersville	12	Hunter
NYS Rt. 55/NYS Rt. 55 A/Rocky Hill Rd./Van Wagner Rd.	Grahamsville	19	Neversink
Brookside Dr.	Tannersville	8	Hunter

2.5.5 Community Wastewater Management Program

The Community Wastewater Management Program (CWMP) provides $10 million in funding for the design and construction of community septic systems, including related sewerage collection systems, and/or the creation of septic maintenance districts, including septic system replacement, rehabilitation and upgrades and operation and maintenance of the district, in up to five identified communities.

CWMP Rules were approved by CWC in February 2004. As spelled out in the program rules, an engineering firm retained by CWC works with each of the participating communities to determine the appropriate wastewater project, develop engineering plans, assist in the formation of septic districts and the adoption of sewer use laws, advertise for bids, manage construction and establish an Operation & Maintenance plan.

CWC sent out CWMP solicitation letters to five identified communities (Bloomville, Boiceville, Hamden, Delancey, and Bovina Center) in early April 2004. (Bovina Center and Hamden had already begun community wastewater projects with grant funding secured from other sources) By June 2004, all five communities had responded affirmatively regarding their participation in the program and a Request for Proposals for the CWMP engineering consultant was issued.

In August 2004, CWC awarded the CWMP Engineering Consultant contract to the firm that was already retained by Bovina and Hamden, ensuring continuity and coordination across CWMP projects. DEP and CWC proceeded to negotiate the legal language necessary to finalize the agreements between CWC and each of the participating communities and the contract between CWC and the engineering consultant. These contracts were finalized and executed by early 2005.

During the second half of 2004, however, the CWMP consultant was able to continue working on community wastewater projects in Bovina and Hamden. Construction of the Bovina Community Septic System (funded in part by other CWC funds and WRDA funds) began in September 2004. In Hamden, with funding from an Appalachian Regional Commission grant, the CWMP consultant continued drafting a "Guide to Developing a Municipal Wastewater Project." This guidance document details a community's tasks for developing a municipal wastewater project and will be used in conjunction with CWMP projects in Hamden, Bloomville, Boiceville and Delancey.

In 2005, the CWMP consultant began the study phase for the participating communities. Aerial surveys necessary for accurate topographic base mapping were flown for Bloomville, Boiceville, Delancey and Hamden. CWC staff, and the CWMP consultant and attorney presented program information to the Town Boards of Kortright (Bloomville), Hamden, Boiceville and Delancey, followed by public meetings in each Town. The Bovina Community Wastewater System is complete, with lateral connections to occur in 2006. The Town of Bovina executed an O&M Agreement with the DEP for the city-share of O&M costs on August 17, 2005. The study phase for the other communities was completed by the end of 2005.

In the 2005 modification to the 2002 EPA Filtration Avoidance Determination, DEP agreed to provide an additional $6 million in funding for the Community Wastewater Management Program. This funding will allow the implementation of a wastewater project in at least one additional community, and, will provide additional funding for Boiceville should it pursue a WWTP.

Going forward, the design phase is scheduled to occur in 2006, followed by the construction phase in 2007 and 2008.

2.5.6 Septic Maintenance Program

Because the City's west of Hudson watersheds are sparsely developed, many communities rely on individual septic systems to treat and dispose of sanitary waste. Proper septic maintenance is important in prolonging the life and optimizing the functioning of a septic system. A key component to avoiding septic failure is periodic tank pumping. Without periodic pumping, sludge and scum layers become too thick and solid materials may flow from the septic tank into the leach field, clogging the pipes and soils and causing the system to fail. Routine maintenance prevents groundwater pollution and surfacing effluent. While the cost of repairing or replacing a septic system can be expensive, the effort and expense of routine maintenance is relatively minor.

The $1.5 million Septic System Maintenance Program, administered by CWC, it is a voluntary program intended to reduce the occurrence of septic system failures through regular pump-outs and maintenance.

CWC adopted program rules in October 2003. Per the rules, CWC pays 50% of eligible costs for pump-outs and maintenance. Another component of the program is the development and dissemination of septic system maintenance educational materials.

Program implementation began in early 2004 on a pilot program basis, as program information letters were mailed to 172 residents. Information was also provided to local septic haulers. Because of limited response to this initial mailing, the program was expanded in the third quarter of 2004 to any homeowner whose septic system was repaired or replaced prior to 2001 under the CWC Septic Rehabilitation and Replacement Program. Program information letters were mailed to 1,074 additional homeowners. By the end of 2004, over 60 homeowners had availed themselves of the program.

In 2005, the program was opened to repairs or replacements funded by CWC during 2002. This resulted in an additional 104 homeowners being eligible to participate in the program. Letters to these homeowners were mailed in April 2005.

Through November 2005, 142 residential property owners out of 1,350 eligible elected to avail themselves of the Septic Maintenance Program. These homeowners were reimbursed 50% of eligible pumping and maintenance costs by the program.

The Septic Maintenance Program is intended to encourage homeowners to have their septic systems pumped on a regular basis – every three to five years. In 2005, CWC included Septic Maintenance Program information in its revised Septic Programs brochure available for general distribution. An increase in program participation is expected as the date from system repair/replacement extends from three years to five years.

2.5.7 Stormwater Programs

Stormwater Retrofit Program

The Stormwater Retrofit Program is administered jointly by CWC and DEP. Since its inception, the total program budget has risen to $13,925,000; $11,836,250 for capital expenditures, $2,088,750 for maintenance activities and $1,250,000 to conduct community-wide stormwater infrastructure assessment and planning initiatives.

The CWC currently maintains an open application timetable for construction grant project applications, evaluating each application as it is submitted, but gives funding preference to construction grant project applications where a Planning and Assessment contract has already been successfully completed or where a New Infrastructure Program project or Community Wastewater Management Program project is in progress. Required “local share” contribution has been reduced from 25% to 15%. In New Infrastructure and Community Wastewater project areas, the local share requirement has been eliminated to promote the synergistic effect.

During the period from 2002 through 2005, 17 construction grants were reviewed and approved for funding for a total of $2,000,094. Projects focused upon street drainage, stormwater separation and highway maintenance activities.

The "Stormwater Retrofit Sampling Partnership Program" to assess the pollutant removal efficiency of several stormwater BMP retrofit projects is in its second year. DEP drafted the Quality Assurance Project Plan (QAPP) for this sampling project. DEP provides project staff and equipment for field sample collection and data analysis, funding for laboratory analysis work is provided through the Retrofit Program in the amount of $60,000 over three years. At this time, water quality monitoring has begun at the Margaretville Central School and the Roxbury Central School.

Planning and Assessment project applications are received through November 1. Completed projects will provide a basis for future capital construction projects. During the period from 2002 through 2005, 10 planning and assessment projects were reviewed and approved for funding for a total of $250,518.

Table 2.9. Completed planning and assessment projects that were reviewed and approved for funding.

	Completed Projects	
Applicant	Project Description	Grant Amount
Cannonsville		
Village of Hobart Various Locations	Sewer Separation, I/I Reduction	$21,375
Village of Walton Bruce Street	Collection, Conveyance, Filtration	$475,989
Delaware County DPW Bovina Center	Collection, Conveyance, Sedimentation	$1,345,500
Delaware County DPW	Truck-Mounted Vacuum Equipment (Vac-All)	$168,297
Village of Stamford Railroad Avenue	Sewer Separation, Collection, Conveyance and Sedimentation	$231,448

Table 2.9. Completed planning and assessment projects that were reviewed and approved for funding.

Completed Projects		
Applicant	Project Description	Grant Amount
Clark Co.	Collection, Conveyance, Sedimentation and Infiltration	$148,304
Pepacton		
Margaretville Central School	Collection, Conveyance, Filtration	$128,070
Roxbury Central School	Collection, Conveyance, Sedimentation	$34,149
Village of Margaretville Academy Street	Sewer Separation, Collection, Conveyance and Sedimentation	$493,482+
Town of Halcott Elk Creek Road	Collection, Conveyance, Sedimentation	$40,492+
Town of Roxbury Ridge Street	Collection, Conveyance, Sedimentation	$23,467
Village of Margaretville Park	Collection, Conveyance, Sedimentation and Infiltration	$6,878
Schoharie		
Town of Roxbury Johnson Hollow Road	Conveyance	$9,900
GCS&WCD	Critical Area Seeding Program / Hydroseeder	$58,243
Town of Windham Mitchel Hollow Road	Collection, Conveyance, Sedimentation	$25,125
Village of Tannersville Various Locations	Sewer Separation, I/I Reduction	$107,161
Town of Windham Hickory Hill Road	Collection, Conveyance, Sedimentation	$87,671
Windham Ventures Parking Lot	Collection, Conveyance, Sedimentation	$20,500
Hunter Mt. Parking Lot	Collection, Conveyance, Sedimentation	$63,367
Rondout		
Grahamsville Deli Parking Lot	Collection, Conveyance, Sedimentation	$5,625
Neversink		
Town of Denning Transfer Station	Collection, Conveyance, Sedimentation and Infiltration	$9,931

Future Stormwater Controls Program

The Future Stormwater Controls Program pays for the incremental costs of stormwater measures required solely by the New York City Watershed Regulations above State and federal requirements. It provides funds for the design, construction and maintenance of stormwater measures included in stormwater pollution prevention plans and individual residential stormwater plans for new construction after May 1, 1997.

There are two separate programs developed to offset additional compliance costs incurred as a result of the implementation of the City's Regulations. The Future Stormwater Controls Program was established by Paragraph 128 of the MOA, funded to a total amount of $31.7 million over ten years, is administered by the CWC and reimburses municipalities and large businesses 100% and small businesses 50% for eligible costs. Paragraph 145 of the MOA is a separate program known as Future Stormwater Controls Paid for by the City and reimburses low income housing projects and single family homeowners 100% and small business 50% for eligible costs.

To date, CWC has funded $1,858,996 in stormwater BMPs and allocated $23,022 in maintenance funding. CWC has also, pursuant to contract terms, transferred $7,919,273 to other eligible watershed protection programs.

Local Technical Assistance

The Local Technical Assistance Program is administered jointly by CWC and DEP through evaluation of grant proposals for program funding. The total program budget is $1,250,000, and provides for eligible projects that support watershed protection and community planning to improve water quality in the watershed and enhance the quality of life in watershed communities. CWC is currently accepting the first round of applications for grant funding through February 3, 2006.

The Stormwater Retrofit Program, the Local Technical Assistance Program and the Future Stormwater Controls programs provide a full array of stormwater funding options to watershed communities. These programs provide watershed communities with the opportunity to advance land use policies that will guide future development and mitigate the associated stormwater impacts.

2.6 Waterfowl Management Program

DEP'S Waterfowl Management Program (WMP) was established to measure the level of pollutant impact imposed by wildlife on the New York City water supply. The management of waterbird populations at coliform-restricted reservoirs throughout the New York City Water Supply is essential to meet stringent water quality regulations as stated in the Environmental Protection Agency's (EPA) Surface Water Treatment Rule (SWTR) of 1991. The WMP was developed to research the relationship between wildlife, particularly waterbirds (geese, gulls, cormorants, swans, ducks, and other duck-like birds), that inhabit the reservoirs and fecal coliform bacteria concentrations in the surface water prior to disinfection. The preliminary baseline data collected by DEP has been used to initiate a Waterfowl Management Program which consists of the following components:

1. Identify all sources of pollutant impacts by wildlife;
2. Attempt to quantify wildlife pollutant contributions by species including land cover (i.e. forested lands, agricultural lands, urbanization, etc.);
3. And develop a management plan to mitigate identifiable pollutant sources where possible.

The WMP was designed to study the relationship between spatial and temporal trends in bird populations on the reservoirs and trends in fecal coliform concentrations both within the reservoir and at the regulatory sampling locations. The monitoring of waterbird populations began in 1992 under the direction of an in-house wildlife biologist. Bird fecal samples and water samples were analyzed by DEP microbiologists and used to identify birds as a significant source of fecal coliform at the Kensico Reservoir. In an attempt to eliminate these waterbird populations from the reservoir system, DEP implemented standard bird population management techniques approved by the United States Department of Agriculture Wildlife Services (USDA) and the New York State Department of Environmental Conservation (DEC). Bird dispersal and deterrent techniques began in 1993 resulting in a dramatic reduction in both bird populations and fecal coliform levels, thus maintaining high quality water in compliance with SWTR.

Migratory populations of waterbirds utilize NYC reservoirs as temporary staging areas and wintering grounds thus significantly contributing to increases in fecal coliform loadings during the autumn and winter. High precipitation events also tend to scour the adjacent landscape and stream corridors of the reservoirs, flushing animal waste into the water. Bacterial elevations also occur from direct fecal deposition in and alongside the reservoirs.

Migrant waterbirds generally roost nocturnally and occasionally forage and loaf diurnally on the reservoirs, however, it has been determined that most of the feeding activity occurs away from the reservoir. Fecal samples collected and analyzed for bacteria concentrations from both Canada Geese (*Branta canadensis*) and Ring-billed Gulls (*Larus delawarensis*) revealed relatively high fecal coliform concentrations per gram of feces. Gulls and geese are considered the most significant contributors of bacteria to the water supply. Water samples collected near waterbird roosting locations have shown bacteria increases corresponding with waterbird populations at several NYC reservoirs. Thus, DEP has determined that waterbirds contribute the greatest quantity of fecal coliform bacteria seasonally at Kensico Reservoir and other terminal reservoirs (West Branch, Rondout, and Ashokan, Croton Falls, and Cross River).

The bird dispersal program was more recently expanded on an “as needed” basis to include five additional reservoirs that provide source water to Kensico Reservoir. The specific criteria for initiating this program can be found in the November 2002 FAD, Section 4.1.

Additional measures that include managing local breeding populations of Canada Geese, Double-crested Cormorants, and Mute Swans have also been instituted by DEP throughout the entire upstate water supply system. This program includes identification of all nesting locations of the aforementioned species and depredation of the eggs and nests under a United States Department of the Interior Depredation Permit and a DEC permit. To assure DEP's program activities remained in compliance with all federal, State, and local laws, an Environmental Impact Statement was completed in 1996 for Kensico, and in the spring of 2004 for the additional five reservoirs. A Final Environmental Impact Statement including a "findings statement" can be found on the DEP website.

2.6.1 Program Activities

Waterbird species were surveyed to determine species richness (species diversity) and evenness (species population). Prior to the onset of bird mitigation, preliminary surveys conducted by DEP indicated population fluctuations occurred daily (diurnal/nocturnal), seasonally, and spatially throughout the reservoirs. Changes in fecal coliform bacteria levels collected from the key outflow structures at Kensico indicated seasonal elevations and temporal elevations in response to precipitation events. The short-term (late autumn/winter) trend of elevated bacteria in the water samples became the focus of the bird relationship during the autumn migration season in the Atlantic Flyway - a migratory pathway for birds along the Atlantic Coast of the U.S.

Currently, reservoir bird surveys are conducted throughout the calendar year. A breakdown of the survey schedule by reservoir from January of 2002 to the end of December of 2005 is listed in Table 2.10.

Table 2.10. Frequency of bird observation surveys by reservoir 2002 – 2005.

Reservoir	Bird Surveys Scheduled
Kensico	Pre-dawn to Post-dusk Daily August 1 to March 31; Pre-dawn and Post-dusk Weekly April 1 to July 31
West Branch	Pre-dawn, Midday, and Post-dusk Weekly all year; Increased to daily "as needed"
Rondout	Pre-dawn, Midday, and Post-dusk Weekly all year; Increased to daily "as needed"
Ashokan	Pre-dawn, Midday, and Post-dusk Weekly all year; Increased to daily "as needed"
Croton Falls	Pre-dawn, Midday, and Post-dusk Bi-weekly all year; Increased to daily "as needed"
Cross River	Pre-dawn, Midday, and Post-dusk Bi-weekly all year; Increased to daily "as needed"

Bird observation survey results for each reservoir are charted with fecal coliform bacteria levels at reservoir intake sampling locations and on-reservoir sampling areas to detect relationships (Figures 2.29 through 2.35). If it is suspected or determined that the presence of birds is causing fecal coliform bacteria elevations, mitigative actions to eliminate the birds are initiated. With the exception of Kensico, all reservoirs listed in Table 2.10 conform to an "as needed" action based on specific criteria listed in the November 2002 FAD. The Kensico program remains a permanent program. Without such a robust program for Kensico, bird populations would continue to rise through the winter period and therefore potentially cause bacteria levels to correspondingly increase. In fact, occasional increases in bird numbers often occur when the bird hazing operations have to temporarily shut down due to inclement weather (i.e. heavy precipitation, wind, fog).

Waterbird hazing activities are listed by reservoir in Table 2.11. Bird hazing occurs annually from August 1 through March 31 at Kensico corresponding to migratory and wintering patterns of several bird species that inhabit the reservoirs. The goal of the program at Kensico is to remove all birds from the reservoir to prevent fecal coliform bacteria contamination at several water intake structures. In comparison, bird harassment activities at the Rondout Reservoir are only conducted up to a two mile zone from the water intake.

Table 2.11. Reservoir bird mitigation (2002 – present).

Reservoir	Dates of Bird Harassment/Deterrence	Bird Harassment/Deterrence Measures Used
Kensico	August 1, 2002 – March 31, 2003 August 1, 2003 – March 31, 2004 August 1, 2004 – March 31, 2005 August 1, 2005 - Ongoing	Bird Harassment: Motorboats, Husky Airboats, Pyrotechnics, Bird Distress Tapes, and Alewife Collections
West Branch*	None	None
Rondout*	December 2002 – January 2003 December 2003 – January 2004 December 2005 - Ongoing	Bird Harassment: Pyrotechnics and Bird Distress Tapes
Ashokan*	None	None
Croton Falls*	January – February 2002	Bird Harassment: Motorboats, Pyrotechnics, and Bird Distress Tapes
Cross River*	None	None

*Indicates reservoir mitigation only occurs "as needed" under the November 2002 FAD, Section 4.1.

The time period outlined for reservoir bird hazing in Table 2.11 represents the migratory (autumn and spring) and over wintering period for waterbirds (August through March). Both local on-reservoir movements of Canada Geese and the onset of early migration for Ring-billed Gulls begin by late July/ early August. During times of inclement weather when water craft are not permitted for bird hazing, the use of pyrotechnics only from the reservoir shoreline is often ineffective.

Bird hazing efforts have been largely successful where implemented. Figures 2.29 and 2.30 show bird populations versus fecal coliform bacteria levels at the two main water intakes at Kensico Reservoir (Shaft 18 and CatLeff). The data still reflects minor seasonal elevations of both birds and bacteria with few samples above the SWTR limit of 20, however DEP has remained in compliance with the federal rule stating values should not exceed 20 CFU (fecal coliform forming unit/100ml water sample) more than 10% over a 6-month running average. Spikes in the bird counts generally reflect intense precipitation events (i.e. rain, snow, fog, etc.) during which time hazing is limited.

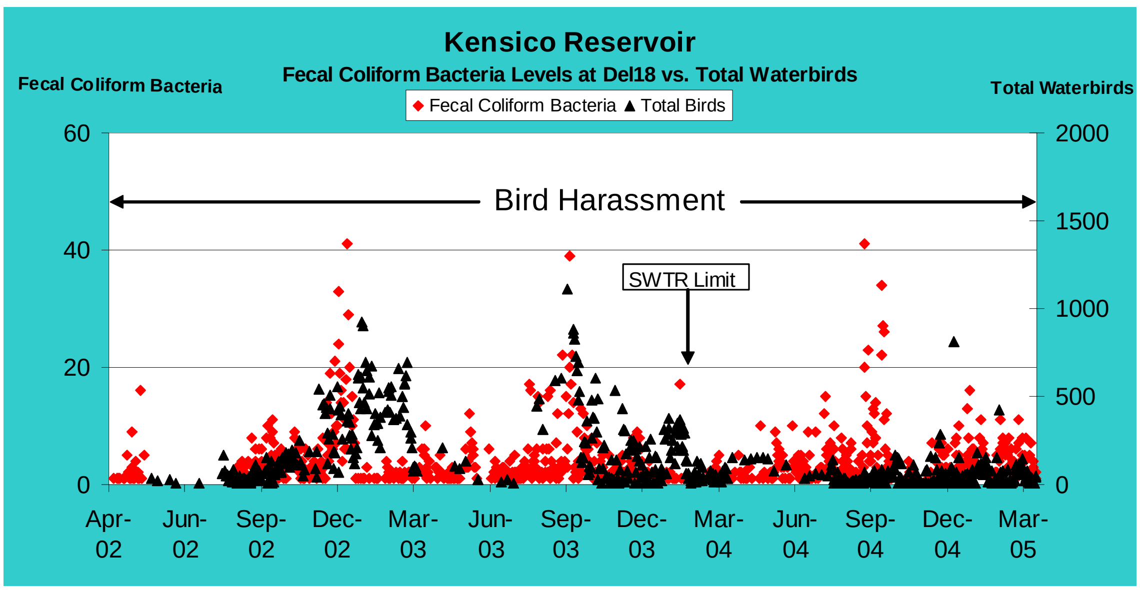

Figure 2.29 Kensico bird populations versus fecal coliform bacteria levels at the Shaft 18 Intake Facility.

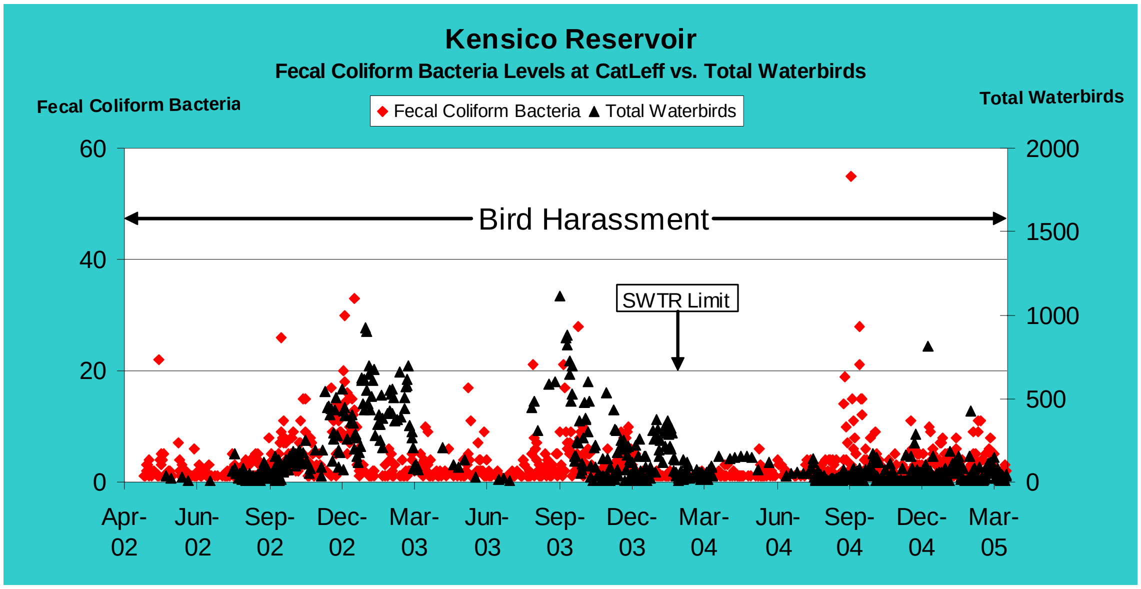

Figure 2.30 Kensico bird populations versus fecal coliform bacteria levels at the CatLeff Intake Facility.

Kensico Reservoir

Breeding populations of Canada Geese at Kensico are counted annually. A slight decline in the nesting pairs in 2005 was recorded when compared to the previous three years. Forty-two nests were identified in 2005 compared to 63 in 2004, 64 in 2003, and 69 in 2002. Heavy precipitation events in the spring of 2005 may account for the lower nesting numbers. A total of 978 goose eggs from 238 nests from 2002 to 2005 were depredated under a United States Fish & Wildlife Service Migratory Bird Permit.

West Branch Reservoir

West Branch Reservoir, like many other NYC reservoirs, can be kept in full flow-through operations, float operations, or bypassed depending on the water quality conditions. West Branch is an intermediate reservoir which receives water from Rondout and supplies water to Kensico. Results of the bird populations and fecal coliform bacteria in the water samples from the Shaft 10 Facility are shown in Figure 2.31. To date, DEP has not used the “as needed” bird harassment option at this reservoir. Bird counts (especially gulls) tend to decrease by late December coincidental with the onset of ice cover.

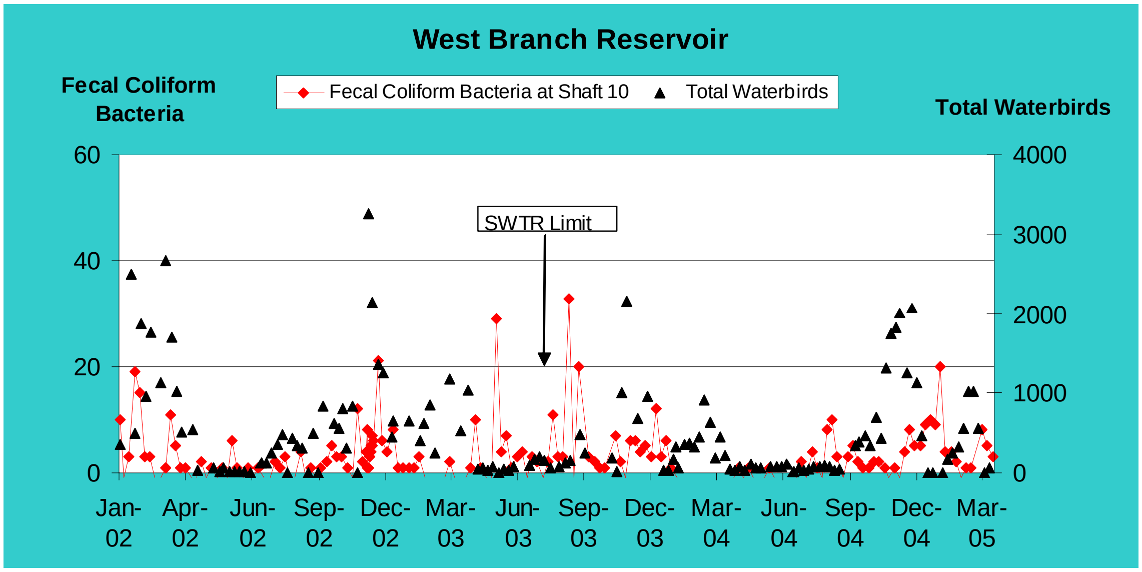

Figure 2.31 West Branch bird populations versus fecal coliform bacteria levels recorded at the Shaft 10 Facility.

A total of five Canada Goose nests containing 28 eggs were depredated in 2005. This compares to six nests with 36 eggs in 2004 and two nests with 10 eggs in 2003. There were no geese nests found in 2002. In addition, there were five Double-crested Cormorant nests with 28 eggs depredated in 2005.

Rondout Reservoir

The relationship between bird counts and fecal coliform bacteria levels at Rondout Reservoir is shown in Figure 2.32. DEP annually records an increase in the gull population coincidental with a change in nocturnal roost location each December and January, which results with elevated bacteria levels. Typically the birds roost in the reservoir between 2 to 3 miles away from the water intake, however by the beginning of the winter (late December) the roost moves to directly adjacent to the water intake. As a result, DEP has implemented an “as needed” bird harassment program from late-December until mid-January for three of the past four years. The program generally persists until there is ice-cover on the reservoir. DEP is currently implementing another “as needed” bird harassment program at Rondout for the winter of 2005/2006.

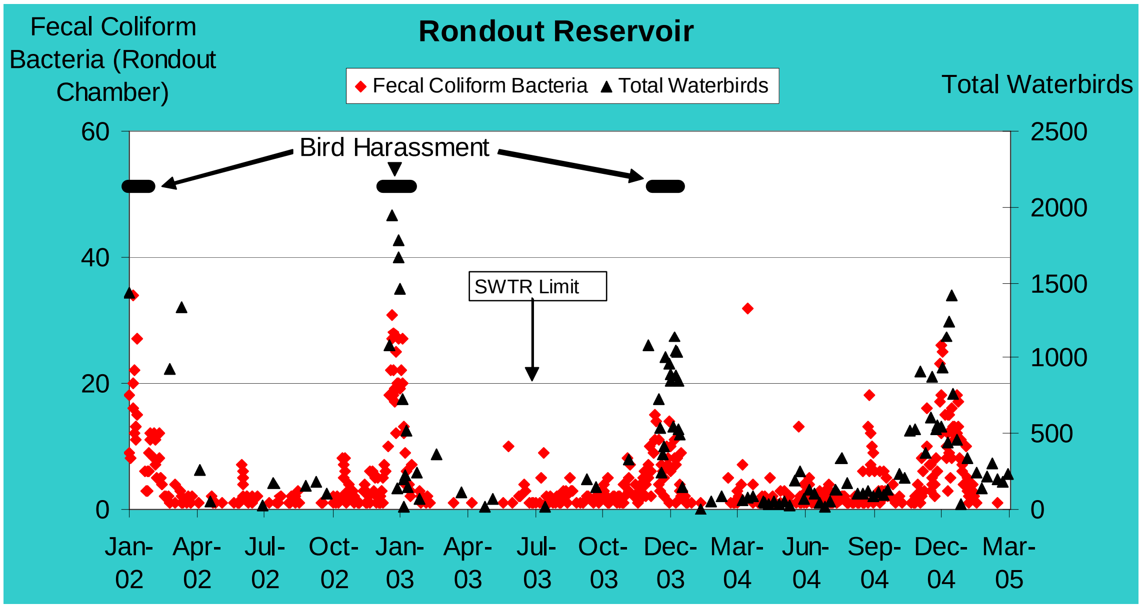

Figure 2.32 Rondout Reservoir bird populations versus fecal coliform bacteria at the Rondout Effluent Facility.

A total of two Canada Goose nests with 12 eggs were depredated in 2005 compared to three nests and 11 eggs in 2004, and three nests and 14 eggs in 2003. Breeding numbers generally remain low throughout the Rondout Reservoir. It is suspected that the increase in numbers of nesting Bald Eagles (*Haliaeetus leucocephalus*), a natural predator of the goose, may be deterring the geese from nesting.

Ashokan Reservoir

The highest bird counts are found at the Ashokan Reservoir. Gull counts reaching a few to several thousand are common during the late autumn and winter period up to ice cover. However, fecal coliform bacteria counts have remained low throughout the bird elevation period as bird roosting areas typically remain far enough away from the water intakes. This allows sufficient bacteria die-off prior to the reaching the water intakes. DEP did not implement any bird harassment measures at this reservoir from 2002 through 2005.

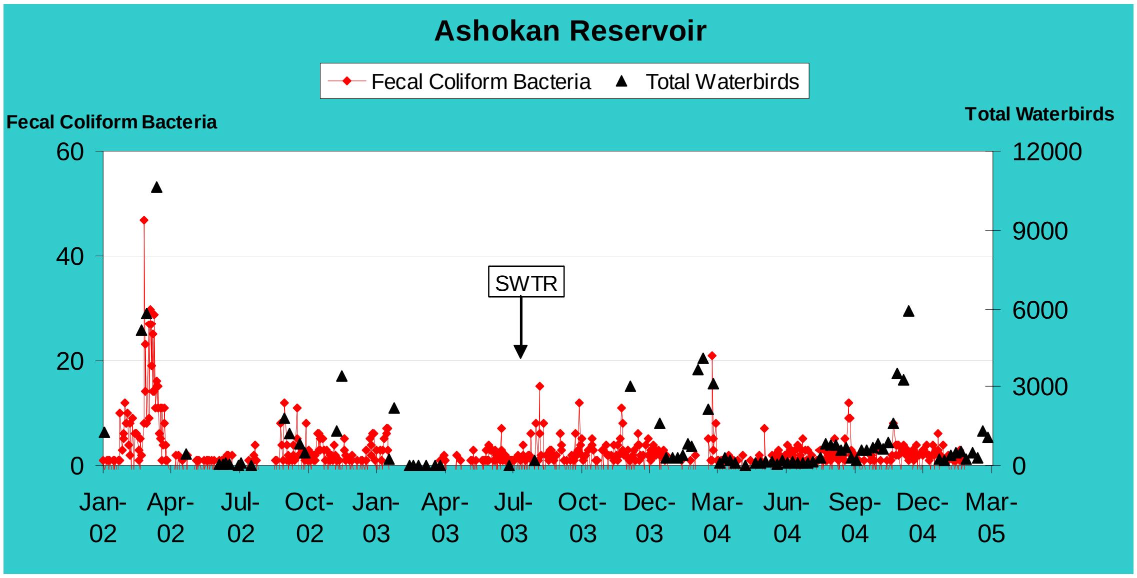

Figure 2.33 Ashokan Reservoir bird populations versus fecal coliform bacteria at the Ashokan Effluent Facility.

Canada Goose breeding numbers at the Ashokan Reservoir remain low due to frequent reservoir elevations fluctuations and the presence of breeding and resident Bald Eagles. A total of six nests containing 29 eggs were destroyed in 2005 compared to five nests and 27 eggs in 2004.

Croton Falls Reservoir

Bird populations fluctuate seasonally at Croton Falls Reservoir and generally increase in the autumn and winter period up through ice cover. Fecal coliform bacteria levels correspondingly increase with bird counts, particularly when gulls are present. Operational changes in water distribution from Croton Falls to Kensico are determined by environmental conditions and demand. When Croton Falls is in-service, such as during the drought conditions during the winter of 2001 and 2002, DEP responds with an “as needed” bird harassment program. The “as needed” program has only been implemented once from 2002 through 2005.

DEP has used its egg-depredation permit for nesting Canada geese at Croton Falls since 2004. A total of 23 nests with 88 eggs were depredation in 2005 compared to 23 nests and 81 eggs in 2004.

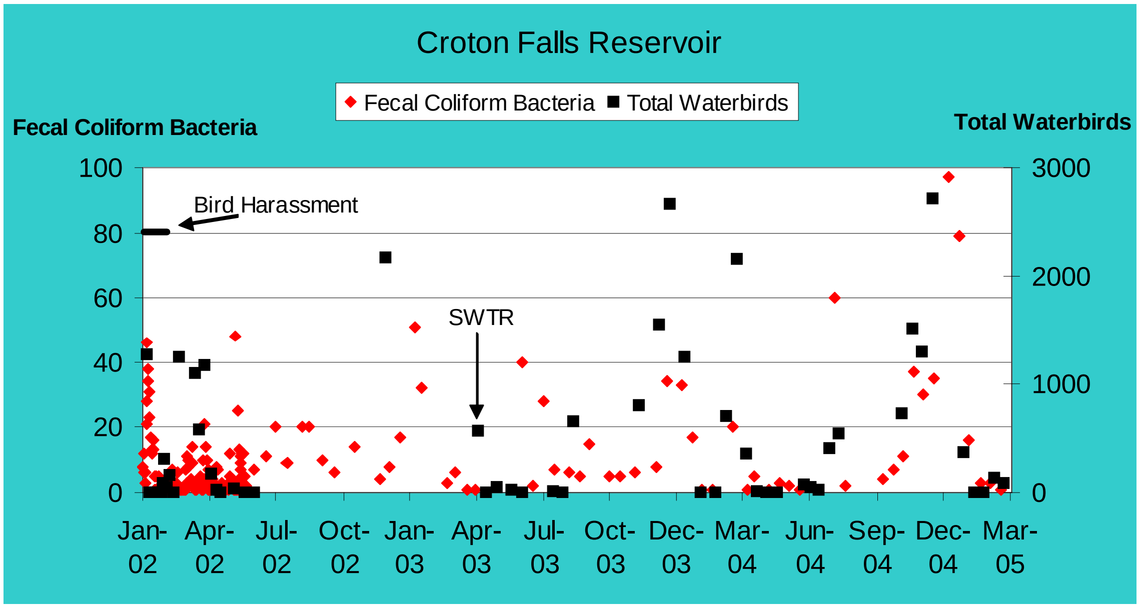

Figure 2.34 Croton Falls bird populations versus fecal coliform bacteria at the Croton Falls Effluent Facility.

Bird populations fluctuate seasonally but remain relatively low compared to other DEP reservoirs. Bird numbers generally increase in the autumn and winter period up through ice cover. There is a less well-defined relationship between fecal coliform bacteria levels and bird counts. Operational changes in water distribution from Cross River to Kensico are also determined by environmental conditions and demand, similar to Croton Falls Reservoir. The "as needed" program was not implemented during the period from 2002 through 2005.

Cross River Reservoir

DEP has used its egg-depredation permit for nesting Canada geese at Cross River since 2004. A total of 10 nests with 53 eggs were depredation in 2005 compared to 5 nests and 81 eggs in 2004.

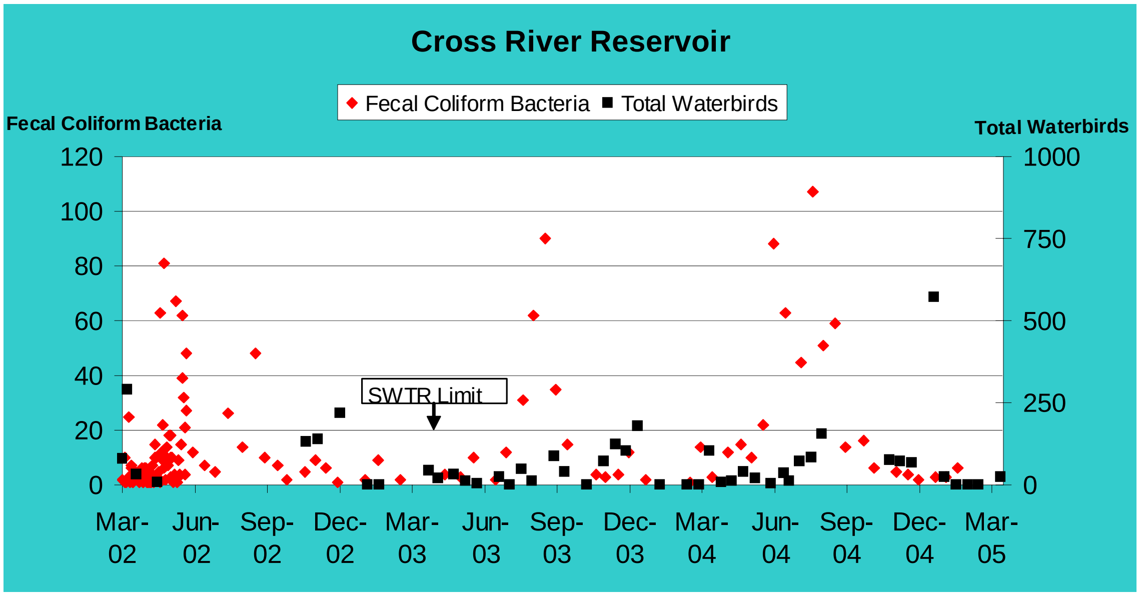

Figure 2.35 Cross River bird populations versus fecal coliform bacteria at the Cross River Effluent Facility.

2.7 Wetlands Protection Program

DEP's Wetlands Protection Strategy was implemented in 1996 and enhanced in 2001 to preserve wetlands and their valuable water quality protection functions in the watershed. DEP's strategy takes an interdisciplinary approach, combining regulatory and non-regulatory protection programs, supported with information gained from extensive wetland mapping and research. In addition to its land acquisition and voluntary protection programs, DEP reviews wetland permits at the federal, State, and municipal levels to ensure enforcement of existing regulations, and comments on any proposed changes to such regulations to maintain or improve protection levels in the watershed. An extensive mapping and research program supports DEP's protection and legislative review programs.

2.7.1 Wetland Mapping and Research

The wetland mapping and research program provides information on the extent, distribution, characteristics, and functions of wetlands to support DEP's watershed protection programs. Central to the mapping and research program is the National Wetlands Inventory (NWI), which DEP continued to build upon. The NWI was updated in 2005 for the entire watershed and provided the basis for an assessment of wetland trends and a watershed-scale wetland functional assessment. These programs, combined with an expanded Reference Wetlands Monitoring Program, have provided further information on the status and functions of wetlands to guide DEP's interdisciplinary Wetlands Protection Strategy.

Wetland Mapping and Trend Analysis

During the reporting period, NWI maps for the watershed were updated to reflect current conditions, and the EOH wetland trends analysis was extended to include the period from1994 to 2004. The recent NWI updates for the east and west of Hudson watersheds were based on larger scale (1:40,000) color infrared (CIR) aerial photography acquired specifically for the updates and trend analysis. The photography for west of Hudson was acquired in spring 2003, while the east of Hudson photography was acquired in spring 2004. A total of 25,838.8 acres of wetlands were mapped in the New York City watershed. The Delaware system had 6,534.3 acres, the Catskill system had 4,096.1 acres and the east of Hudson watershed had a total of 15,208.4 acres of wetlands.

The wetland mapping showed that for west of Hudson**,** wetlands occupy roughly one percent of each of the two major watershed areas with palustrine wetlands being the most common and abundant type of wetland. Over 14,000 acres of deepwater habitats were inventoried. They comprise about 2.2 percent of the watershed. Lacustrine waters totaled 13,518 acres, while riverine waters occupied 562 acres (Figure 2.36).

In 2003, 943 more acres of wetlands were mapped west of Hudson than in the original 1980s NWI. Most of the additional palustrine acreage mapped in the update is attributed to the ability to detect and map more small ponds and emergent wetlands (additions of 429 acres and 157 acres, respectively). The differences in acreage of palustrine wetlands for the two inventories reflect the availability of more extensive ground-truthing for the palustrine emergent wetland class, and the use of better quality and larger scale photography for the update. A detailed discussion of the results of the NWI remapping west of Hudson can be found in Tiner, et.al., 2005a.

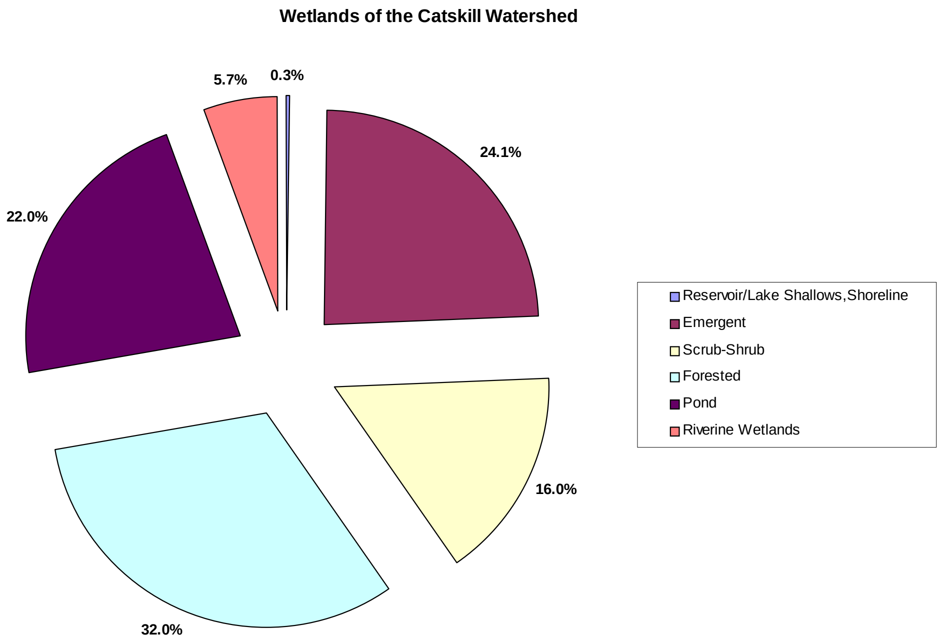

Figure 2.36 Breakdown by wetland type for the Catskill and Delaware watersheds.

Nearly 15,210 acres of wetland were mapped east of Hudson in the 2004 NWI update, representing about six percent of the east of Hudson watershed, with the vast majority being forested wetlands (72%) and ponds (palustrine unconsolidated bottoms) were second-ranked in acreage (13%). A detailed discussion of the results of the NWI remapping east of Hudson can be found in Tiner, et.al., 2005b.

The wetland trends analysis for the east of Hudson watershed was updated for the period 1994-2004 through a contract with the US Fish and Wildlife Service (USFWS) using spring 2004 aerial photography. This is a continuation of trend analyses previously done for the periods 1968-1984 and 1984-1994. From 1968 to 1984, the watershed experienced an average annual loss of 9.1 acres. The annual loss rate dropped to 4.3 acres/yr between 1984 and 1994. Since 1994, the east of Hudson watershed has experienced a net increase in wetland acreage. Overall from 1994-2004, wetlands (vegetated plus non-vegetated types) increased by a net of 49 acres, primarily due to pond construction (40.9 acres) and colonization of other aquatic habitat (21.6 acres). It is currently unclear whether a gain in wetland acreage through pond construction relays a net water quality functional gain. A more detailed discussion of the results can be found Tiner, et. al., 2005b.

Wetland Functional Assessment

Pursuant to the previous FAD, DEP contracted the USFWS to conduct a Wetland Characterization and Preliminary Assessment of Wetland Functions (W-PAWF) in the West Branch and Boyd Corners sub-basins to develop and test watershed-scale functional assessment methodology for East of Hudson wetland types. A report summarizing the findings of the W-PAWF for Boyd Corners and West Branch basins was produced in 1999 (Tiner et. al., 1999). During the current reporting period, a second pilot was completed for the Cannonsville and Neversink basins to test the W-PAWF methodology in the west of Hudson watershed (Tiner et. al., 2002). Using methods developed in the pilot studies, the USFWS then completed a W-PAWF for the entire Croton, Catskill, and Delaware watersheds (Tiner et. al. 2004; Tiner and Stewart, 2004).

For the W-PAWF, the USFWS interpreted maps and aerial photography to add hydrogeomorphic-type descriptors of landscape position, landform, and water flow path (LLW) to each NWI wetland in the digital database (Table 2.12). Other modifiers were added to depict features such as headwater, drainage-divide, and human-impacted wetlands. These modifiers provide the basis for a preliminary, watershed-scale assessment of the following wetland functions: surface water detention, streamflow maintenance, nutrient transformation, sediment retention, shoreline stabilization, provision of fish, waterfowl, waterbird and other wildlife habitat. A series of 13 maps for each reservoir basin was prepared to highlight wetland types that may be important for these functions (Figure 2.37). DEP reviewed the draft LLW classification maps, functional protocols, and reports issued for both pilot and the final watershed-wide W-PAWFs and issued comments on hundreds of wetland polygons throughout the 64 quadrangles in the New York City watershed. Through this process, USFWS and DEP jointly improved the LLW classification and functional assessment methodology.

Table 2.12. USFWS Landscape position, Landform and Water Flow Path (LLW) descriptors typical of the New York City water supply watersheds (Tiner 2003). A ‘Headwater’ modifier was added to wetlands along intermittent, first, and second order streams, and to terrene outflow wetlands.

Landscape Position - defines relationship between wetland and adjacent waterbody, if present
Lotic - along rivers and streams
Lentic - along lakes and reservoirs
Terrene - wetlands surrounded by uplands, lack influent wetland or watercourse, can be the source of streams

Table 2.12. USFWS Landscape position, Landform and Water Flow Path (LLW) descriptors typical of the New York City water supply watersheds (Tiner 2003). A 'Headwater' modifier was added to wetlands along intermittent, first, and second order streams, and to terrene outflow wetlands.

Landform - shape or physical form of the wetland

Basin - a depressional landform
Slope - a landform extending uphill
Floodplain - landform shaped by fluvial processes
Flat - a relatively level landform
Fringe - a landform occurring along or within a flowing or standing waterbody
Island - landform completely surrounded by water

Water Flow Path - describes direction of water flow in the wetland

Inflow - water enters via an upslope wetland or waterbody, no surface water outlets exist
Outflow - lack a wetland or waterbody upstream, discharge to wetland or water body
Throughflow - have a wetland or waterbody upstream and downstream
Isolated - closed depression, lack channelized surface water inflow and outflow
Bidirectional - lentic wetlands where lake fluctuation is water level primary control

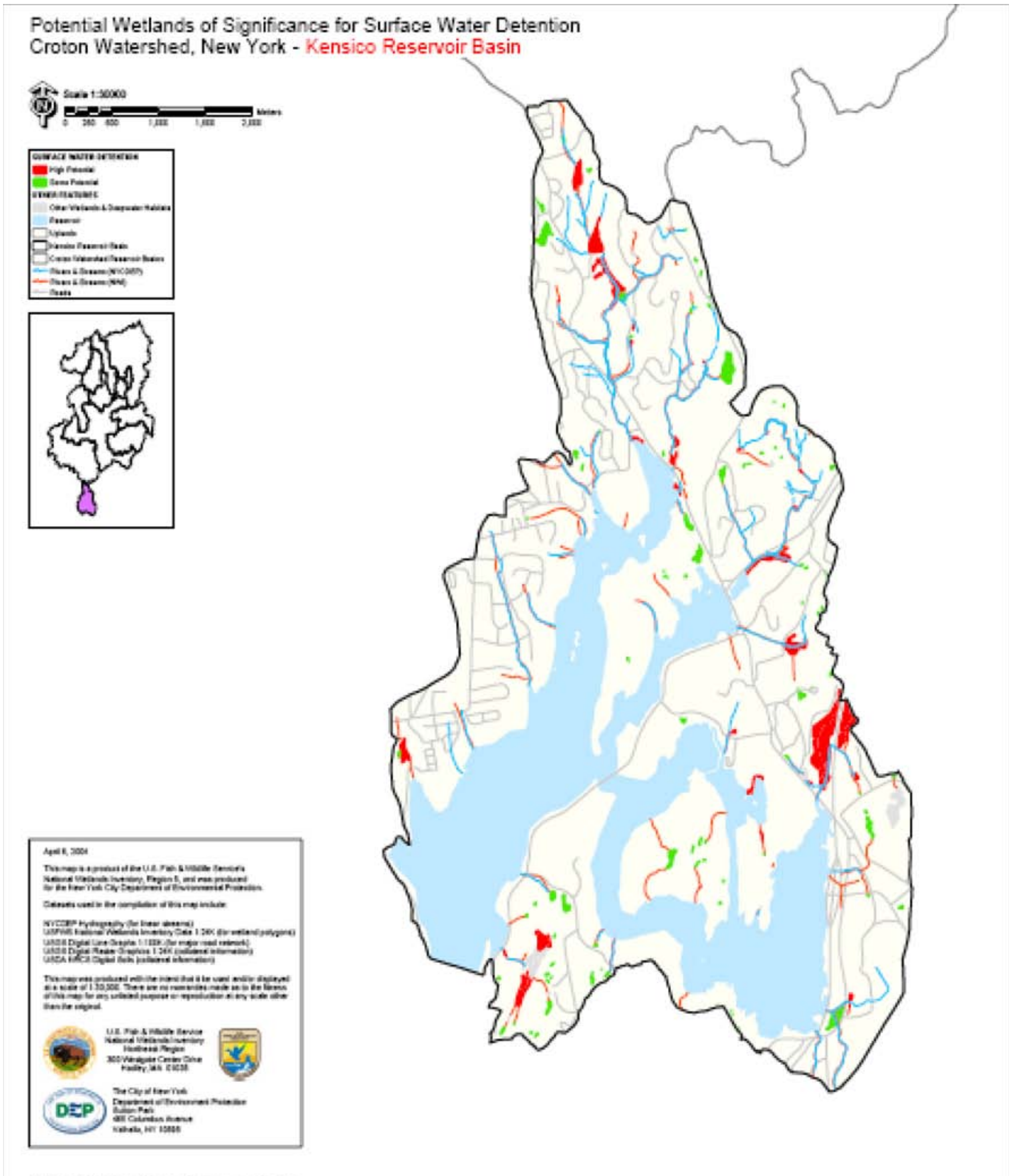

Figure 2.37 Example of LLW classification map for the Kensico Reservoir basin.

It is important to emphasize that the W-PAWF provides a preliminary evaluation based on wetland characteristics interpreted through GIS data sources and best professional judgment. The LLW classification is useful for general natural resource planning, as an initial screening for considering prioritization of wetlands (for acquisition or strengthened protection) and for characterizing the differences among wetlands in terms of both form and function within a watershed. This type of assessment does not eliminate the need for site-specific field investigations, which is the focus of the Reference Wetlands Monitoring Program.

Reference Wetlands Monitoring Program

DEP developed the Reference Wetlands Monitoring program in conjunction with the pilot W-PAWF in the West Branch and Boyd Corners Reservoir basins. The objectives of the pilot monitoring program were to 1) to assess the LLW classifications and functional assessments ascribed to wetlands by the USFWS; 2) to compare baseline characteristics and water quality functions across wetland types and 3) to guide the design of future DEP wetland monitoring programs. Data collection for this program was completed in 2002 and included vegetation, soils, water table, and routine surface water quality sampling at six wetlands located throughout the pilot study area. A total of 504 routine water quality samples were collected from the six study sites over a two-year period. Preliminary findings from this monitoring program are described in DEP's 2004 Reference Wetland Monitoring Program Annual Report (Machung and Kane, 2004).

DEP has expanded the Reference Wetlands Monitoring program to the Catskill and Delaware watersheds partly through an SDWA grant. The components of the monitoring program include a broad-scale synoptic sample of surface waters from several wetlands located throughout the Catskill and Delaware watersheds, a fixed-frequency baseflow water quality sampling regime at 22 reference sites, a characterization of vegetation, soils, and ground water at the 22 reference sites, and an intensive storm-water sampling regime at four of the reference wetlands. The synoptic, storm, and base flow sampling was conducted through a contract with SUNY School of Environmental Science and Forestry (SUNY ESF), while vegetation, soils, and water table monitoring was conducted by DEP staff. Synoptic, baseflow, groundwater and storm water quality analytes are shown in Table 2.13.

Table 2.13. Analytes included in the synoptic, baseflow, and storm flow monitoring program.

Analyte	Sample Types			
	Synoptic	Baseflow	Storm	Ground-water
Total Cations (Ca, Mg, Na, K, Si, Fe)	✔	✔	✔	✔
Total alkalinity	✔	✔	✔	✔
SO_4	✔	✔	✔	

Table 2.13. Analytes included in the synoptic, baseflow, and storm flow monitoring program.

Analyte	Sample Types			
	Synoptic	Baseflow	Storm	Ground-water
Cl	✔	✔	✔	✔
TDN	✔	✔	✔	✔
NO_3	✔	✔	✔	✔
NH_4	✔	✔	✔	✔
TP, TDP	✔	✔	✔	✔
DOC	✔	✔	✔	✔
Fluorescence	✔	✔		
Isotopes of strontium	✔	✔		
Isotopes of water and Carbon	✔	✔		
Tritium	✔	✔		
pH, spcon, DO	✔	✔		

The synoptic sampling was completed in August 2004. Water quality samples were collected from the outflows of 56 wetlands to characterize water quality and bedrock-water interactions of several wetlands located among terrene and lotic landscape positions throughout the Catskill and Delaware watersheds (Figure 2.38). Results from the synoptic sampling are summarized in west of Hudson Wetland Water Quality Assessment Synoptic Report (Siegel and Azzolina 2005).

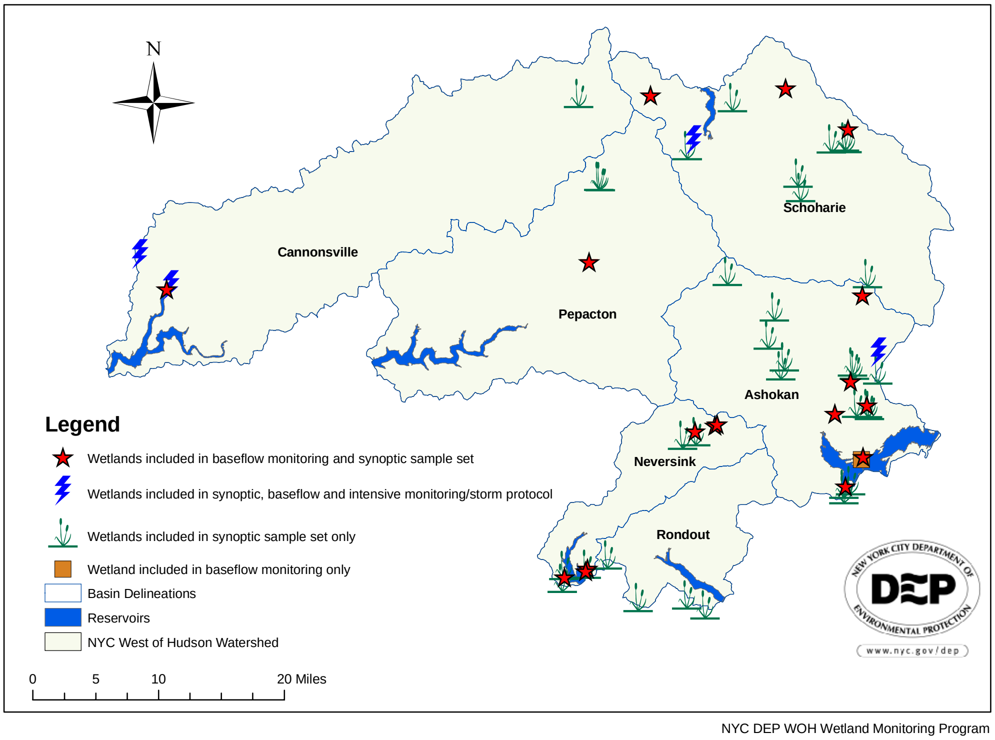

Figure 2.38 West of Hudson wetland sampling locations for the Reference Wetland Monitoring Program.

A total of 22 reference wetlands were selected for monthly baseflow monitoring. The reference wetlands were also included in the synoptic sampling. SUNY ESF initiated baseflow sampling in June 2004 at the reference wetlands and conducted 12 quality sampling runs on an approximate monthly schedule, ending in June 2005. A subset of four (two lotic and two terrene) of the 22 reference wetlands were selected and instrumented for storm flow monitoring in the spring of 2004 (Figure 2.39a and b). Storm and baseflow samples were collected from the outflows of terrene wetlands, and from the inflows and outflows of lotic wetlands. Storm sampling was completed in October 2005, with multiple summer, spring, and autumn events sampled at each site. DEP is currently reviewing all base and storm flow data reports submitted from its contractors and has worked extensively to ensure complete data submissions and adherence to the QAPP.

a)

b)

Figure 2.39 a) A lotic stream headwater reference wetland in the Ashokan basin. b) A terrene basin outflow headwater reference wetland in the Ashokan basin.

DEP collected data to characterize the hydrology, soils, and vegetation of the 22 baseflow sites. DEP installed 35 automated water-table monitoring wells the 22 study sites during the early 2004 growing season. Data from the wells are routinely downloaded to create time series plots of stage. Hydrolab™ measurements of temperature, pH, oxidation-reduction potential, dissolved oxygen, and specific conductance were collected biweekly after well installation during the 2004 and 2005 growing seasons. Soil samples were collected from the well bore holes during the Ecotone™ well installations. Samples were separated by horizon, oven dried and submitted to Cornell Nutrient Analysis Laboratory for analysis of pH, exchangeable acidity, exchange capacity, organic matter, total carbon, organic carbon, and nitrogen, extractable P, K, Ca, Zn, Mg, Al, Mn, and Nitrate, and total Al, Fe, Na, Mg, Ca, P, S, Cd, Co, Cr, Cu, Ni, Zn, Mn, Pb, Ti, and V.

Vegetation sampling grids (50m x 50m) were constructed for all of the study sites using GIS. DEP staff sampled 136 plots located throughout the 22 reference sites during the 2004 and 2005 growing seasons. At each plot, the percent cover and dominant herbaceous vegetation species were recorded in a 1 m^2 area, the species and number of stems of shrubs and saplings were recorded in a 12.6 m^2 area, the diameter at breast height (dbh) and species of trees (dbh > 4 in) were recorded in a 314 m^2 area.

The data from the Catskill/Delaware Reference Wetland Project is currently in the final stages of review and data analysis is ongoing. The monthly baseflow water quality data collected from the 22 reference sites will be statistically and graphically analyzed to characterize temporal changes in the dissolved organic carbon (DOC), nutrient, and major water-quality parameters of streams hydraulically connected to various wetland types present in the Catskill and Delaware watersheds, and to determine how DOC, nutrients, and stream chemistry are related to wetland LLW class. Precipitation, groundwater, and stream water quality and quantity data will be used to calculate rudimentary nitrogen and phosphorus mass balances for each intensive site. Data from intensive sites will also be analyzed to test the hypotheses that wetlands are temporal sources/sinks of nitrogen, phosphorus and other substances important to water quality, and that these water quality functions vary among wetland types and with antecedent moisture conditions and seasons. Correlations among soil and water chemistry, water table dynamics, plant communities and LLW classes will be investigated to assess major controls on wetland vegetation characteristics. A final report, summarizing the findings of the Reference Wetlands Monitoring Program will be issued in 2006.

DEP has combined the GIS-based W-PAWF with a Reference Wetlands Monitoring Program to provide information in support of its protection programs. DEP uses information gained from the Wetland Monitoring and Functional Assessment Program to assess the conditions and functions of wetlands that would be impacted from proposed land use and development projects. Data collected in the monitoring program has been used extensively to guide wetland mitigation, restoration, or enhancement designs under review. The LLW classification of the W-PAWF can be applied to prioritize wetlands for strengthened protection based on their landscape settings or predicted functions.

2.7.2 Wetland Regulatory Program

DEP's wetland regulatory program includes the review of federal, State, and municipal permit applications, assistance in intergovernmental enforcement actions, review of proposed legislative or regulatory changes affecting wetlands, revisions to New York State Freshwater Wetland Maps, as well as wetland training and outreach efforts. The effectiveness of the regulatory program was enhanced by increased intra- and inter-agency coordination. The wetland mapping and research program provided baseline information to assess the extent and functions of proposed wetland impacts, and the appropriateness of proposed mitigation. DEP also coordinated with external agencies to pursue enforcement actions, and to conduct the New York State Freshwater Wetlands remapping program. DEP staff has extensive wetlands management and impact assessment experience to implement and track the regulatory program.

Project Reviews

A main component of DEP's Wetlands Protection Strategy is review of applications for federal, State, and municipal wetlands permits, as well as proposals subject to review under the State Environmental Quality Review Act (SEQRA) and the New York City Watershed Rules and Regulations (WR&Rs). As the level of protection afforded to wetlands varies among regulatory authorities, reviewing applications pending before all of the agencies for the same project helps to ensure that all activities that potentially threaten the water quality functions of wetlands in the watershed are carefully reviewed by DEP. All wetland proposals are assessed by DEP staff for compliance with applicable wetland regulations and for the potential impact on water quality. Measures to avoid, minimize or mitigate impacts on the water quality protection functions of wetlands are often recommended.

- Army Corps of Engineers Applications - The United States Army Corps of Engineers (ACOE) forwards Pre-Construction Notifications (PCNs) and Individual Permit Applications under the Clean Water Act in the watershed for review and comment by DEP. DEP reviews PCNs to confirm that the proposed activity complies with federal wetland regulations, and the activity will not have an adverse impact on federally designated wetlands or water quality in the watershed. DEP reviewed 24 ACOE wetland applications from 2002 - 2005.
- New York State Applications - DEP continued to review permit applications pending before NYSDEC under Articles 15 and 24 of the Environmental Conservation Law. In addition, NYSDEC agreed to DEP's request to forward 401 Water Quality Certifications for projects in the watershed to DEP's wetland unit for review. DEP reviewed at total of 37 permit applications pending before NYSDEC from 2002-2005.
- Municipal Applications - DEP reviews proposals involving wetlands before East of Hudson municipal regulatory bodies to assess compliance with municipal land use regulations and potential impacts to wetlands and water quality in the City's drinking water supply watershed. Citing the importance of protecting the water quality functions of wetlands and the potential

impact a proposal represents on a wetland, DEP may advocate denial or revision of applications under consideration at the municipal level. DEP reviewed a total of 39 local wetland applications in New York State and Connecticut between 2002 and 2005.

- New York City Watershed Rules and Regulations - The adoption of the NYC Watershed Regulations in 1997 provided another level of wetland protection. DEP reviews applications to conduct regulated activities to ensure that prohibitions in the WR&Rs, such as the creation of impervious surfaces or installation of septic systems within limiting distances to DEC-mapped wetlands, are complied with. DEP also regulates other activities that may adversely affect wetlands, such as discharges of stormwater and wastewater from new developments. Further details on DEP's project review activities can be found in Section 2.10 of this report

Regulatory Enforcement

In addition to exercising its independent regulatory authority, DEP provides technical assistance to other regulatory agencies in intergovernmental enforcement cases as requested. In 2005, DEP staff met with EPA to discuss the their involvement in enforcement of federal wetland regulations in certain important geographic locations, such as the New York City watershed. Through notifications from the EPA, local municipalities, and DEP staff, DEP was made aware of and investigated 4 alleged wetland violations during the period of 2002-2005.

Staff Training

In 2005, DEP provided a training course entitled, "Development Guidelines for the Protection of the Water Quality Function of Wetlands" for DEP staff who regularly review development proposals in the watershed. Specific emphasis was placed on the wetland permit application review guidelines for federal, State and municipal permits. Thirty-seven DEP staff members attended this training course.

NYS State Freshwater Wetland Map Amendments

At DEP's request, NYSDEC examined data sources and conducted field work to revise the NYS Freshwater Wetland Maps for the east of Hudson watersheds. NYSDEC assessed the boundaries of existing regulated wetlands, located additional wetlands that meet the state regulatory threshold of 12.4 acres, and identified smaller wetlands of Unusual Local Importance (ULIs) that are adjacent to the reservoirs. NYSDEC completed review for the west of Hudson watershed in 2001, adding 650.7 acres.

DEC completed field work for this effort in Westchester County in 2002, and the final amended maps were accepted in July 2004. Through this process, NYSDEC added approximately 2,400 acres in Westchester County. This includes 91 acres of ULI wetlands added through DEP's review of the draft map revisions. Field work for Putnam and Dutchess counties was completed in 2004. Draft maps, identifying approximately 4,500 acres of wetland for amendment in Putnam and Dutchess counties were issued in August 2005, with final map issuance expected in early 2006. These amendments will increase the extent of wetlands subject to review under both the Watershed Rules and Regulations and the NYS Freshwater Wetlands Law by nearly 7,000 acres.

2.8 Watershed Forestry Program

The Watershed Forestry Program is a partnership that supports well-managed working forests as a beneficial land use for watershed protection. Since 1997, DEP has contracted with the Watershed Agricultural Council (WAC) to administer and implement four core program tasks: (1) forest management planning; (2) BMP implementation; (3) logger training; and (4) research, demonstration and education. Through WAC, the Forestry Program also receives matching grants from the USDA Forest Service (USFS) to strengthen the economic viability of the wood products industry and to promote forest stewardship through education.

During the past few years, both WAC and the Watershed Forestry Program underwent a period of growth and transition. In 2003, WAC hired four new forestry staff, including their first east of Hudson forester based in Westchester County. The hiring of this forester has allowed WAC to fully expand its range of forestry services throughout the east of Hudson watershed, resulting in greater landowner outreach and increased participation in forester training, forest management planning, and forestry education programs. In 2004, WAC created a forestry intern position to assist DEP with evaluating 5-year old WAC forest management plans. Finally, WAC as an organization undertook a long-term strategic planning process during 2004 which produced greater integration of its agricultural and forestry programs. This strategic planning process provided several opportunities for WAC and DEP to review and update the core policies of the Watershed Forestry Program and begin to assess its future direction.

2.8.1 Forest Management Planning

The Watershed Forestry Program provides training to foresters and funding to landowners to encourage their development of written forest management plans. Over the years, WAC has revised and expanded its forest management planning program to include several new policies and opportunities for promoting good forest stewardship. Some key examples of these program enhancements include: improved plan specifications to address water quality concerns, higher cost-sharing rates for east of Hudson landowners, expanded eligibility requirements for certain municipalities, cost-sharing to support plan updates and plan upgrades, new riparian planning requirements for all plans completed after January 2005, and improved coordination with Whole Farm Planning staff to promote forest management planning among watershed farmers.

To date, WAC has conducted 19 forester training workshops attended by more than 200 participants. As a result of these workshops, 43 foresters are trained to write WAC forest management plans, and at least half of these foresters provide services to East of Hudson landowners. In total, more than 529 landowners have completed WAC forest management plans covering more than 94,100 watershed acres. These figures include 28 east of Hudson plans covering 2,580 total acres and 66 riparian plans covering 2,841 riparian acres. DEP continues to support the development of new forest management plans, with an ongoing focus on riparian planning, 5-year updates, landowner evaluation surveys, and property site visits.

Since 2002, DEP and WAC have annually evaluated 5-year old WAC plans to better understand landowner activities and assess their progress in implementing forest management recommendations. This evaluation includes mailed written surveys, free on-site visits, personal interviews, and a complete database analysis for all 5-year old WAC plans. Of the 98 plans evaluated to date, 66% recommend some type of silvicultural prescription over a 10-15 year period, with commercial thinning, timber stand improvement, and pre-commercial thinning comprising the top three prescriptions. Of the 46 landowners who completed an evaluation survey (47% response rate), 43% identified recommendations they had not yet implemented, with timber stand improvement and wildlife enhancement ranking among the most common practices to be implemented. These 46 landowners also ranked hunting/wildlife, economic values, and aesthetic enjoyment as their top three reasons for owning a WAC plan.

In response to these preliminary evaluation results, the Watershed Forestry Program initiated a two-year pilot project in 2005 called the Management Assistance Program (MAP). The purpose of this new program is to provide watershed landowners with limited funding assistance to implement specific practices recommended in their WAC plans. MAP is modeled after the federal Forest Land Enhancement Program (FLEP), which was intended for the same purpose but thus far has been significantly under-funded by Congress (60% of the original ten-year allocation has been reallocated) with less than $730,000 in federal cost-sharing funds being provided to New York State since 2003. MAP covers 100% of a landowner's costs, up to $2,500, for implementing the following practices: timber stand improvement, tree planting (including tree shelters and deer fencing), riparian improvements and wildlife improvements. At least 20 pilot participants will be selected each year, with WAC and DEP planning to evaluate this program during 2006-2007.

2.8.2 BMP Implementation

The Watershed Forestry Program provides cost sharing, technical assistance and other incentives to loggers and landowners for implementing forestry BMPs that prevent pollution during timber harvests and associated management activities. Over the years, WAC developed a number of forestry BMP programs to support the temporary installation of portable bridges, the proper construction of new timber harvest roads, the remediation of existing forest roads having erosion problems, the planting of riparian buffers along watershed streams, and the use of new erosion control technology such as geotextile road fabric, silt fencing, pipe culverts, open-topped culverts, non-petroleum chainsaw oil, rubber tire land mats, and rubber belt water deflectors. In addition, WAC recently modified its forestry BMP eligibility requirements to provide increased incentives for loggers who are fully certified under the Trained Logger Certification Program.

To date, 51 portable bridge projects have been completed, including 19 bridges that were purchased, constructed or rented, and 32 bridges that were temporarily loaned to loggers (WAC owns several short-span bridges and one long-span bridge). In addition, 97 road BMP projects have been completed to date, including 50 timber harvest roads and 47 remediated forest roads. These road BMP projects represent more than 140 miles of properly designed and stabilized forest access roads containing more than 4,885 water bars, 315 broad-based dips, and more than 7,300 feet (1.5 miles) of geotextile road fabric, silt fencing and traditional pipe culverts. DEP continues to support BMP implementation, with a focus on portable bridges, road BMP projects, and riparian buffer protection. In addition, WAC is currently exploring options for purchasing additional east of Hudson loaner bridges using USFS funds.

2.8.3 Logger Training

The Watershed Forestry Program has always supported a voluntary logger training program to improve the quality of timber harvesting and promote logger safety among the 220+ timber harvesters who are estimated to work in the watershed at least a portion of the year. Between 1999 and 2002, WAC supported a “watershed qualified” training option whereby loggers who attended at least one water quality BMP training workshop (typically a Forest Ecology and Silviculture course) would be eligible to participate in certain WAC cost-sharing programs. Although nearly 150 loggers became “watershed qualified” during this time, less than 5% also became fully certified through the New York State Trained Logger Certification (TLC) Program. After conducting a logger training study in 2002, WAC agreed to harmonize watershed training activities by merging with the State-wide TLC Program effective June 30, 2003.

Currently, the Watershed Forestry Program promotes voluntary participation in the State-wide TLC Program. To become fully certified, loggers must complete three one-day courses: Forest Ecology & Silviculture, First Aid & CPR, and Chainsaw Safety (Game of Logging – Level 1). Over the years, WAC has partnered with the Catskill Forest Association, Cornell Cooperative Extension, New York Logger Training and others to sponsor more than 150 training workshops attended by more than 1,300 participants throughout the watershed. A total of 39 individuals working in the Catskill/Lower Hudson region are fully certified as of December 31, 2005. These numbers represent nearly 20% of the estimated year-round population of watershed timber harvesters. To increase participation in the TLC program, the Watershed Forestry Program is developing a TLC signage program for watershed loggers, encouraging local sawmills to pay premiums for wood harvested by TLC participants, and promoting an aggressive schedule of TLC workshops during 2006 and beyond. DEP supports these efforts.

2.8.4 Research, Demonstration and Education

The Watershed Forestry Program collaborates with a wide range of upstate and downstate partners to implement research, demonstration and forestry education programs throughout the watershed and within New York City. The following is a summary of the major programs:

Model Forest Program

WAC partners with SUNY ESF to oversee research at two model forests established using funds from DEP, USFS, and the US Army Corps of Engineers. Model forests integrate forest health monitoring, water quality research, erosion control BMPs, silvicultural demonstrations, interpretive education and public outreach opportunities. The Lennox Memorial Forest was opened in 2001, and contains 167 forest inventory plots covering 80 acres. The Frost Valley Model Forest was opened in 2003, and contains 620 forest inventory plots covering 290 acres. Both model forests contain deer exclosure units, informational kiosks and numerous interpretive signs. The Frost Valley Model Forest also contains several USGS stream monitoring gages in addition to hosting a variety of research projects dealing with nutrient cycling and the effectiveness of wood chips as a potential BMP following a timber harvest. In recent years, the Watershed Forestry Program experienced setbacks with respect to establishing two model forests on public lands. As a result, WAC has reconvened a model forest advisory committee to review and assess future project directions. DEP supports the continuation of the model forest program, with a renewed focus on selecting sites that promote interpretive education and watershed forestry demonstrations.

WAC Research Projects

Through WAC, the Watershed Forestry Program has supported a number of special research projects over the years. These projects have included a forestry BMP effectiveness study (1998-1999), a forestry economic development study (1999), a low-grade wood chipping research project (2000), a watershed logger training study (2002), a watershed taxation study (2002-2003), a forestry BMP monitoring protocol (2004-2005), a model forest diffusion of knowledge study (2005), and a sustained yield forestry research project (2005). The latter three projects are funded by the USFS and will remain ongoing throughout 2006.

Landowner Education

The Watershed Forestry Program traditionally partners with the Catskill Forest Association, Cornell Cooperative Extension, SUNY ESF, and New York Forest Owners Association to sponsor and implement a wide range of education programs for the purpose of promoting sustainable forest management and a beneficial land stewardship ethic among watershed forest landowners. Examples of these programs held over the years include landowner workshops and conferences, model forest events, watershed woods walks, landowner site visits, a six-month "Friday Forestry School" offered in three watershed counties, periodic informational mailings, and the distribution of a forestry newsletter (*Watershed Woodlands*) to approximately 20,000 forest landowners in both the Catskill/Delaware and Croton watersheds. Educating watershed landowners about the role and importance of well-managed healthy forests and engaging these landowners in proper land stewardship activities will continue to remain a top priority for DEP and WAC. Towards this end, the Watershed Forestry Program is currently developing a six-part distance learning course with Cornell Cooperative Extension targeting watershed landowners who live outside the region and are unable to attend traditional classes.

School-based Education

During the past few years, both WAC and DEP strengthened their partnerships with the Catskill Center for Conservation and Development to consolidate school-based educational programs for upstate/downstate audiences and to promote their locally-based environmental curriculum (*The Catskills: A Sense of Place*) which addresses New York State Learning Standards. As a result, the Catskill Center now oversees the annual Watershed Forestry Institute for Teachers, the Green Connections School Education Program, and the Watershed Forestry Bus Tour Program. Through DEP's Stream Management Program, the Catskill Center also implements the Catskill Stream and Watershed Education Program, which further enhances school-based education dealing with healthy forests and water quality. Another positive development which DEP, WAC and the Catskill Center have supported during 2004-2005 has been to improve collaborations with the CWC's Public Education Program and particularly Trout in the Classroom. These collaborations have allowed the Watershed Forestry Program to support watershed field trips (including trout releases and tree planting) and to maximize grant funding opportunities for upstate/downstate schools.

Forestry Outreach

In addition to its targeted educational programs, the Watershed Forestry Program also conducts a number of public outreach activities every year that promote the many benefits of a working forest landscape. Recent highlights include a forestry media campaign targeting New York City newspapers and National Public Radio stations in the Albany and the Hudson Valley region, the development and installation of watershed forestry kiosks at the Empire State Plaza and State-owned Belleayre Mountain Ski Lodge, model forest field days, watershed forestry tours for environmental groups and national/international audiences (including the United Nations Forum on Forestry), regular publication of forestry articles in local newspapers and national trade magazines, and annual participation in dozens of county fairs, watershed logging festivals, local government events, and national/international woodworking expos. During the past year, DEP has been collaborating with NYSDEC through its regional New York ReLeaf committees to initiate development of a multi-partner watershed forestry outreach strategy for detecting and preventing the spread of invasive insect pests such as the Asian Longhorned Beetle and others. Implementing this collaborative strategy and supporting other forestry outreach projects will be an ongoing activity of the Watershed Forestry Program during 2006 and beyond.

Forestry Economic Development

Since 2001, WAC has received more than $2.5 million from the USFS to improve the economic viability of local wood-using businesses through an Economic Action/Rural Development Through Forestry Grants Program. To date, 75 grants totaling $2.29 million have been awarded to watershed businesses to support projects such as developing new furniture products, advertising and marketing, staff training and professional development, supporting an apprenticeship program, purchasing new equipment, upgrading computer technology, preparing long-term business plans, researching new kiln-drying methods, expanding or improving facilities, and other activities related to forest products manufacturing and wood crafts/artistry. In 2004, WAC published a watershed directory of primary and secondary wood-using businesses which was distributed at more than a dozen woodworking expos and furniture fairs throughout the Northeast. Given that future USFS funding for this program has been phased out, WAC is currently conducting an economic program evaluation to be completed during 2006. In the interim, WAC has received two smaller USFS grants totaling $72,000 to develop a "Catskill WoodNet" website and to promote and market a Catskill/New York City wood collaborative. These projects will be ongoing during 2006-2007.

2.8.5 Summary

The past few years have been a productive time for the Watershed Forestry Program. Many important issues were addressed through WAC's strategic planning process, such as the adoption of new program policies, the integration of forestry into Whole Farm Planning, the strengthening of educational partnerships, and a renewed emphasis on riparian planning, logger training, and program evaluation. During 2006, the Watershed Forestry Program will continue to support its educational programs for upstate and downstate audiences (especially landowners and school groups), while exploring potential new programs that support forest management planning and implementation. In particular, as DEP and WAC continue to evaluate 5-year old forest management plans and other forestry incentive programs, this should improve our understanding of landowner needs, interests, attitudes, behaviors and stewardship activities.

2.9 Public Outreach and Education

Public education and outreach efforts have been a component of the City's watershed protection strategy since the expansion of the protection program in the early 1990s. DEP's activities are built on the principle that an informed base of watershed residents and water consumers facilitate development and implementation of protection strategies. An effective outreach program enhances consumer confidence in the safety and quality of the water supply, while teaching watershed residents and consumers alike the importance of watershed protection.

DEP's efforts have included, and will continue to include, both program-specific education efforts and broad-based outreach. In many cases, program-specific outreach efforts are conducted in coordination with DEP partner agencies and organizations – CWC, WAC, KEEP and the watershed counties, to name a few. It is important to acknowledge the contributions of these locally-based groups in spreading the word about the links between land use activities and water quality.

2.9.1 WOPA Education Program

Through the Watershed Office of Public Affairs (WOPA), DEP takes a comprehensive approach to watershed education. DEP visits schools in New York City and watershed counties and offers students an educational, action-oriented, multi-disciplinary curriculum. DEP programs promote investigation, allowing students to analyze all factors, past and present, human and nonhuman, which affect the entire watershed. DEP also organizes staff development for teachers, providing them with an opportunity to meet and work with DEP scientists, engineers, and environmental educators.

In 2004, *Trout in the Classroom* continued to be one of the most popular classroom programs. DEP environmental educators visited over 40 schools in the watershed. This program teaches stewardship and science through the rearing of brown trout. Classes receive hatchery-bred eggs in the fall and students monitor the life cycle of the fish and the water quality until the end of the school year when the fish are then released into an appropriate stream. Through the aquaculture of brown trout, students discover the connections between aquatic systems, life cycles, water quality and drinking water.

DEP continues to work with towns that surround the Kensico Reservoir to organize the Kensico Environmental Enhancement Program (KEEP), an outreach effort designed to protect and enhance water quality in the Kensico Reservoir. Joint efforts coordinated by DEP and KEEP promote watershed protection by providing opportunities for watershed residents to learn how they and their communities can prevent non-point pollution. In May, KEEP held the very successful Kensico Reservoir Watershed Water Conservation and Water Quality Preservation Art and Poetry Contest involving schools surrounding the Kensico Reservoir. This Art and Poetry Contest was a culmination of classroom lessons which focused on historical and present-day aspects of the New York City water supply system; the role that the Kensico watershed plays in the overall system; water quality issues; and the value of water and water conservation. Through their artwork and poetry the students were able to express their understanding and appreciation of our water supply system as well as the need to protect this vital resource.

DEP's watershed education program includes participation in major events in the region, especially county fairs. DEP's education staff provides visitors of these events with valuable information; offers workshops and demonstrations; and explains the role of DEP as a cooperative partner with its upstate neighbors and environmental groups. A variety of materials are distributed to the public including booklets, pamphlets and fact sheets about the water supply system, drinking water quality, the Whole Farm Program, wetlands, land acquisition and conservation easements, as well as other related materials. During the summer months, thousands of watershed residents visit the DEP education display booth, where they are presented with materials that explain the agency and its programs. In 2005, DEP participated in more than 50 events throughout the watershed.

2.9.2 Watershed Agricultural Program

WAC implements the Watershed Agricultural Program and several related education/outreach initiatives. Historically, in addition to funding the Whole Farm Planning Program, DEP has supported a WAC Outreach Program and Natural Resource Viability Program. During 2004-2005, WAC underwent a strategic planning process which consolidated many of these efforts under one umbrella: WAC's Agriculture Economic Sustainability Outreach Program. This effort coincided with the continued implementation of WAC's 2001 communication plan, which among its recommendations called for improved integration and promotion of all WAC programs under a common outreach message.

Through its Agriculture Economic Sustainability Outreach Program, WAC currently employs a Communications Director, whose primary responsibilities include developing publications, attending and promoting events, and supporting the outreach needs for all WAC programs. WAC also employs a Farm-to-Market Program Manager, who focuses on supporting WAC's direct marketing Buy Local campaign ("Pure Catskills") using additional grant funding through the Kellogg Foundation and other sources. Finally, WAC partners with Cornell Cooperative Extension to implement a Farmer Education Program, the goal of which is to empower Watershed Agricultural Program participants with the knowledge and skills necessary to continue implementing their Whole Farm Plans. The following is a summary of WAC's major education and outreach activities that support the Watershed Agricultural Program.

- *Farmer Education*. In partnership with Cornell Cooperative Extension, WAC implements a Farmer Education Program that conducts workshops and Whole Farm Plan refresher courses covering the following topics: nutrient management, pathogen management, precision forage and feeding systems management, manure storage safety, pasture grazing, calf assess (livestock nutrition and health management), and other issues as needed. To date, the Farmer Education Program has reached more than 600 total participants.
- *Publications*. During 2002-2005, WAC produced a series of new publications and promotional materials with a redesigned logo and print format. Foremost among these are the WAC quarterly newsletter (*Watershed Farm and Forest*) and the WAC annual report (*Farm and Forest Participant*), of which 3,000 copies each are published. In 2002, WAC published the Green Connections Project Guide, an update logger training brochure, and two full-color postcards promoting farms and forests. In 2003, WAC published a new conservation easement fundraising brochure and a new Forestry Program brochure with separate full-color inserts promoting forest management planning and economic action grants. In 2004, WAC published its first wood products directory for the watershed (300 copies) and 10,000 copies of its first "Pure Catskills" brochure (*Delaware County Guide to Farm Fresh Products*). In 2005, WAC published an updated Small Farms Program brochure, a new organizational brochure describing all WAC programs, an updated wood products directory (1,000 copies), an updated conservation easement fundraising brochure, and 30,000 copies of its second "Pure Catskills" brochure (*2005-2006 Guide to Farm Fresh Products)* covering six counties.
- *Outreach Events*. WAC participates in numerous outreach events and professional speaking engagements every year. Annual event highlights include: Delaware County Fair, Yorktown Grange Fair, Margaretville Cauliflower Festival (approximately 2,000 participants each year), Local Government Day, Pakatakan Farmer's Market, and Watershed Protection and Partnership Council meetings.
- *WAC Website*. During 2002-2005, WAC continued to update and expanded its website: www.nycwatershed.org. Among the various features to be enhanced: a redesigned navigation menu to improve usability, greatly expanded farm and forest virtual tours, new "Farm to

Table" links to support WAC's partnership with Earthpledge Foundation, and new pages/links to support online donations to WAC's conservation easement stewardship campaign.

- *"After the Storm" Television Special*. During 2004-2005, the Watershed Agricultural Program was featured in a half-hour television special ("After the Storm") airing on The Weather Channel and co-produced by the EPA. The show focused on watersheds and stormwater pollution prevention issues by showcasing three case studies. The New York City watershed segment featured farmer testimonials and WAC staff interviews.
- *Countryside Exchange*. The Countryside Exchange is a program of the Glynwood Center (based in Cold Spring, NY) that brings together international teams of volunteer professionals to work with communities on their most important issues. In 2003, the Catskills were selected as one of nine host communities based on an application submitted by WAC in collaboration with the Catskill Watershed Business Roundtable. During the week-long exchange, an international team of six professionals toured the watershed, met with farmers and business leaders, and developed recommendations for WAC and its agricultural partners to consider implementing.
- *"Pure Catskills" - Buy Local Campaign*. In 2004, WAC sponsored a Buy Local workshop for nearly 50 farmers and WAC staff/partners. This workshop facilitated the development of a watershed Buy Local campaign centered on the "Pure Catskills" marketing logo.
- *Farm Beautification Projects*. Between 1999 and 2004, WAC received several matching grants from the O'Connor Foundation to support farm beautification projects that promote agri-tourism and direct marketing among retail and wholesale farms in Delaware County.
- *CleanSweep Chemical Disposal Day*. Since 1998, WAC has co-sponsored this annual Delaware County event with local and state partners such as Cornell Cooperative Extension, Soil and Water Conservation District, Department of Public Works, and the New York State Department of Environmental Conservation.

2.9.3 Watershed Forestry Program

Education and outreach has always been a significant focus of the Watershed Forestry Program. The primary message, as originally outlined by the Watershed Forest Ad Hoc Task Force nearly ten years ago, is that well-managed working forests provide the most beneficial land cover for watershed protection. Towards this end, WAC utilizes both DEP and USFS funding to collaborate with a wide range of partners to educate upstate and downstate audiences about the role and importance of the watershed forests. Target audiences include watershed landowners, loggers, consulting foresters, members of the wood products industry, policy makers (local officials and state legislators), environmental groups, and both upstate and downstate teachers and students. Many of these initiatives are highlighted in the Forestry Program section of this report. Others are summarized below.

- *Watershed Forestry Institute for Teachers*. Since 1999, the Watershed Forestry Program has sponsored this annual week-long educational program for up to 20 science teachers from New York City and watershed schools. WAC partnered with the Catskill Forest Association to develop and implement the first six Institutes during 1999-2004. In 2005, the Catskill Center assumed leadership for the Institute in an effort by WAC and DEP to consolidate the Watershed Forestry Program's school-based educational programs. To date, 123 teachers have attended the first seven successful Institutes.

- *Green Connections*. Initially developed by DEP and WAC as a pilot project involving four partner schools during the 2000-2001 school year, Green Connections has evolved into a year-long extension of the Watershed Forestry Institute for Teachers. The purpose of this program is to connect upstate and downstate classrooms through written communication, shared curriculum, common lesson plans, and facilitated upstate/downstate field trips that focus on the relationships between healthy forests and safe, clean drinking water. To date, Green Connections has been conducted during four separate school years, reaching more than 1,100 upstate/downstate students in 15 separate schools.
- *Watershed Forestry Bus Tour Program*. Since 2002, the Watershed Forestry Program has sponsored a forestry bus tour grants program to support upstate watershed field trips for many downstate audiences (primarily school groups). Through 2005, a total of 27 bus tours have been conducted for more than 1,000 participants.

2.9.4 Stream Management Program

DEP's Stream Management Program (SMP) has given priority to creating a new paradigm for stream management within watershed communities, one in which the stream's function and geomorphic processes are better understood and accounted for by those who live, work or recreate near them. DEP adopted this approach at a time when previous practices such as patching failing banks, excavating gravel deposits, and engineering hardened structures were just giving way to current geomorphic concepts of stream corridor protection and restoration. To support this approach, SMP implements a comprehensive education and outreach effort. Many of these activities are focused on specific planning or restoration projects. Some of SMP's other outreach efforts are described below.

- *SMP Presentations*. During 2002-2005, DEP participated in numerous meetings and conferences to conduct presentations dealing with every aspect of stream management planning and restoration, in addition to presenting poster sessions and providing informational handouts. Many of these presentations were conducted in partnership with Greene County SWCD and the USGS.
- *Workshops and Training*. DEP conducts many SMP educational workshops for watershed stakeholders in addition to providing specific training opportunities for SMP staff. Highlights of workshops that were sponsored for SMP watershed stakeholders include: "Streamside Landscaping for Bank Stabilization and Ecosystem Enhancement" (45 landowner and agency participants), "What a Small, Mostly Rural Watershed Association Can Do" (about 12 participants from the Stony Clove Watershed Association), "Stream Assessment & Restoration Activities in the West Branch Delaware Watershed" (20 farmers along the West Branch Delaware River), and "DEP's Stream Management Program" (19 participants in the Watershed Forestry Institute for Teachers). Highlights of DEP staff and partner training workshops include: "Applied Fluvial Geomorphology" (Rosgen 1), "River Morphology & Applications" (Rosgen 2), "River Assessment & Monitoring" (Rosgen 3), "River Restoration and Natural Channel Design" (Rosgen 4), "Ecological Restoration" (John Munro, Society for Ecological Restoration), "Stream Restoration Principles and Design" (various instructors), "Hydrologic Analysis for Ecosystem Restoration" (US Army Corps of Engineers), and "Integrating GIS &

GPS Technologies" (New York State GIS Clearinghouse). In addition, Greene County SWCD has participated in five stormwater management training courses offered through SUNY ESF.

- Catskill Stream and Watershed Education Program. In 2003, DEP and the Catskill Center launched this new program focusing on west of Hudson schools within stream management planning watersheds. The program uses hands-on learning experiences in both the classroom and field to educate students about stream water quality, aquatic environments, natural stream processes, and good stream stewardship activities. More than 260 students (grades 4-12) representing five schools participated during the first year. The program was expanded during the second year to include a teacher training component, reaching 536 students from eight schools and training eight teachers.
- Knotweed Demonstration Site. During 2005, DEP and the Delaware County SWCD supported non-chemical management of Japanese knotweed along the West Branch Delaware River. Most of this work, which includes cutting/mowing twice per month, was completed by the Catskill Outdoor Education Corps. A kiosk with informational materials also exists.
- Satellite Offices. In 2005, Cornell Cooperative Extension of Ulster County opened an SMP satellite office in the Town of Shandaken to be more accessible to watershed stakeholders and to provide a meeting space with GIS technology. Greene County SWCD is similarly interested in opening a satellite office to be housed in the Town of Ashland near the Batavia Kill.

2.9.5 Land Management and Recreation Programs

The City of New York is the second largest owner of public lands in its water supply watersheds, behind only the State of New York. Through 2005, approximately 69,000 acres of City-owned watershed lands have been opened to the public for passive recreation such as hiking, hunting, fishing, boating and other aesthetic enjoyment activities. In addition to overseeing public recreation opportunities on City-owned water supply lands, DEP also conducts various education/outreach activities throughout the year that promote good land stewardship behaviors.

- Publications. DEP produces two publications aimed at recreational visitors to the City's water supply lands: the biannual *Watershed Recreation* newsletter and the annual *Guide to Hunting on New York City Water Supply Lands*. Published in the fall and spring, *Watershed Recreation* is mailed to more than 96,500 current holders of DEP's Access Permit and is intended to promote their recreational enjoyment and stewardship of water supply lands. The *Guide to Hunting on New York City Water Supply Lands* is mailed to more than 11,000 current holders of DEP Hunting Tags. This guide contains hunting conditions, maps of all hunting areas, and a positive land stewardship message geared towards recreational hunters.
- Displays and Exhibits. DEP has produced exhibit panels describing land management, forest improvement, agricultural uses, and recreational uses of City water supply lands. These exhibits have been displayed at the various events in the watershed and the region.
- Events. Every year, DEP hosts seasonal interpretive hikes on water supply lands, facilitates numerous reservoir clean-up events, and participates in "Take a Kid Fishing Day". Since 2003, interpretive hikes have been offered monthly at diverse locations throughout the watershed. These hikes are intended to orient recreational users with water supply lands while providing valuable outreach opportunities for DEP land stewards, foresters and land managers. In addition, DEP sponsored 21 reservoir clean-up events during 2005 with many diverse vol-

unteers such as sportsmen clubs, youth groups, environmental clubs, neighborhood associations, and assorted individuals.

- *Outreach Plan*. DEP recently drafted a comprehensive recreation outreach plan to improve communications with recreation users, watershed neighbors and other visitors to City-owned water supply lands. This outreach plan specifies long-term strategies and tools for communicating about watershed recreation and potential land stewardship opportunities.

2.9.6 Catskill Watershed Corporation

The following is a list of education and outreach highlights accomplished through DEP's partnership with CWC during the past few years.

- *Watershed Museum*. During 2002-2003, DEP, CWC and the Catskill Watershed Museum Board continued their discussions about the possible commitment of CWC funds available through the New York City Watershed Memorandum of Agreement (MOA). Despite an extension to September 2003, the Museum was not able to meet its deliverable deadlines, so it was agreed that these museum funds would be applied to support CWC's Public Education Grants Program. Following meetings and discussions between DEP's Commissioner and the CWC Public Education Committee, the Museum concluded that their short-term focus would be to secure contacts and assistance as part of their capital fundraising campaign. DEP provided the museum with a letter of support and agreed to assist with parts of their campaign. The Museum was awarded $30,000 from New York Community Trust to hire a professional fund-raiser.
- *Public Education Grants*. During the period 2002-2005, CWC awarded $516,557 in MOA public education funds to support 117 projects through 4 competitive grant rounds. To date, CWC has provided a total of 188 grants totaling $942,571 to 102 grant recipients. The primary audience for most of these grants have been K-12 students, with about 28% of CWC's grant recipients serving New York City audiences and about 53% serving west of Hudson audiences. The remainder of these grants have served combined upstate/downstate audiences through partnerships or collaborations with other organizations.
- *Commemorative Projects*. In 2002, CWC completed the construction and installation of new commemorative kiosks at all six west of Hudson reservoirs (Ashokan, Cannonsville, Neversink, Pepacton Rondout, and Schoharie). Dedication ceremonies took place at all six reservoirs, where each kiosk describes the construction of specific parts of the New York City water supply while paying tribute to the 5,500 people who were displaced between 1907 and 1965. In addition to these educational kiosks, CWC also installed new roadside signs during 2004 that commemorate the hamlets and villages that were lost to the construction of the City's reservoirs.
- *Activities and Events*. Over the years, CWC has built education and outreach into many of its program activities. Highlights include: presentations to schools and educators, hosting numerous foreign delegations, promoting economic development and watershed protection programs to the general public, septic system maintenance classes for homeowners and installation training workshops for local contractors, business and entrepreneurial training courses, stream clean-up programs, and the periodic sponsorship and ongoing support of many watershed conferences, such as the increasingly popular Local Government Day and the December

2005 Watershed Education Teacher Conference. In addition to these activities, CWC also maintains a website (www.cwconline.org) that was recently redesigned and updated with several new features.

2.9.7 Lawn Fertilizer Reduction

Watershed Nutrient Workgroup

In an effort to reduce the amount of nutrients, particularly phosphorus, entering the water supply reservoirs east of Hudson, DEP is working cooperatively on an education program to reduce the amount fertilizer applied to residential lawns. DEP participates in the Watershed Nutrient Workgroup along with the Environmental Protection Bureau of the NYS Office of the Attorney General, Putnam and Westchester County Cornell Cooperative Extension, Putnam County Planning, Westchester County Planning, NYSDOH, NYSDEC, NYS Turf Grass Association, Chem Lawn and U.S. EPA.

The principal result of this joint public-private effort in 2004 was the generation of a brochure that effectively presents the link between residential lawn practices and the potential impact on water quality. Through the brochure, residents are urged to complete a soil test prior to fertilizing and use non-phosphorus fertilizers whenever possible. DEP procured 50,000 copies of the brochure for distribution to watershed residents.

Lake Association Pilot Test

An additional effort targets the amount of phosphorus entering the watershed through improper application of fertilizers. DEP is working cooperatively on an education program with the Lake Carmel Lake Association. DEP, through Putnam County Cornell Cooperative Extension (CCE), works to inform residents of the impact of phosphorus fertilizer on their lake and ultimately the watershed.

DEP and Putnam CCE performed over thirty free soil tests for residents within the Lake Carmel basin. DEP and CCE also distributed to the Lake Carmel Lake Association information on techniques to reduce the water quality impact of managed lawns and the results of the soil tests showing that over 80% of the soils tested had adequate levels of soil phosphorus and did not need additional phosphorus fertilizer.

2.10 Regulatory Review and Enforcement

The Watershed Rules and Regulations (WR&R) provide DEP with regulatory authority over activities that could possibly degrade the water supply. The control of sewage collection and treatment, stormwater discharges, impervious surfaces and erosion and sediment practices form the major components of DEP's regulatory program. In general, the WR&R require that sponsors proposing projects that involve a regulated activity meet stringent standards, and obtain DEP review and approval of that activity. In addition, DEP enforces applicable environmental regulations including the federal Clean Water Act, the NYS Environmental Conservation Law, the NYS Public Health Law and the NY State Environmental Quality Review Act (SEQRA) among others. DEP's regulatory efforts are focused on three major areas: review and approval of projects within the watershed; regulatory compliance and inspection; and environmental enforcement.

Since DEP has specific review and approval authority granted by State law, it is considered an "Involved Agency" under SEQRA for projects where a DEP approval is required, and must review and issue findings statements regarding projects that have potential environmental impacts in the watershed. A special SEQRA Division has been created within DEP to consolidate and track SEQRA activities within the watershed.

2.10.1 Project Review

Each project proposed in the watershed is reviewed by DEP to ensure compliance with the WR&R, as well as federal, State and local laws. Projects that require DEP review and approval include all wastewater treatment plants (WWTPs), subsurface sewage treatment systems (SSTSs), preparation of specific stormwater pollution prevention plans (SPPPs) and the construction of certain impervious surfaces. In addition, DEP staff reviews and issues permits or approvals for individual residential stormwater plans (IRSPs) and for impervious surfaces associated with stream crossings, piping or diversions (CPDPs). DEP also ensures that during and after construction, projects that require SPPPs or IRSPs have the necessary BMPs in place, and that erosion controls are properly installed and maintained. DEP also reviews applications that have been sent to NYSDEC for special permits involving mining operations, timber harvesting, stream crossings and wetland issues. These applications are forwarded to DEP for review and comment as provided for in the DEP/NYSDEC MOU.

In 2003, DEP initiated a process to revise and update the WR&R. The primary change proposed was to incorporate a reference to the revised State General Permit (GP-02-01). In addition, DEP proposed to modify and update a number of references in the WR&R and clarify certain language. DEP circulated the proposed changes to a number of watershed stakeholders and sought comments. In response to comments received, DEP has substantially revised the proposed regulatory changes. In late 2005, DEP notified the watershed parties that the revised regulatory proposals would be re-circulated in early 2006. DEP intends to proceed with completion of the regulatory modification process after further consultation with the watershed stakeholders.

In 2003, DEP began the upgrading of its database and the creation of a new, more extensive database that combined the data from both east of Hudson and west of Hudson sections. This database has proven to be extremely helpful in creating reports, analyzing data, copying files, storing information, and, with its GIS component, locating projects in the watershed.

In 2004, an addition to the DEP/NYSDEC MOU provided for a joint Stormwater Compliance Committee that functions in a manner similar to the Watershed Enforcement Coordinating Committee (WECC). These committee meetings have served to consolidate and expedite enforcement activities relative to the failure of stormwater projects in the watershed. Staff from EPA, NYSDOH, and the Attorney General's Office also participate in these meetings.

Since the promulgation of the new WR&R in 1997, DEP has received and reviewed an increasing number of applications for regulated activities in the watershed. Of particular interest is the number of SSTS applications received, especially in the Towns of Jewett, Windham and Hunter in Greene County. The following graph illustrates the increase in septic system applications in the west of Hudson watershed, a major indicator of overall development.

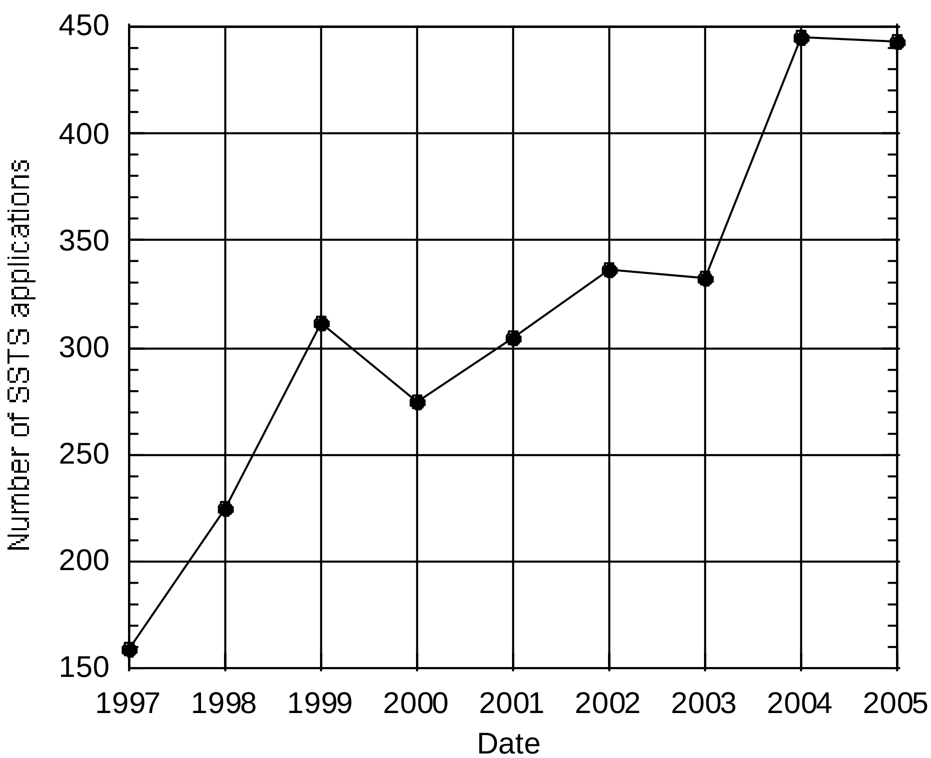

Figure 2.40 Total septic applications received in the Catskill and Delaware systems, including those in the Croton system, since the WR&R became effective (1997).

Concurrent SPPP, IRSP and CPDP applications are also rising. The following table details the total number of applications received, approved or denied for certain regulated activities in each reservoir basin since 2002.

Table 2.14. Number of applications received, approved, or denied for certain regulated activities in each reservoir basin since 2002.

	YEAR			
ASHOKAN BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	4	2	1	1
Delegated Septic Systems	56	48	43	60
Individual Septic System Repairs	48	56	64	78
TOTAL	108	106	108	139
CANNONSVILLE BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	0	4	8	0
Subsurface Sewage Treatment System	66	68	73	82
Individual Septic System Repairs	28	22	51	66
TOTAL	94	94	132	148
PEPACTON BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	2	2	6	1
Delegated Septic Systems	3	4	4	1
Subsurface Sewage Treatment System	55	55	89	96
Individual Septic System Repairs	11	16	44	58
TOTAL	71	77	143	156
NEVERSINK BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	1	0	0	1
Delegated Septic Systems	2	1	2	2
Subsurface Sewage Treatment System	2	3	5	9
Individual Septic System Repairs	6	6	6	16
TOTAL	11	10	13	28
RONDOUT BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	0	2	1	0
Delegated Septic Systems	2	0	1	5
Subsurface Sewage Treatment System	18	12	5	13
Individual Septic System Repairs	28	33	15	20
TOTAL	48	47	22	38

Table 2.14. Number of applications received, approved, or denied for certain regulated activities in each reservoir basin since 2002.

	YEAR			
SCHOHARIE BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	6	7	10	15
Delegated Septic Systems	1	0	0	2
Subsurface Sewage Treatment System	5	7	8	9
Individual Septic System Repairs	0	0	0	0
TOTAL	12	14	18	26
BOYD CORNERS BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	0	1	1	1
Delegated Septic Systems	1	0	0	2
Subsurface Sewage Treatment System	5	7	8	9
Individual Septic System Repairs	0	0	0	0
TOTAL	6	8	9	12
CROSS RIVER BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	2	1	1	0
Delegated Septic Systems	25	16	7	11
Subsurface Sewage Treatment System	2	2	8	9
Individual Septic System Repairs	0	0	0	0
TOTAL	29	19	16	20
CROTON FALLS BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	1	5	4	3
Delegated Septic Systems	6	6	4	3
Subsurface Sewage Treatment System	2	4	2	0
Individual Septic System Repairs	0	0	0	3
TOTAL	9	15	10	9
KENSICO BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	1	2	5	0
Delegated Septic Systems	0	0	0	1
Subsurface Sewage Treatment System	2	5	5	5
Individual Septic System Repairs	0	0	0	1

Table 2.14. Number of applications received, approved, or denied for certain regulated activities in each reservoir basin since 2002.

	YEAR			
TOTAL	3	7	10	7
WEST BRANCH BASIN	2002	2003	2004	2005
Stormwater Pollution Prevention Plan	1	0	0	2
Delegated Septic Systems	1	0	1	2
Subsurface Sewage Treatment System	4	9	8	12
Individual Septic System Repairs	0	0	2	0
TOTAL	6	9	11	14

Specific data regarding applications received for regulated activities is available in the Quarterly FAD Reports submitted by DEP.

2.10.2 Regulatory Compliance and Inspection (RCI)

At each surface discharging WWTP that operates on a year-round basis, DEP conducts one inspection during each calendar quarter. At minimum, two inspections per year are conducted at seasonal surface discharging facilities during the facility's operating season. Similarly, at least two inspections per year are conducted at non-contact cooling water discharges to surface waters. Treated industrial waste discharges to groundwater, via surface application, are inspected four times per year.

Exclusive of the new the New Infrastructure Program WWTPs, a total of 44 west of Hudson and 11 east of Hudson wastewater treatment facilities are inspected on a regular schedule. In addition to regular inspections, DEP conducts follow-up inspections when necessary. If it is determined at the initial inspection that non-complying conditions exist and corrective action is necessary, a follow-up inspection is scheduled to ensure that corrective actions are implemented, and that an effort is being made to return the facility to compliance or to correct operational deficiencies. If chronic violations of the State Pollutant Discharge Elimination System (SPDES) parameters are occurring, DEP will initiate a Compliance Conference with the owner/operator to discuss problems and possible corrective actions. Following such an enforcement initiative, DEP may periodically conduct a follow-up unannounced visit to ensure that the facility is continuing in its efforts to remain in compliance. If corrective action is not taken by the owner/operator, further enforcement actions are discussed at the quarterly WECC meetings with NYSDEC.

Wastewater treatment plants in the watershed continue to show improvement in complying with their SPDES Permits, due in large part to DEP's Compliance Inspection Program. Many facilities have been remediated or have made improvements to reduce the risks of non-compliant discharges. These have been initiated by DEP through the inspection program and/or by NYS-

DEC in cooperation with DEP. Several facilities awaiting connection to other wastewater treatment plants or sewer extensions have implemented enhanced UV disinfection. Seasonal facilities such as Camp Nubar, Camp Timber Lake, Camp L'man Achai, Harriman Lodge and Golden Acres have undergone dramatic improvements which resulted, thus far, in the full upgrade of three WWTPs, the conversion of one facility to subsurface disposal (Camp Harriman), and the impending conversion of one facility (Camp Nubar) to subsurface disposal. Prior to the RCI inspection program, all these summer camps routinely violated their SPDES permit for parameters such as ammonia, BOD, TSS and DO. The DEP immediately targeted the facility owners, and, either through owner cooperation or enforcement action, required proper WWTP operations and maintenance. In all cases, RCI staff conducted regular inspections, often twice monthly, assisted the operator in trouble-shooting the facilities, had the WWTP owner make necessary repairs to their system and had the owners hire or train personnel to become certified operators. DEP also recommended installing additional structural components that were lacking, suggested certain process controls to improve effluent quality and assisted the operator in determining the extent of Inflow/Infiltration (I/I) problems. Since the onset of the stringent quarterly inspections and follow-up inspections, these seasonal summer camps have shown consistent SPDES permit compliance. Now all the upgraded or converted facilities are anticipated to operate well within their SPDES permitted values for many years to come.

In another case, the Regis Hotel had, over the years, been in chronic WWTP failure due to its severely undersized sand filters, large flows, inflow/infiltration (I/I) problems, and the extreme age of the overall system (70+ years). DEP contacted the facility owner and had the owner hire a qualified operator to operate and maintain the facility. DEP conducted site visits and identified deficiencies such as broken collection mains, a non-working siphon chamber, a failure of the retaining wall which was allowing effluent to escape the sand filter and lack of disinfection. Through enforcement action, DEP forced the owner to repair the collection lines and the retaining wall, to repair the alternating siphon, to replace the entire distribution system of one sand filter, to construct a new concrete disinfection building, to reduce I/I by conducting comprehensive inspections of interior and exterior plumbing works, to improve settling by installing additional septic tank capacity, to conduct more frequent grease trap and septic tank pump outs and to reduce kitchen flows by having water-saving fixtures installed. DEP also conducted special sampling of the effluent as well as extensive dye testing to assist the operator in trouble-shooting the entire system. The facility immediately began to show effluent improvements. However, BOD and ammonia exceedances were still a concern due to the undersized sand filters. By utilizing funds from the Upgrade Program, DEP assisted in the installation of a STEP 3 Mobile Treatment Unit, as well as additional sludge holding capacity. With the exception of minor disinfection issues, the facility now consistently meets its SPDES permit. The facility is slated for connection to the Fleischmanns NIP WWTP once the collection line becomes available in 2006.

In addition to its rigorous inspection program, DEP coordinates enforcement activities with NYSDEC through the quarterly WECC meetings. At these meetings the status of watershed WWTPs is discussed, and steps are taken to ensure that adequate enforcement activities are pursued to achieve compliance. Staffs from EPA, NYSDOH, and Attorney General's Office also participate in the WECC.

Reports of inspections for specific facilities as well as enforcement actions are available in the Quarterly FAD Reports submitted by DEP

Case Study
Protozoan Monitoring of Upgraded WWTPs

To test the efficiency of the WWTP Upgrade Program and compliance inspection efforts, DEP conducted a study to monitor 10 WWTPs for *Giardia* cysts and *Cryptosporidium* oocysts following upgrades in their treatment systems. WWTPs were selected for monitoring if they had been upgraded to microfiltration treatment or its equivalent. Monitoring began in July 2002 at most of the plants, and by the end of the year at the remaining plants after upgrades were completed. Monitoring consists of quarterly sampling for *Giarida* and *Cryptosporidium* at the WWTP's final effluent outfall. All samples collected were analyzed using US EPA Method 1623 with a 50 liter volume.

Table 2.15. Wastewater treatment plant sampling sites and their mean daily flow within NYC Catskill Delaware system watersheds.

WWTP	Treatment Type	Flow (mgd)
Grahamsville	Microfiltration	0.18
Tannersville	Microfiltration	0.8
Grand Gorge	Microfiltration	0.5
Pine Hill	Microfiltration	0.5
Margaretville	Microfiltration	0.4
Hunter Highlands	Dual Sand	0.08
Delhi	Dual Sand	0.515
Hobart	Dual Sand	0.2
Stamford	Dual Sand	0.5
Walton	Dual Sand	1.017

To date, 124 samples have been collected and analyzed for *Cryptosporidium* and *Giardia.* Each WWTP was sampled between 11 and 13 times from July 2002 through December 2005. Tables 2.16 and 2.17 present *Cryptosporidium* spp. and *Giardia* spp.

(oo)cyst occurrence and average concentration results at each WWTP, respectively. Of the 10 plants, only four produced one positive sample for *Cryptosporidium*: Pine Hill, Hunter Highlands, Margaretville, and Hobart. The highest protozoan concentration found in among all samples was three oocysts, at Hunter Highlands. No *Cryptosporidium* was found at the remaining six plants.

Only five of the ten plants produced positive samples for *Giardia*: Delhi, Pine Hill, Grahamsville, Stamford and Walton. Of the five plants, three produced only one positive sample: Delhi, Pine Hill and Walton while Stamford produced three and Grahamsville eight. The concentrations of *Giardia* in positive samples ranged from 2 to 40 cysts in a 50 liter volume.

Of the ten plants monitored two, Tannersville and Grand Gorge, have not produced any positive *Cryptosporidium* or *Giardia* samples.

Due to the occurrence of *Giardia* at the Grahamsville plant, special investigations were conducted by DEP and the USEPA to investigate the source of protozoan load and the possible failure of the membrane filtration units (DEP 2005a). The results of these studies revealed that small mammals, amphibians (frogs) and birds frequently inhabit the uncovered area of the system, potentially producing the protozoan loads post microfiltration.

The data compiled thus far suggest that microfiltration and and equivalent dual sand treatment can lead to reductions in the occurrence of *Cryptosporidium* oocysts and *Giardia* cysts in plant effluent.

Table 2.16. Summary of results for 1623 *Cryptosporidium* data from 7/02 through 10/05 at upgraded WWTP within NYC Catskill Delaware system watersheds.

SITE	No. of Samples	Positive Samples	% Detect	Mean oocyst/50L	Total oocyst Count	Maximum
Delhi	12	0	0	0	0	0
Pine Hill	13	1	7.6	0.0769	1	1
Hunter Highlands	12	1	8.3	0.25	3	3
Hobart	13	1	7.6	0.0769	1	1
Margaretville	11	1	9	0.182	2	2
Grahamsville	13	0	0	0	0	0
Grand Gorge	13	0	0	0	0	0
Tannersville	13	0	0	0	0	0

Table 2.16. Summary of results for 1623 *Cryptosporidium* data from 7/02 through 10/05 at upgraded WWTP within NYC Catskill Delaware system watersheds.

SITE	No. of Samples	Positive Samples	% Detect	Mean oocyst/50L	Total oocyst Count	Maximum
Stamford	12	0	0	0	0	0
Walton	12	0	0	0	0	0

Table 2.17. Summary of results for 1623 *Giardia* data from 7/02 through 10/05 at upgraded WWTP within NYC Catskill Delaware system watersheds.

SITE	No. of Samples	Positive Samples	% Detect	Mean cyst/50L	Total cyst Count	Maximum
Delhi	12	1	8.3	1.42	17	17
Pine Hill	13	1	7.6	3.08	40	40
Hunter Highlands	12	0	0	0	0	0
Hobart	13	0	0	0	0	0
Margaretville	11	0	0	0	0	0
Grahamsville	13	8	61.5	6.38	83	39
Grand Gorge	13	0	0	0	0	0
Tannersville	13	0	0	0	0	0
Stamford	12	3	25	0.333	4	2
Walton	12	1	8.3	2.58	31	31

2.11 Kensico Remediation Programs

DEP has long recognized the importance of strategic watershed management to protect the high quality drinking water in the Kensico Reservoir. Since the early 1990s DEP has prioritized watershed protection in the Kensico through the Kensico Water Quality Control Program (KWQCP).

2.11.1 Stormwater Management and Erosion Abatement Facilities

Construction

In the early 1990s, DEP developed a Stormwater Management Program for the Kensico watershed that was based upon an evaluation of watershed conditions including;

- Subbasin level digital mapping of key parameters including topography, soils, land use, natural resources, and impervious surfaces;
- Monitoring and modeling stream quality and hydrology;
- Ranking potential sites and retrofit types using selection criteria that included opportunities to minimize adverse environmental impacts, maintenance requirements, suitability of existing

conditions (soils, hydrology, topography, and property ownership), conforming to physical and property ownership site constraints, ensuring public benefit, and maximizing measurable water quality benefits.

The evaluation concluded that stormwater loads of fecal coliform bacteria and turbidity delivered to the Kensico Reservoir could be significantly reduced by installing a series of stormwater management and erosion abatement facilities in the watershed. The initial plan was substantially refined in 1998, to address site constraints, permitting issues, and private property and water quality considerations. The final plan included installation, operation and maintenance of 44 stormwater and erosion abatement facilities shown in Figure 2.41 that were designed to:

- Repair and control erosion of reservoir tributaries;
- Treat stormwater flows to reduce loads of fecal coliform suspended solids and associated pollutants conveyed to the reservoir;
- Manage erosive flows of stormwater by controlling peak loads.

The plan was later modified to include 46 BMPs in total.

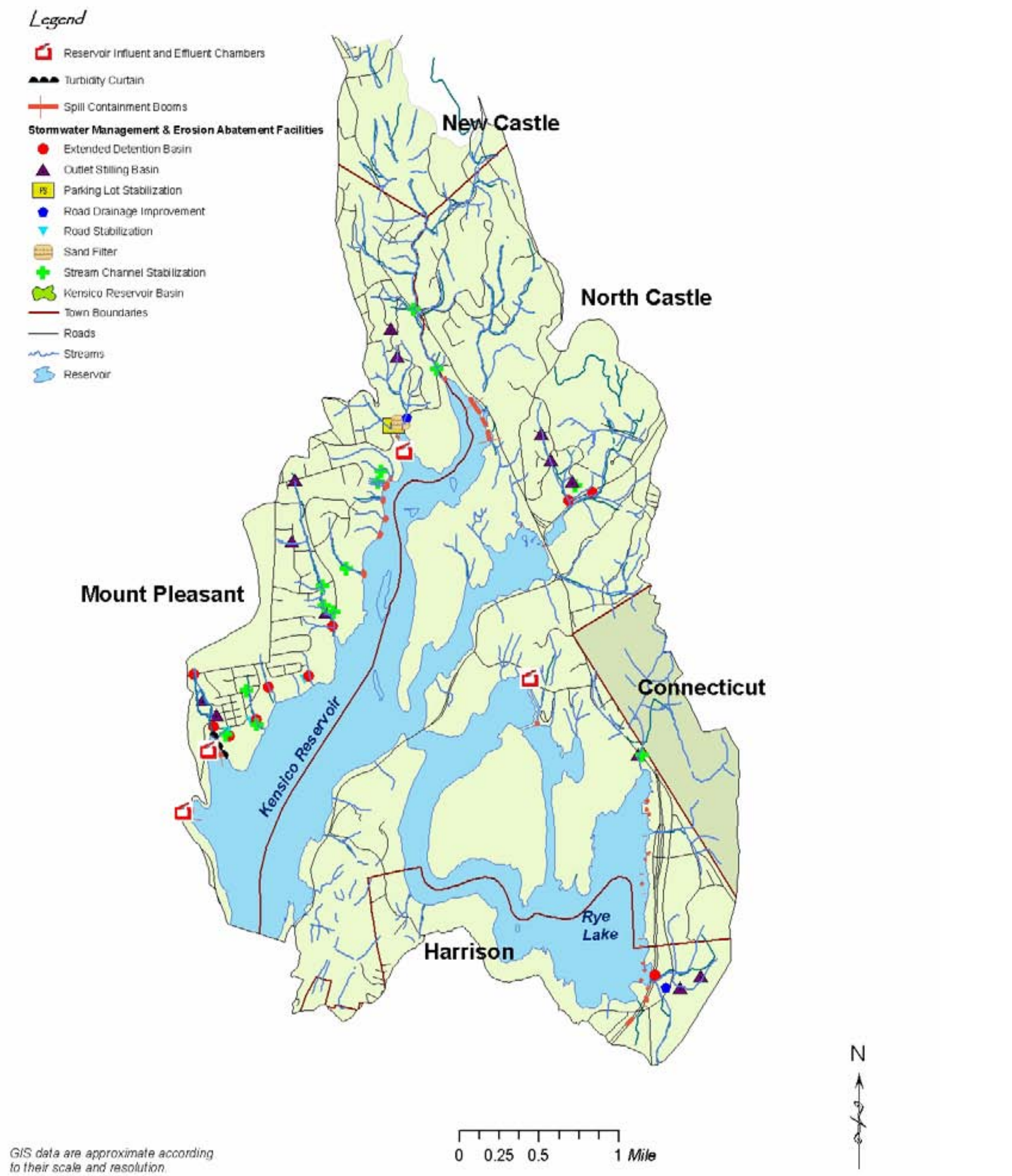

Figure 2.41 Stormwater management and erosion abatement facilities in the Kensico Reservoir watershed.

Between 1998 and 2000, 40 facilities were constructed. Five more were built and operational by 2004. Table 2.18 lists all facilities and their construction dates. During construction, DEP inspected each site daily to ensure compliance with all regulatory approvals, erosion and sediment control plans, construction sequences and contract specifications. Numerous design errors associated with field conditions, permitting constraints, utilities, and property owners were reconciled during construction.

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
Malcolm Brook	2, extended detention basin	11/21/00	Plantings (trees and shrubs for visual screening from road and neighbors), Topdress embankment with topsoil and grass, install gate operator lock mechanism, inflow monitoring weirs, stock basin with mosquito larvae eating fish	Sediment removal from forebay and outlet (2002, 2003, 2004 and 2005) from main basin 2005 Remove dead and damaged trees (2003, 2003, 2005) Repair fence (2002,2005) Clear forebay drain 2002 Mow yearly Replace all valve and gate locks (2005)
	4, stilling basin	9/13/99		Remove accumulated sediment (2002 and 2005)
	8, drop pipe, velocity dissipation, outlet stabilization	8/20/99	Landscaping, alter velocity dissipation box to eliminate mosquito larvae habitat	Remove accumulated sediment (2002, 2004, and 2005) cut outlet in velocity dissipation box to prevent ponding water replace gate lock (2005)
	12, extended detention basin	11/5/99	Plantings, stock forebay and main basin with mosquito eating larvae fish, install 2 gate operator locking mechanisms, manufacture and install new trash shield over weir slot to prevent clogging, install inlet monitoring weirs Install sampling access steps	Remove accumulated sediment from inlet channel, outlet sampling pool and upstream from weirs (2002, 2003 and 2005) and from main basin (2005) Remove debris from main basin (2004 and 2005) remove dead and damaged trees (2002 and 2005) clear pond drain (2002) Mow embankment (yearly) replace all valve and gate locks (2005) Install sampling access steps (2005) and repair washout of bottom step (2005)

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
Young Brook	13, extended detention basin	11/5/99	Install inlet monitoring weir and install gate operator locking mechanisms	Sediment removal from forebay (2002 and 2005) from main basin (2005) Remove dead and damaged trees (2003, 2003, 2005) Repair fence (2002,2005) Mow yearly Trim overgrown weeds from areas adjacent to stream bank (2005) Replace all valve and gate locks (2005)
Young Brook	14, 15 Road, outlet and channel stabilization,	11/5/99	Item 4 on stone portion of access road to improve vehicle access and stabilize road	Mow yearly; place Item 4 on stone portion of access road (2004)
N2	16, outlet stabilization	10/27/99		Remove accumulated sediment and debris (2002 and 2005)
N2	18, 19, 20, extended detention basin, and road and outlet/ channel stabilization	9/14/00	Install drainage improvements adjacent to basin to prevent embankment erosion and stabilize road	Sediment removal from main basin and forebay 2005 Repair fence (2002,2005) Mow yearly Install drainage improvements adjacent to basin to prevent embankment erosion and stabilize road (2000) Clean out and improve adjacent drainage (2002) Reposition rip rap (2005) Replace all valve and gate locks (2005)
N3	2A, extended detention basin	9/14/00	Landscaping (screening for neighbors) converted portion of access road to seeded area (for neighbors), install gate operator mechanism, design and install curtain drain	Install curtain drain Remove accumulated sediment from basin (2005) Repair road drainage (2003) Stabilize road (2002) Repair eroded slope Add Item 4 to stone portion of access road to improve vehicle passage (2004)

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
N4	23, 24, extended detention basin and road stabilization	9/14/00	Landscaping, install new section of chain link fence and gate operator locking mechanism	Remove accumulated sediment and debris from basin (2005) Mow yearly Remove dead tree Replace all valve and gate locks (2004)
N5	37, 39, and 40, extended detention basin, road stabilization and channel stabilization	9/14/00	Construct wall of field stone along top of bank, repair watershed wall, pre and post construction pest inspections (for homeowner), stock basin with mosquito larvae eating fish, install 2 gate operator locking mechanisms, install new stormwater culvert under adjacent roadway, install monitoring facilities, Install sampling access steps. Propose permanent installation of bypass pipe for sediment removal from main basin. The price of the modification is over $100,000.	Remove accumulated sediment from 2 forebays (2005 and 2005) and upstream from weir (2002, 2003 and 2005) Remove debris from forebay and main basin (2005) Mow yearly Repair crack in weir wall, leak in box culvert (2003) Repair spillway between and erosion damage between forebay and main basin (2003) Remove dead trees (2005) Replace all valve and gate locks (2004) Repair washed out spillway (2003) and (2005) Add Item 4 to stone portion of access road to improve vehicle passage (2004) Install sampling access steps (2005)
N5	5A, drop pipe, stabilized manhole	4/25/00	Alter trash rack to prevent clogging	
N5	35, outlet stabilization	5/25/00		
N5	34, stream channel stabilization	5/23/00		
N5	31, stream channel stabilization	11/22/99		Install erosion control mat downstream from facility

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
N5 tributary	28, outlet and stream channel stabilization	10/25/99	Landscaping and large stone in channel to slow velocity	Reposition and replace rip rap and filter fabric (2002 & 2004) Remove accumulated sediment (2002, 2003, 2004, and 2005) Remove dead tree (2003) Restabilize stream channel, add large stone check dams to dissipate velocity (2005) after severe summer storms
N5	25, outlet stabilization	11/12/99	Seed and create grassy area adjacent to facility at property owners request	Extend outlet stabilization to encompass new paved apron conveying road runoff to stream Remove accumulated sediment (2002 & 2005)
N6	41, stream channel stabilization	12/28/99		Reposition rip rap Remove debris Stabilize road Replace live stake plantings
Bear Gutter	63, outlet stabilization	4/5/00	Forest management downstream from the facility for the property owner	Remove accumulated sediment (2002, 2003, 2004, and 2005) Remove select dead and dying trees
Bear Gutter	64, outlet stabilization	5/26/00		Remove accumulated sediment (2002, 2003, 2004, and 2005)
Bear Gutter	65, outlet stabilization	5/27/00		Remove accumulated sediment (2002, 2003, 2004, and 2005)
Bear Gutter	66, extended detention basin	9/14/00	Landscaping, install gate operator locking mechanism	Mow yearly Remove accumulated sediment (2005) Replace locks on access gate (2005)

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
Bear Gutter	67, extended detention basin	11/8/00	Install monitoring facilities Open guide rail, extend maintenance access road	Repair fence (ice damage) (2002) Mow yearly Replace damaged coconut roll (2002) Replace locks on access gate (2005) Repair berm near outlet (2002)
Bear Gutter	8A, stream channel stabilization	4/20/00		Replace live stake plantings Reposition field stone
N8	43, stream channel stabilization	4/3/99	Propose to restabilize stream channel with 2 drop pools and a series of large stone check dams. The repair cost is estimated to be $72,000.	Reseed eroded areas (2002) Replace live stakes (2002) Reposition rip rap (2003) Mow yearly
N9	44, stream channel stabilization,	4/18/00	Landscaping	
N12	7A, outlet stabilization	11/17/99		Remove accumulated sediment (2002, 2003, 2004, and 2005)
N12	47, outlet stabilization	11/18/99		Remove accumulated sediment (2002, 2003, 2004, and 2005)
N12	57, sand filter 58, road drainage improvements 59, parking area stabilization	12/15/00 (57) 8/2002 (58 & 59)	Install monitoring facilities	Remove debris from under Nanny Hagen Road (2002) Checked filter in 2003 and 2004, media satisfactory, and maintenance not necessary. Maintenance is scheduled for early 2006.
Whip	60, Stream channel stabilization	12/3/99		Remove accumulated sediment (2002)

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
Whip	61, Stream channel stabilization	12/3/99	Construct alternate maintenance access (sampling site moved upstream & across the road) Clear vegetation in line of site	Remove accumulated debris Stabilize erosion caused by road drainage (2002) Construct alternate access (2004) to sampling site Repair road drainage (2005) Stabilize sampling/fishing access parking area (2005) Clean out clogged culvert (2002, 2003) Repair eroded slope adjacent to headwall (2005) Clear vegetation in line of site Repair eroded bank downstream from site (2004)
E9	68	4/10/00		Video inspect box culvert and pipe under Route 120
E9	68A	11/28/04		
E11	70, outlet stabilization	4/7/00		Remove accumulated sediment (2002, 2003, 2004, and 2005)
E11	71, outlet stabilization	4/7/00		Remove accumulated sediment (2002, 2003, 2004, and 2005) Clean out clogged culvert (2002)
E11	74, 75	11/28/04	Install access road turn around near sampling site and impervious liner in one forebay	Both post construction enhancements installed in 2004 Mow yearly
Con Ed Access Road	Additional locations	Not Applicable	Stabilize washed out sections of the road	North of Nanny Hagen road, repair two significant washouts, install headwalls, culverts and stabilized embankments. Stabilize numerous portions of the road south of Nanny Hagen

Table 2.18. Kensico stormwater and erosion abatement facility construction and completion schedules, post construction enhancements and maintenance activities.

Basin	Facility Number and Type	Completion Dates	Post Construction Enhancements	Maintenance Activities
Spill containment			Redesign anchor line and marker buoy connections to prevent premature failure	Repair marker buoys, replace missing flotation, Repair anchor lines and connections, replace missing anchors
Turbidity curtain			Repair damaged sections, propose to engage diving contractor in 2006 to inspect anchor lines. Curtain replaced in 2003 and extended in 2004	Inspect curtain yearly Repair damaged sections (around exposed floats and replace missing floats, re-stitch sections together and secure steel anchor cables) 2002 and 2004)

Construction of two facilities, extended detention basin 75 and stormwater drainage improvement 74, was delayed when an unmapped fiber optic cable was discovered on site during initial earth moving. The basin is located on Stream E11, on the eastern shore of the Kensico Reservoir between Route 120 and Interstate 684. Discussions with the owner of the cable (Verizon), took several years to resolve. Ultimately, Verizon agreed to relocate the cable. Verizon began relocating the cable upon receipt of permit approvals from the New York State Department of Transportation in January 2002. Verizon encountered numerous difficulties in the field during relocation. The contract to construct the facility commenced in February 2004, the basin was operational in late summer of 2004, and final site landscaping was finished by November 2004.

In response to requests from the Town of Mount Pleasant, DEP redesigned road drainage improvements (facilities 58 and 59) needed to direct additional runoff to facility 57 (an existing sand filter). The new design, made necessary by road repaving, added two catch basins, 240 linear feet of drainage pipe, 1,200 linear feet of concrete curbing and the repair of a badly eroded section of public road. After several iterations, the Town and telephone, electric and gas utility companies approved the design revisions in April 2001. The revisions increased construction costs from $140,000 to $400,000 but improved road conditions, safety and performance of the sand filter. Construction began in the spring of 2002, when hazardous winter conditions could be avoided, and was completed in August 2002.

DEP added one facility to the series installed around the Kensico reservoir. The need for the facility was based upon the infrastructure inspection program, stormwater monitoring and DEP's inspection efforts. The new facility, 68A, was designed to stabilize eroding stream banks at the outfall of a culvert that carries stormwater flows under Route 120 into the Louden's Cove section of the reservoir. The repairs were constructed under the same contract as basin 75. Figure 2.42 shows erosion abatement facility 68A, before and after construction.

Figure 2.42 Photographs of Erosion Abatement Facility 68A.

Maintenance

DEP began inspecting, maintaining and monitoring stormwater control facilities in accordance with the Operation and Maintenance Guidelines (DEP, 2000a) and the Monitoring Plan (DEP, 2000b) as soon as they went on line. DEP revised its facility inspection and maintenance guidelines in 2003 based upon the prior years' experiences. The timing of routine and post-storm inspections did not change. Until March 2005, when the 3-year maintenance contract commenced, short-term 6 to 12 month contracts were used to complete the necessary repairs.

Eighteen of the facilities are on the Con Ed Access Road, an unpaved power line road that parallels the western shore of the Reservoir. DEP made significant improvements to the access road during and after construction of the stormwater and erosion abatement facilities to reduce sediment loads delivered to the Reservoir and improve access at a cost of over $1,000,000.

To ensure the facilities are inspected and maintained properly, DEP commissioned the development of a unique computer software application. This Computer Assisted Facilities Management (CAFM) application uses a GIS interface to integrate internal GIS and facility data. The pilot version of the user friendly program displays a graphic illustration of the Kensico Reservoir basin and all of the pertinent infrastructure such as stormwater and erosion abatement facilities, stormwater and sanitary infrastructure, spill containment facilities, as well as land features such as streams, aerial imagery, parcel boundaries.

Evaluation

DEP used multiple approaches to confirm the legitimacy its watershed assessment and stormwater retrofit approach, which was based upon modeled and sampled pollutant load reductions, field observations and modeling of stream flows (storm and base) observed erosion and sedimentation, and community relations.

The success of the program is evaluated in part in case study "Kensico Reservoir Extended Detention Basins for Stormwater Treatment" below.

Maintenance activities are also used to evaluate facility performance and program effectiveness. For example, the amount of sediment removed from detention basins, outlet stilling basins and stabilized stream channels is directly proportional to the amount of sediment that is no longer being conveyed to the reservoir during storms. In 2005, approximately 1,000 cubic yards of material were removed from detention basins as shown in the table below. Approximately 35 cubic yards of sediment were removed from nine outlet stilling basins in 2005.

Table 2.19. Sediment removal from detention basins in 2005.

Subbasin	Detention Basin	Amount of Sediment Removed (cy)	Comment
Malcolm Brook, Perennial	2 forebay & main basin	100	
	12 forebay & upstream from weirs	132	
	12 main basin	230	
N1, Intermittent	13	24	
N2, Intermittent	18 forebay	24	
	18 main basin		
N3, Intermittent	2A	60	
N4, Perennial	23	48	
N5, Perennial	37 small forebay	90	Sediment has not yet been removed from the main basin of 37 as a change order is needed to construct a bypass and access for heavy equipment to enter the basin.
	37 main forebay & upstream from weir	144	
Bear Gutter Creek, Intermittent	66	120	

Table 2.19. Sediment removal from detention basins in 2005.

Subbasin	Detention Basin	Amount of Sediment Removed (cy)	Comment
Bear Gutter Creek, Perennial	67		Sediment depth was measured and has not yet accumulated to removal depths
E11, Perennial	75		As basin 75 was completed in 2004, sediment has not accumulated to removal depths
Total		972	

Case Study
BMP Monitoring

DEP initiated a monitoring program to quantify the fecal coliform, total phosphorus and suspended solids load reductions, and turbidity quasi-load reductions attributable to four basins and one sand filter. The facility monitoring schedule is as follows:

Table 2.20. Kensico stormwater treatment facility monitoring schedule.

Facility Number	Sub-Basin	Years Monitored
12, detention basin	MB	3/2000 – 2002 (completed)
37, detention basin	N5	10/2003 – 11/2004 (completed)
75, detention basin	E11	3/2006 – 11/2007
13, detention basin	N1	3/2005 – 11/2007 (ongoing)
57, sand filter	N12	3/2005 – 11/2007 (ongoing)

Monitoring is intended in part to evaluate the design efficiency of the detention basins and sand filter by comparing the average load reductions measured to the design values for each facility. The schedule is intended to measure the removal efficiencies of extended detention basins constructed on three primary and one intermittent stream. In addition, the removal efficiency of one sand filter will also be assessed.

Table 2.21. Pollutant removal design values for detention basins.

Facility Number	Subbasin	Design Storm (inches of rainfall)	Design TSS Removal Efficiency	Design Fecal Coliform Bacteria Removal Efficiency
12	Malcolm Brook	1.0	86%	65%
37	N5	1.2	78%	54%
13	N1	1.5	91%	60%
57	N12	1.0	35%	Increase by 104%
75	E11	1.0	96%	70%

Table 2.22. Pollutant removal rates measured in the Kensico Reservoir extended detention basins (*Source*: Kensico Annual Reports/DWQC).

Detention Basin	Total Phosphorus	Fecal Coliform	Turbidity	Total Suspended Solids
12 (reported in 2002)	54%	41%	51%	72%
37	61%	33%	77%	81%

DEP's inspection program confirms the stability of the repaired banks and channels at erosion abatement facilities during regular inspections. Reductions in loads of suspended sediments delivered to the reservoir are realized, as anticipated, where stabilized stream banks and channels prevent sediment from entering surface waters and the reservoir during base and storm flows.

2.11.2 Spill Containment Facilities

In 2002, the Spill Containment Plan for Kensico was revised to incorporate DEP's improved Spill and Emergency Response Protocol. The plan improved DEP's ability to respond to and clean up spills on major roads around the reservoir including Interstate 684 and Routes 22 and 120. Under the plan, a series of permanently anchored containment booms was installed at roadway storm drain outlets to ensure material spilled on the road is contained to prevent migration through the reservoir, improve clean up and recovery, and minimize water quality impacts.

The booms were tailored to the hydraulic load of each storm drain or stream at the installation location. In 2003, spill containment facilities were installed at the outlets of 26 storm drains along Interstate 684 and Route 120. Thirteen additional spill containment facilities were installed at existing stormwater outfalls in the Kensico Reservoir in 2004.

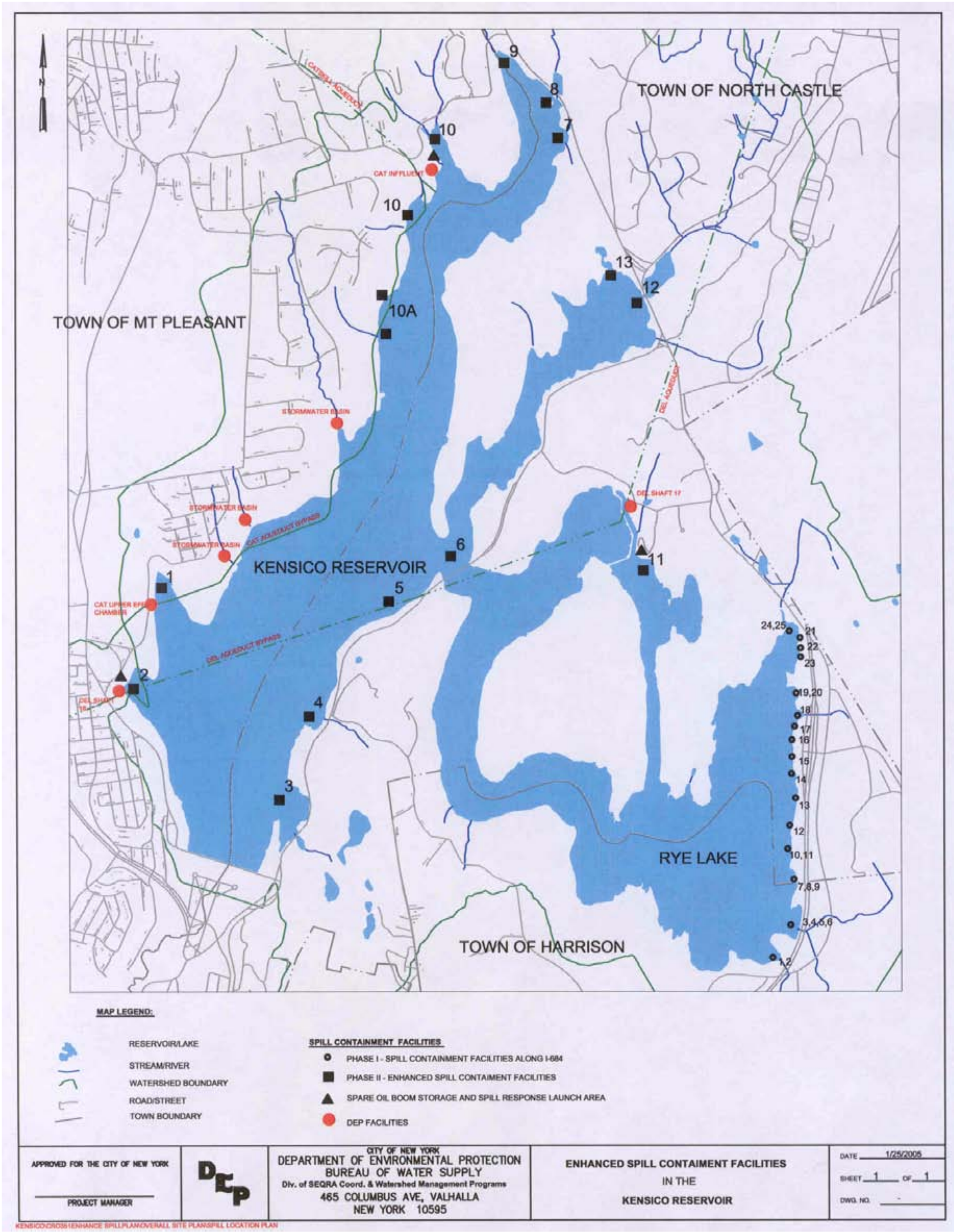

Figure 2.43 Spill Containment Facilities in the Kensico Reservoir.

2.11.3 Turbidity Curtain

Since its installation in 1995, the 500-foot long turbidity curtain between the Catskill Upper Effluent Chamber and Malcolm and Young Brooks has effectively deflected discharges from the two watercourses away from the effluent chamber. Figure 2.44 shows the location of the turbidity curtain and its flow deflection function.

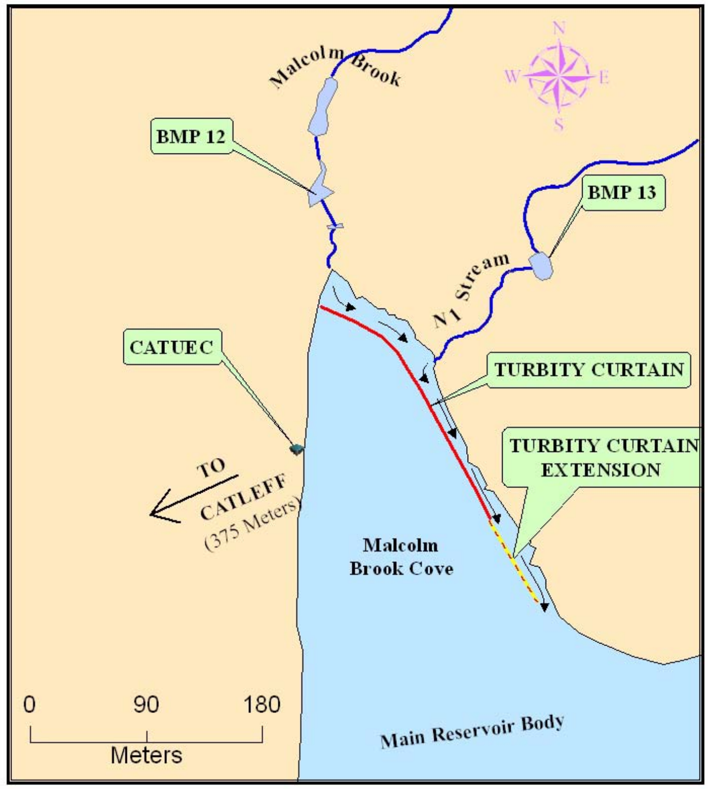

Figure 2.44 Schematic of the turbidity curtain.

To confirm the effectiveness of the structure, DEP conducted several special water quality monitoring studies, evaluated routine stream and reservoir water quality data, and routinely inspected the curtain. All maintenance needs identified during inspections were promptly completed. The amount of maintenance required was minimal and included only replacing floats damaged by waterfowl, restitching sections of curtain together, and securing steel anchoring cables. Refer to Table 2.18 for additional details. Two subsurface inspections were conducted on the first curtain. The divers also surveyed the reservoir bottom between the curtain and the two brooks. The reservoir floor was very stable, as evidenced by a vegetated buffer approximately 5 feet wide along the length of the curtain, and by the size and shape of minor accumulations of sediment at the mouths of the brooks, which have not changed since the dredging operation was completed in1999.

To provide an additional safeguard for the quality of water entering the effluent chambers, the curtain was repaired in 2002, replaced in 2003 and extended by 300 feet in 2004, before it reached the end of its design life span. In the fall of 2004, DEP also installed animal deterrent grates at the stormwater outfalls in the Malcolm Brook subbasin as described in the Stormwater Infrastructure Inspection Program Section.

2.11.4 Dredging

Accumulated sediment was removed from the intake channels at the Catskill Upper Effluent Chamber and Shaft 18 in May 1999. The approximately 2,000 cubic yards of sediment was removed to prevent resuspension and increased turbidity in the water column. Prior to dredging, a diving investigation was conducted to estimate the volume of sediment that had accumulated in the intake channels and at the mouths of Malcolm and Young Brooks. It was determined that dredging was not necessary at the mouths of the brooks. DEP continued to monitor sediment accumulations in the Malcolm Brook cove each year.

2.11.5 Kensico Watershed Improvement Committee (KWIC)

At the Town of North Castle Supervisor's request, the five largest corporations on Route 120 (King Street) and the Town established the Kensico Watershed Improvement Committee in 1996, to assess land management practices being employed by the Town and the corporations to identify potential sources of reservoir pollution from municipal and corporate facilities, and to formulate a plan to reduce the threat to the reservoir from those sources of pollution. The King Street Corridor Management Plan (Plan) sets forth sound environmental practices for the corporations and the Town to manage their facilities in ways that prevent contamination of the Kensico Reservoir. The Plan was completed in the fall 2000, with the full support of the five corporations and the Town. The corporations pledged to minimize water quality threats by voluntarily implementing the pollution prevention and remediation practices contained in the Plan and periodically reevaluating and updating the Plan. Through the reporting period, the corporations continued to implement the Plan and meet periodically to discuss implementation difficulties and successes. Most of their meetings in recent years were combined with NYSDOT coordinating committee meetings. DEP actively supported KWIC.

DEP met with the North Castle Supervisor and the KWIC chairs in 2001 to discuss the expansion of KWIC. The Supervisor enthusiastically supported expansion, and offered to assume a lead role. Based upon these discussions, DEP inventoried potential members of KWIC in the other three communities in the Kensico watershed, and developed an expansion strategy that was endorsed by the North Castle Supervisor and KWIC chairs. The inventory included corporations, institutions and other entities in the Kensico watershed that may impact water quality in the Reservoir. DEP met with other town supervisors who also endorsed the program. In 2004, DEP decided to solicit corporate participation directly, rather than going through supervisors or the prior KWIC co-chair.

2.11.6 Wastewater

Sewer System Protocol

Due to personnel changes at DEP and the towns, additional members of KWIC have not been solicited. DEP is evaluating further expansion of KWIC.

Sanitary Infrastructure Inspection

DEP engaged a contractor to digitally map and video inspect certain sanitary sewer systems in the Kensico Reservoir watershed to determine the threat that any defects in the system pose from the exfiltration of wastewater. Videotape inspection and digital mapping was performed on the segments of sewer pipe in the designated areas of the Kensico watershed (those portions of the 95,000 linear feet that were not inspected under prior DEP investigations). The purpose of the inspection is to evaluate the sewer system and identify defects that may result in exfiltration with the potential to contribute pollutants to the drinking water supply. Pump station failures and defects with the potential to contribute pollutants to the drinking water supply were also identified. The mapping provided information for system assessment and maintenance.

Comprehensive digital data including the location size, age, and material composition of all sewer lines, manholes, pump stations, and any other sewer system components (appurtenances) was collected.

A comprehensive report will summarize the results of the mapping and inspection, including:

- exfiltration of wastewater with the potential to contribute pollutants to the drinking water supply;
- pump station failures and other defects with the potential to contribute pollutants to the drinking water supply; and
- any illicit wastewater connections found during the inspection program.

Prior to initiating field work, the contractor searched municipal records for installed sanitary infrastructure and visually inspected the uninspected portions of the watershed. The largest uninspected segment is the Westchester County sewer line which parallels the Reservoir's western shore as shown in Figure 2.45. The entire length of County sewer was inspected, some 21,864 linear feet of sewer line and 120 manholes. No defects were found that might result in exfiltration. The results will be forwarded to the County for review.

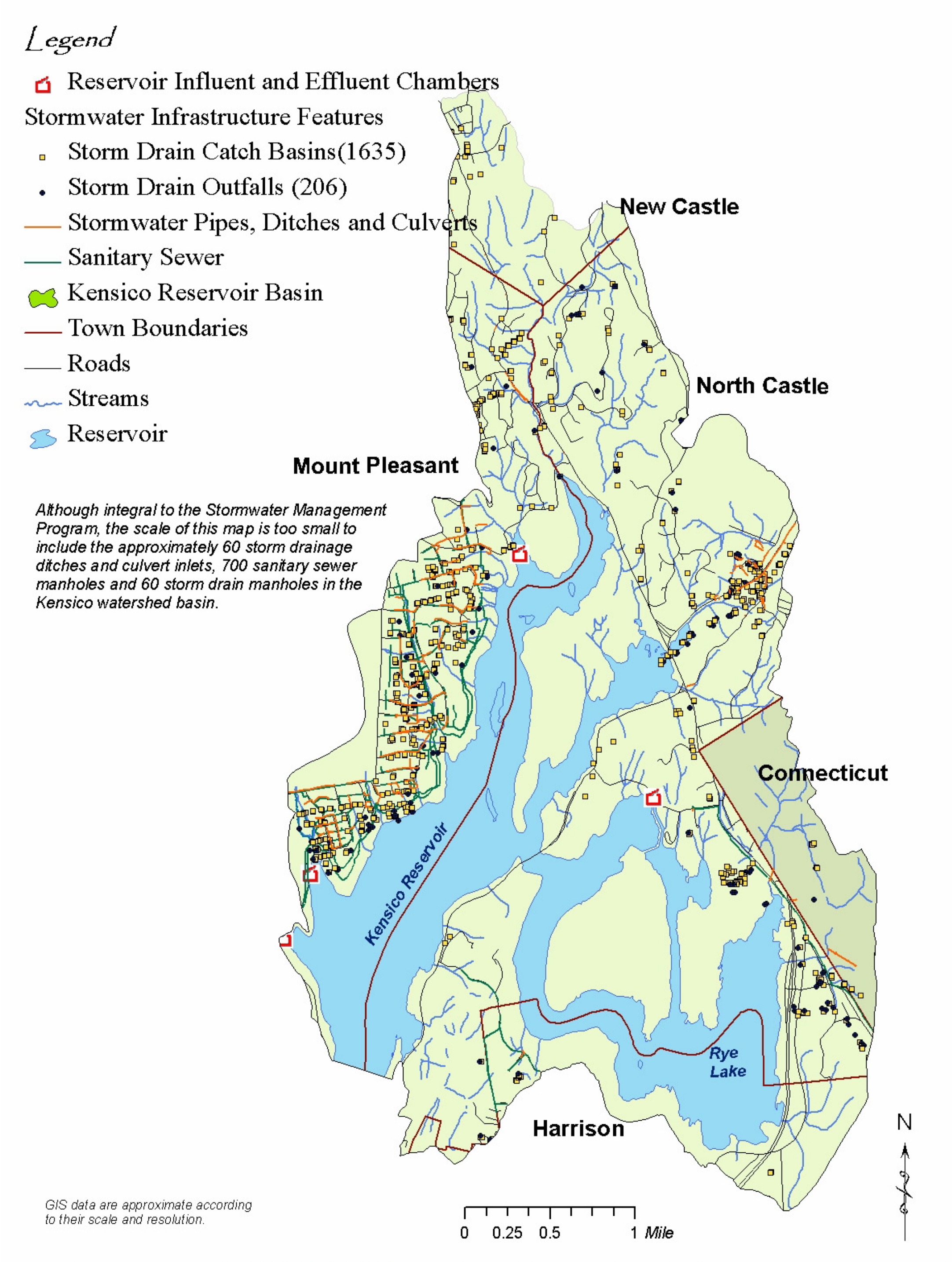

Figure 2.45 Mapped sanitary sewer and stormwater infrastructure in the Kensico watershed.

Septic Survey

To satisfy the mandate to identify and remediate failing septic systems in the Kensico Reservoir watershed, DEP surveyed and inspected residential septic systems in the watershed in 1991 and again in 2002. The more than 700 homes in North Castle, New Castle, Harrison and Mount Pleasant, shown in Figure 2.46, thought to be on septic where queried. The 2002 survey involved mailing an introductory letter explaining the program's purpose to residents and requesting their participation. DEP inspectors visited the homes and investigated the systems in the watershed. As reported in 2003, only 2 potential malfunctions were identified.

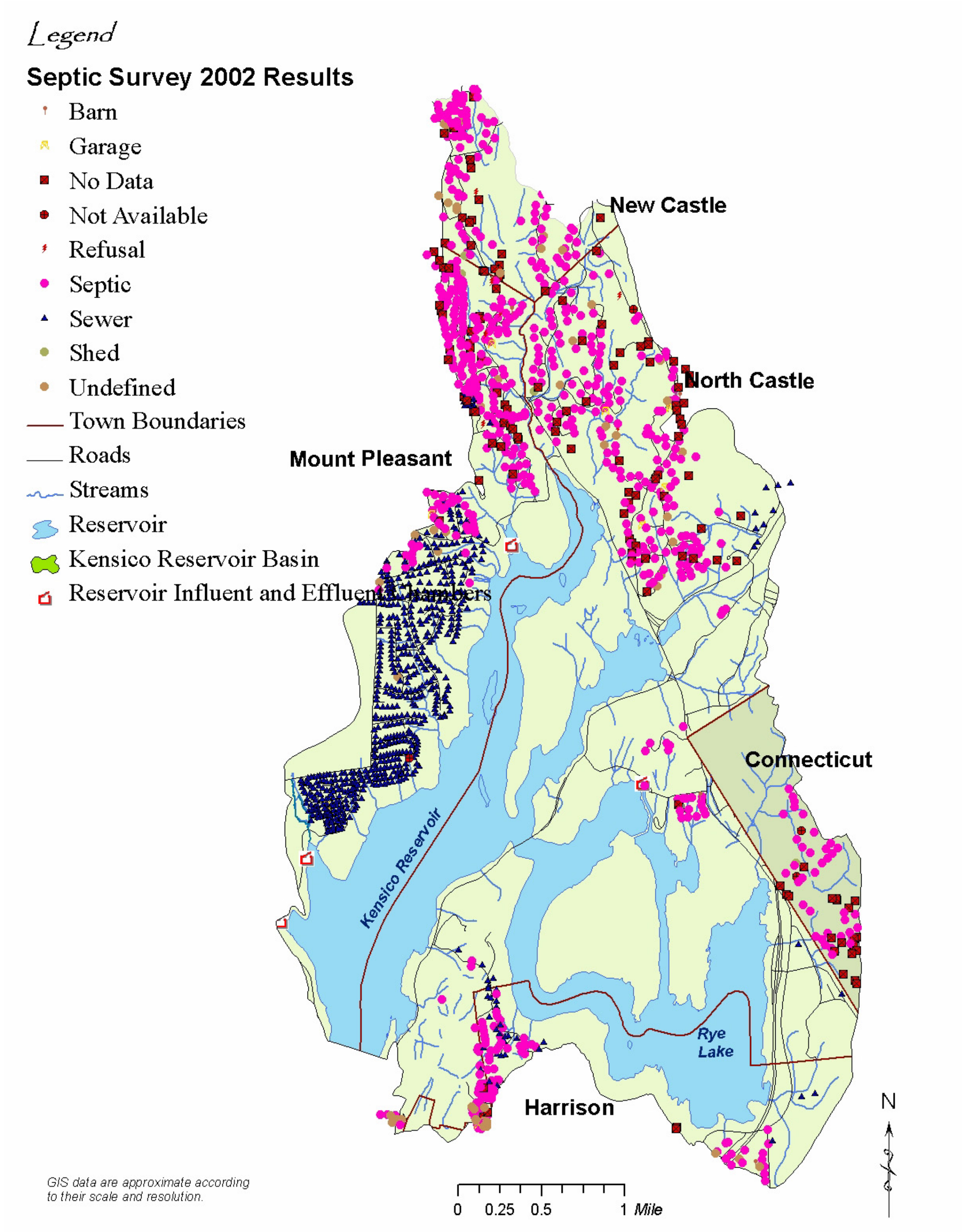

Figure 2.46 Homes on septic systems in the Kensico watershed.

Table 2.23. Kensico house to house septic survey results.

Town	Number of Houses Mailed Surveys	Number of Surveys Returned by mail	Number of Houses Visited by DEP 1	Number of Surveys2 and Inspections Completed by DEP During House Visits	Number of Potential Failures Identified & Investigated	Number of Failures Identified by Visual Inspections and Dye Testing	Number of Remediations Initiated
Harrison	85	48 (56% of the owners completed surveys)	37 (DEP was unable to reach 10 owners by phone)	26 (31%) surveyed & inspected by DEP 11 sewered 0 refused to participate	0	0	0
Mount Pleasant	209	108 (52% of the owners completed surveys)	90 (DEP was unable to reach 18 owners by phone)	80 (38%) surveyed & inspected by DEP 8 (0.4%) sewered 2 refused to participate	4	1	1
New Castle	106	44 (42% of the owners completed surveys)	31 (DEP was unable to reach 11 owners by phone)	31 (29%) surveyed & inspected by DEP 0 sewered 0 refused to participate	0	0	0
North Castle	301	163 (54% of the owners completed surveys)	154 (DEP was unable to reach 26 owners by phone)	129 (43%) surveyed & inspected by DEP 17 sewered 8 refused to participate	0	0	0
Total	701	363	312	266 (38%) surveyed & inspected by DEP 36 (13%) sewered 10 refused to participate	4	1	1

1. DEP Inspectors stopped at all 701 homes thought to be served by a septic system in Harrison North Castle, New Castle, and Mount Pleasant at least once and attempted to speak with owners. The number of houses visited by DEP represents the number of owners DEP spoke with about completing a survey and conducting an inspection.
2. The number of completed surveys represents the total number of completed surveys (52% of the owners completed surveys). Inspectors confirmed mail in responses during house to house visits. Some private property owners (10) did not permit their septic system to be visually inspected. Approximately 36 homes in the watershed were found to be connected to sewer systems. DEP was unable to reach 65 owners who returned the mail survey by phone.

2.11.7 Stormwater Infrastructure Mapping and Inspection

As part of the effort to fully identify and eliminate possible sources of fecal coliform bacteria and turbidity, DEP expanded its infrastructure mapping and inspection program to include certain portions of the stormwater infrastructure. In 1999, DEP began mapping the storm sewer system in non-sewered areas of the Kensico Reservoir watershed. The program was expanded in 2002, to include inspection of the infrastructure, data collection on the age and composition of the system (pipe size, type and so forth), and identification of illicit wastewater connections to the storm sewer system, future needs for erosion abatement and maintenance of existing stormwater facilities.

The stormwater infrastructure is shown in Figure 2.45. Inspection of the some 30,000 linear feet of drainage pipe and more than 260 structures (catch basins, inlets and outlets) found no evidence of illicit connections that might contribute wastewater to the system. The only potential pollutant source (fecal coliform bacteria) attributable to the infrastructure was animals living in the stormwater drainage system. DEP approached municipalities about placing grates over the outlets of the drains where animals, primarily raccoons, were found living. Due to concern about debris jams in the pipe behind the outlet grates, DEP was not able to install animal deterrent grates until fall 2004. The grates, designed to prevent debris jams, were installed in the Malcolm Brook basin and still remain in place today.

2.11.8 Westchester County Airport

DEP continued to closely coordinate with Westchester County Airport on a variety of matters concerning the airport's operation and potential impacts on the Reservoir. Key issues included:

- Tree removal from a 5-acre stand that blocked the site line of a taxiway near Route 120 in Harrison. After discussions, the County agreed to selectively remove certain trees in an area of less than two acres. While the alternative eliminated the need for permits and approvals, it also eliminated the potential for erosion and subsequent sedimentation in the Kensico Reservoir. The tree removal project was completed without incident.
- Deicing Facility: The airport abandoned its proposal to construct and operate a deicing facility to avoid potential impacts on the water supply.
- Stormwater Management: By 2000, 90 percent of the stormwater runoff from the airport's

impervious surfaces had been diverted outside the Kensico watershed. DEP remains committed to addressing the remaining storm flows through treatment and/or diversion.

- DEP continues to participate in the NYSDOT coordinating committee for the Route 120 and Interstate 684 improvement projects. Under the improvements, NYSDOT has committed to treating flows from outfall 7. The draft SPPP, dated April 28, 2004, describes the proposed treatment measures which also include addressing contaminated spills, including fuel spills. To ensure that spills do not reach the Kensico Reservoir, its tributaries or wetlands, all of the proposed outflow structures leading directly to waterbodies have a measure of fuel spill containment. The project's stormwater treatment practices are designed to discourage the breeding of mosquitoes by replicating natural habitats where mosquito larvae are exposed to predation. Construction is scheduled for 2008.
- Airport Master Plan: DEP maintains a dialog with the County concerning proposed alternatives to its Master Plan and alternate development strategies.

2.12 Pilot Phosphorus Offset Program

Overview

The WR&Rs prohibit the construction of new or expanded WWTPs with surface discharges in phosphorus restricted reservoir basins of the watershed. However, the Pilot Phosphorus Offset Program (Pilot Program), established in the WR&Rs and MOA, permits construction of up to three new WWTPs with a combined surface discharge of no more than 150,000 gallons per day (gpd) in phosphorus restricted basins in the Croton watershed in Putnam County. West of Hudson, the program allows up to three new, or expanded, WWTPs with a combined surface discharge not to exceed 100,000 gpd. Every kilogram of phosphorus discharged from the new or expanded WWTP and accompanying nonpoint source runoff, must be offset by the removal of three kilograms of phosphorus from the same reservoir basin in which the WWTP is located or, in Putnam County only, from an upstream hydrologically connected phosphorus restricted basin.

The WR&Rs require that offset mechanisms proposed to meet the required phosphorus reductions must be surplus, quantifiable, permanent and enforceable. In addition, the participants are required to conduct water quality monitoring of both the project site and offset mechanism, and to regularly report to DEP on the results and phosphorus load calculations. These requirements are incorporated into the SPDES permit for the WWTP.

As of December 2005, there are two participants in the Pilot Program in Putnam County (Emgee Highlands and Campus at Field Corners) and one active applicant (Kent Manor). No applications have been received for the west of Hudson program and in July 2002, the Cannonsville Reservoir was removed from the list of phosphorus restricted basins.

Per the MOA, the effectiveness of the Pilot Program was to have been evaluated in 2002. Since there have been few applicants and even fewer projects constructed, DEP determined that there was not sufficient data on which to base a program evaluation. Accordingly, and in keeping with the provisions of the MOA, DEP, in consultation with the watershed parties, will evaluate the program in 2007.

Emgee Highlands

Emgee Highlands Incorporated (Highlands) submitted an initial application to participate in the Pilot Program and a conceptual offset proposal in June 1998. The application proposed construction of 384,000 square feet of retail, restaurant and office space, and a WWTP with a 35,000 gpd discharge, on 61 acres in the Town of Southeast. The proposed development and WWTP discharge are in the phosphorus restricted Middle Branch Reservoir basin. The proposed offset was enhanced on-site stormwater treatment.

DEP issued a Conceptual Approval to Highlands to participate in the Pilot Program on September 15, 1998. The approval was conditioned upon the use of recycling wastewater to reduce the WWTP discharge to 12,000 gpd, a modification of the SPDES permit for a phosphorus effluent limit of 0.1 mg/l, and submittal of a Quality Assurance Project Plan (QAPP) and Contingency Plan for DEP approval. The Highlands QAPP was approved in September 2001. Construction of the Highlands shopping center commenced in November 2000 and was substantially complete at the end of 2001. Some stores and ancillary structures continue to open, but the shopping center footprint was complete by the end of 2001 and monitoring of the stormwater system and WWTP started in January 2002.

Nonpoint Source Monitoring

From January 2002 through September 2005, Highlands collected and analyzed a total of 179 baseflow samples and 528 storm event samples (44 storms) at the outflow point of the stormwater system (site MS#4). Monitoring at the other locations in the stormwater system has been less consistent.

WWTP Monitoring

From January 2002 through September 2005, 110 samples have been collected and analyzed from the WWTP discharge pipe, in addition to the in-plant monitoring required by the SPDES permit. It should be noted that the discharge pipe is not a compliance point for the SPDES permit. On several occasions, the discharge pipe phosphorus concentrations exceeded the phosphorus effluent limit for the plant but the in-house monitoring did not. In each of these instances, after a few months the discharge pipe concentrations would return to concentrations similar to those monitored in-house. In 2005, DEP required a more detailed investigation of the problem to determine if the elevated concentrations were originating in the pipe itself or in the lift station. Highlands completed a targeted study of the problem, which suggested that algae growth in the discharge pipe was the cause of the elevated concentrations. The discharge pipe will be reinstalled in the spring of 2006 so that it has a greater pitch, making it less likely to have standing water and regrowth problems.

Reporting and Data Analysis

While the amount of water quality sampling at the project site has been very good, DEP has had a number of data analysis and reporting issues with the Highlands project that have been difficult to resolve. Twice in 2005, DEP held a compliance conference with Highlands and most of these issues have now been resolved. At this time, the phosphorus load calculations from 2002 through 2005 will be recalculated using a consistent, DEP-approved method.

Campus at Field Corners

Putnam Seabury Partnership (Campus) submitted an initial application to participate in the Pilot Program and a conceptual offset proposal in December 1997. After numerous discussions, a revised application and offset proposal was submitted and DEP issued a Conceptual Approval in March 1999. The approved proposal consists of 142 single-family homes in a cluster development and a WWTP with a 68,000 gpd discharge on 163.5 acre site in the Town of Southeast in the Middle Branch Reservoir basin. The proposed offset was street sweeping in the towns of Kent and Carmel. Because the approved WWTP flow was less than the original proposal, Campus needed to reduce the scope of the development and secure new municipal approvals for the revised proposal.

In mid-2004, Campus submitted revised site plans and a draft QAPP. The final QAPP was approved and baseline monitoring commenced in May 2005.

Kent Manor

Lexington Realty (Kent Manor) submitted an initial application to participate in the Pilot Program and a conceptual offset proposal in January 1998. The proposal consisted of 303 condominium units and a WWTP with an 81,600 gpd discharge on a 113 acre site in the Town of Kent in the Croton Falls Reservoir basin. The applicant proposed both on- and off-site mechanisms to meet the phosphorus offset requirement. After numerous discussions, a revised application and offset proposal was submitted and DEP issued a Conceptual Approval in May 1998, contingent upon a lower WWTP flow of 70,000 gpd and a letter from the Town of Kent or Putnam County agreeing to participation of the project in the Pilot Program (required under section 18-82(g)(1) of the WR&Rs). In January 1999, DEP received letters from the Town of Kent and Putnam County refusing to support Kent Manor’s inclusion in the Pilot Program and in July 1999, DEP revoked Kent Manor’s conceptual approval.

In April 2005, DEP and Corporation Counsel staff met with new project sponsors, at their request, for a pre-application meeting. Shortly thereafter, the new sponsors submitted an updated application and QAPP. At that time, the new sponsors were told that DEP review would not commence until the application was complete, including a letter from the Town of Kent. In October 2005, the Putnam County Supreme Court determined that the Town of Kent was required to issue the letter recommending Kent Manor for participation in the Pilot Program and DEP received the town letter in a revised application and revised QAPP on November 17, 2005. The revised application and QAPP are currently under review by DEP.

2.13 Catskill Turbidity Control

Due to the nature of the underlying geology, the Catskill system is prone to elevated levels of turbidity in streams and reservoirs. High turbidity levels are associated with high flow events, which can destabilize stream banks and also mobilize the streambeds, suspending the glacial clays that underlie the streambed armor. Studies have demonstrated that by far the majority of turbidity in Ashokan Reservoir comes from high flow event on Ashokan basin streams. The design of the Catskill system accounts for the local geology, and provides for settling within Schoharie, Ashokan West basin, Ashokan East basin and the upper reaches of Kensico Reservoir. Under normal circumstances the extended detention time in these reservoirs is sufficient to allow the turbidity-causing clay solids to settle out, and the system easily meets turbidity standards at the Kensico effluents. Periodically, however, the City has had to use chemical treatment to control high turbidities.

DEP is engaged in numerous projects and studies designed to reduce turbidity in the waters of the Catskill system. A summary of the major projects and studies that are underway is provided below. In addition, certain other turbidity control efforts are discussed elsewhere in this report.

Analysis of Engineering Alternatives

DEP is undertaking a comprehensive analysis of potential effective and cost-effective engineering and structural alternatives to reduce turbidity levels in the Catskill system. DEP has engaged the Hazen and Sawyer-Gannett Fleming Joint Venture to conduct the engineering analyses. In addition, DEP has hired the Upstate Freshwater Institute (UFI) to enhance the existing Schoharie Reservoir model to allow for full assessment of the effectiveness of potential engineering alternatives in reducing turbidity. UFI has been working closely with the Joint Venture.

DEP developed a two-phase approach for this study. Phase I was a screening level evaluation to select alternative that showed the most promise. Phase II will further evaluate these measures carried forward from Phase I. The "Phase I Final Report, Catskill Turbidity Control Study" was completed in December 31, 2004. The Study involved a review of historical water quality and physical data for the Schoharie Reservoir and Shandaken Tunnel discharge, review of State and federal regulatory programs affecting these water supply facilities, and evaluation of six alternatives for potentially improving water quality. These alternatives included:

- Alternative 1 - Multi-Level Intake, to allow selective withdrawal of water from strata with desired turbidity levels;
- Alternative 2 - Turbidity Curtain, to filter out silt and clay particles;
- Alternative 3 - In-Reservoir Baffle, to reduce short-circuiting of Schoharie Creek inflows and improve settling;
- Alternative 4 - Modification of Reservoir Operations, to reduce discharge turbidity while meeting water demands;
- Alternative 5 - Engineered Treatment Facilities, including coagulation, flocculation, and settling; and
- Alternative 6 - Ashokan Reservoir Modifications, to increase overall turbidity removal capacity in the Catskill system.

Summary of findings for each alternative follow:

Alternative 1: Multi-Level Intake

Results of a two-dimensional modeling effort conducted by UFI indicated that selective withdrawal capability through a multi-level intake could help reduce turbidity export from Schoharie Reservoir and provide additional control over discharge temperature. Further modeling over longer simulation periods will be conducted in Phase II to accurately quantify the long-term performance of selective withdrawal structures under a wider range of demand and climactic conditions. In addition, the Joint Venture will evaluate other issues, including cost, environmental impacts, and permitting.

Four potential sites for a new intake with selective withdrawal capability were evaluated. Of these, three sites were recommended for further evaluation in Phase II. Water quality differences between these three sites will be assessed further, following completion of Phase II modeling efforts.

In addition to new multi-level intake structures, modification to provide selective withdrawal capability at the existing Shandaken Tunnel Intake was also recommended for evaluation in Phase II. Such modifications could provide benefits associated with selective withdrawal capability, but in a more cost-effective manner.

Alternative 2: Turbidity Curtain

A comprehensive turbidity curtain study was conducted, including bench-testing, in-reservoir pilot testing, and conceptual design of a full-scale system. In-reservoir pilot testing indicated that a permeable turbidity curtain showed some potential for reducing turbidity export from Schoharie Reservoir. However, the ability of a full-scale system to provide consistent turbidity control performance is questionable. Factors contributing to this assessment include the inconsistent performance exhibited in the majority of bench and pilot tests and the potential negative impact of the air cleaning process on the overall particle removal provided by the curtain system.

In addition, a turbidity curtain at Schoharie Reservoir would constitute a large-scale implementation of a novel, complex technology in a challenging physical environment. Based on performance and reliability concerns, this alternative was not recommended for further development in Phase II, either as an interim or a long-term measure.

Alternative 3: In-Reservoir Baffle

Preliminary three-dimensional modeling conducted by UFI indicated that an impermeable baffle structure around the existing intake would reduce the short-circuiting of Schoharie Creek inflows into the intake, thus increasing mixing, dilution of inflows, and settling time. These factors have the potential to reduce turbidity export from Schoharie Reservoir. Further modeling of turbidity/particle transport over longer simulation periods will be performed in Phase II, to accurately quantify the turbidity reduction benefits of baffle structures under a wider range of demand, drawdown, and climate conditions.

A baffle structure at the Schoharie intake could be constructed using either a floating, anchored impermeable membrane material, or a more conventional concrete barrier. The impermeable membrane curtain would have a significantly lower life cycle cost than the concrete barrier, and was recommended for further evaluation in Phase II.

Alternative 4: Modification of Reservoir Operations

This alternative involves modifying the operation of Schoharie and Ashokan Reservoirs to reduce the turbidity of discharges to Esopus Creek and to the Catskill Aqueduct. These alternative management strategies could also provide improved control over peak summer temperatures in water discharged to Esopus Creek. However, water quality-driven changes in the timing of withdrawals must be considered in the context of overall water supply needs. Note that changes in operation of the Catskill system can only be evaluated in the context of overall system operations.

To further assess the feasibility of modifying reservoir operations to meet water quality objectives while still meeting supply constraints, a linked water quality/quantity modeling tool was proposed, using the GWLF watershed models operated by DEP, the two-dimensional CE-QUAL-W2 reservoir water quality models established by UFI for the west of Hudson reservoirs, and the OASIS reservoir operations model developed by HydroLogics for the DEP reservoir system. This modeling tool would be developed incrementally. Stage 1 (a proof-of-concept model) will begin development during Phase II of the Catskill Turbidity Control Study, in two stages. Stage 1a will focus on Schoharie Reservoir, while Stage 1b will extend the model linkage to include Ashokan and Kensico Reservoirs. The Stage 1a work is expected to yield an evaluation (by the end of Phase II) of the possibility of modifying Schoharie Reservoir operations to address turbidity and temperature concerns.

Alternative 5: Engineered Treatment Facilities

Various engineered treatment and settling facilities were evaluated under Alternative 5. Several of the sub-alternatives considered (including ballasted flocculation, or coagulation, flocculation and clarification using inclined plate settlers) could reduce turbidity export from Schoharie Reservoir and could reliably reduce the turbidity of Shandaken Tunnel discharges to low levels. However, due to the very high cost of such large capacity treatment facilities, as well as the significant environmental, permitting, and public acceptance issues involved in their implementation, none of the engineered treatment facilities evaluated under Alternative 5 was recommended for further evaluation in Phase II.

Alternative 6: Ashokan Reservoir Modifications

Under this alternative, five Ashokan Reservoir modifications that could potentially reduce the turbidity of water entering the Catskill Aqueduct were evaluated. These modifications included providing capacity to discharge turbid West basin water downstream, increasing West basin storage capacity to allow longer detention time of turbid inflows, providing selective transfer capacity between West and East basins, installing a baffle wall in the East basin to reduce short-circuiting, and installing permeable turbidity curtain(s) around the Catskill Aqueduct intake(s). Three of these five alternatives were found to be potentially feasible and effective and were recommended for further evaluation in Phase II. These include: increasing West basin storage; providing waste discharge capacity in the West basin; and installing a baffle wall in the East basin.

Additional work will include further development and evaluation of the surviving alternatives identified above. This evaluation will include an assessment of the effectiveness and cost-effectiveness of selected combined alternatives. Tasks will include refinement of conceptual designs, additional modeling to quantify turbidity control performance, detailed cost estimation, cost-benefit analysis, and further assessment of potential environmental issues and permitting requirements.

Upstate Freshwater Institute Monitoring and Modeling

Monitoring

In 2004, The Upstate Freshwater Institute (UFI) continued a comprehensive monitoring program of Schoharie Creek, Schoharie Reservoir, and Esopus Creek, that featured elements of robotic monitoring technology, as well as manual efforts. The monitoring effort is a key component of the initiative to develop mathematical models of temperature, transport, and water quality to support related rehabilitation initiatives for these systems.

Robotic monitoring

Reservoir Remote Underwater Sampling Station (RUSS) units — RUSS units have been placed on Schoharie reservoir to allow for continuous data collection at key locations. A single RUSS unit was tested in 2002 near the intake. Two additional units were deployed in May 2003, one near the dam and one approximately mid-way between the intake and the dam.

Stream robotic sampling units (Robohuts) — Specially fabricated for this effort, Robohuts have been placed along streams to collect continuous stream data for several key parameters. A Robohut was placed on Schoharie Creek in March 2003. A second Robohut was installed near the mouth of Esopus Creek in July 2003. An additional Robohut was installed on Esopus Creek, above the Shandaken Tunnel outfall, in late 2003. Operation of this unit, delayed because of permitting issues, commenced in early 2005. Plans to install another Robohut downstream of the outfall have been discontinued, because it would not add substantively to the integrated monitoring/modeling initiative.

Non-robotic monitoring

UFI continues to conduct manual monitoring on these systems to provide groundtruth information for the robots and augment spatial characterization of water quality, particularly following runoff events, in support of model development and testing. This effort features the use of modern rapid profiling instrumentation in the reservoir, and the deployment of a number of recording thermistors in Esopus Creek. UFI has collaborated with DEP in morphometric characterization of Esopus Creek, necessary to support development of models for that stream.

Modeling

Mathematical models of transport and water quality (particularly temperature and turbidity) are being developed, preliminarily tested, and preliminarily applied by UFI. These quantitative tools will provide credible predictive capabilities to support deliberations by the Joint Venture and DEP managers concerning rehabilitation alternatives for the system, and will eventually support design efforts by the Joint Venture for engineered solutions.

Preliminary testing of the following models was completed by UFI:

(1) two-dimensional hydrothermal transport model for temperature for Schoharie Reservoir.
(2) three-dimensional hydrodynamic/transport model for Schoharie Reservoir.
(3) two-dimensional interim turbidity model for Schoharie Reservoir.
(4) temperature model for Esopus Creek.

Models (1) and (3) were applied to support Joint Venture evaluations of Alternative 1 (described above). Model (2) was applied to support Joint Venture evaluations of Alternative 3 (described above). Model (4) will be applied to evaluate the interplay between the Shandaken Tunnel discharge and the temperature of Esopus Creek, and relates to the SPDES permit (described below).

State Pollutant Discharge Elimination System (SPDES) permit for the Shandaken Tunnel Discharge to the Esopus Creek

Following the decision of Judge Scullin on February 6, 2003, requiring the City to diligently pursue a SPDES permit for the water releases from the Shandaken Tunnel into the Esopus Creek, and directing the State to make a determination about the required SPDES permit for the discharge, a first Draft permit was noticed for public comment by NYSDEC in the Environmental Notice Bulletin on February 18, 2004. DEP responded to NYSDEC on March 19 with a letter of comments. Based on comments received from a number of parties, NYSDEC withdrew the initial Draft Permit.

A second Draft Permit was noticed for public comment by NYSDEC in the Environmental Notice Bulletin on August 4, 2004. NYSDEC received a number of comments including a lengthy submission from DEP.

A legislative hearing and issues conference were held in April 2005 to determine whether the comments received by NYSDEC warrant an administrative hearing. The Administrative Law Judge issued a decision in June 2005 finding that several issues warranted adjudication. An adjudicatory hearing was held in October 2005. Post-hearing briefs were submitted on December 9, 2005, and response briefs on January 13, 2006. After the matter is fully submitted, the administrative law judge will issue a decision as to whether the permit should be issued as a Final Permit in its form as of the close of the adjudicatory hearing, or whether modifications to that Draft should be made in the Final Permit. A final determination will not be issued for several months, and it is likely that the ALJ's decision will be appealed to the NYSDEC Commissioner.

Simultaneously, the City is pursuing its appeal of the federal court decisions holding that a permit is required for the transfer of water through the Shandaken Tunnel. The appeal was argued before the U.S. Court of Appeals for the Second Circuit on November 21.

2.14 East of Hudson Nonpoint Source Control Program

DEP developed a comprehensive plan to address nonpoint source pollution in the Catskill\Delaware basins east of Hudson[1]. The plan, based upon watershed surveys, water quality monitoring, and the Croton Watershed Strategy (CWS) (DEP 2003a), was designed to eliminate known nonpoint sources and identify and eliminate other sources and incidents of nonpoint pollu-

1. The East of Hudson Catskill Delaware Reservoirs includes West Branch, Croton Falls, Cross River and Boyds Corners.

tion. The nonpoint sources targeted for remediation programs include wastewater, stormwater, turf management chemicals, and hazardous materials. The plan was released in October 2003 and revised in December 2003. The implementation schedule was revised several times to reflect changes in program status.

2.14.1 Wastewater Programs to Reduce Nonpoint Pollution

Nonpoint sources of wastewater include exfiltration or other releases from defective sewer lines, failing septic systems, and illicit connections to the storm sewer. The four target watersheds contain 12 wastewater treatment plant discharges and a system of sewer infrastructure within several sewer districts. Wastewater generated outside of the existing sewer districts is treated exclusively by septic systems. Within the districts served by wastewater treatment plants, most septic systems have been decommissioned. Both the CWS and the Croton Diversion Feasibility Study, identified certain areas for remediation of defective sewer infrastructure and potentially failing septic systems. In many cases, site constraints, and other issues have precluded sewering these areas. Septic focus areas are defined as “areas experiencing septic system failures, areas that may experience failures in the future due to current development, or areas that may require sewering the in the future due to future development.”

Wastewater Infrastructure Mapping and Inspection

To locate and identify the composition of the sanitary infrastructure in the four basins, DEP funded a program to video inspect and digitally map the sanitary infrastructure. Video inspection was the selected technique as it provides the most conclusive means of assessing defects that may result in exfiltration of effluent to surface water.

Digital data of each wastewater system is essential for maintenance. Collected data includes sewer pipe size, estimated age, composition, and precise location; manhole location, size and estimated age; pump station locations, size and flow capacity; interceptor sewer location, size, estimated age; and any other pertinent data concerning cross and illicit connections.

The program will yield:

- GIS maps of all components of the sewer infrastructure and their ownership;
- A summary report that identifies all cross connections, illicit connections, pump station failures, and defects that may lead to exfiltration of wastewater into the water supply; and
- Contacts with municipalities, infrastructure owners and operators to first explain the project, then discuss remediation alternatives and repair mechanisms.

A portion of the work has been completed. No cross connections, illicit connections, pump station failures, or defects that may lead to exfiltration of wastewater into the water supply were identified in the over 6000 feet of sanitary sewer and 40 manholes inspected to date.

Wastewater Infrastructure Remediation Plan

Initially, DEP proposed to use the results of the video inspection and mapping program to develop a Wastewater Infrastructure Remediation Plan. DEP remains committed funding, and overseeing the repair of all defects that may result in nonpoint discharges of wastewater into the water supply. However, the repairs will be completed by municipalities, infrastructure owners and appropriate jurisdictional authorities through negotiated agreements with the City. The final report submitted for the infrastructure inspection program, with its findings report, will constitute the remediation plan.

In the event any illicit connections to the infrastructure are identified during the inspection program, DEP will forward any relevant information to infrastructure owners and appropriate regulatory agencies for possible enforcement action.

Locate, Map, and Ensure Remediation of Failing Septic Systems

The Croton Watershed Strategy identified certain areas where septic systems have the potential to malfunction and fail, thereby threatening the water supply. DEP has coordinated with Putnam County on a program patterned on the successful septic repair program that DEP instituted west of Hudson. DEP provided the necessary funds to carry out the County's Septic Repair Program (SRP) through the of east of Hudson Water Quality Investment Program (WQIP) funds, as provided for in Section 140 of the MOA.

Using $3.3 million of the WQIP funds, Putnam County will notify homeowners within select septic focus areas of the opportunity to have a failing septic system repaired or replaced. To maximize participation, Putnam County will bear the entire cost of the repair or replacement so that there would be no cost to the homeowner. Homeowners who agree to the conditions of the program would be required by the County to adequately maintain their systems.

At the County's request, DEP provided Putnam County with prioritization criteria based on maximizing the water quality benefit. DEP based the project prioritization largely on prior studies that determined focus, and on water supply factors (e.g., 60-day travel time, basin location). Putnam County used this information, as well as data from the Putnam County Department of Health, to develop a three-stage program roll-out. Figure 2.47 shows the program priority areas.

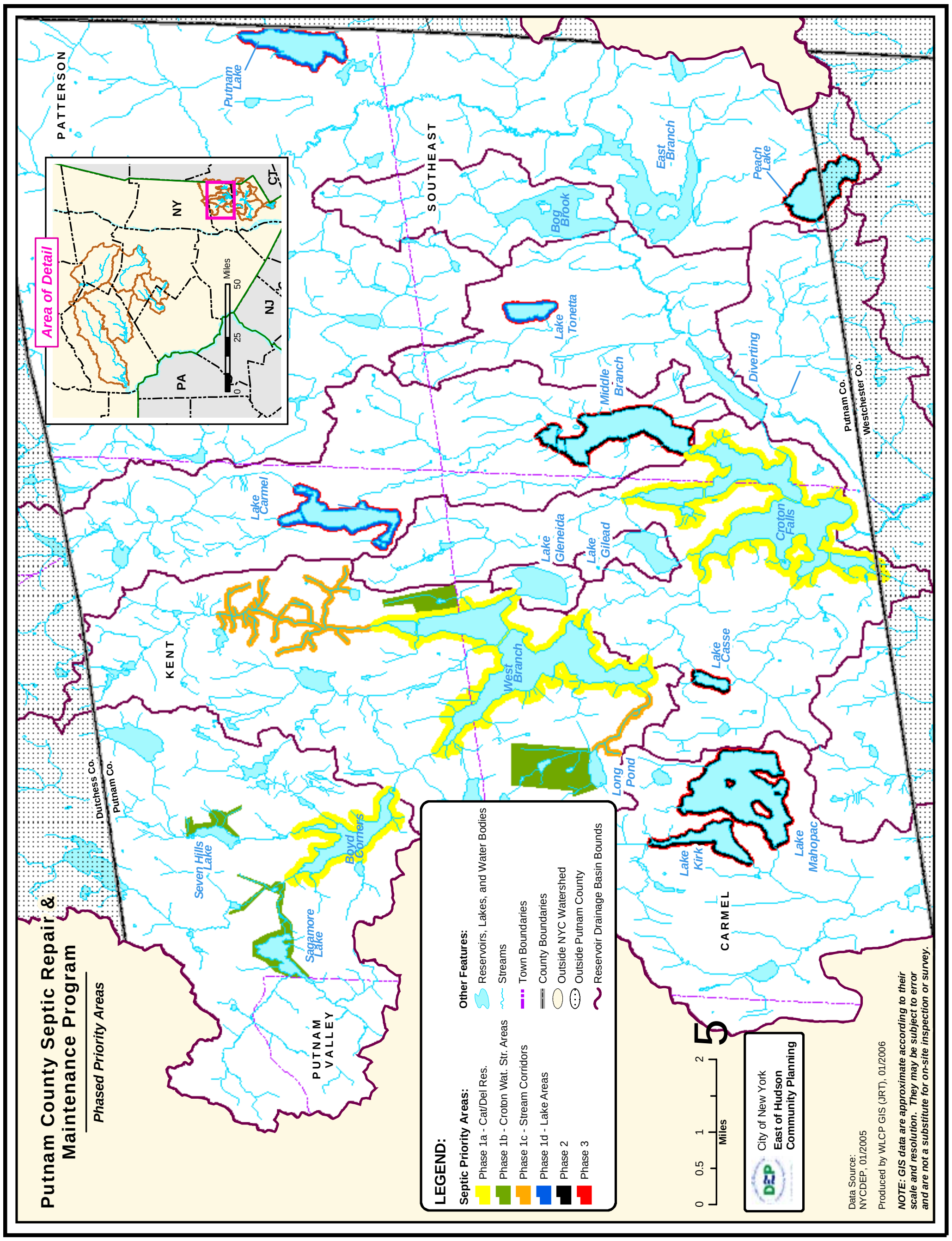

Figure 2.47 Putnam County Septic Repair and Maintenance Program.

Program implementation will occur through a process that includes participation from SRP staff, the County Health Department, DEP, eligible applicants and prospective certified septic installers. The County has hired three staff, including a P.E., to implement the program. The County also sent the first phase of mailings to homeowners within the primary target area in Phase I in December 2005. Over 300 mailings have been sent to date. The mailings include an introductory letter, a reference guide to septic systems and a brief informational form. SRP staff have coordinated with local news organizations to educate residents about the program.

DEP will regularly monitor the Putnam County SRP. The results of the program will be evaluated to determine what, if any, modifications to the septic program may be necessary.

2.14.2 Stormwater Nonpoint Management Programs

Nonpoint pollutant loading in stormwater is a direct function of rainfall, land use and cover, topography, and soils. These factors form the stormwater runoff patterns and determine the type and quantity of pollutants conveyed. DEP evaluated land use patterns and cover data described in the Croton Watershed Strategy and the GIS database, including impervious cover mapping, to identify existing nonpoint source loads of turbidity and potential remediation solutions. Based on this analysis, DEP identified means and measures to reduce existing nonpoint sources of stormwater-based pollutants through remedial and retrofit projects designed to eliminate the sources of pollution or remove pollutants from stormwater.

Stormwater Infrastructure Mapping and Inspection Program

DEP is in the process of digitally mapping and video inspecting stormwater infrastructure. Initially, the program prioritized some 1.1 million feet of infrastructure designated in the Croton Watershed Strategy as stormwater management areas, wastewater management areas, septic focus areas and wastewater treatment plant service areas. The program was later expanded to encompass the entire Cross River, West Branch, Boyd Corners and Croton Falls basins.

During the inspection effort, any illicit connections, or other inputs of pollution, to the storm sewer system are identified and characterized. The goal of the program is to eliminate all illicit inputs and remediate other sources, as appropriate. The condition of the area surrounding stormwater discharges are also examined for information relevant to the stormwater remediation program.

Collection of digital infrastructure data is essential for future inspection and maintenance. Digital data includes stormwater pipe size, estimated age, material and location; catch basin manholes, culverts and outfall location, size and estimated age; and all pertinent data concerning cross, and illicit, connections.

Inspections were completed in April 2004. Table 2.24 shows the amount of infrastructure inspected to date.

Table 2.24. Inspected and mapped stormwater infrastructure in the four basins.

Reservoir Basin	Length of Pipe (linear feet)	Length of Ditches (linear feet)	Number of Structures (manholes, outfalls)
Boyds Corners	3,540	11,275	427
West Branch	49,560	18,279	1,064
Croton Falls	55,850	29,860	3,848
Cross River	46,690	18,515	2,644
Total	155,640	77,929	7,983

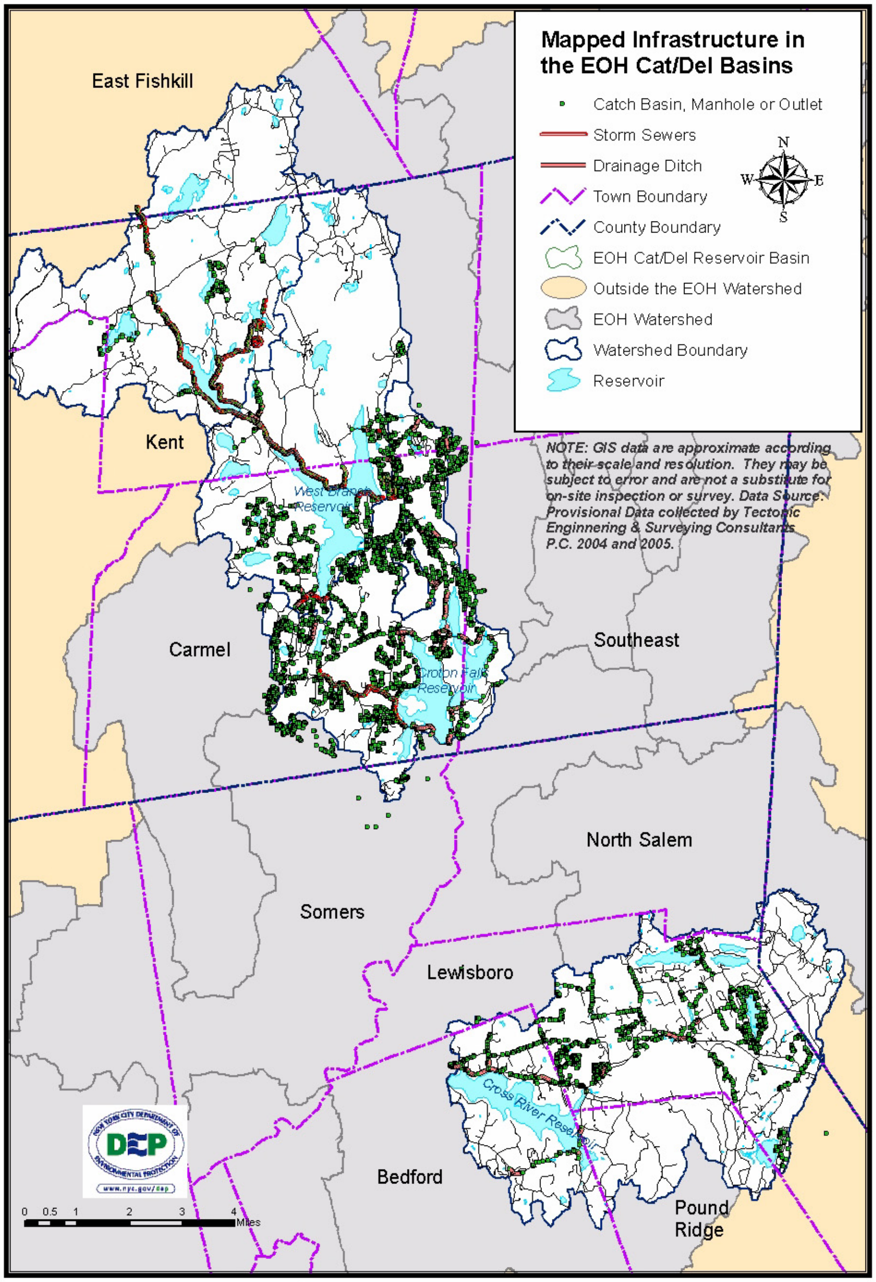

Figure 2.48 Mapped stormwater infrastructure in the EOH Catskill/ Delaware Reservoir basins

During the course of the inspection work, the contractor reported defects shown in Table 2.25 for DEP to investigate and forward to the appropriate authorities.

Table 2.25. Stormwater infrastructure inspection results.

Possible Unauthorized Connections and Their Status			
Site	**Address**	**Town**	**Status**
Arms Acres	75 Seminary Hill Rd.	Carmel	Referred to PCDOH for further investigation.
Carmel Bowl	23 Old Rt. 6	Carmel	Remediated by property owner at DEP's direction.
Durkin Oil	79 Old Rt. 6	Carmel	No signs of illicit discharge
Residence	35 Gregory St.	Mahopac	Connection appeared to be curtain drain, no signs of illicit discharge
Residence	61 Everett Rd.	Carmel	No signs of illicit discharge
Residence	Robin Drive	Carmel	Outlet from dog pen permanently sealed.
Residence	14 Robin Drive	Carmel	Connection appeared to be residential roof drain. No evidence of illicit connection.
Residence	61 Everett Rd.	Carmel	No evidence of illicit discharge
Residence	8 & 10 Lakeview Road	Carmel	Possible residential roof drain connection. Referring to PCDOH.
Residence	9 & 11 Lakeview Road	Carmel	Possible residential roof drain connection. Referring to PCDOH.
Residence	14 & 16 Lakeview Road	Carmel	Possible residential roof drain connection. Referring to PCDOH.
Residence	8 or 10 Columbus Drive	Carmel	PCDOH determined that there was no evidence of illicit discharge.
Residence	31 Bayberry Hill Road	Carmel	Possible residential roof drain connection. Referring to PCDOH.
Residence	6, 26, 46, & 52 Heather Drive and 523 Orchard Court	Mahopac	PCDOH determined that there was no evidence of illicit discharge.
Residence	Hazen Lane/ 29 Colonial Glen	Carmel	PCDOH determined that there was no evidence of illicit discharge.
Northwest Corner of Interlochen Road & Meadow Drive	Northwest Corner of Interlochen Road & Meadow Drive	Croton Falls	Referring to PCDOH for investigation of a sanitary sewer connection that showed signs of seepage infiltration that could lead to possible exfiltration.
Residence	Valley Road	Croton Falls	Soap suds identified in catch basin. Referred to PCDOH for further investigation.

The sites still under investigation will be promptly addressed and described in future reports when the results are available.

The inspection results combined with DEP's field reconnaissance and evaluation identified two substantial remediation projects in the Croton Falls basin: Magnetic Mine Road and Hemlock Dam. Description of the sites and remediation plans are discussed below.

DEP intends to continue reviewing routine project progress and inspection reports with the contractor. Any notifications of potential illicit connections or other potential sources of non-point pollution are promptly investigated and addressed.

Stormwater Retrofit and Remediation Plan

The Stormwater Retrofit and Remediation Plan scheduled, to begin in 2004, includes the following elements:

- Infrastructure Treatment Capacity Assessment - An infrastructure treatment capacity assessment of the existing stormwater conveyance systems using existing subbasin mapping and other information will be used to predict the current level of treatment (pollutant removal) that existing local and regional infrastructure provides. This assessment will examine stormwater flow paths, both piped and open channel, in subbasins of each watershed and identify opportunities to enhance components of the system that are providing some level of treatment and to retrofit components that are providing no treatment. The assessment will be completed when the mapping program is completed.
- New Remediation Sites - Two new large remediation sites were identified, Magnetic Mine Road and Hemlock Dam Road in the Croton Falls basin. Both sites are long stretches of unpaved roads. Remediation would include erosion abatement, drainage improvements, boat parking area stabilization and embankment stabilization. A scope of work and engineering design request has been prepared. Future new sites will be identified under the Basin Management Planning Program.
- Remediation Site Designs - Designs are being prepared for the five remediation sites shown in table 2.26. The EOH sites are shown in Figure 2.49. The contract began in January 2004 and is rapidly advancing.

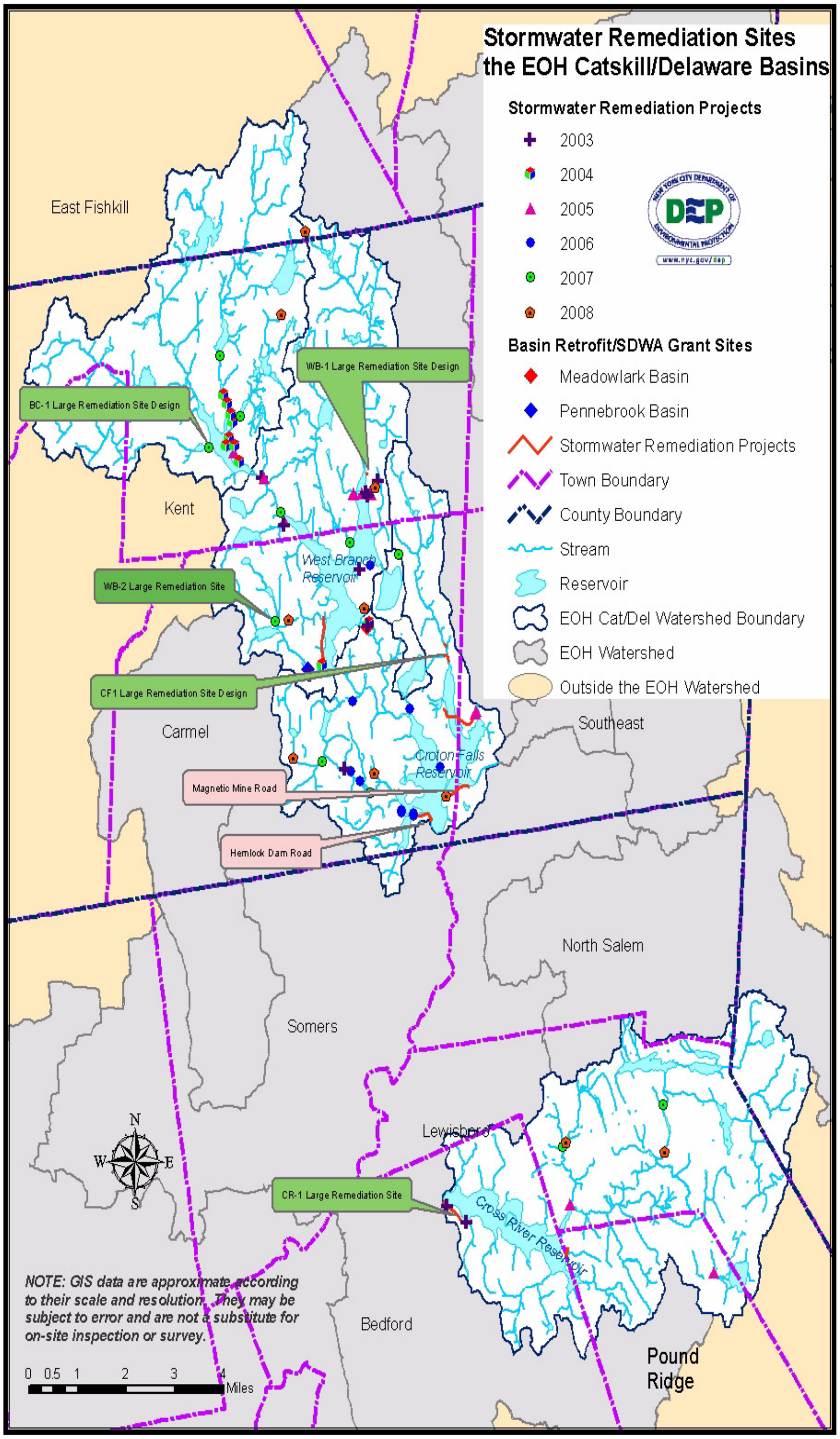

Figure 2.49 Location of proposed new stormwater remediation sites.

Table 2.26. Stormwater remediation design sites and status.

Site Name and Pollutant	Reservoir Basin	Town	Location and Description of Remediation
WB-1 Sediment	West Branch	Kent	Joseph Court: Repair severely eroded channel on steep slope. Install catch basin, drop manhole, stormwater drainage pipe, outlet protection, and wetland plants. In December, property owners requested pond installation. Kent is reviewing the plans and specifications.
CR-1 Sediment	Cross River	Bedford	Maple Road: Install stormwater drainage improvements (swales and forebays), and landscape improvements, stabilize the parking areas with porous pavers, repair the culvert, stabilize embankments, and clean out sediment and debris build up at the outfall. Presented plans and specifications to the Planning Board in December 2005.
CF-1 Sediment	Croton Falls	Carmel	Stonleigh Avenue: Stabilize the eroded length of stream channel, install road drainage improvements at Kelly Road (swales and erosion mat on eroded slopes) and Hughson Road (install swale and repair severely eroded drainage ditch).
BC-1 Sediment	Boyd's Corners	Kent Cliffs	Richardsville Road: install a new drainage culvert, stabilize the embankment and channel, headwalls and endwalls, construct a forebay, remove accumulated sediment at the pond weir, remove accumulated woody debris immediately downstream from the weir, and replace guide rail. Property owners are amenable. Kent is reviewing the plans and specifications.
WB-2 Sediment	West Branch	Carmel	Long Pond Road/Crane Road: Install porous pavers to stabilize parking area, drainage improvements including forebays, and landscape improvements, and clean out sediment and debris build up at outfall. Presented plans and specifications to the Planning Board in December.

DEP is reviewing the designs, construction specifications, supporting calculations and is seeking private property owner and municipal approvals. Obtaining comments and approvals before the designs are final helps to prevent contract change orders and delays during the construction phase. To date, the private property owners are amenable to the designs and allowing access. The proposed project plans and designs were presented to the planning departments in Kent, Carmel and Bedford in December 2005.

Three Large Remediation Sites

DEP designed and constructed three remediation sites:

Washington Road

Washington Road, an unpaved road adjacent to the West Branch Reservoir, is characterized by the lack of adequate stormwater infrastructure, accelerated erosion of the road's surface, shoulders and existing stormwater conveyance channels, and the discharge of sediment into the West Branch. The retrofit to eliminate the direct discharge of pollutants into the reservoir from the unpaved road included installation of stormwater collection and conveyance facilities to eliminate the uncontrolled flow of runoff, stabilization of the eroding road shoulders, and reestablishing channels that were initially constructed to convey stormwater to the reservoir, but have long since been obstructed with sediment.

The repairs were made in the winter of 2004 and 2005. The site was enhanced with approximately $80,000 dollars of landscaping in the spring of 2005. The Town of Carmel requested the road be resurfaced with Item 4 upon completion of the project. Resurfacing to Town specifications is estimated to cost just under $50,000. Because the contract used its budget, the resurfacing is scheduled to be completed and paid for under another contract. Observations, including the accumulation of sediment in the drainage ditches and forebays suggest that the repairs have reduced turbid discharges to the streams and reservoir.

Pennebrook Lane

Pennebrook Lane, the existing basin at the Pennebrook Subdivision was improperly designed and constructed, and maintained. These factors led to the basin's failure, allowing contaminant laden runoff from the subdivision to discharge directly into a reservoir tributary. Retrofit involves the replacement of an existing stormwater treatment basin with a one that has been properly designed to retain nonpoint pollutants.

Retrofit of the Pennebrook basin began in March 2005. Wetland plant installation began in June and the site was fully stabilized in September 2005.

Meadowlark Drive

Meadowlark Drive, a basin adjacent to Route 6 in the Croton Falls watershed, was redesigned to improve water quality treatment altering its shape, size, retention time and volume, and installing wetland plants. The retrofit also included aesthetic enhancements such as stone facing and landscaping.

Site work began in September of 2004. Wetland plant installation began in June and the site was fully stabilized in September 2005.

For both Meadowlark and Pennebrook basins, preconstruction storm sampling was conducted between June 2003 and September 2004. Post-construction storm sampling will resume after DEP finalizes the next round of SDWA grant funding with NYSDEC.

Small Remediation Projects

DEP's Stormwater Remediation Small Projects Program was initiated to identify and repair erosion that might impact water quality. Site selection is based upon proximity to watercourses, wetlands and reservoirs; the severity or risk of erosion (or other stormwater condition); and the absence of other programs for which the project would qualify. As documented in prior annuals reports, ten sites have been repaired each year since 2003. Typical erosion abatement repairs include embankment stabilization, headwall and endwall repair or construction, road drainage improvements (swales, forebays, storm drains, culverts, curbs), pull off parking area stabilization, and trail stabilization. The parking areas and trails typically lead to boat storage areas.

The small project program has advanced quite a bit since the first sites were remediated in 2003. With each year, the program, design, and construction managers learned enhancement techniques that improved the effectiveness and aesthetics of the facility without significantly affecting cost. The community, watershed characteristics and flow conditions warrant more these advanced remediation practices.

As many of the sites are within limiting distances of reservoir tributaries or within road easements, federal, State, municipal and City approvals were required and obtained.

Inspection and Maintenance of Stormwater and Erosion Abatement Facilities

As each facility is brought on line, it is added to the routine inspection list, first established for the Kensico facilities. Facility maintenance is promptly completed, under the construction contract warranty for the first year and under the 3-year maintenance contract thereafter, in accordance with the Operation and Maintenance Guidelines (DEP, 2000a). Facility types not described in the Guidelines were incorporated into the facility maintenance contract with explicit maintenance instructions. This includes the spill containment facilities.

Summary of the Erosion Abatement Sites Identified by Trout Unlimited

Trout Unlimited, the Croton Watershed Clean Water Coalition and New York Water Watch identified erosion sites in the Croton watershed that resulted in siltation of reservoir tributaries, watershed streams and wetlands, and reservoirs. The report describes the 50 most egregious erosion sites identified in the New York City east of Hudson water supply system. Most of the identified sites are located outside the Catskill/Delaware basins east of Hudson. However, four fall within the Catskill/Delaware basins.

- Route 35 and Old Shop Road (Cross River basin): DEP remediated the swales, channels and embankments at the intersection of Route 35 and Old Shop Road, in the Cross River Reservoir basin. The repairs were made under DEP's Small Remediation Projects. Similar improvements were made at the intersection of Routes 35 and 121 and across the street from the two intersections.
- Route 121, South of Boutonville Road (Cross River basin): DEP is not remediating the Boutonville intersection. However, erosion abatement and stormwater remediation is planned further south on Route 121, just south of the intersection with Honey Hollow road where the drainage swale flows into the Cross River Reservoir.
- Cross River Shopping Center (Cross River basin): This site is being investigated for inclusion in the Small Remediation projects program.
- Route 6 Bridge Over the West Branch of the Croton River (Croton Falls basin): The site in Croton Falls adjacent to Route 6 near Meadowlark Drive was repaired when NYSDOT reconstructed the bridge over the West Branch of the Croton River.

2.14.3 Turbidity Curtain

DEP assessed turbidity curtain deployment in the four reservoirs and determined that curtains would not be effective management tools in the Cross River, Croton Falls, and Boyd Corners Reservoirs. A turbidity curtain at the mouth of Long Pond Brook in the West Branch Reservoir would deflect nonpoint pollutants conveyed to the Reservoir by the Brook away from the intake at Shaft 10. DEP applied for permits to install the curtain from NYSDEC, stating in the project description that the curtain would be positioned to avoid impeding fish passage. DEP was not able to secure the permits in the absence of water quality data to justify the curtain's usefulness. Pursuant to a reevaluation of the water quality data and discussions with NYSDEC, DEP elected not to install the curtain.

2.14.4 Spill Containment Plan

DEP developed a Spill Containment Plan, modeled after the Kensico spill containment plan. The following factors were considered when developing the plan:

- Protecting public health and safety;
- Protecting the water supply and aqueduct systems;
- Continued safe operation of the water supply and DEP/City facilities;
- Employee safety;

- Potential for conflict with public uses of water supply lands (boat storage areas and fishing access);
- History of spills (DEP/DEC database);
- Environmental and visual impacts;
- Clean up and recovery capability;
- Access to potential spill/release sites; and
- Location of effluent chambers and reservoir releases

The plan to contain spills of certain pollutants that may be discharged from the stormwater drainage systems of roads adjacent to the reservoirs and their tributaries includes:

- Floating booms anchored to the reservoir shore to prevent the migration of any petroleum products discharged from roads into the reservoir. 11 booms will be permanently deployed and anchors are in place for the deployment of 14 booms that will quarantine sections of the reservoir. The booms will allow for containment, clean up and recovery of spilled substances.
- Boat ramps to access the reservoirs.
- Storage buildings to house the deployable booms, replacement permanent boom material and spill response materials.

Table 2.27. Proposed Spill Containment Plan.

Reservoir	Boat Ramps New	Boat Ramps Improve Existing	Buildings	Booms Number of Deployable & Permanent
West Branch	Shaft 9	Belden Road provide turn around, move gate off road	2 15' x 30', capable of housing boats, one at Belden Rd., one at Shaft 9	2 Deployable 3 Permanent
Boyd Corners	East Boyds Road	none	12' x12' @ E. Boyds Rd ramp	3 Deployable 4 Permanent
Croton Falls	Magnetic Mine Road, Hemlock Dam Road	Drewville Road at sharp curve, improve entrance/egress, move gate	1 12'x12' @ Mag. Mine Rd, 1 15'x'30' @ Hemlock Dam Road. Provide extra security for Magnetic Mine Rd building.	5 Deployable 0 Permanent
Cross River	none	Route 35	1 15'x30'	4 Deployable 5 Permanent

The Spill Containment Plan, including contract specifications and plans, was prepared in January 2004. The contract was registered in May 2005 and revised twice before implementation could begin. Significant changes in the Bureau's Emergency Spill Response Procedure[1] (DEP, 2005b) outlines the steps to be followed in the event of a release of a petroleum product, hazardous substance, wastewater, and/or an uncontrolled leak of a harmful material that has the potential to contaminate the drinking water supply. The plan was also revised to coordinate with other contracts and reservoir management programs (fishing access, forestry management, wetland protection). Installation is scheduled to begin in 2006.

The facilities will be incorporated into the inspection and maintenance schedule upon completion. Maintenance is similar to the Kensico spill containment facilities.

2.14.5 Impervious Cover Threshold Evaluation

A DEP program to map, analyze and track impervious cover in the watershed also included a component to evaluate the thresholds at which the water quality impacts from development are measurable and irreparable. The aerial photography to estimate impervious surface cover in east of Hudson reservoir basins was collected in the fall of 2001. While DEP and its contractors were mapping impervious surfaces, the scientific literature concerning investigations of potential correlations between impervious surface cover (development) and water quality was reviewed. The results of the literature search were used to draft a scope of work to evaluate the published "impervious cover" thresholds using east of Hudson watershed data (the impervious cover and existing water quality data). The literature suggests that the greater the area of impervious cover, the poorer the surface water quality. Some literature suggested that a threshold value of 10% impervious cover exists at which water quality impairment is observed while later work revealed that such a threshold may not exist.

The final report (NYCDEP, 2002) concluded that "there is no observable threshold of impervious cover where water quality becomes so poor the water quality standards are consistently exceeded." Instead, the data showed a slight trend towards decreasing water quality that corresponds to an increase in impervious cover. No thresholds were evident in the trend.

To gain a more comprehensive understanding of the correlation between impervious cover, any potential thresholds and water quality, DEP engaged a contractor to expand upon the 2002 evaluation (NYCDEP, 2002). The expanded investigation was designed to further evaluate, and statistically validate, substantiate or refute literature suggesting that specific percentages of impervious cover constitute thresholds at which water quality impacts (incurred by runoff from the impervious surfaces) are irreparable.

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1. The Emergency Spill Response Procedure identifies authorities that have jurisdiction over spills and releases; notification procedures; incident command system and site control, including effective site control; response and reporting procedures; and follow up evaluation requirements.

DEP's contractor refined the scope of work in 2005, to incorporate the results of the Croton Process Studies and the Croton Watershed Study's impervious cover evaluations. The paired subbasin assessment will compare environmental variables in Michael Brook in the Croton Falls watershed with the Horsepound subbasin in the West Branch watershed. The assessment is designed to supplement the understanding of impervious cover's role in creating water quality and ecological thresholds. The intent of the contract is to strengthen the statistical analyses of the water quality and biotic data and identify a threshold percentage of impervious surface, if such a threshold exists, that can be used to determine when water quality impacts will be evident and irreparable. DEP provided water quality and quantity data and some GIS data which is under analysis. A preliminary report is expected in the spring of 2006.

2.14.6 Proposed Hazardous Materials Programs

In 2004, DEP initiated a hazardous material audit of sites in four east of Hudson Catskill/ Delaware reservoir basins that generate, treat, or store hazardous materials and/or petroleum products. Sites selected for the audit program were previously identified through the CWS. The types of sites included in the audit were automobile refueling and service stations, car washes, automobile body shops, greenhouses/nurseries, pavement manufacturing facilities, mason supply shops, schools, and government facilities, among others.

Field visits included inspections of the facility by DEP staff to identify potential threats to water quality by the operations at these facilities based on previously developed protocols. DEP staff then developed recommendations for property owners based on the results of site inspection. Participation in the audit program was voluntary with the decision to participate left to the property owner.

DEP has inspected 64 of the 80 sites identified for inclusion in the program. All of the sites with improper chemical storage or other similar concern identified during initial inspections were resolved at the time of re-inspection.

2.14.7 Turf Management Chemicals

Turf Management Workgroup

DEP has participated in an interagency workgroup, spearheaded by the New York State Attorney General's Office (NYS OAG), to evaluate and develop management strategies to address the use of turf management chemicals in the New York City watershed. The group was made up of representatives from the NYS OAG, US Environmental Protection Agency, NYS Department of Health, Westchester County Department of Planning, Cornell Cooperative Extension, the New York State Turf and Landscape Association, DEP, and various non-for-profit organizations.

The interagency workgroup met approximately quarterly between 2002 and 2005. The group's main goal was to promote the use of no or low phosphorous fertilizers in the New York City watershed, to educate residents on the link between individual turf management activity and water quality, and promote soil testing prior to turf management activities. Since 2002, the group has developed educational brochures for homeowners in the watershed, produced short presentations to deliver to landscape professionals and individual residents regarding turf management and water quality, and has approach local retailers about carrying low or no phosphorous fertilizer for sale in the watershed. DEP has provided financial, technical, and political support in the in these endeavors.

Survey of Turf Management Practices

DEP, in conjunction with Cornell Cooperative Extension offices in Westchester and Putnam County, initiated a survey of individual residents and commercial landscaping firms that service residential properties throughout the east of Hudson watershed basins to evaluate existing turf management practices. The survey was funded by a Safe Drinking Water Act (SDWA) grant.

The survey was developed by DEP and CCE staff, and reviewed by scientists at the NYS OAG and Cornell University. The goal of the survey was:

- To characterize existing residential lawn care practices in the Croton watersheds (including Catskill/Delaware basins located east of Hudson). Toward that end, this study targeted both individual homeowners and commercial landscaping firms that service residential properties;
- To assess the potential for adverse water quality impacts due to over-application of lawn care products and the potential for improving lawn management practices to mitigate any adverse impacts to water quality; and
- To gauge residents' knowledge of existing lawn care resources and interest in additional educational/outreach programs.

Two survey questionnaires, one targeting homeowners and one targeting commercial landscaping companies, were developed and administered. To date, CCE has received 504 completed surveys from homeowners. This was in excess of the target of 500 responses. A total of 27 responses were received from commercial landscaping firms. The 27 responses from commercial landscaping firms fell short of the target of 50 responses. However, given the number of responses, and number of clients served by each company responding, fertilization practices of at least an additional 1,000 residents were obtained.

Currently, DEP and CCE are in the process of developing a final report that summarizes the survey findings. The report will include recommendations for future management activities that will be included in the turf and pesticide management plan. In accordance with the contract terms under the SDWA grant, the survey report is to be completed by June 2006.

The educational materials have provided watershed residents with an improved understanding of the connection between individual turf management practices and water quality. The meetings of the interagency workgroup have provided a mechanism for various stakeholder groups to discuss strategies for reducing the impact of turf management activities on water quality. Discussions between the interagency workgroup and local retailers has initiated a dialogue to address phosphorous loading from residential fertilizer application. The fertilizer survey, in conjunction with previous surveys related to pesticide use, will be an invaluable tool in formulating an effective and efficient Turf and Pesticide Management Plan.

2.15 Monitoring, Modeling and GIS

Monitoring

DEP conducts extensive water quality monitoring throughout the watershed. An "Integrated Monitoring Report" was delivered to EPA and DOH in October 2003 (DEP, 2003b). This report presented reviews of DEP's three key upstate water quality monitoring programs: Hydrology, Limnology, and Pathogens. These reviews were designed to meet the expanding scope of DEP’s data uses including requirements for watershed and reservoir models, mandates, and regulations, as well as fulfilling data needs to ensure that management requirements are adequately addressed. The programs are designed to meet the current and future data requirements of DEP.

The overall goal of the conceptual framework is to establish an objective-based water quality monitoring network, which provides scientifically defensible information regarding the understanding, protection, and management of the New York City water supply. The information needs required to achieve this goal are compiled as objectives, each of which is clearly defined (in statistical terms if possible). The list of objectives for each program was derived by compiling the information needs of existing and prospective DEP programs, and the review of legally binding mandates, agreements, and/or documents which pertain to New York City’s Watershed Water Quality Monitoring Program. The definition of objectives was the starting point for this comprehensive review because, ultimately, the objectives define the temporal, spatial, and analytical requirements of the programs. Statistical features of the historical database were used to guide the sampling design.

To ensure the most efficient gathering of data, the monitoring programs are integrated with each other through common data requirements. Several data collection programs (e.g., Hydrology and Limnology) may contribute to a single objective (e.g., Reservoir Modeling) so it is essential that data from each collection program be coordinated.

Minor changes to any of these monitoring programs are being formally documented and maintained as an annual addendum to the Integrated Monitoring Report (IMR). After a five-year period, a new version of the IMR will be issued that incorporates the changes reported in the annual addenda. Major modifications in these monitoring programs will be submitted to appropriate agencies for prior review and approval, as appropriate. These will be documented in the annual addenda and revised IMR.

Samples collected under the auspices of the Integrated Monitoring program are brought to DEP laboratories for analysis. The laboratories are certified by the New York State Department of Health Environmental Laboratory Approval Program (ELAP) for over 100 environmental analyses in the non-potable water and potable water categories. These analyses include physical analytes (e.g., pH, turbidity, color, conductivity), chemical parameters (e.g., nitrates, phosphates, chloride, chlorine residual, alkalinity), microbiological parameters (e.g., total and fecal coliform bacteria, algae), trace metals (e.g., lead, copper, arsenic, mercury, nickel), and organic parameters (e.g., organic carbon).

The data collected through the Integrated Monitoring Program is used in numerous reports. Pursuant to the City's Long-Term Watershed Protection Program, for example, DEP now produces a Watershed Water Quality Annual Report which is submitted to EPA in July of each year. This document contains chapters discussing issues, including: water quantity (e.g., the effects of droughts during the reporting period); water quality of streams and reservoirs; watershed management; and water quality models (terrestrial and reservoir). For the 2004 annual report (DEP, 2005c), the limnology and hydrology components of the document drew largely on information obtained from approximately 225 routinely-sampled reservoir and stream sites resulting in about 7,000 samples and over 99,000 analyses conducted during the year. For the pathogens component, a total of 1,895 samples were analyzed for *Cryptosporidium* and *Giardia* (oo)cysts (3,790 measurements) at 206 sampling sites (including keypoints), and 331 samples were collected for human enteric virus examination.

This data are also reported monthly (e.g., Filtration Avoidance Report and Croton Consent Decree Report), and semi-annually (e.g., DEP Pathogen Studies of *Giardia* spp. and *Cryptosporidium* spp. and Human Enteric Viruses).

DEP submits a semi-annual "Kensico Watershed Management Report" to EPA in January and July. The report’s January submission presents, discusses, and analyzes monitoring data from the Kensico Reservoir watershed. This report contains information such as fecal coliform bacteria and turbidity results obtained at various keypoint, stream, and reservoir locations. Additionally, the document reports observations from assessment of Kensico’s BMPs, groundwater, toxic substances, as well as from employment of the Kensico water quality model.

The annual Research Objectives Report (DEP, 2005d) provides the status of various research programs addressing the sources, fate, and transport of key constituents, and the status of the evaluation of data generated by other agencies. This report is essentially a supplement to the activities described in the IMR. The Research Objectives Report also addresses research on watershed processes affecting water quality such as key modeling programs. It also identifies special research projects that will be conducted during the following year. Many of the programs and their results are described in watershed monitoring seminars, and the report is posted on DEP website.

Finally, DEP recognizes the need for regular evaluation and appropriate revision and refinement of its watershed protection program. A previous assessment of the watershed, its water quality and protection activities, was conducted five years ago (DEP, 2001). The watershed protection program includes, but is not limited to, remedial activities, protection activities, land acquisition and the Watershed Rules and Regulations. The data generated through DEP's extensive monitoring program (described above), in conjunction with other defensible scientific findings, is used to conduct the City's assessment of the effectiveness of the watershed protection program. Information on water quality trends in streams, reservoirs and at keypoint locations used in this assessment, for example, will draw upon data collected from 1993 through 2004. Details about how the data have been used in the Status and Trends analysis sections of this report (Chapters 3-6) are described in Appendix 3.

Modeling

DEP has developed a eutrophication modeling system, consisting of the GWLF watershed-loading model linked to a reservoir receiving water model, to evaluate the effects of land use, watershed management, and climate on nutrient loads and trophic status of NYC reservoirs. The modeling system was used in 2001 to evaluate the effectiveness of watershed programs to control eutrophication in the Cannonsville and Pepacton basins (DEP, 2001). Since then the models have been improved, monitoring data to support modeling has been expanded and updated, and additional GIS data has been developed and incorporated. The model applications in the current FAD Assessment utilize these improvements.

The eutrophication modeling system has been developed with the capability to evaluate non-point source (NPS) management practices as well as Point Source (PS) reductions. This involves: quantification of Best Management Practice (BMP) implementation by watershed programs; estimation of BMP nutrient reduction efficiencies by literature review and data analysis; and application of BMP efficiencies and implementation rates to source-specific GWLF loading estimates. The simulations resulting from watershed scenarios that evaluate various BMPs are then used as loads to the reservoir water quality model. The output from the reservoir model is a probabilistic frequency distribution of a given water quality parameter. The results of these model outputs can be compared against a baseline (prior to implementation of BMPs) option, or they can be evaluated to see how effective these watershed strategies are in meeting specified reservoir water quality goals. This strategy for evaluation NPS management practices (Figure 2.50) and PS reductions is used in the current FAD assessment.

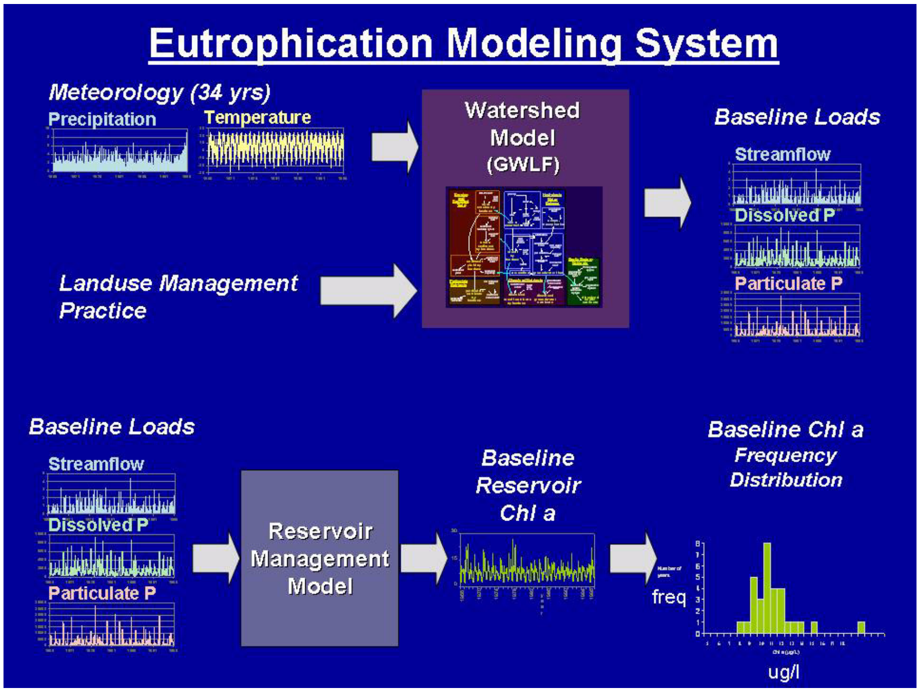


Figure 2.50 NYC DEP's Eutrophication Modeling System for evaluating land-use management practices.

The GWLF model (Haith *et al.*, 1992; Schneiderman *et al.*, 2002) is a lumped-parameter model that simulates water, nutrients and sediment loads from non-point and point sources. The model generates the following daily time series that are subsequently used as input for the reservoir receiving-water model:

- streamflow,
- dissolved phosphorus and nitrogen from non-point and point sources, and,
- particulate phosphorus from non-point and point sources
- total suspended solids (TSS)

Loads in surface runoff from different land uses, sub-surface flows including inputs from septic systems, and from point sources are explicitly tracked in GWLF and summed to provide total loads delivered to the reservoir.

A major improvement in the GWLF watershed model was made in 2004 by incorporating Variable Source Areas (VSAs) into the model (DEP, 2005e). This modification was made to address the growing body of evidence that the predominant mechanism for runoff generation in the NYC watersheds is saturation-excess on VSAs, as opposed to an infiltration-excess runoff generating mechanism upon which the standard GWLF is based. The revised GWLF model simulates runoff volumes using the US Soil Conservation Service (SCS) Curve Number (CN) Method, similarly as in the standard GWLF model, but spatially-distributes the runoff response according to a soil wetness index. The spatial distribution of runoff by soil wetness index provides a more realistic identification of runoff generating areas in the NYC watersheds, with important consequences for simulation of pollutants that are typically transported by runoff. Use of the revised GWLF model with VSAs in the current FAD Assessment increases the accuracy and spatial resolution of watershed management scenarios, and gives greater focus on watershed management practices that influence nutrient transport in surface runoff.

Other GWLF model improvements were made in 2004 (DEP, 2004a; DEP, 2005e). A runoff Curve Number (CN) parameter calibration procedure was developed, applied and tested on 31 USDA-gauged WOH watersheds. Calibration of CN parameters greatly improved accuracy of simulated runoff when compared to baseflow-separated runoff data. An alternative formulation of the CN algorithm that is used in the Soil and Water Assessment Tool (SWAT) model (Arnold *et al*., 1998) was also tested, and incorporated into DEP's GWLF model. This alternative algorithm was found to produce good runoff results and is more compatible with the method used to incorporate VSAs into GWLF. Additional GWLF improvements in 2004 included algorithms for evapo-transpiration from saturated areas, and lagging of surface runoff by travel time through the stream network.

Improvements to the NYC reservoir eutrophication models have focused on simulation of sediment re-suspension and the effects of sediment re-suspension on phosphorus cycling and light attenuation (DEP, 2003c). A diverse and extensive program of measurements and process studies was conducted to support the development of modeling algorithms describing sediment re-suspension and its related effects. Based on an extensive program of measurements and process studies, the reservoir nutrient-phytoplankton models were upgraded to include:

- A new inorganic particle/particulate matter sub-model that adds inorganic (or fixed) suspended solids as a model state variable (predicted by the model).
- A modified phosphorus sub-model to accommodate the effects of phosphorus adsorption/desorption associated with re-suspended inorganic particulate matter. Mass balance calculations are conducted on a new state variable in this sub-model, total reactive phosphorus, composed of both particulate reactive (subject to adsorption/desorption transformations) and soluble reactive components.
- A strong empirical relationship that was developed from observations, that describes the influence of suspended sediments on the underwater light levels that regulate phytoplankton growth.

Use of the updated reservoir models in the current FAD Assessment improves predictions of suspended solids, particulate phosphorus and parameters related to phytoplankton primary production.

Geographic Information System (GIS)

The upstate Geographic Information System (GIS) was used throughout the BWS for mapping, spatial analysis, data development, visualization and analysis of remotely sensed imagery, and water quality modeling. These activities supported numerous FAD and MOA watershed management applications as described in annual and semi-annual reports to EPA.

System growth and expanded use were evident in: application of GIS resources to the diverse program activities of several Divisions; significant hardware and software upgrades; transition to an object-oriented data model; automated library replication from a central server to distant sites; full-time, in-house contractual support; an increased number of better-trained users; and continued conscientious efforts of data acquisition, management, and dissemination.

Thousands of hardcopy and digital map products were used to plan, implement, track, and review FAD and MOA programs. Among others, these programs included: land acquisition, land management, watershed agricultural, and stream management programs; watershed management, wildlife, and wetland studies; water quality monitoring and impact assessment; terrestrial and reservoir modeling; stormwater and sewer infrastructure inspection and remediation; SEQRA review; project locations; project site constraints; and stormwater management and erosion abatement. The GIS was used more extensively for emergency planning, watershed communications, and security.

Notably, maps were created for a December 2003 press conference at City Hall with Mayor Bloomberg. The event recognized the Land Acquisition Program's milestone of acquiring 50,000 acres for watershed protection and the City's commitment of an additional $25 million to the Croton acquisition effort. Graphics were produced for the press to use as reference materials in newspaper articles.

In addition to map products, these FAD and MOA program activities often required extensive and sophisticated spatial analyses. Of particular significance were those supporting DEP's review of the Crossroads Ventures proposed Bellayre Resort. Maps, data, and statistical information were used to inform BWS Management, DEP Legal, and the Commissioner of the status and potential impacts of the project.

The GIS was used not only to develop criteria for program implementation, but also to identify constraints to implementation. It was used to establish baseline documentation and initial conditions for a variety of projects. Spatial analyses and maps were important to fulfilling mandated reporting requirements.

The BWS upstate GIS was integrated as a component of other BWS information systems at varying stages of development. The Watershed Lands and Information System (WaLIS) linked data from the Land Acquisition Tracking System (LATS) to tax parcel data and other appropriate spatial features. WaLIS allowed the user to retrieve information about any property as well as track city activities and communications related to DEP lands. Similar information systems were under development for Engineering Project Review and Regulatory Compliance, and Streambank Protection. The Division of SEQRA Coordination and Watershed Management Programs commissioned the development of a GIS-based pilot computer assisted facilities management system, initially designed to address DEP's Kensico watershed protection programs but expanding to the other EOH Catskill/Delaware reservoirs.

Upstate GIS staff developed, managed, and disseminated spatial data. Significantly, the GIS spatial data library was converted from the NAD 1927 datum to the NAD 1983 datum, keeping the BWS current with national standards and facilitating data sharing with collaborators. Given the datum conversion, the ESRI geodatabase model, a third-generation, object-oriented model for representing geographic information, was implemented. The geodatabase was deployed within Oracle using ArcSDE (ESRI), a gateway for managing spatial data in a relational database management system. The geodatabase was in full-production use and replicated nightly from Kingston to Valhalla. Staff continued to maintain and update the GIS coverage library. It was routinely duplicated to Valhalla, Grahamsville and Ashokan. These processes of replication and duplication ensured that staff accessed a common data source.

The BWS contracted for several data development efforts during the reporting period. Significant deliverables included: a 10-meter land-cover/land-use classification based upon 2001 Enhanced Thematic Mapper satellite imagery, supplemented with information from tax parcel and other ancillary data; a 1-foot raster of impervious surface extracted from EMERGE and NYS digital orthoimagery; surrogate locations for individual septic systems derived from impervious surface and tax parcel data; an update of the National Wetlands Inventory and the EOH wetlands trend analysis; and LIDAR elevation data for more precisely delineating reservoir shorelines and stream channel topography.

Spatial data were also acquired from the NYS Data Sharing Cooperative, the Cornell University Geospatial Data Information Repository (CUGIR), and other sources. These included DOT political boundaries, NYS ALIS roads, SSURGO2 soils, the National Hydrologic Dataset, and 2001 NYS orthoimagery. In-house work continued on creating new data and periodically updating existing layers, including tax parcels and associated derivative datasets portraying land ownership, water quality monitoring locations, and hydrologic buffers.

The data development effort also was focused upon thematic layers necessary for modeling of nutrient and sediment loading, and transport. These layers included updated versions of runoff curve number, erosion potential, wetness index, land cover/land use, and drainage areas above water quality monitoring sites. The modeling effort was linked to the GIS by the GWLF-VSA Inputs Tool, developed in-house to derive terrestrial model inputs from spatial data, the AVSWAT2000 extension for ArcView 3, and the NRCS Soil Data Viewer. Spreadsheet tools were also used to evaluate and format GIS-derived data for model input.

Throughout the reporting period staff shared data with contractors, researchers, government agencies, environmental non-profits, regulators, and other stakeholders according to data sharing policies developed in cooperation with DEP Legal. In lieu of not having a data dissemination internet site due to security issues, the data were shared by CDROM and email.

ArcIMS (ESRI) was successfully installed as a server-based GIS application, one of several information services directly linked to an internal web site supported by the BWS, and configured to work with pre-selected GIS feature datasets managed in the geodatabase. The application allowed staff to use MS Internet Explorer browsers for access to GIS data. The service was available to all DEP employees with network connections to the BWS intranet. An ArcIMS map service was also deployed as a tool for Division of Engineering project review.

BWS upstate GIS infrastructure was substantially upgraded throughout the reporting period. ArcGIS (ESRI) software was installed for all users and upgraded regularly. Staff continued to use other packages, including ArcInfo, ArcView 3, ERDAS Imagine, and MrSid GeoExpress. Desktop PCs were identically configured to access the spatial data stored in server libraries.

Four SUN V880 Unix servers were acquired; two were deployed for library replication between the Kingston and Valhalla sites. Individual workstations were regularly replaced in response to new computing and data storage requirements. Additional GPS units were obtained for field data collection; hand-held computers with ArcPad (ESRI) were also used for this purpose. New large-format plotters, large-format color scanners, and tabloid-size color printers were purchased. Hard drives, backup power supplies, and other peripherals were routinely upgraded.

DEP GIS staff members were assisted in these extensive programs of data development and system administration by full-time, on-site contractors. An ArcSDE/Oracle Database Administrator established the geodatabase at Kingston and Valhalla and oversaw its structure and functioning. An UNIX/Windows System Administrator handled a variety of hardware and software requirements, including regular backup of all servers. A GIS Specialist worked predominantly on FAD and MOA projects falling within the purview of the Division of Watershed Lands and Community Planning but also provided general support for BWS GIS and GPS activities.

GIS staff members continued their professional development. Nearly 100 people participated in on-site, 2-day ESRI training in ArcGIS. Several attended more specialized workshops and participated in monthly ESRI on-line seminars. GPS training was offered in-house by WayPoint Technologies and BWS staff. The Kingston and Valhalla sites each had meetings of GIS staff to review and influence development of the upstate GIS.

GIS staff members were involved in the larger GIS community. Papers were presented at the ESRI International User Conference and the NYS GIS Conference. Others attended these events, as well as meetings of the Northeast Arc User Group, the Capital District Arc User Group, the Catskill GIS User Group, and the NYS Remote Sensing Symposium.

The upstate GIS continued to evolve as an enterprise solution supporting programmatic requirements of the Bureau and other stakeholders. Supported by DEP staff and in-house consultants, the GIS provided an increasing number of users throughout the Bureau with access to hardware, software, and spatial data appropriately configured to support diverse applications. A collaborative and deliberate planning process moved the GIS towards this more mature implementation, a process that continues.

2.16 Disease Surveillance Program

New York City's Waterborne Disease Risk Assessment Program was established to: (a) obtain demographic and risk factor data on case-patients with giardiasis and cryptosporidiosis, (b) provide a system to track diarrheal illness to assure rapid detection of outbreaks, and (c) determine the contribution (if any) of tap water consumption to gastrointestinal disease. The Program, jointly administered by the Department of Health and Mental Hygiene (DOHMH) and the Department of Environmental Protection (DEP), began in July 1993 with the establishment of the Parasitic Disease Surveillance Program and the implementation of active laboratory surveillance of giardiasis. Over the years the Waterborne Disease Risk Assessment Program (or WDRAP) has been enhanced and modified with the addition of cryptosporidiosis active disease surveillance and the implementation of syndromic surveillance systems.

Active Disease surveillance, which is the original foundation of WDRAP, was implemented to ensure complete reporting of all laboratory-diagnosed cases of giardiasis and cryptosporidiosis, and to collect demographic and risk factor information on cases. Syndromic surveillance systems have been implemented with the aim of monitoring gastrointestinal (GI) disease trends in the general population via tracking of sentinel populations or surrogate indicators of disease. Such syndromic tracking programs provide greater assurance against the possibility that an outbreak would remain undetected.

In 2001, organizational changes were made and the staff of the Parasitic Disease Surveillance Unit was merged with staff from the DOHMH Bureau of Communicable Disease. Staff members employed by DEP and DOHMH now work jointly on the Parasitic Disease Surveillance Program activities as well as on other communicable disease activities. This merger greatly improves the efficiency of the office and gives both units access to more resources but does not in any way detract from the Parasitic Disease Surveillance Program operations. For purposes of this report, staff will be referred to as "DOHMH staff."

Data collected from WDRAP programs are reported to EPA three times a year. Beginning January 2003, data collected from WDRAP programs have been reported to EPA on a semi-annual and annual basis (rather than a quarterly basis and annual basis, as has been done in the past). The semi-annual reports contain primarily case rates and demographic findings (and data are preliminary), while the annual report contains final rates, demographics, and also information from cryptosporidiosis case-investigations, including break-downs of exposure risk factors by immune status. Both reports also include syndromic surveillance data. Reported cases of both cryptosporidiosis and giardiasis have been declining in NYC as well as nationally. This year, however, we have begun a more in-depth analysis of the demographic and exposure risk factor data.

2.16.1 Active Disease Surveillance

DOHMH staff perform active disease surveillance at laboratories licensed to do testing for *Giardia* or *Cryptosporidium* on specimens from New York City residents. Laboratories are visited to obtain all positive results, or called if the laboratory is located out of state. All clinical laboratories located in New York City holding a New York State Department of Health Parasitology Permit and currently performing parasitology examinations for *Giardia* and *Cryptosporidium* (n=47), as well as certain laboratories outside of New York City which receive specimens from New York City residents (n=7), are contacted on a regular basis to solicit case reports on all positive specimens.

Interviews of all case-patients with giardiasis were completed from 1993-1995. However, beginning in 1995, the focus of case-investigations shifted to cryptosporidiosis and interviews of patients with giardiasis were only completed for those patients with giardiasis who had a risk factor for transmission of disease in an employment or group care setting (foodhandlers, daycare attendees etc.). Letters continue to be sent to physicians to determine basic demographic information missing from giardiasis case reports. Active laboratory surveillance for cryptosporidiosis began in November 1994 and cryptosporidiosis patient interviews were initiated in January 1995. All patients diagnosed with cryptosporidiosis continue to be interviewed regarding their risk factors for illness.

A preliminary look at trends using a poisson regression model demonstrates a significant decline in rates of cryptosporidiosis among patients who are immunocompromised ($P < .01$) from 1995-1997. This decline is generally thought to be due to highly active anti-retroviral therapy (HAART) which was introduced from 1996-1997. The poisson model showed no significant decline since 1997 among immunocompromised patients ($P = .14$) suggesting that the effect of HAART has plateaued. Using poisson regression to compare immunocompromised patients to immunocompetent patients showed the overall decline from 1995 to 2004 was significantly greater in patients who were immunocompromised than in those who were not ($P < .01$).

DOHMH also collects information on risk factors from patients. While we do not collect information from control patients, data can be compared between patients who are immunocompromised and patients who are not. Looking at four main risk categories using the chi square test for comparison of data since 2001, patients who were immunocompetent were significantly more likely to report international travel in all years ($P < .01$) and recreational water use in most years (2001-2002 $P < .01$, 2003 $P = .17$, 2004, $P < .05$). There was no statistically-significant difference among these two groups in the proportion of cases reporting animal contact or high risk sex. It should be noted that high risk sex in this context refers to having a penis, finger or tongue in a partner's anus. Information about sexual practices is gathered via phone interview and may not be reliable. It does appear, based on these data that immunocompetent patients are more likely to acquire the illness when traveling to endemic areas than immunocompromised patients. Based on these data we cannot comment on whether or not either group of patients was more likely to acquire illness due to sexual practices.

Regarding giardiasis, poisson regression analysis showed an overall decline in cases of giardiasis from 1995 to 2004. Additional analyses showed the decline was significant in males ($p < .01$) and females ($p < .01$) and was also significant in all age groups (< 10, 10-19, 20-44, 60 + years $P < .01$) except the 45-59 age group (P=.055). The decline in both sexes and across age groups suggests that it is not related to HAART. Although it is unclear why the rates have declined, this decline has been seen nationally*, and it does not appear to have to do with the water supply since testing for *Giardia* at the source water supply keypoints for New York City has revealed quite stable results over the same time period**.** (* MMWR 2005;54;SS01:9-16. Hlavsa MC, Watson JC, Beach MJ. Giardiasis surveillance---United States, 1998--2002.)

2.16.2 Syndromic Surveillance

In addition to our active disease program, WDRAP maintains a syndromic surveillance program. Syndromic surveillance systems collect data not on etiologic diagnosis, but on symptoms, such as chief complaints in emergency room visits, or on behaviors, such as purchasing of over-the-counter medications, or ordering of tests. Such surrogate markers of disease may provide indication of an outbreak prior to the establishment of an etiologic diagnosis. This may be especially important in the case of cryptosporidiosis since *Cryptosporidium* is not routinely included in standard tests done on stool specimens for diarrheal illness and many people may attempt to self-treat diarrhea before presenting to a doctor's office. Over the past several years, the City has established and maintained a number of distinct and complementary outbreak detection systems.

There are essentially four components to the syndromic surveillance system as described below. One system monitors and assists in the investigation of GI outbreaks in sentinel nursing homes. Another monitors the number of stool specimens submitted to clinical laboratories for microbiological testing, and a third system utilizes hospital Emergency Department chief complaint logs to monitor for outbreaks. NYC also utilizes three systems for monitoring sales of anti-diarrheal medication. One tracks the weekly volume of sales of non-prescription anti-diarrheal medication at a major NYC drug store chain. An additional pharmacy system tracks daily sales of over-the-counter anti-diarrhea medications at another drug store chain (referred to as the OTC system). A third system tracks retail pharmacy data obtained from the National Retail Data Monitor (referred to as the NRDM system). All systems rely upon the voluntary participation of the institutions providing the syndromic data.

In 2001, the program commissioned the Center for Urban Epidemiologic Studies to evaluate the city's syndromic surveillance programs. The study, titled "*Evaluation of New York City's Syndromic Surveillance for Diarrhea,*" made recommendations, including that a move should be made to more electronic use of data. Some of the changes in the syndromic program occurred were a result of the WDRAP team's consideration of that report and others were made as a result of the team's experience with the systems and improved funding. For example, in 2002, a new anti-diarrheal medication system with daily, electronic reporting was added and significant changes have been made to other systems as well. Significant changes were also made to the nursing home system and a statistical program, CUSUM was added to the clinical laboratory system.

Nursing Home Sentinel Surveillance

The nursing home sentinel surveillance system began in March of 1997 and was modified significantly in 2002, at which time nine New York City nursing homes were participating. Under the original system, nursing homes in the five city boroughs, serving different populations (i.e., serving persons with HIV/AIDS, persons without HIV/AIDS, and mixed populations), reported the daily number of cases of diarrhea in the nursing home. The number of cases reported was most commonly zero. The NYAM evaluation recommended changing this system given that the data did not appear to be that useful. In response to recommendations in the NYAM evaluation, DOHMH conducted a survey to determine whether Nursing Home Sentinel Surveillance could be made more acceptable to facility participants and whether data quality could be improved. Based on the results of this survey, the system was changed in 2002. Under the current system the daily reporting requirement has been eliminated. The emphasis is now placed on specimen collection as part of outbreak investigations with the goal of determining etiologic agents. When a participating nursing home notes an outbreak of gastrointestinal illness that is legally reportable to the New York State Department of Health, the nursing home also notifies DOHMH. Such an outbreak is defined as onset of diarrhea and/or vomiting involving 3 or more patients on a single ward/unit within a 7-day period, or more than the expected (baseline) number of cases within a single facility. All participating nursing homes have been provided with stool collection kits in advance. When such an outbreak is noted, specimens are collected for bacterial culture and sensitivity, ova and parasites, *Cryptosporidium* and viruses. DOHMH Bureau of Communicable Disease staff facilitates transportation of the specimens to the City's Public Health Laboratory. Testing for culture and sensitivity, ova and parasites, and *Cryptosporidium* occurs at the Public Health Laboratory. If preliminary tests for bacteria and parasites are negative, specimens are sent to the New York State Department of Health laboratories for viral testing. All nine nursing homes are participating in the current system. As feedback, nursing homes are provided with copies of Waterborne Disease Risk Assessment Program semi-annual and annual reports. One advantage of the current system is that, in the event of concern regarding a citywide outbreak, DOHMH has easy access to specimens which can be collected and tested promptly in an effort to make an etiologic diagnosis.

Since implementation of the new system in August, 2002, there have been 9 reported GI outbreaks in participating nursing homes. Five of them were in 2003. Bacterial and parasitic specimens collected in those outbreaks were all negative, and 13 of 17 specimens submitted for viral testing were positive for norovirus. In 2004 there was one outbreak; stool specimens submitted for bacterial, ova and parasite and viral testing were all negative. In 2005 to date, there have been 3 GI outbreaks. In an April, 2005 outbreak, the facility determined that 5 of 6 specimens from ill residents were positive for Clostridium difficile and notified DOHMH of the etiologic agent. As the etiology of this cluster was clear, no tests were done for *Cryptosporidium*. In a September, 2005 investigation, DOHMH determined that specimens from 2 ill residents were negative for O&P and *Cryptosporidium*. A recent outbreak that began in late November, 2005 is still under investigation. None of the outbreaks were found to be due to cryptosporidiosis or other water-related illness.

Clinical Laboratory Monitoring

The number of stool specimens submitted to clinical laboratories for bacterial and parasitic testing also provides information on gastrointestinal illness trends in the population. This is especially important because *Cryptosporidium* is not included in the standard ova and parasite panel when providers request stool testing. DOHMH has been monitoring clinical laboratory submissions since 1995. Participating laboratories transmit data by fax or by telephone report to DOHMH's Bureau of Communicable Disease indicating the number of stool specimens examined per day for: (a) bacterial culture and sensitivity, (b) ova and parasites, and (c) *Cryptosporidium.* Participation of two clinical laboratories (Laboratory A and Laboratory B) continued through 2005. A third clinical laboratory (Laboratory C), which had been participating in the Clinical Laboratory Monitoring system since 1995, discontinued business operations in March 2004.

Clinical Laboratory Monitoring results are reviewed upon receipt. Daily data is received weekly. Prior to August 2004, reviewers visually compared current results to previous data to assess whether current submissions appeared to be unusually high. Beginning in August 2004, DOHMH started implementation of a computer model to establish statistical cut-offs for significant increases in clinical laboratory submissions. First, raw data are adjusted for average day-of-week and day-after-holiday effects using a linear regression model applied to the historical dataset, beginning November 1995 and continuing to the present for Laboratory A and beginning January 1997 and continuing to the present for Laboratory B. Sundays and holidays are removed because the laboratories do not test specimens on those days. Next, the cumulative sums

(CUSUM) method is applied, using a two-week baseline, to identify statistically significant aberrations (or "signals") in the adjusted submissions for ova and parasites and for bacterial culture and sensitivity. CUSUM is a quality control method that has been adapted for aberration-detection in public health surveillance. (CUSUM is described further in: Hutwagner L., Maloney E., Bean N., Slutsker L., Martin S. Using Laboratory-Based Surveillance Data for Prevention: An Algorithm for Detecting Salmonella Outbreaks. *EID.* 1997; 3(3): 395-400.)

Signals, especially those sustained for more than one day, may trigger phone calls to the laboratories to assist in the determination as to whether the increase in submissions may be due to an internal business event (such as a merger with another laboratory) or to a change in the health status of the community served by the laboratory. In general, patient-level follow-up is not done based on clinical laboratory signals. Rather the system is compared with other syndromic systems. Signals for GI illness in multiple systems may trigger an investigation.

Anti-diarrheal Medication Monitoring

The monitoring of sales of anti-diarrheal medication (ADM) is a useful source of information about the level of diarrheal illness in the community. New York City now utilizes three systems for tracking ADM sales. Two of these systems have been added since 2001. As reported in the 2001 FAD report, an earlier ADM program involving a regional independent distributor to pharmacies had to be discontinued due to market shifts away from independent pharmacies.

In the first program, volume-of-sales information of non-prescription ADMs is obtained on a weekly basis from a major drug store chain. Information is also obtained on the chain's promotional sales. Weekly sales volume data (i.e., electronic point-of-sale data for loperamide and non-loperamide ADMs) is graphed and visually compared to data collected since the program's inception in 1996. In interpreting the data, consideration is given to the weekly promotions of monitored products.

In 2002, a new more comprehensive monitoring system for over-the-counter (OTC) drugstore sales was established with a second large pharmacy chain. The goal was to develop a system that would provide more timely and detailed data than the existing ADM tracking system. The new OTC system better serves bioterrorism surveillance since it also collects data on other medicines, including GI remedies. In August 2002 daily electronic transmission began. Each daily file contains data on an average of 6,000 prescription and 32,000 non-prescription medication sales. Routine daily analyses began in mid-December 2002. Drugs are categorized into key syndromes, and trends are analyzed for citywide increases in sales of anti-diarrhea and cold medications. The GI category contains only non-prescription medications and includes generic and brand name loperamide-containing agents and bismuth subsalicylate agents. As this system is more automated than the ADM system we are currently considering integrating the ADM system into the OTC system. This would assure the reception of more up-to-date data from the pharmacy chain participating in the ADM system, and more automated analysis of data. However, participation in all of these systems is voluntary and would involve a time commitment on the part of the pharmacy to switch to an automated system.

In May 2003, DOHMH began receiving daily data from a third tracking program, the National Retail Data Monitor (NRDM). This system, operated by the University of Pittsburgh, gathers retail pharmacy data from national chains for use in public health surveillance. The NRDM provides a daily file containing over-the-counter "stomach remedies" (bismuth subsalicylate, attapulgite, and loperamide) and electrolyte sales data from retail stores located in New York City. Citywide counts are adjusted for day-of-week variability and analyzed using the CUSUM method with a two-week baseline. The data received by the City is aggregate and therefore less reliable and more difficult to analyze than the OTC data, however, it does cover pharmacies not in the OTC or ADM database and therefore provides an additional data source to check when there are signals.

The data from these systems is not linked to any patient level information, so signals usually trigger a comparison to other data systems. If signals are noted in multiple systems, investigations will occur through the Emergency Department system which links to patient contact information, or through Nursing homes or other means. Over the years the system of when to investigate has been refined, however, none of the investigations have ever suggested a problem with the water-related illness. All citywide signals have seemed consistent with seasonal viral trends.

Emergency Department Data

DOHMH currently receives electronic data from 48 of New York City's 64 emergency departments (EDs), reporting 9000 visits per day, roughly 89% of ED visits citywide. Hospitals transmit electronic files each morning containing chief complaint and demographic information for patient visits during the previous 24 hours. Patients are classified into syndrome categories (the two syndromes for gastrointestinal illness are vomiting and diarrhea), and daily analyses are conducted to detect any unusual patterns. Data are analyzed every day (including weekends and holidays) for both citywide trends and spatial clusters. Temporal ("citywide") analyses assess whether the frequency of ED visits for the syndrome has increased in the last one, two or three days compared to the previous fourteen days. The spatial analyses scan the data for "clustering" of syndrome visits by two geographic variables, hospital and residential zip code. A single day of ED visit data is compared by syndrome and geographic variable to the previous fourteen days. Unusual clusters are denoted as signals and statistically this is determined by ranking the cluster in question alongside 9999 simulated distributions of the data to produce a Monte Carlo estimate of the probability. Significant signals are defined as a probability of the clustering occurring fewer than 50 times out of 10000. (The system is described further in: Heffernan R., Mostashari F, Das D., Karpati A., Kulldorf M., Weiss D. Syndromic Surveillance in Public Health Practice, New York City. *EID*. 2004; 10(5): 858-864.)

Summary of Syndromic Data Since 2001

Although WDRAP has included syndromic surveillance data since its inception, beginning in 2001 two new systems, the OTC pharmacy system and the Emergency Department System were added. In addition, the clinical laboratory and nursing homes have been significantly revised since that time.

The data from our syndromic surveillance systems have proven useful to us in demonstrating annual citywide outbreaks of norovirus and rotavirus. Demonstration of these trends is useful in two ways. First, it provides us with a general baseline to understand what is happening which allows us to determine whether or not activity is unusual. Investigations of these annual citywide trends of diarrhea and vomiting suggest that they are caused by norovirus (during fall and winter) and rotavirus (during the spring). We also detected one citywide increase in diarrhea following a citywide blackout in 2003 where illness was thought to be due to food spoilage. (Marx MM, Rodriguez CV, Greenko J, Das D, Heffernan R, Karpati AM, Mostashari F, Balter S, Layton M, Weiss D. Diarrheal illness detected through syndromic surveillance after a massive power outage, NYC, 2003. *AJPH (in press)*).

Our experience in detecting citywide increases in gastrointestinal symptoms during these seasonal gastrointestinal viral outbreaks, and after the power outage suggest that these systems would likely also be useful in detecting a large, city-wide outbreak of gastrointestinal illness due to *Cryptosporidium.* Traditional surveillance, which depends on laboratory testing, might take longer than syndromic systems, since appropriate diagnostics for *Cryptosporidium* might not routinely be done for affected patients.

A recent review of syndromic surveillance for smaller GI outbreaks suggests that these systems may not be as good as traditional surveillance involving laboratory and physician reporting in detecting small, localized outbreaks. DOHMH receives reports of outbreaks from a variety of sources including physicians, schools, restaurants and patients themselves. Section 11.03(b) of the NYC Health Code requires immediate reporting of a suspect outbreak among three or more persons, and members of the Bureau of Communicable Diseases give talks throughout the city promoting awareness of the need for reporting not only notifiable diseases but suspect outbreaks. In 2004, we did a review of syndromic surveillance signals and GI outbreaks reported to DOHMH through other means (Balter S, Weiss D, Hanson H, Reddy V, Das D, Heffernan R. Three years of emergency department gastrointestinal (GI) syndromic surveillance in New York City: what have we found? *MMWR* 2005;54(suppl): 175-180). During the study period, 98 citywide signals and 138 spatial GI outbreaks were identified. Multiple outbreaks suspected to be caused by the seasonal occurrence of norovirus and rotavirus were identified. Of citywide signals, 73 (75%) occurred during these annual outbreaks. During the same time period, 49 localized GI outbreaks were reported to DOHMH; none was simultaneously detected by syndromic surveillance. Since that time, syndromic surveillance did detect one local foodborne outbreak, although this outbreak had been reported by providers in two emergency departments one day prior to the syndromic signal. (Syndromic Surveillance Case Study: Detection of an Outbreak of Gastroenteritis in New York City. Marc Paladini MPH, Richard Heffernan MPH, Farzad Mostashari MD MSc, Don Weiss MD MPH, Heather Hanson MS, Faina Stavinsky MS, Vasudha Reddy MPH. Presented at the Fourth Annual Syndromic Surveillance Conference, Seattle, 2005).

Syndromic surveillance has thus far not been useful in detecting small, localized GI outbreaks in NYC. One reason is that by setting the sensitivity of the system to potentially detect localized outbreaks, too many false signals are generated that require investigation and compete for staff resources conducting traditional surveillance activities. Another problem is misclassification. Patients with GI complaints such as vomiting as their chief complaint may have another underlying problem, such as a cerebral hemorrhage or meningitis. Similarly, patients with other chief complaints, such as headache and fatigue may have GI complaints which are the underlying cause of the chief complaint. Although less a problem during large-scale citywide outbreaks, misclassification of patients who have other underlying problems obscures limited, localized signals caused by real outbreaks and can cause spurious signals composed of unrelated cases. The development of rapid, point-of-care diagnostic assays for gastrointestinal pathogens that allow clinicians to make rapid diagnoses as with influenza may help address this in the future.

In addition to Syndromic Surveillance's utility in detecting large city-wide outbreaks of the magnitude and geographic distribution that might be seen if there were contamination of the City's water system, syndromic surveillance has provided reassurance during times of concern (e.g. the 2001 anthrax attacks), states of elevated security (e.g. during the 2004 Republican National Convention), and during turbidity elevations or seasonal *Giardia* increases in the water supply, that an excess number of patients citywide had not sought care. Although it may not have proven value as an early warning system so far, it has functioned as a back-up system to traditional surveillance. Also, syndromic surveillance may *indirectly* aid in the detection of small outbreaks by strengthening relationships with emergency departments, nursing homes, clinical labs, pharmacies, etc., so that providers are more likely to report any unusual findings to DOHMH.

More research into the use of syndromic surveillance data is needed to see whether additional data or analyses can be used to make the systems better able to detect acute localized outbreaks. Using additional data or more refined coding or statistical algorithms may improve the ability to detect localized outbreaks. DOHMH's syndromic surveillance unit continues to conduct on-going research and modeling of the data and collaborates with outside agencies and academic institutions that are looking at ways to make such systems more useful. Additionally, a pilot project has been started with Bellevue Hospital to look at the feasibility of routine rapid diagnostics in order to more rapidly identify etiologic agents during citywide signals.

2.16.3 Community Outreach

Community outreach is an important part of the DOHMH's activities. On a regular basis members of the Bureau speak to providers in the community about what the Health Department does and about the importance of disease reporting. When requested, staff members give specific talks about waterborne illness and the City's water system. In addition, the DOHMH has an emergency health alert system that allows us to send health alerts to providers and community groups through a fax and e-mail system when health emergencies arise. This system has been used for water-related illness twice since 2001. In 2002, an elevation in the numbers of *Cryptosporidium* oocysts was noted on routine testing. At that time an alert was sent to providers and community groups alerting them to the issue and reminding them that NYC water is not filtered and severely immunocompromised patients who wish to reduce their risk of possibly contracting cryptosporidiosis should consider drinking bottled or filtered water. The second time occurred in 2005 following severe rains and an increase in turbidity. A provider alert was sent at that time advising at-risk populations of a possible slight increased risk of giardiasis.

Additionally, DEP and DOHMH participated in a focus group as part of a study being done by George Washington University, with funding from AWWA Research Foundation, which evaluated communication among water and health agencies and the community. Two community physicians were invited to participate in the study giving the DEP and DOHMH a chance to understand how providers receive and use our information. NYC's level of communication between agencies was viewed as very high in comparison with other systems studied.

2.16.4 Conclusions

Since 2001, substantial changes have been made in the WDRAP program, especially in the area of syndromic surveillance with the addition of two pharmacy systems and the emergency department system. In addition, changes were made to the clinical lab system to allow for more standardized analyses, and in nursing home sentinel surveillance. These changes provide us with greater data on behaviors and syndromic complaints that may allow us to identify a city-wide diarrhea outbreak earlier than traditional methods. Our increased experience with this type of data has also allowed us to better understand its strengths and limitations. The merger of the Parasitic Disease Surveillance Unit with the main Bureau of Communicable Disease Surveillance Unit increased our efficiency in the area of traditional active surveillance. Since the last FAD assessment in 2001, there has been no evidence of an outbreak of waterborne disease in NYC. In the coming year we are planning to continue to enhance our analyses of epidemiologic data to allow us to identify any changing trends in giardiasis or cryptosporidiosis, should they occur. We will also continue to do community and provider outreach and maintain our active surveillance which is the core of the WDRAP program.

3. The Catskill System

3.1 The Schoharie Basin

Schoharie Reservoir is located at the intersection of Schoharie, Delaware and Greene Counties, about 36 miles southwest of Albany and roughly 110 miles from New York City. Placed into service in 1926, it was formed by the damming of the Schoharie Creek, which continues north and eventually drains into the Mohawk River, which flows into the Hudson north of Albany. The reservoir consists of one basin, almost 6 miles in length and holds 17.6 billion gallons at full capacity.

Figure 3.1 Schoharie Reservoir.

The Schoharie is one of two reservoirs in the City's Catskill system, and the northernmost reservoir in the entire water supply system. For a reservoir of its size, the Schoharie has a very large watershed. It was designed to collect water and divert it quickly down to the next reservoir downstream. Consequently, water stays in the reservoir a short time before it is drawn into the Shandaken Tunnel and travels southeast 18 miles, where it enters the Esopus Creek at the Shandaken portal in Ulster County. It flows another 11 miles down the Esopus into the Ashokan Reservoir for longer-term storage and settling. When it leaves the Ashokan, it is carried southeast under the Hudson River via the 92-mile Catskill Aqueduct. It ordinarily makes its way to the Kensico Reservoir in Westchester for further settling and mixing with Delaware system water, before moving down aqueducts to the Hillview Reservoir in Yonkers and entering New York City's water supply distribution system.

The Schoharie watershed's drainage basin is 316 square miles and includes parts of 15 towns in three counties. Schoharie Creek is the primary tributary flowing into the reservoir, supplying 75% of flow, while Manor Kill and Bear Kill provide 10% and 8%, respectively. Presently there are eighteen WWTPs sited in the Schoharie watershed producing an average flow of 2.158 MGD. As per the most recent SPDES permits, the plants are limited to a collective release of 0.659 MGD of flow; this number however, does not include flow amounts for Windham WWTP, as this plant is newly connected to the system.

Of the 202,045 acres of land in the Schoharie watershed, 172,080 acres (85.2%) are forested, 5,152 acres (2.6%) are urban in nature, 3,295 acres (0.7%) are roads, 11,081 acres (5.5%) are brushland, and 6,367 acres (3.2%) are classified as grass land. Wetlands comprise 3,295 acres (1.6%) of the watershed, while 1,659 acres (0.8%) are under the reservoir. The remaining 979 acres (0.5%) are in agricultural use.

3.1.1 Program Implementation

DEP has greatly enhanced watershed protection in the Schoharie basin during the course of the current FAD. Program activity in the Schoharie watershed basin up to December 31, 2004, is summarized in Figure 3.2. The Septic Remediation Program has been particularly active, having repaired nearly 500 failing septic systems. Under the New Infrastructure Program, two new Wastewater Treatment Plants (WWTPs), Hunter and Windham, were nearing completion. Two City-owned WWTPs in the Schoharie basin, Tannersville and Grand Gorge, were upgraded to state-of-the-art tertiary treatment in the late 1990s.

There were 19 non-City-owned WWTPs in the basin that are either being upgraded or consolidated into New Infrastructure Projects (NIP). Of the facilities being consolidated, flow from two –Liftside and Ski Windham – has already been directed to the NIP plants. Six more – Whistletree Development, Forester Motor Lodge, Camp Loyalton, Colonel’s Chair, Frog House and Thompson House – are scheduled to be consolidated in the near future. One facility, Ron De Voo Restaurant, has been closed and its SPDES permit has been revoked.

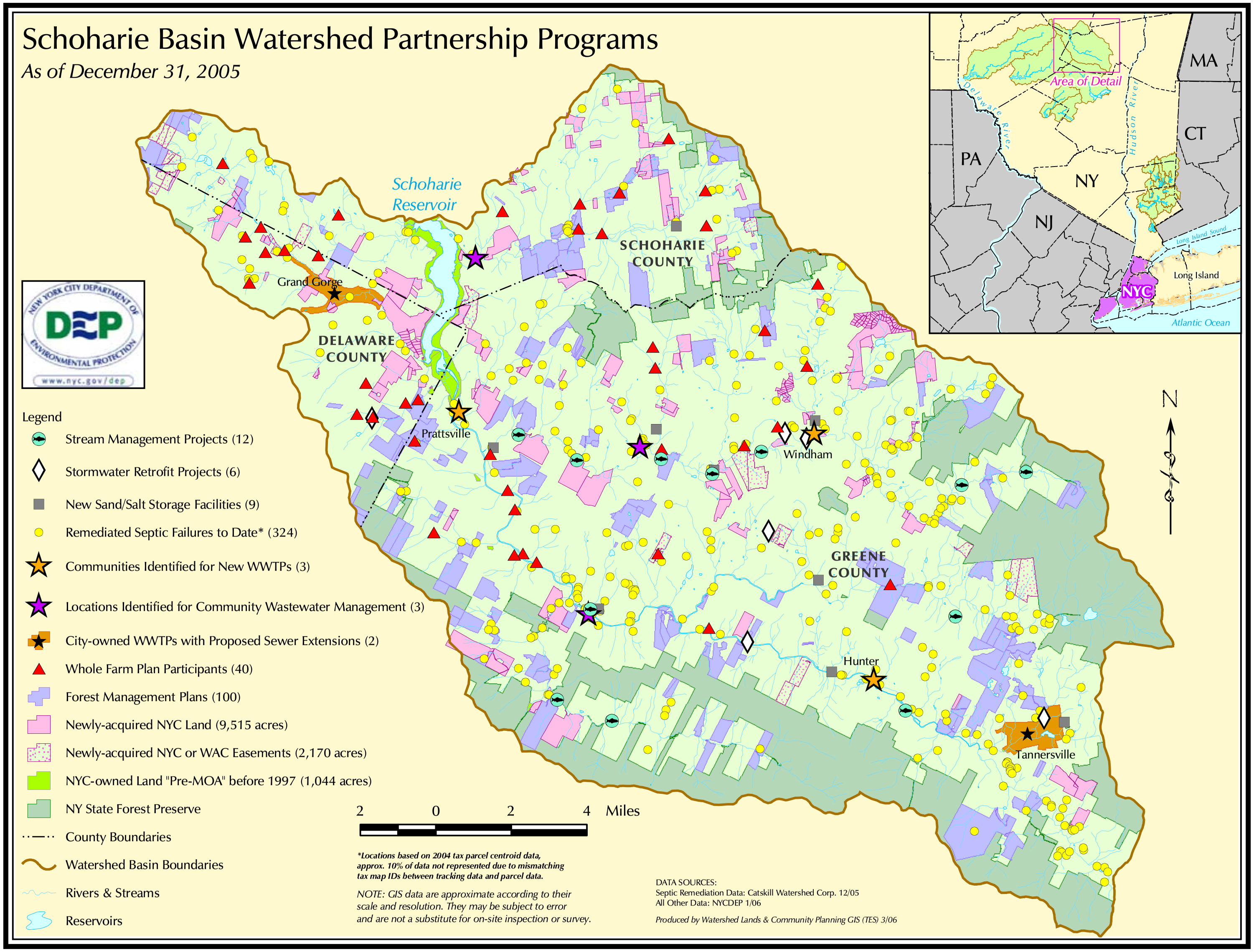


Figure 3.2 Schoharie Basin Watershed Partnership Programs as of December 31, 2005.

In addition, three communities have been identified for potential Community Wastewater Management Program (CWMP) projects. DEP has moved ahead with negotiations with one of the three communities and is currently working with Ashland to solicit participation in the program. DEP expects the town to opt into this voluntary program, making Ashland the sixth and most recent addition to the CWMP.

Six stream restoration projects in the Schoharie Basin have been completed – Big Hollow, Brandywine, Maier Farm, Farber Farm, Lexington, and West Kill at Shoemaker. Due to high summer stream flows in 2003 and 2004, construction of stream restoration projects has proven quite difficult.

Also active in the Schoharie basin has been the Whole Farm Program. Currently there are 23 large farms participating in the program, with 17 farms substantially implemented.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Schoharie Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Schoharie Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging WWTPs, including upgrades of the City-owned plants at Tannersville and Grand Gorge, and also through the intervention and involvement of the Engineering Division's Regulatory Compliance and Inspection (RCI) group. As illustrated in Figure 3.3, phosphorus (as Total Phosphorus) loads, considerably reduced from 1994 to 1999, mainly as a consequence of the upgrades of the largest plants at Tannersville and Grand Gorge, remain low in 2004. Beyond 2004, phosphorus inputs will be further reduced with the completion of new plants constructed as part of DEP's New Infrastructure Program (NIP). Table 3.1 highlights significant contributing events and accomplishments at several of the plants.

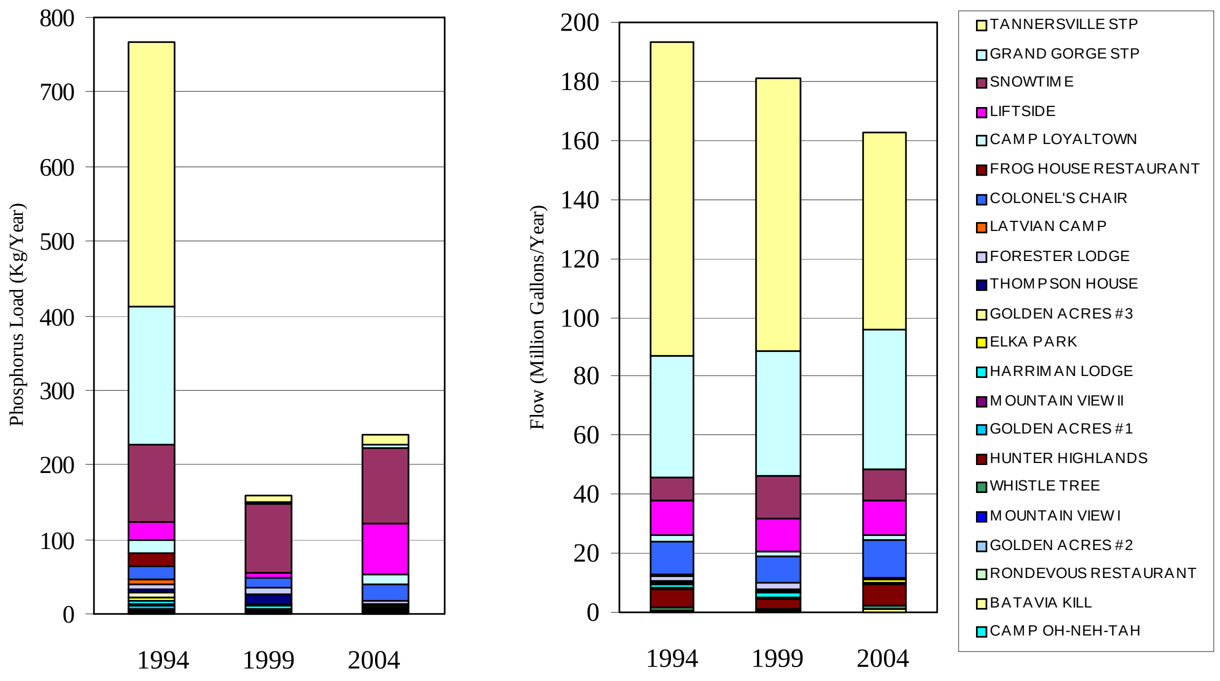


Figure 3.3 Total phosphorus loads and total volume of WWTP effluent flow to Schoharie Reservoir in 1994, 1999, and 2004.

Table 3.1. Significant events and accomplishments at WWTPs in the Schoharie Reservoir Basin since 1994.

WWTP	COMMENTS *
Tannersville	Upgrade permit date Apr 1998
Grand Gorge	Upgrade permit date Apr 1998
Snowtime	To be connected to NIP - Windham in 2005
Liftside	To be connected to NIP - Hunter in 2005
Camp Loyaltown	To be connected to NIP - Hunter
Frog House Restaurant	No surface discharge since 1997. To be connected to NIP - Windham
Colonel's Chair	To be connected to NIP - Hunter
Latvian Church Camp	No surface discharge since 1998
Forester Motor Lodge	To be connected to NIP - Hunter
Thompson House	To be connected to NIP - Windham in 2005
Golden Acres #3	-----
Elka Park	-----
Harriman Lodge	No surface discharge since Jul 2002

Table 3.1. Significant events and accomplishments at WWTPs in the Schoharie Reservoir Basin since 1994.

WWTP	COMMENTS *
Mountain View Estates II	-----
Golden Acres #1	-----
Hunter Highlands	Upgrade permit date Nov 2002
Whistle Tree	To be connected to NIP - Hunter
Mountain View Estates I	-----
Golden Acres #2	-----
Rondevous Restaurant	Closed Aug 2004
Batavia Kill Recreation Area	-----
Camp Oh-Neh-Tah	Opened Summer 2003

* The permit date referred to in this table is six months after plant upgrade is completed. Allowing for a start-up period, this is the date on which the requirements of each plant's final SPDES permit take effect.

Case Study: Effects of Tannersville and Grand Gorge Wastewater Treatment Plant Upgrades on Water Quality in the Schoharie Basin

The benefits of the WWTP Regulatory and SPDES Upgrade Program can be demonstrated by examining the water quality of the receiving waters of the WWTP effluents. This has been accomplished visually by plotting the data and producing a LOWESS smoothing pattern (using a 30% smoothing factor) through the data. A vertical line on the plot shows when the upgraded SPDES permit went into effect for the WWTP, but it should be noted that WWTP upgrades and modifications were occurring prior to this date.

Figure 3.4 shows the total phosphorus concentrations and fecal coliform levels at sampling sites in Gooseberry Creek above and below the Tannersville WWTP's discharge. Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were much higher than those seen in the creek above the plant. Also, fecal coliform levels downstream of the plant were slightly higher than the upstream levels. The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 35 µg L^{-1} and 5 CFU 100 mL^{-1}, respectively, and were 14 µg L^{-1} and 5 CFU 100 mL^{-1} after the upgrade. Following the plant improvements and the upgraded SPDES permit, the difference in the upstream and downstream median TP values was only 5 µg L^{-1}, as opposed to a difference of 21 µg L^{-1} before the upgrade. Thus, total phosphorus concentrations were reduced to less than half their former values. Fecal coliforms were fairly low upstream and downstream of the plant before and after the upgrade.

Similar improvements in total phosphorus concentrations were seen for the Grand Gorge WWTP on the Bear Kill (Figure 3.4). However, the upstream fecal coliform levels (median value = 100 CFU 100 mL^{-1}) were often higher than the downstream site before the WWTP upgrades (median value = 75 CFU 100 mL^{-1}). This may have been due to agricultural activity in the watershed. The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 101 µg L^{-1} and 75 CFU 100 mL^{-1}, respectively, and were 28 µg L^{-1} and 40 CFU 100 mL^{-1} after the upgrade. Following the upgrade the total phosphorus concentrations at the upstream and downstream sites were very similar. However, the decline in fecal coliform levels was also observed in the upstream location, indicating the decline in fecal coliforms was due to something other than the WWTP. One possibility is that the number of cows in the basin has been reduced by 700 head, and the impact of 300 others has been mitigated through the implementation of BMPs as a result of Whole Farm Plans.

The observed reduction in total phosphorus concentrations in the streams below the plants supports the findings of reduced phosphorus loads from the WWTPs.

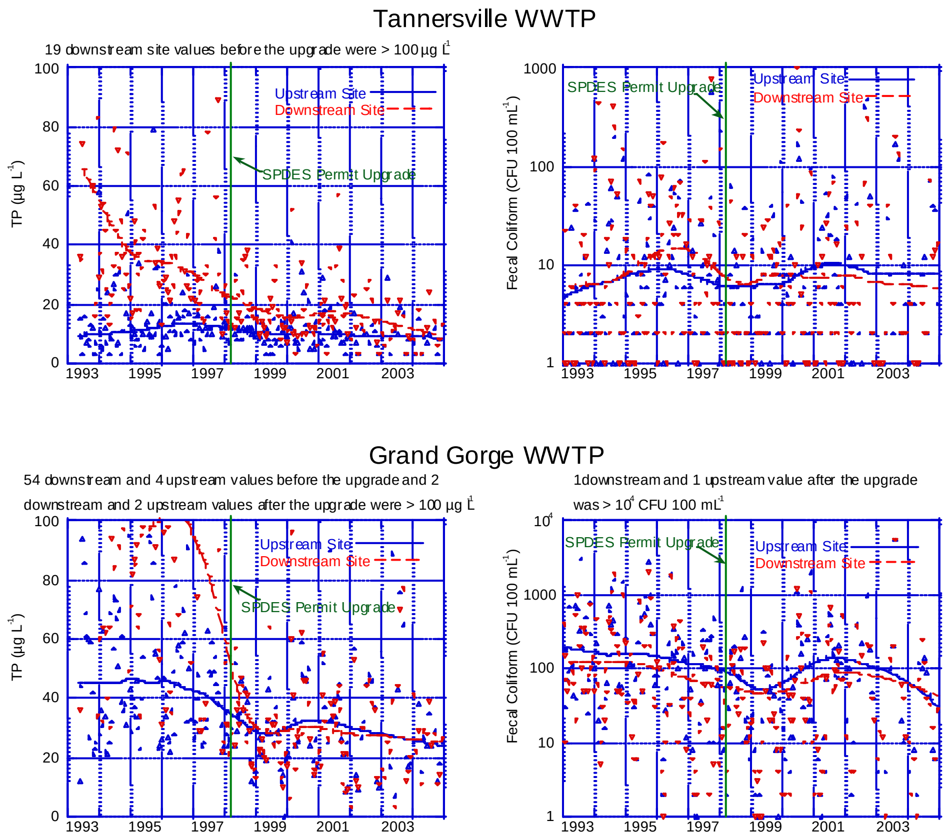
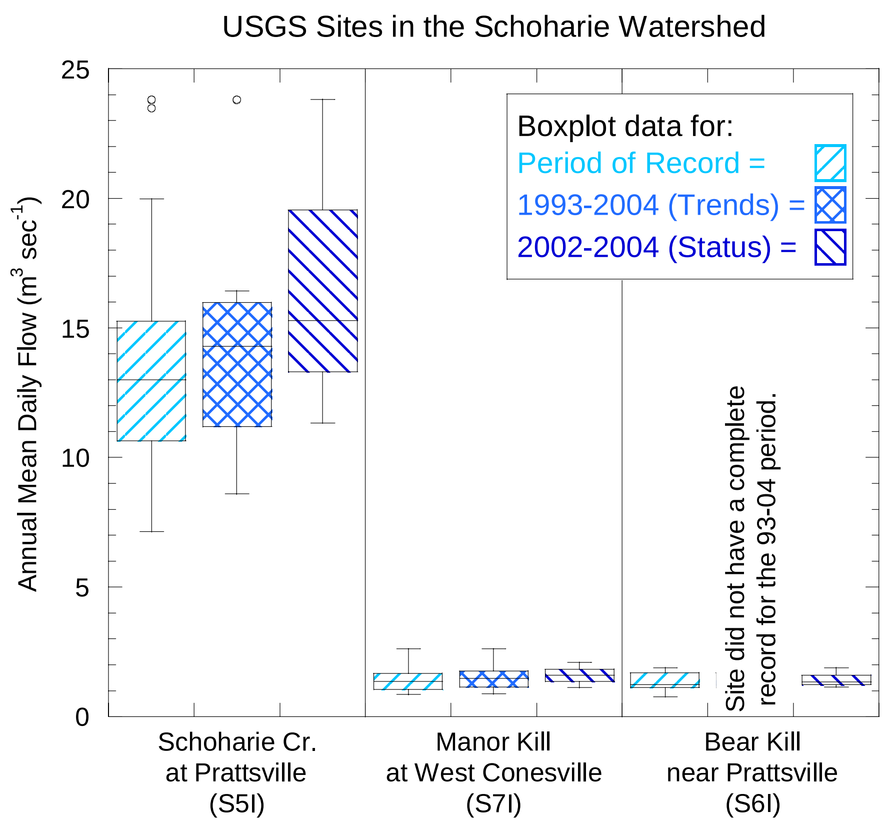


Figure 3.4 Total phosphorus and fecal coliform concentrations at stream sampling sites above and below wastewater plants in the Schoharie Basin, 1993-2004. Loess trend lines using a 30% smoothing coefficient are also plotted. a) Tannersville WWTP (upstream site=S1, downstream site=S2), b) Grand Gorge WWTP (upstream site=S8, downstream site=S9).

3.1.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 3.5. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

Schoharie Creek at Prattsville is the primary inflow to Schoharie Reservoir. It drains 75% of the basin. The flow distributions show that the 12-year mean representing the trends period was about 1 $m^3 sec^{-1}$ greater than the long-term mean, and the 3-year mean representing the status period was about 2 $m^3 sec^{-1}$ greater than the long-term mean. Therefore, flows in both the status and trends time periods are higher than usual.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
S5I	Schoharie Cr. at Prattsville	74.9%	Nov. 1902 - present
S7I	Manor Kill at West Conesville	10.3%	July 1986 - present
S6I	Bear Kill near Prattsville	8.3%	Oct. 1998 - present

Figure 3.5 USGS stream gauge sites in the Schoharie watershed.

Status (Schoharie Basin)

The Schoharie Basin status evaluation is presented as a series of box plots in Figure 3.6. The input is Schoharie Creek (S5I), the reservoir is designated as SS, and the output is SRR2.

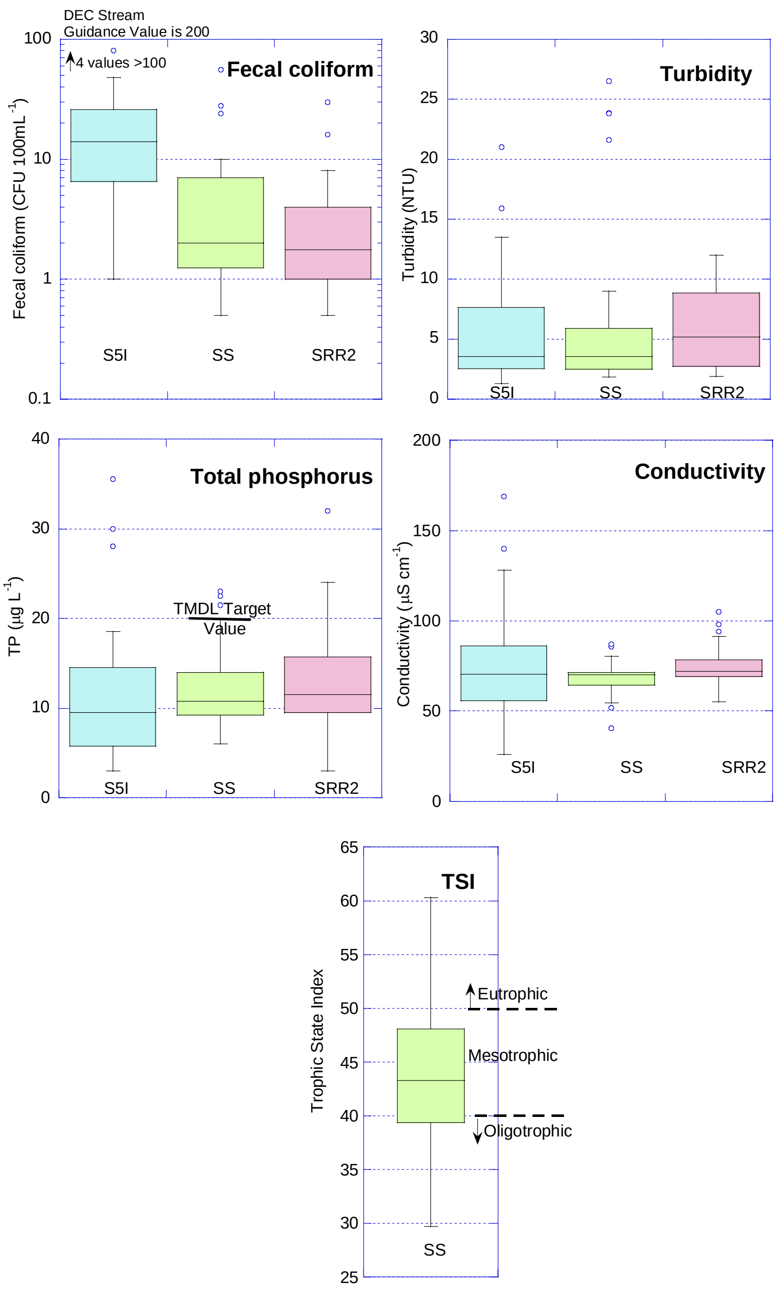


Figure 3.6 Water Quality status boxplots using 2002–2004 monthly data for the Schoharie basin for: the main stream input, Schoharie Creek at S5I; the reservoir, SS; and the effluent aqueduct keypoint, SRR2.

Note: For methodology details and boxplot interpretation, see Appendix 3.

In general, one would expect input stream levels of fecal coliform bacteria to be higher than the corresponding reservoir or output levels, and that is demonstrated in the box plots. All but two points for the input stream to Schoharie Reservoir, were well below the NYSDEC Stream Guidance Value of 200 CFU 100 mL^{-1} during the 2002 – 2004 analysis period. The reservoir-wide values and the values for the output for fecal coliform during this same time period were much lower than the stream, and also below the 20 CFU 100 mL^{-1} SWTR benchmark used for source waters.

Turbidity values were broadly similar amongst the input, reservoir and output. The particulates that cause turbidity in the basin do not settle quickly, so attenuation through the system is low. Some of the wider variability in the output may have been due to turbidity fluctuations caused by sharply contrasting hydrological regimes during the reservoir operation in these three years.

Total phosphorus (TP) concentrations show a broadly similar pattern to turbidity, because TP is associated with the same clay particulates that cause turbidity. Reservoir-wide TP values were generally well below the TMDL target value of 20 µg L^{-1} with a few exceptions.

The trophic status index value for Schoharie Reservoir was primarily within the mesotrophic range for the three year period. In general, light penetration is a limiting factor for primary production in this reservoir due to suspended particulates.

There was greater variability in the conductivity in the input stream than either the reservoir or the output of Schoharie Reservoir. During times of drought, the conductivity in the input stream generally increases, and higher conductivities typically occur in late summer and early fall during periods of lower stream flow. Low conductivities generally occur during storm events. Depending upon the corresponding reservoir elevation, the effects from the stream may be diminished by dilution in the reservoir.

In general, water quality was good during the 2002 – 2004 analysis period in the Schoharie Basin. The data for the selected variables show that there were few times when the monthly values exceeded established benchmarks.

Trends (Schoharie Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 3.7. Results of the Seasonal Kendall trend analysis are provided in Table 3.2.

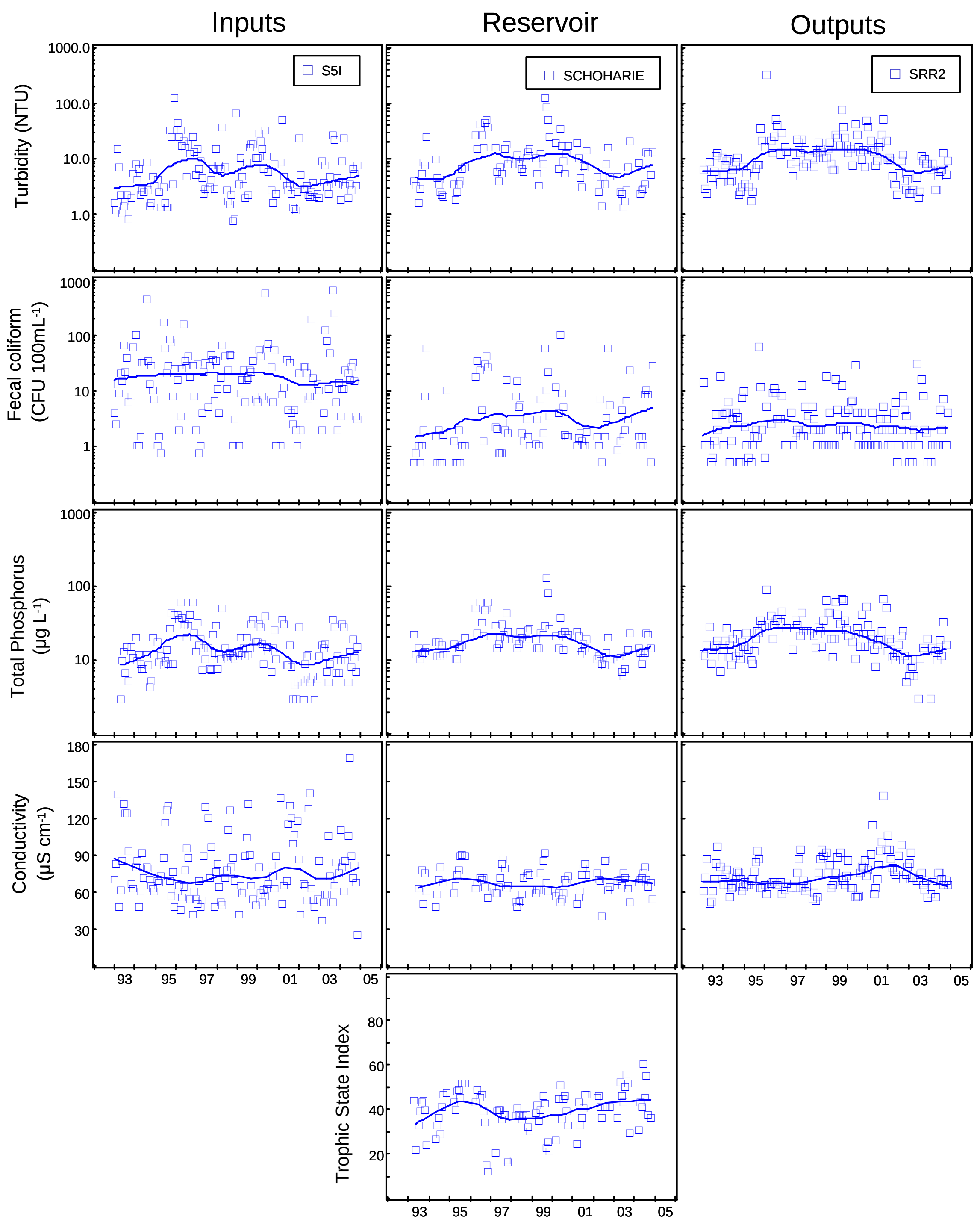


Figure 3.7 Water Quality trend plots for the Schoharie basin for: the main stream input, Schoharie Creek at S5I; the reservoir, Schoharie; and the effluent aqueduct keypoint, SRR2.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 3.2. Schoharie Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[3]	*p*-value[2]	Change yr^{-1}
S5I [1]	Input	Turbidity	12	144	0.00	NS	0.00
Schoharie	Reservoir	Turbidity	9	108	-0.04	NS	-0.06
SRR2	Output	Turbidity	12	144	-0.04	NS	-0.06
S5I	Input	Fecal coliform	12	144	-0.03	NS	-0.14
Schoharie	Reservoir	Fecal coliform	9	108	0.14	**	0.00
SRR2	Output	Fecal coliform	12	144	-0.07	NS	0.00
S5I [1]	Input	Total Phosphorus	12	144	-0.18	***	-0.40
Schoharie	Reservoir	Total Phosphorus	9	108	-0.15	**	-0.40
SRR2	Output	Total Phosphorus	12	144	-0.06	NS	-0.14
S5I [1]	Input	Conductivity	12	144	0.23	***	1.00
Schoharie	Reservoir	Conductivity	9	108	0.03	NS	0.00
SRR2	Output	Conductivity	12	144	0.12	**	0.57
Schoharie	Reservoir	Trophic State Index	9	108	0.38	***	0.60

1. Data was adjusted for flow prior to trend analysis—see Appendix 3.
2. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
3. Tau refers to the Seasonal Kendall Test Tau statistic.

Long-term turbidity trends were not detected in the Schoharie Basin. Apparently several short-term, upward turbidity trends (1995-97 and 2003-4) associated with flood events were offset by a short-term downward trend in the latter portion of the data record (2000-2003). The downward trend represents recovery from the high turbidity levels imparted by the floods as particles settle out of the water column (and recovery of the stream beds via armoring). Also contributing to the decline are the low turbidity loads associated with drought in 2001 and 2002.

Despite the fact that no long-term turbidity trends were detected, phosphorus declines were apparent in the input and reservoir. In this case, short-term declines, again associated with recovery and drought, plus WWTP upgrades resulting in smaller loads of TP being delivered to the streams, were sufficient to offset the short-term increases associated with above average runoff in the mid to late 1990s and in 2003 to 2004.

The change in fecal coliforms in the reservoir .per year is estimated as zero, however the Tau value is positive, indicating an upward trend. Additional evidence is indicated by the direction of the LOWESS curve. The increase is probably related to the change in precipitation patterns from 2001-04 when there were two dry years followed by two wet years.

Small increases in conductivity were detected in the input (+1.00 µS cm^{-1} yr^{-1}) and in the output (+0.57 µS cm^{-1} yr^{-1}). Most of the higher values occurred from mid-2001 through 2002, as expected during a period characterized by drought.

Primary production appears to be increasing in the reservoir with an upward trend of +0.60 yr^{-1} being detected for Trophic State Index values. An increase in surface water pH (not reported here) is further suggestive of this increased production. The increase in production can be attributed to improvements in water clarity. Although turbidity trends were not detected, Secchi and photic zone depth have increased (data not shown), apparently enough to support increased algal growth.

In summary, downward trends were detected for total phosphorus while upward trends were detected for conductivity and trophic state. The decline in phosphorus is attributed to recovery from high loads produced by flood events in the mid to late 1990s from low loads associated with the drought occurring from 2001-2002 and from WWTP upgrades. The drought is also thought to explain the increase in conductivity. Improvements in water clarity explain the upward trend in trophic state.

3.2 The West and East Ashokan Basins

Ashokan Reservoir is located in Ulster County, about 13 miles west of Kingston and 73 miles north of New York City. It was formed by the damming of the Esopus Creek, which eventually flows northeast and drains into the Hudson River. Consisting of two basins separated by a concrete dividing weir and roadway, it holds 122.9 billion gallons at full capacity and was placed into service in 1915. On average, Ashokan supplies 344 million gallons per day (MGD), or roughly 28.4% of the total average daily consumption, to New York City and an additional one million upstate consumers.

Figure 3.8 Ashokan Reservoir, West Basin.

The Ashokan is one of two reservoirs in the City's Catskill water supply system. The other is the Schoharie, located 27 miles to the north, whose water flows into the Ashokan via the Shandaken Tunnel and the Esopus Creek. Including the water it receives from the Schoharie Reservoir, the Ashokan supplies about 40% of New York City's daily drinking water needs in non-drought periods. Under normal operating conditions, water enters the Ashokan's West Basin and, after a settling period, is withdrawn from its East Basin. It is carried southeast under the Hudson River via the 92-mile Catskill Aqueduct, which has a maximum depth of 1,114 feet. It ordinarily enters the Kensico Reservoir in Westchester for further settling, where it mixes with Delaware system water and then travels south in two aqueducts before entering New York City's water supply distribution at the Hillview Reservoir in Yonkers, just north of the City line.

Figure 3.9 Spillway at Ashokan Reservoir, East Basin.

The Ashokan watershed's drainage basin is 255 square miles and includes parts of 11 towns. Bush Kill and Esopus Creek are the two primary tributaries flowing into Ashokan, with the former providing 6.4% and the latter, 75.2% of water entering the reservoir. Presently there are four wastewater treatment plants sited in the Ashokan watershed producing an average flow of 0.279 MGD. As per the most recent SPDES permits, the plants are limited to a collective release of 0.573 MGD of flow.

Of the 163,407 acres of land in the Ashokan watershed, 146,784 acres (89.8%) are forested. Close to 2,367 acres (1.4%) are urban in nature, 1,390 acres (0.9%) are roads, 1,410 acres (0.9%) are brushland, and 957 (0.6%) acres are classified as grass land. Wetlands comprise 2,056 acres (1.3%) of the watershed, while 8,375 acres (5.1%) are under the reservoir. The remaining 68.7 (>0.01 %) acres are in agricultural use.

3.2.1 Program Implementation (West and East Basin)

DEP's watershed protection efforts have been very active in the Ashokan watershed basin. Program activity in the Ashokan basin up to December 31, 2004, is summarized in Figure 3.10. The Septic Remediation Program has been particularly active, having repaired over 550 failing septic systems.

Under the New Infrastructure Program, DEP has identified one community eligible for a new WWTP, as well as two locations identified for Community Wastewater Management Program (CWMP) projects. Currently, CWMP is in the final stage of the study phase for project installation in Boiceville. DEP expects to begin the one-year design phase for the CWMP project shortly. The City-owned Pine Hill WWTP was upgraded to state-of-the-art tertiary treatment in the late 1990s. Presently there are four non-City-owned wastewater treatment plants sited in the Ashokan basin producing an average flow of 0.279 MGD. Camp Timberlake has been upgraded. The remaining three facilities in the basin are either being upgraded or consolidated into New Infrastructure/CWMP projects.

DEP's Stream Management Program has constructed three projects intended to restore natural stability to the stream channel: Broadstreet Hollow, Stony Clove at Lanesville, and Esopus Creek at Woodland Valley.

Also of note in the Ashokan basin has been DEP's Land Acquisition Program. The Ashokan basin land area is 155,344 acres, all categorized as either Priority 1 or 2. As of 1997, DEP owned 4,854 acres of reservoir buffer land, or 3.1% of the basin, with another 83,242 acres (53.6%) protected by non-City entities. Since that time DEP has protected 9,707 acres in fee or easement. Total land protected by City and non-City entities is 97,803 acres, or 63.0% of basin land area.

Wastewater Treatment Plants and Phosphorus Load Reductions in the West Ashokan Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Ashokan Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging plants, including upgrade of the City-owned Pine Hill plant, and also through the intervention and involvement of DEP's Regulatory Compliance and Inspection (RCI) Program. As illustrated in Figure 3.11, phosphorus (as Total Phosphorus) loads, considerably reduced from 1994 to 1999, remain low in 2004. The reduction was largely due to the upgrade of the largest plant, Pine Hill, and improvements at Onteora Central School. Phosphorus load fluctuations at Camp Timberlake are proportionate to changes in flow. Final upgrade in 2005 will reduce phosphorus loads from that facility. Mountainside Restaurant, a small plant that will discharge sub-surface starting in 2005, is the only plant in the East Ashokan Basin, and is included in this section. Table 3.3 highlights significant events and accomplishments at plants in the Ashokan basin. Overall, phosphorus loads to Ashokan Reservoir were reduced from 220 kg yr^{-1} to about 50 kg yr^{-1}.

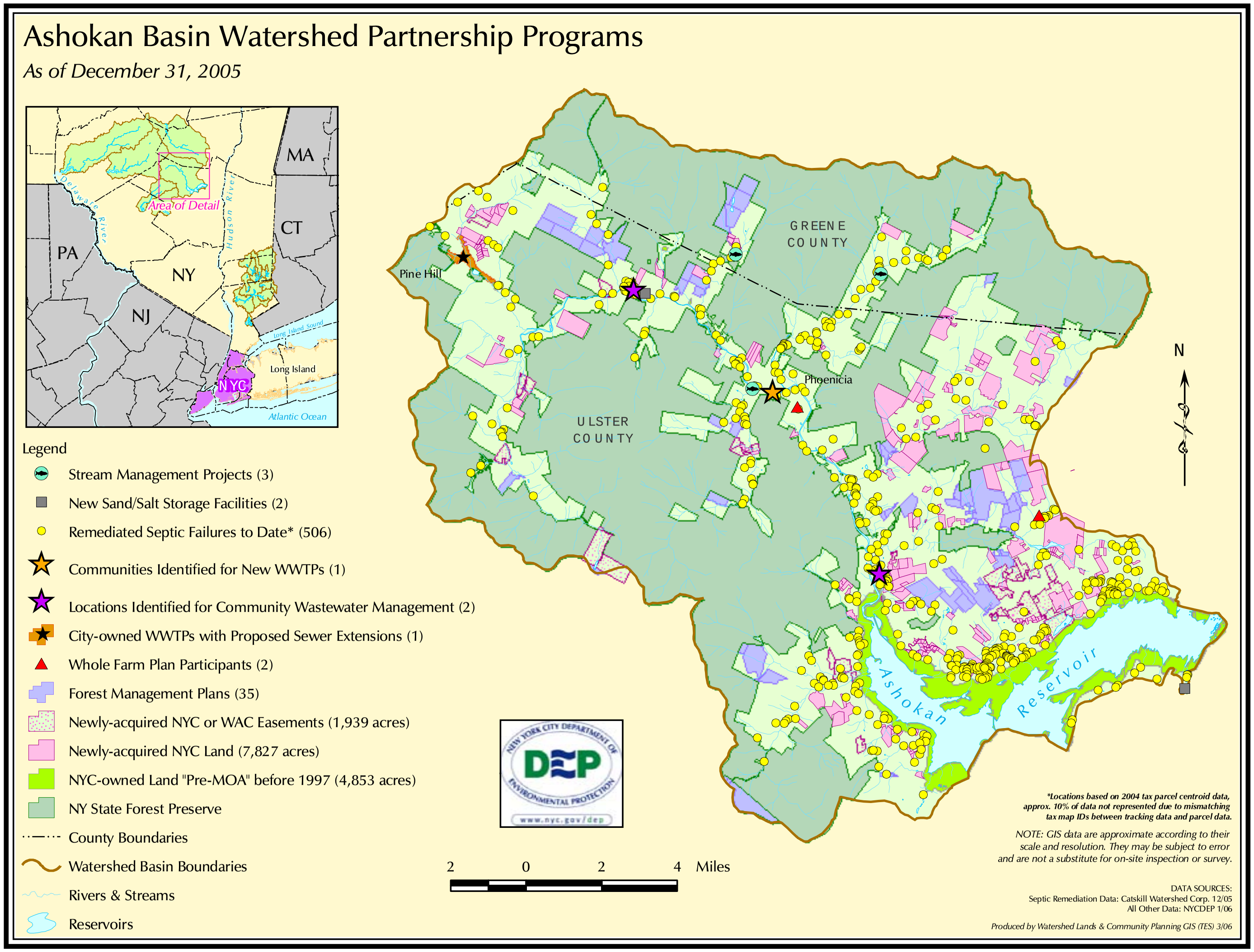


Figure 3.10 Ashokan Basin Watershed Partnership Programs as of December 31, 2005.

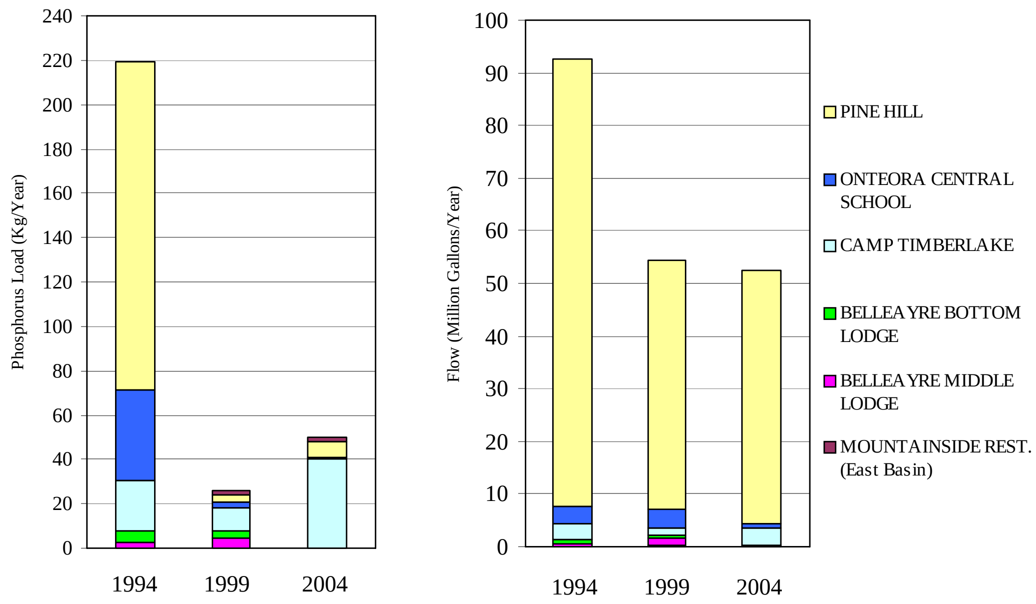


Figure 3.11 Total phosphorus loads and total volume of WWTP effluent flow to Ashokan Reservoir in 1994, 1999, and 2004.

Table 3.3. Significant events and accomplishments at WWTPs in the Ashokan Reservoir basin since 1994.

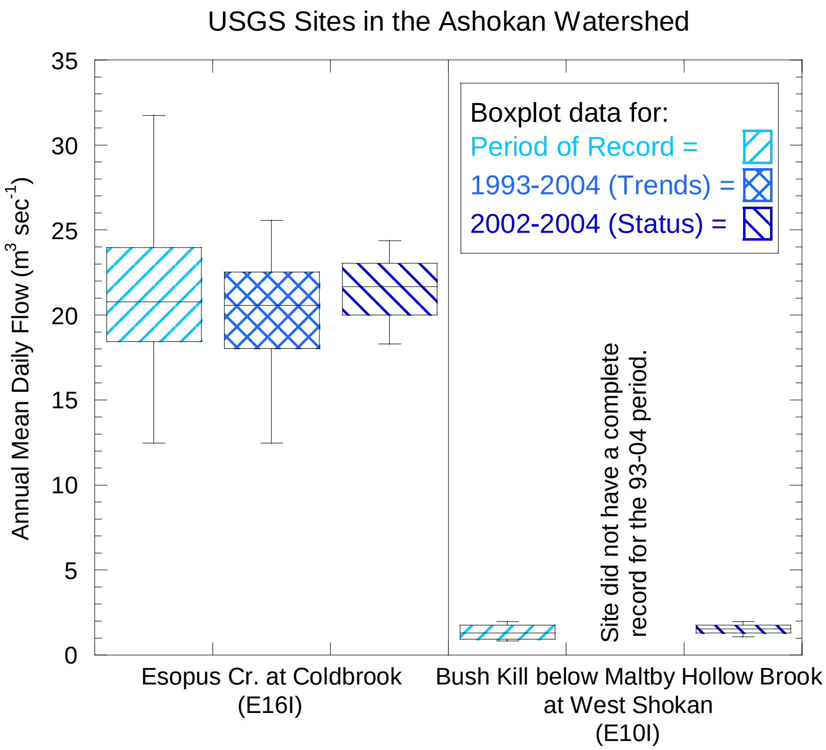
WWTP	COMMENTS *
Pine Hill	Upgrade permit date Feb 1999
Onteora Central School	Partial upgrade 1997
Camp Timber Lake	Partial upgrade Dec 2000 Final upgrade in 2005
Belleayre Bottom Lodge	Connected to Pine Hill Dec 1999
Belleayre Middle Lodge	Connected to Pine Hill Dec 1999
Mountainside Restaurant	No surface discharge after 2005

* The permit date referred to in this table is six months after plant upgrade is completed. Allowing for a start-up period, this is the date on which the requirements of each plant's final SPDES permit take effect.

3.2.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 3.12. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

Esopus Creek at Coldbrook is the primary inflow to Ashokan Reservoir. It drains 75% of the basin. The flow distributions (of the annual mean daily flows) show that the 12-year median representing the trends period and the 3-year median representing the status period were both very similar to the long-term median. It should be noted that flows at Coldbrook are greatly influenced by the discharge from the upstream Shandaken Portal and as a consequence they are not the natural regime.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
E16I	Esopus Cr. at Coldbrook	74.7%	Oct. 1931 - present
E10I	Bush Kill below Maltby Hollow Brook at West Shokan	7.3%	Aug. 2000 - present

Figure 3.12 USGS stream gauge sites in the Ashokan watershed.

Status (West Basin)

Ashokan's West Basin status evaluation is presented as a series of box plots in Figure 3.13. Only the input stream (E16I) and the reservoir basin (EAW) are included because water is rarely withdrawn directly from this basin. The output goes directly into the East Basin of Ashokan. For all four input variables, there is a decrease in the median and in the range of the analytes going from the input to the reservoir.

All but one monthly value for fecal coliform in the input stream were below the NYSDEC Stream Guidance Value of 200 CFU 100 mL^{-1} during the 2002 – 2004 analysis period. The reservoir-wide values during this same time period were much lower than the stream, and also below the 20 CFU 100 mL^{-1} SWTR benchmark used for source waters.

The turbidity values were generally lower in the reservoir as compared to the input stream. Most of the monthly turbidity values in the reservoir were below the 5 NTU SWTR benchmark value for source waters. This reference line is included for the West Basin because as a terminal reservoir, Ashokan can become source water if Kensico Reservoir is by-passed.

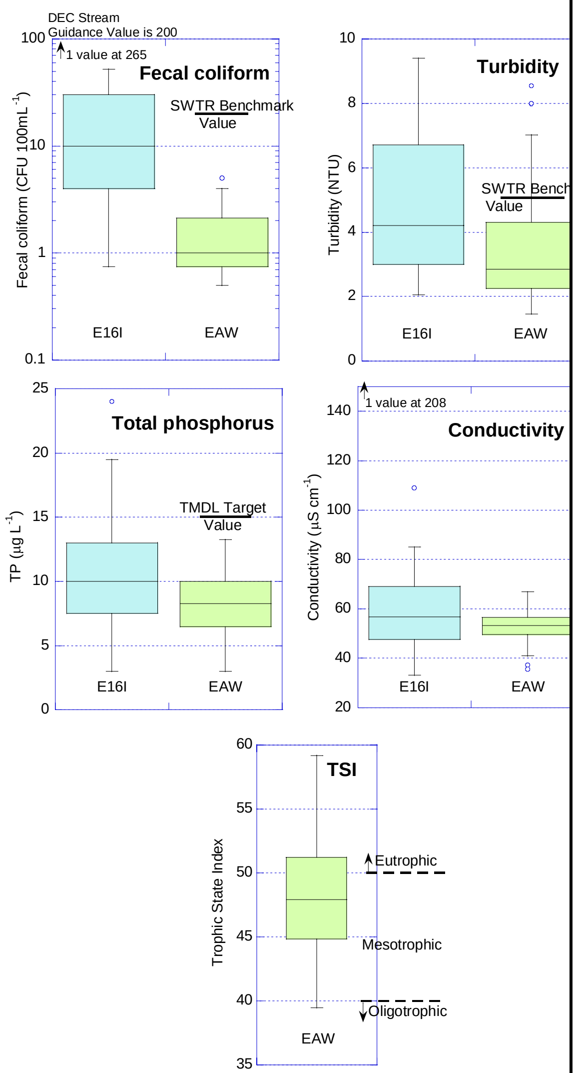


Figure 3.13 Water Quality status boxplots using 2002–2004 monthly data for the Ashokan West basin for: the main stream input, Esopus Creek at E16I; and the reservoir, EAW.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Total phosphorus values were also generally lower in the West Basin as compared to the Esopus Creek, suggesting settling of suspended material, and were well below the TMDL target value of 20 µg L^{-1}.

The trophic status index value for Ashokan's West Basin was primarily within the mesotrophic range for the three year period. As with Schoharie Reservoir, light penetration can be a limiting factor for primary production in this reservoir due to suspended particulates. The

TSI values in the eutrophic range probably occurred during years of improved water clarity.

There was greater variability in the conductivity in the input stream as compared to the reservoir. The early part of 2002 was particularly dry and consequently, the conductivity in the input stream increased. This dry period was followed by relatively wet years in 2003 and 2004, which tended to dilute the ionic content of the stream. In addition, the reservoir has a large volume that attenuates the influence of the incoming stream.

In general, water quality was good during the 2002 – 2004 analysis period in the West Basin of Ashokan Reservoir. The data for the selected variables show that there were very few times when the monthly values exceeded established benchmarks.

Trends (West Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used. The LOWESS smoother plots are presented in Figure 3.14 and results of the Seasonal Kendall trend analysis are provided in Table 3.4.

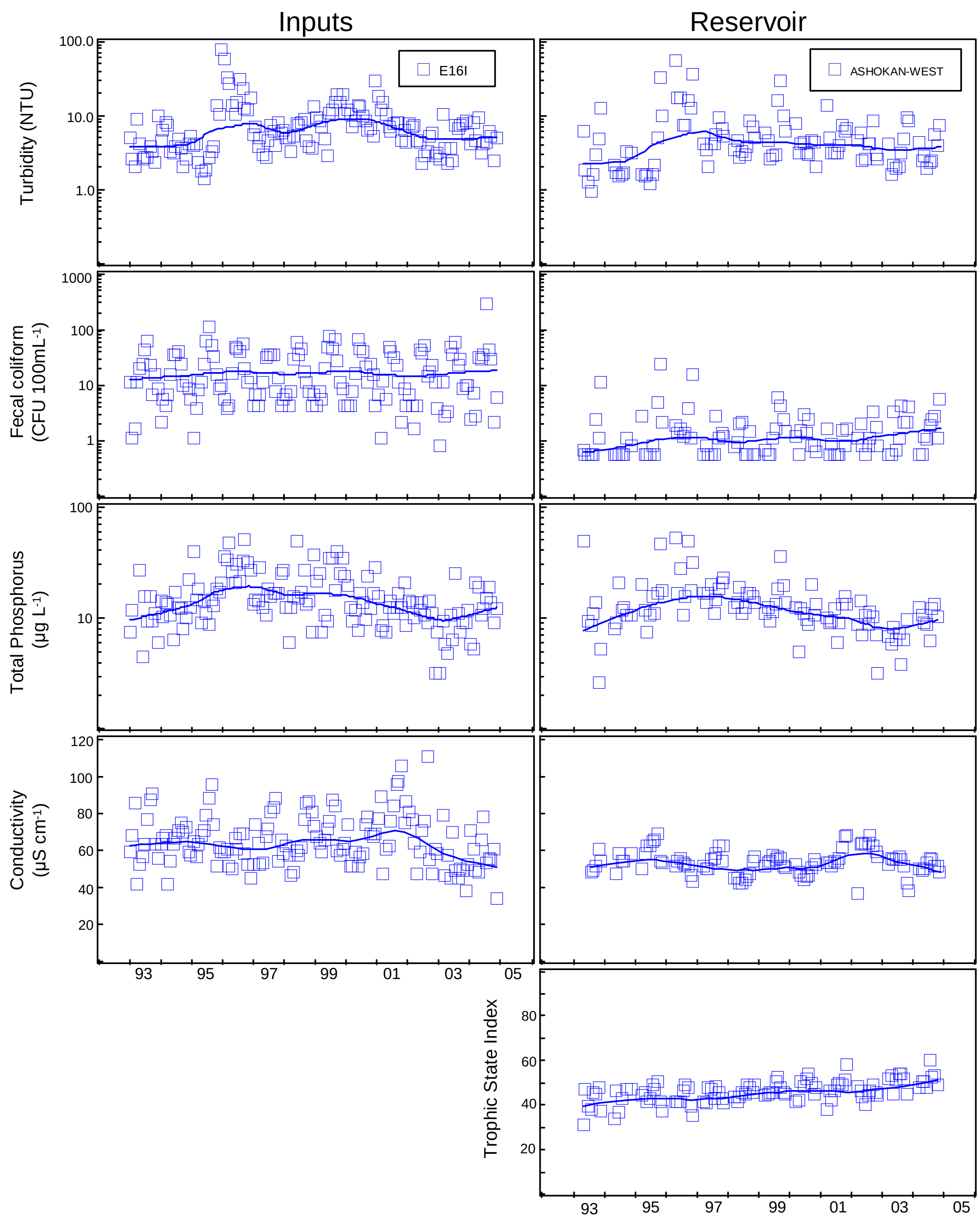


Figure 3.14 Water Quality trend plots for the Ashokan West basin for: the main stream input, Esopus Creek at E16I; and the reservoir, Ashokan-West.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 3.4. Ashokan West Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
E16I	Input	Turbidity	12	144	0.08	NS	0.11
Ashokan-West	Reservoir	Turbidity	9	108	0.06	NS	0.04
E16I	Input	Fecal coliform	12	144	0.00	NS	0.00
Ashokan-West	Reservoir	Fecal coliform	9	108	0.07	NS	0.00
E16I	Input	Total Phosphorus	12	144	-0.15	***	-0.50
Ashokan-West	Reservoir	Total Phosphorus	9	108	-0.29	***	-0.60
E16I	Input	Conductivity	12	144	-0.04	NS	-0.17
Ashokan-West	Reservoir	Conductivity	9	108	0.00	NS	0.00
Ashokan-West	Reservoir	Trophic State Index	9	108	0.47	***	0.75

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).

2. Tau refers to the Seasonal Kendall Test Tau statistic.

Turbidity trends were not detected in the West Basin of the Ashokan Reservoir. Although it appears that turbidity is slowly dropping since the late 1995/early 1996-flood events, turbidity has not reached pre-event levels.

Statistically significant trends were not detected for fecal coliforms. However, the LOWESS curve superimposed on the reservoir data certainly suggests an increase coinciding with extremely “wet” years in 2003 and 2004.

The input, output and reservoir all experienced an overall downward trend in total phosphorus with most of the decrease occurring from 1997 to 2002. Many factors contributed to this decline. In part, the decrease represents recovery following the high phosphorus concentrations produced by above average runoff from the mid to late 1990s. Another factor is the reduction in phosphorus load during drought years 1999, 2001 and 2002. A large portion of the decline can be attributed to upstream (including Schoharie watershed) WWTP upgrades resulting in smaller loads of TP being delivered to the streams.

No long-term trends were apparent for conductivity in the basin. Drought conditions in 2002 were responsible for the temporary increases observed in the input, reservoir and output.

The Trophic State Index values show a consistent increase during the period of record. The increase in productivity is likely due to improving water clarity as the turbidity introduced by flooding in 1995-96 continues to settle. Although a downward trend in turbidity was not detected, more direct measurements of water clarity, Secchi and photic zone depth, have increased during the period of record.

In summary, downward trends were evident for total phosphorus and an upward trend for trophic state. The decrease in phosphorus is due to recovery from a high loading period (floods in mid to late 1990s), and WWTP upgrades. The increase in trophic state is associated with seasonal improvements in water clarity.

Case Study: Effects of Pine Hill Wastewater Treatment Plant Upgrade on Water Quality in the Ashokan Basin

The benefits of the WWTP Regulatory and SPDES Upgrade Program can be demonstrated by examining the water quality of the receiving waters of the WWTP effluents. This has been accomplished visually by plotting the data and producing a LOWESS smoothing pattern (using a 30% smoothing factor) through the data. A vertical line on the plot shows when the upgraded SPDES permit went into effect for the WWTP, but it should be noted that WWTP upgrades and modifications were occurring prior to this date.

Figure 3.15 shows the total phosphorus concentrations and fecal coliform levels at sampling sites on Birch Creek above and below the Pine Hill WWTP's discharge. Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were higher than those seen in the creek above the plant. Although still fairly low, the fecal coliform levels downstream of the plant were also higher than the upstream levels. The median TP and fecal coliform levels in the river below the plant before the upgraded SPDES permit were 25 µg mL^{-1} and 8 CFU 100 mL^{-1}, respectively, and were 15 µg mL^{-1} and 8 CFU 100 mL^{-1}after the upgrade.

The observed reduction in total phosphorus concentrations in the streams below the plants supports the findings of reduced phosphorus loads from the WWTPs as discussed in the description of WWTP load reductions for the Ashokan Basin.

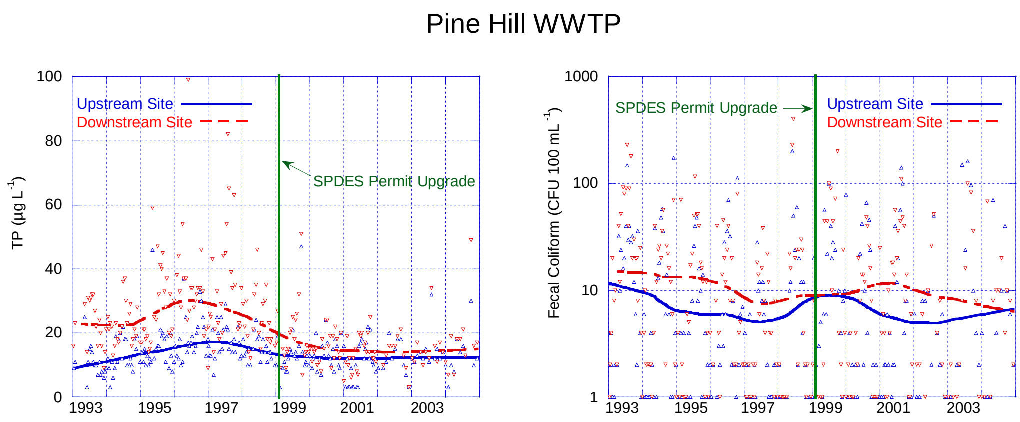


Figure 3.15 Total phosphorus and fecal coliform concentrations at stream sampling sites above and below the Pine Hill WWTP (upstream site=E3, downstream site=E15) in the West Ashokan Basin, 1993-2004. Loess trend lines using a 30% smoothing coefficient are also plotted.

Status (East Basin)

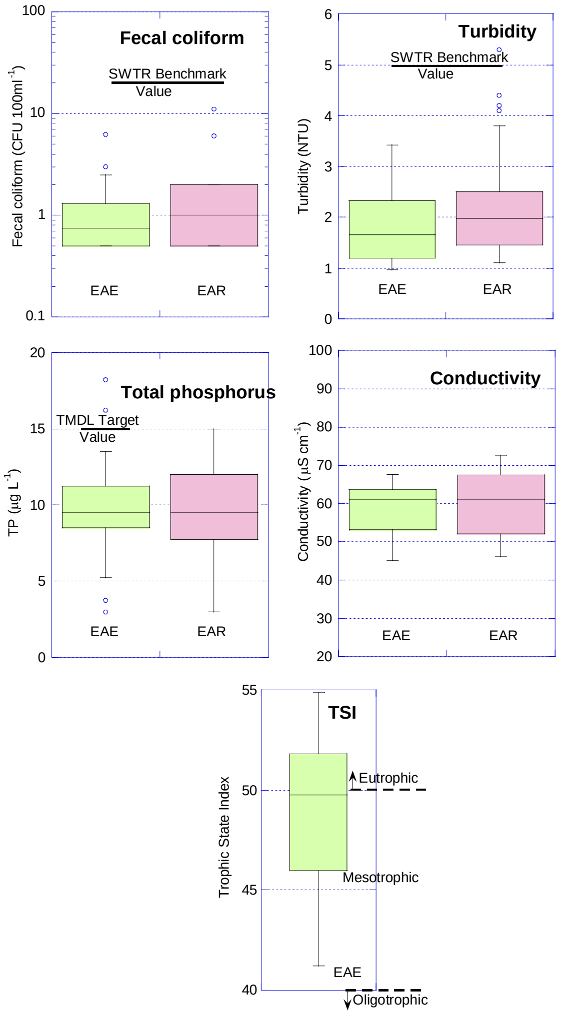


Figure 3.16 Water Quality status boxplots using 2002–2004 monthly data for the Ashokan East basin for: the reservoir, EAE; and the effluent aqueduct keypoint, EAR.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Ashokan's East Basin status evaluation is presented as a series of box plots in Figure 3.16. The reservoir (EAE) and the output (EAR) only are included because water from the West Basin flows directly to the East Basin.

Fecal coliform values were very low for both the reservoir and the output. Many of the values were at or below the detection limit, and none exceeded the 20 CFU 100 mL^{-1} SWTR benchmark used for source waters.

The turbidity values were broadly similar in the reservoir and the output from the East Basin. Median values are well below the 5 NTU SWTR benchmark value for source waters. This reference line is included for the East Basin because Ashokan can become source water if Kensico Reservoir is by-passed. The output had a median and some values that were higher than the reservoir, primarily because of the location of the effluent structure relative to the incoming water from the West Basin. Wind and mixing patterns can cause turbidity levels to increase at EAR in contrast to the rest of the East Basin where turbidity levels tend to be the lowest in the impoundment.

Total phosphorus values were also generally similar in the East Basin as compared to the output. Only two individual sample values were above the TMDL target value of 15 µg L^{-1} in the reservoir, with the median value of less than 10 mg L^{-1}.

The trophic status index value for Ashokan's East Basin was at the high end of the mesotrophic category to for the three year period. Light penetration can be a limiting factor for primary production in this reservoir due to suspended particulates, but to a much lesser degree than either the West Basin or Schoharie Reservoir.

There was slightly more variability in the conductivity in the output as compared to the reservoir. The keypoint data was collected year-round as compared to the reservoir data. Since the output data included the winter months, it also represented times when the conductivity increased, possibly due to road salt, as well as times when runoff was dilute.

In summary, water quality was generally good during the 2002–2004 analysis period in the East Basin of Ashokan Reservoir. The data for the selected variables show that medians are well below the established benchmarks.

Trends (East Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 3.17.

Results of the Seasonal Kendall trend analysis are provided in Table 3.5. Most input is from the West Basin (Figure 3.17) as discussed.

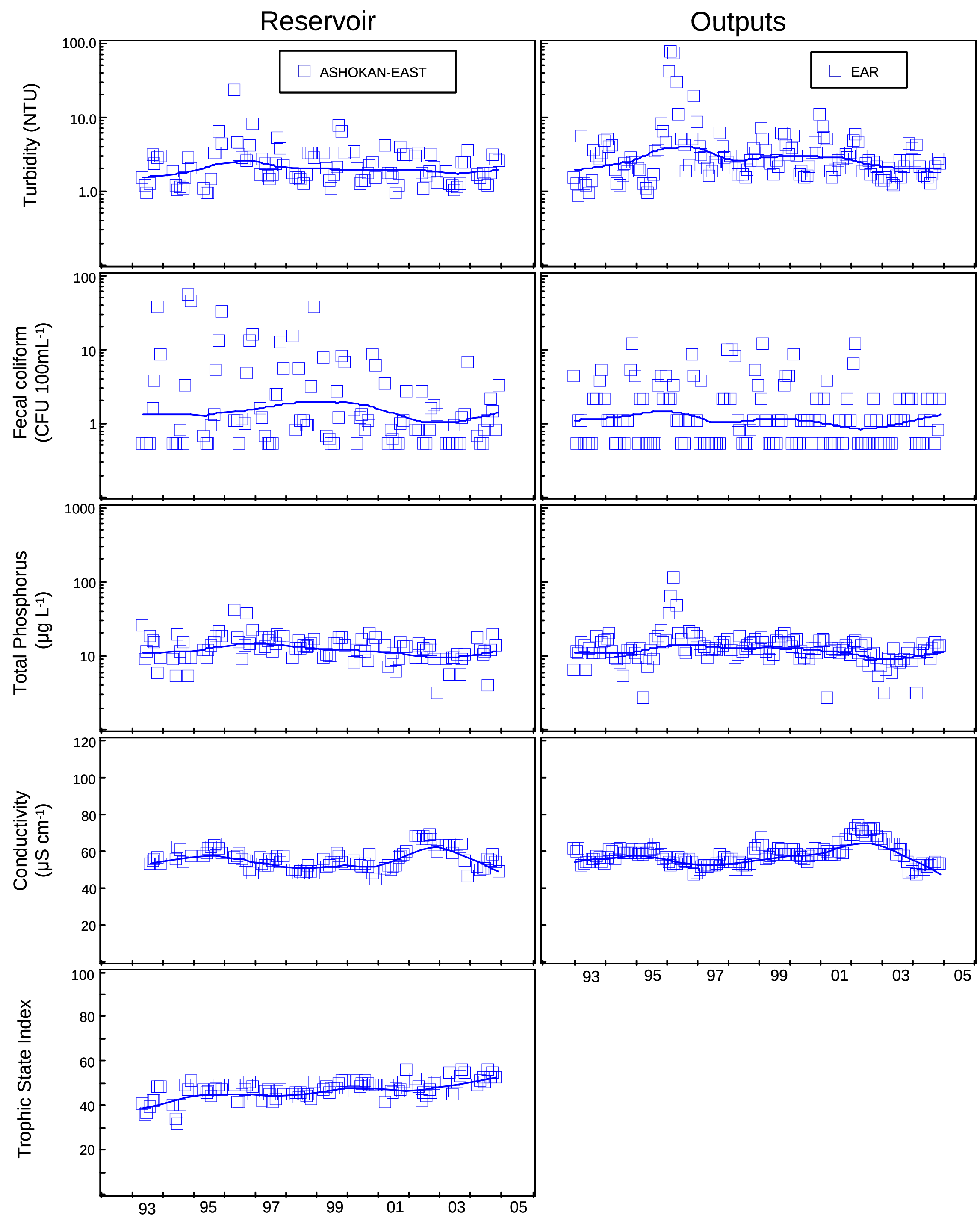


Figure 3.17 Water Quality trend plots for the Ashokan East basin for: the reservoir, Ashokan-East; and the effluent aqueduct keypoint, EAR.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 3.5. Ashokan East Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
Ashokan-East	Reservoir	Turbidity	9	108	-0.06	NS	0.00
EAR	Output	Turbidity	12	144	-0.05	NS	-0.02
Ashokan-East	Reservoir	Fecal coliform	9	108	-0.23	***	0.00
EAR	Output	Fecal coliform	12	144	-0.08	**	0.00
Ashokan-East	Reservoir	Total Phosphorus	9	108	-0.25	***	-0.36
EAR	Output	Total Phosphorus	12	144	-0.15	***	-0.20
Ashokan-East	Reservoir	Conductivity	9	108	0.02	NS	0.00
EAR	Output	Conductivity	12	144	0.12	*	0.31
Ashokan-East	Reservoir	Trophic State Index	9	108	0.49	***	0.79

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
2. Tau refers to the Seasonal Kendall Test Tau statistic.

Turbidity trends were not detected in the reservoir or in its output, EAR.

Fecal coliform trends were detected statistically, but were too small to be of any practical significance. The Tau statistic values (which measure the strength, and indicate direction, of a monotonic trend) were negative. The decreases shown in the LOWESS plots mostly coincide with the drought period 2001-02, suggesting that loads via surface runoff were low. It should be noted that fecal coliform concentrations are generally very low with the medians at 1 CFU 100 mL^{-1}.

Declines were detected for total phosphorus indicating continued recovery from flooding events in the mid to late 1990s and perhaps also indicating low phosphorus loads during drought years 1999, 2001 and 2002. A large portion of the decline can be attributed to upstream (including Schoharie watershed) WWTP upgrades resulting in smaller loads of TP being delivered to the streams.

Conductivity trends were not detected in the reservoir although a temporary increase caused by drought is apparent during 2002. A significant trend of increasing conductivity was apparent in the output, however, driven in large part by the 2002 drought (or by more frequent sampling since the reservoir is not sampled in the winter).

Primary production appears to be increasing in the reservoir as indicated by a consistent upward trend in Trophic State Index. As was the case in the West Basin, this increase is attributed to increases in surface water clarity.

In summary, downward trends were evident for total phosphorus and an upward trend for trophic state. The decrease in phosphorus is due to recovery from a high loading period (floods in mid to late 1990s), and WWTP upgrades. The increase in trophic state is associated with seasonal improvements in water clarity.

3.3 Water Quality Summary for the Catskill System

DEP has greatly enhanced watershed protection in the Schoharie basin during the course of the FAD. Tannersville and Grand Gorge WWTPs were upgraded to state-of-the-art tertiary treatment in the late 1990s. Another 19 smaller WWTPs are in the process of being upgraded or consolidated into new infrastructure. As a result, phosphorus loads were reduced from more than 750 kg yr^{-1} to less than 250 kg yr^{-1}. In addition, nearly 500 failing septic systems were repaired. In the Whole Farm Program, 17 of 23 participating farms are substantially implemented. Exceptionally high stream flows in 2003 and 2004 hindered stream restoration projects.

A case study at Tannersville and Grand Gorge WWTPs showed that the upgrades led to significant reductions in phosphorus concentrations in the receiving streams. At Tannersville, median total phosphorus concentrations dropped from 35 µg L^{-1} to 14 µg L^{-1}, and at Grand Gorge median TP concentrations were reduced from 101 µg L^{-1} to 28 µg L^{-1} after the upgrades were completed. Those are decreases to 40% and 27% of the former values.

The water quality status in Schoharie Reservoir during 2002 to 2004 was good with very few values for the selected analytes (i.e., fecal coliform, turbidity, TP , conductivity, and TSI) were above the benchmarks. Median fecal coliform concentration was 2 CFU 100 mL^{-1} and turbidity was 3.6 NTU. The total phosphorus median was 10.8 µg L^{-1} and trophic status was towards the lower side of mesotrophic.

Water quality trends in the input tributary and reservoir showed significant declines in phosphorus concentrations, as a reflection of the loading reductions, in combination with flood years followed by drought in 2001 to 2002. Despite the decline in nutrients, the tropic state index showed an upward trend and is attributed to improvements in water clarity.

In the Ashokan basin, the Pine Hill WWTP was upgraded to tertiary treatment, and four other smaller plants are being upgraded. Phosphorus loading was reduced from 220 kg yr^{-1} to about 50 kg yr^{-1}. In addition, over 550 failing septics were repaired. The total percentage of land protected in this basin is 63% in large part due to the NYS Catskill Forest Preserve.

Water quality status in the West Ashokan basin was very good during the 2002 to 2004 period with very few values above the established benchmarks. The fecal coliform median was 1 CFU 100 mL^{-1} and the turbidity median was 2.9 NTU. The phosphorus median was

8.3 µg L^{-1}. The trophic state index was on the high side of mesotrophic.

Trends in the West Basin show that although phosphorus has declined, the trophic state index shows an increase that may be related to improvements in clarity following recovery from the 1995 to 1996 flood.

A case study of the Pine Hill WWTP showed that the median TP at a stream site below the plant was reduced from 25 µg L^{-1} to 15 µg L^{-1} after the plant was upgraded.

Water quality status in the East Ashokan basin was also very good during the 2002 to 2004 period, and similar to the West Ashokan basin. The primary difference in the two was lower turbidity in the East basin with a median of 1.7 NTU. The trophic status index was also higher than the West basin, and close to eutrophic.

Trends for the East Ashokan basin show the same as the West basin, namely, that although phosphorus has declined, the trophic state index shows an increase that may be related to improvements in clarity following recovery from the 1995 to 1996 flood. Flooding due to occasional heavy rains in the Catskills remains the dominant factor controlling water quality for this system. Excellent water quality prevails for the majority of time when the impacts of such intermittent floods subside to background levels.

4. The Delaware System

4.1 The Neversink Basin

Neversink Reservoir is located in Sullivan County, approximately 5 miles northeast of the Village of Liberty and more than 75 miles from New York City. Placed into service in 1954, it was formed by the damming of the Neversink River, which continues south and eventually drains into the lower Delaware River. The reservoir holds 34.9 billion gallons at full capacity and provides 163 million gallons per day (MGD), or 13.5% of the total average daily consumption to New York City and an additional one million upstate consumers.

Figure 4.1 Neversink Reservoir.

The Neversink is one of four reservoirs in the Delaware water supply system, the newest of the City's three systems. The water withdrawn from the reservoir travels six miles in the Neversink Tunnel to the Rondout Reservoir. There it mixes with water from the other two Delaware system reservoirs, Cannonsville and Pepacton, before heading south via the 85-mile-long Delaware Aqueduct, which tunnels below the Hudson River. Neversink water ordinarily makes its way to the West Branch and Kensico Reservoirs for further settling. At Kensico, it mixes with Catskill system waters before entering the two aqueducts that carry Catskill/Delaware water to the Hillview Reservoir in Yonkers, at the City's northern boundary, where it enters the water supply distribution system.

The Neversink watershed's drainage basin is 92 square miles and includes portions of six towns. The Neversink River is the main tributary supplying the reservoir, providing a 73% water contribution. Presently there are no WWTPs sited in the Neversink watershed basin.

Of the 58,889 acres of land in the Neversink watershed, 54,617 acres (92.7%) are forested, 443 acres (0.8%) are urban in nature, 150 acres (0.3%) are roads, 894 acres (1.5%) are brushland, and 566 acres (1.0%) are classified as grass land. Wetlands comprise 680 acres (1.2%) of the watershed, while 1522 acres (2.6%) are under the reservoir. The remaining 17 acres (>0.01 %) are in agricultural use.

4.1.1 Program Implementation

The Neversink Reservoir basin is one of the more pristine watersheds in the New York City water supply system. A majority of the land in the basin is State-owned and the remainder is sparsely populated. Despite the small amount of privately held lands, DEP's Land Acquisition Program has been very active, having increased land holdings by more than 3,000 acres either through outright purchase or easements.

Presently there are no WWTPs sited in the Neversink watershed basin.

Additionally, DEP has implemented 21 Forest Management Plans, which albeit a relatively small number of projects when compared to other basins, covered very large swaths of land. Also, DEP's Whole Farm Program has enrolled four farms; two of the participating farms have been substantially implemented. Program activity in the Neversink basin up to December 31, 2005, is summarized in Figure 4.2.

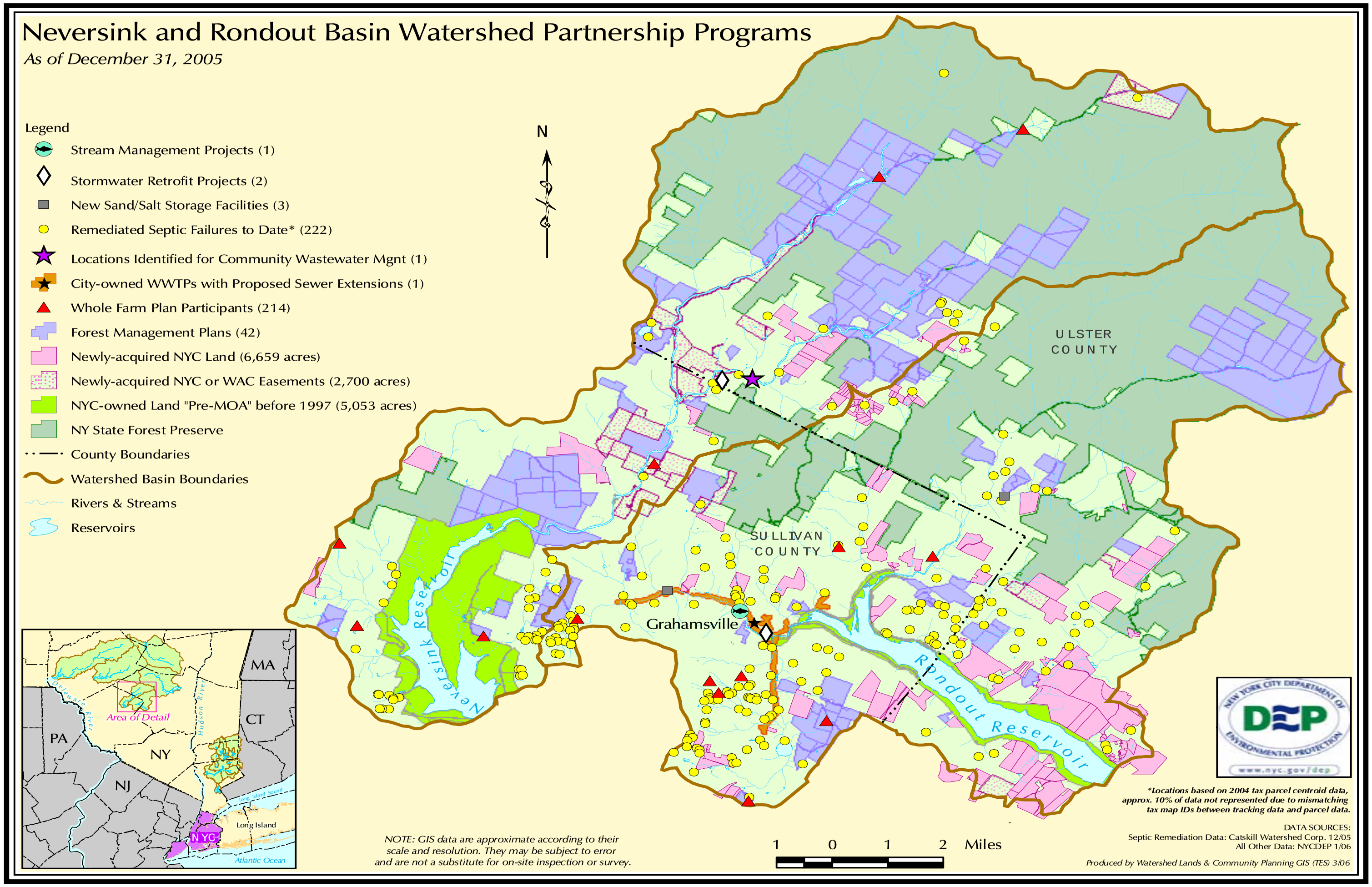
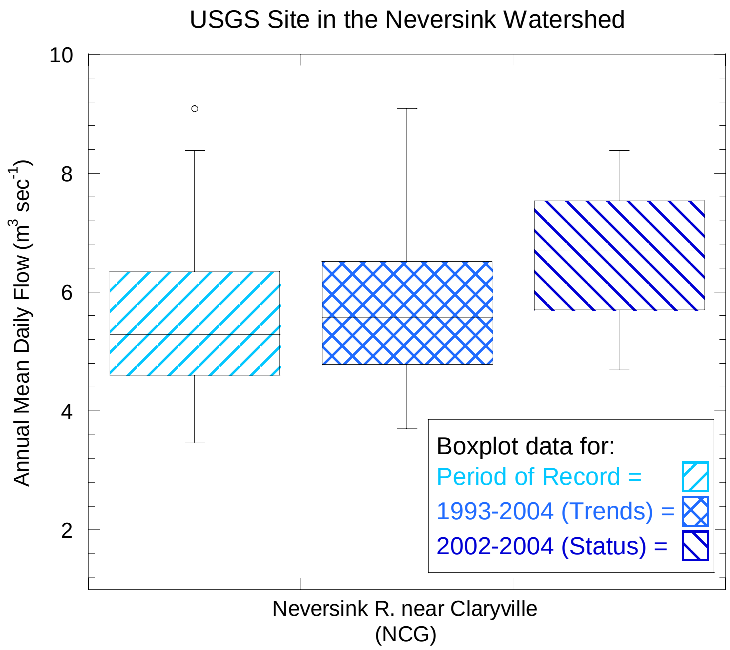


Figure 4.2 Neversink and Rondout basin Watershed Partnership Programs as of December 31, 2005.

4.1.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 4.3. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

The Neversink River near Claryville is the primary inflow to Neversink Reservoir. It drains 72% of the basin. The flow distributions (of the annual mean daily flows) show that the 12-year median representing the trends period was very similar to the long-term median, and the 3-year median representing the status period was about 1.3 m^3 sec^{-1} greater than the long-term median and the overall distribution was slightly biased to higher flows. Therefore, flows in the status time period were somewhat higher than usual.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
NCG	Neversink R. near Claryville	72.4%	July 1951 - present; Nov. 1937 - May 1949

Figure 4.3 USGS stream gauge site in the Neversink watershed.

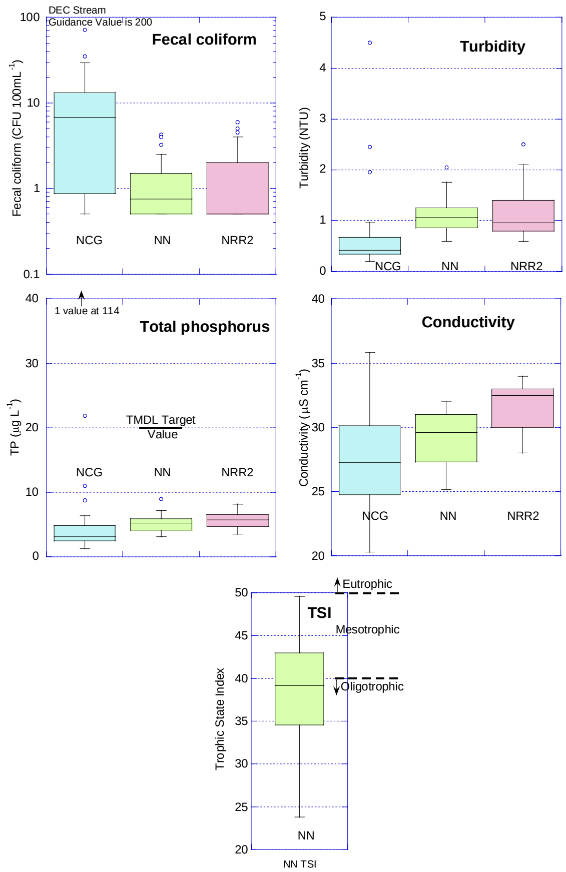


Figure 4.4 Water Quality status boxplots using 2002–2004 monthly data for the Neversink basin for: the main stream input, the Neversink River at NCG; the reservoir, NN; and the effluent aqueduct keypoint, NRR2.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Status (Neversink Basin)

Neversink Reservoir's status evaluation is presented as a series of box plots in Figure 4.4. The input stream (NCG), reservoir (NN) and the output (NRR2) are included for comparison.

Fecal coliform values were very low throughout the basin and all values for the input stream were well below the DEC Stream Guidance Value of 200 CFU 100 mL^{-1} during the 2002 – 2004 analysis period. Many of the values were at or below the detection limit. There was a notable decrease in the median and variability of fecal coliform values as water traveled from the input, through the reservoir and the output.

The turbidity values of the input had less variability and a lower median than both Neversink Reservoir and its output. Although all values were quite low, the slightly higher turbidity in the reservoir may have several potential causes. The reservoir was drawn down to almost 50% in early 2002 and again in late summer-early fall. Draw down can increase the turbidity via resuspension of particulates. Turbidity was higher during these times. Minor algal blooms may be another factor that can easily raise the turbidity by several NTU. This effect would be enough to raise the median turbidity in the reservoir as compared to the input. Another potential factor is that the twice-monthly stream sampling may not capture storm events, whereas the reservoir turbidity values would reflect the effect of storms.

Total phosphorus patterns were similar to turbidity in that the median for the three years was lower for the input than the reservoir. As mentioned for turbidity, this may be the result of missed storm events with fixed-schedule stream monitoring, or resuspension of particulates during times of draw down. None of the values in Neversink Reservoir were above the TMDL target value of 20 µg L^{-1} in the reservoir.

The trophic status index for Neversink Reservoir ranged from oligotrophic to mesotrophic for the three year period. The majority of the values during this period were oligotrophic which is indicative of the relatively low primary productivity in this impoundment.

There was slightly more variability in the conductivity in the input as compared to the reservoir and the output of Neversink. Another distinct feature of this comparison is the increase in the median through the system. Variations in the sample collection frequency and times, and use of different instruments may play a role in these minor differences between the sites.

In summary, water quality was very good during the 2002 – 2004 analysis period in the Neversink Reservoir. The data for the selected variables show that there were no values that exceeded the established benchmarks.

Trends (Neversink Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 4.5.

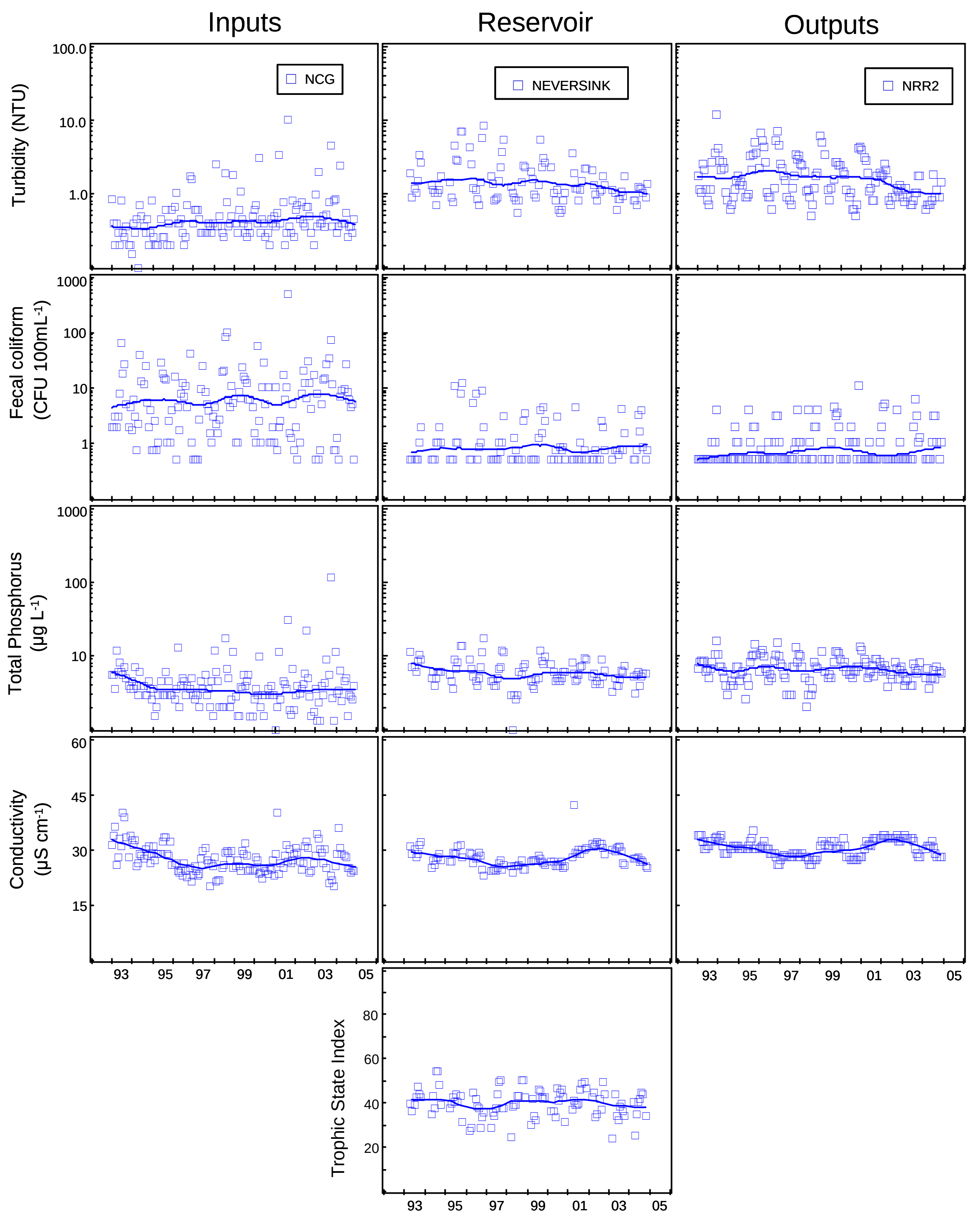


Figure 4.5 Water quality trend plots for the Neversink basin for: the main stream input, the Neversink River at NCG; the reservoir, Neversink, and the effluent aqueduct keypoint, NRR2.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Results of the Seasonal Kendall trend analysis are provided in Table 4.1.

Table 4.1. Neversink Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
NCG	Input	Turbidity	12	144	0.17	***	0.00
Neversink	Reservoir	Turbidity	9	108	-0.23	***	-0.04
NRR2	Output	Turbidity	12	144	-0.21	***	-0.03
NCG	Input	Fecal coliform	12	144	-0.01	NS	0.00
Neversink	Reservoir	Fecal coliform	9	108	0.00	NS	0.00
NRR2	Output	Fecal coliform	12	144	0.05	NS	0.00
NCG	Input	Total Phosphorus	12	144	-0.17	***	-0.09
Neversink	Reservoir	Total Phosphorus	9	108	-0.26	***	-0.17
NRR2	Output	Total Phosphorus	12	144	-0.12	**	0.00
NCG	Input	Conductivity	12	144	-0.19	***	-0.29
Neversink	Reservoir	Conductivity	9	108	0.09	NS	0.00

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
2. Tau refers to the Seasonal Kendall Test Tau statistic.

Declines in turbidity were detected in the reservoir (-0.04 NTU yr^{-1}) and (-0.03 NTU yr^{-1}) representing recovery from flood events in the mid to late 1990's as well as low turbidity loads during the drought period mid 2001-2002. In contrast, an upward trend, based on the positive Tau value, was detected for the main input NCG. Attempts to adjust the data to account for flow did not appreciably affect the trend results. Perhaps turbidity patterns in Neversink Reservoir are not predominantly a function of this input. Moreover, turbidity levels are generally higher in the reservoir and output than in the input indicating a possible additional source of turbidity unique to the reservoir. One potential source may be in-reservoir algal production. While algal particles generally produce very little turbidity, the background turbidity levels in the Neversink watershed are so low that even this small source is likely to exert some control over turbidity patterns in the reservoir. The discrepancy between the reservoir and input may also be an artifact of the sampling programs. Turbidity inputs are sampled on a fixed frequency, which may miss storm events that produce significant turbidity inputs to the reservoir.

Total phosphorus concentrations were found to decrease in both the input stream and the reservoir during the period of record. However, virtually all of the decrease occurred from 1993 to 1994. The elevated concentrations in 1993 were caused by a large early spring rain event that followed two years (1991 and 1992) of extremely dry conditions in the watershed.

Dry conditions also tend to produce higher conductivities (more conductive groundwater relative to more dilute rainfall). These conditions occurred in 1991-92 (data not shown) and were likely the cause of the elevated conductivity observed in the input in 1993. Normal precipitation levels from 1993-96 lowered the conductivity (through dilution) causing the downward trend observed in the data. Although no trend was apparent in the reservoir, an increase can be observed in 2002 (also reflected in the input and output data), which, can be ascribed to the dry conditions prevalent in that year.

Trends were not detected in the Trophic State Index values of the reservoir suggesting that algal populations were relatively steady (and low) during the period of record.

In summary, downward trends were detected for turbidity, phosphorus and conductivity in the Neversink Basin. The phosphorus trend is controlled by the high concentrations at the start of the record and subsequent recovery. The turbidity decline is attributed to recovery from flood induced turbidity highs in the mid to late 1990s and from low turbidity loads during the drought period mid 2001-2002. The decrease in input conductivity is the expected result when a drought period is followed by a period of more typical precipitation patterns.

4.2 The Pepacton Basin

Pepacton Reservoir is located in Delaware County along the southern edge of the State's forever wild Catskill Park, 12 miles south of the Village of Delhi, and more than 100 miles north-west of New York City. The reservoir was formed by the damming of the East Branch of the Delaware River, which continues west and joins the lower Delaware River. Placed into service in 1955, Pepacton consists of one basin, approximately 15 miles in length. The reservoir holds 140.2 billion gallons at full capacity, which makes it the largest reservoir in the City system by volume. Currently, Pepacton supplies 293 million gallons per day (MGD) or roughly 24.2% of the total average daily consumption to New York City and an additional one million upstate consumers.

Figure 4.6 Pepacton Reservoir.

The Pepacton is one of four reservoirs in the City's Delaware water supply system. Water withdrawn from the Pepacton Reservoir enters the East Delaware Aqueduct and flows southeast for 25 miles into the Rondout Reservoir. There it mixes with water from the Cannonsville and Neversink Reservoirs, before heading south via the 85-mile long Delaware Aqueduct, which tunnels below the Hudson River. Pepacton water ordinarily makes its way to the West Branch and Kensico Reservoirs for further settling. After mixing with Catskill system waters in the Kensico, it travels via aqueduct to the Hillview Reservoir in Yonkers, where it enters New York City's water supply distribution system.

The Pepacton watershed's drainage basin is 371 square miles, and includes parts of 13 towns in three counties. Four main tributaries flow into Pepacton: East Branch Delaware River contributes 44%, Platte Kill provides 9.5%, and Tremper Kill and Millbrook Stream provide 9% and 7%, respectively. Presently there are six wastewater treatment plants sited in the Pepacton watershed region producing an average flow of 0.402 MGD. As per the most recent SPDES permits, the plants are limited to a collective release of 0.526 MGD of flow.

Of the 237,478.2 acres of land in the Pepacton watershed, 195,423 acres (83.3%) are forested. Close to 5,881 acres (2.5%) are urban in nature, 410 acres (0.2%) are roads, 18,204 acres (7.7%) are brushland, and 8,956 acres (3.8%) are classified as grass land. Wetlands comprise 1,838 acres (0.8%) of the watershed, while 5,734 acres (2.4%) are under the reservoir. The remaining 1,033 acres (0.4%) are in agricultural use.

4.2.1 Program Implementation

DEP has taken great steps to ensure the continued high quality of water in the Pepacton Reservoir basin. Program activity in the Pepacton watershed basin up to December 31, 2005, is summarized in Figure 4.7. The Land Acquisition Program has been particularly effective, having acquired close to 11,000 acres either through outright purchase or easements. Under the Septic Remediation Program, DEP repaired nearly 385 failing septic systems. DEP's New Infrastructure Program has identified three communities eligible for new WWTPs, as well as two locations identified for Community Wastewater Management. Five Stormwater Retrofit Projects have also been implemented.

Presently there are six wastewater treatment plants in the Pepacton watershed basin, producing an average flow of 0.402 MGD. The City-owned Margaretville WWTP was upgraded to state-of-the-art tertiary treatment in the late 1990s. Additionally, the Camp L'man Achai WWTP, a non-City-owned plant was upgraded. Under the New Infrastructure Program, the Andes WWTP was constructed; currently, the Fleischmanns WWTP is under construction.

Also active in the Pepacton basin has been the Whole Farm Program. Currently there are 33 farms participating in the program with 22 farms substantially implemented.

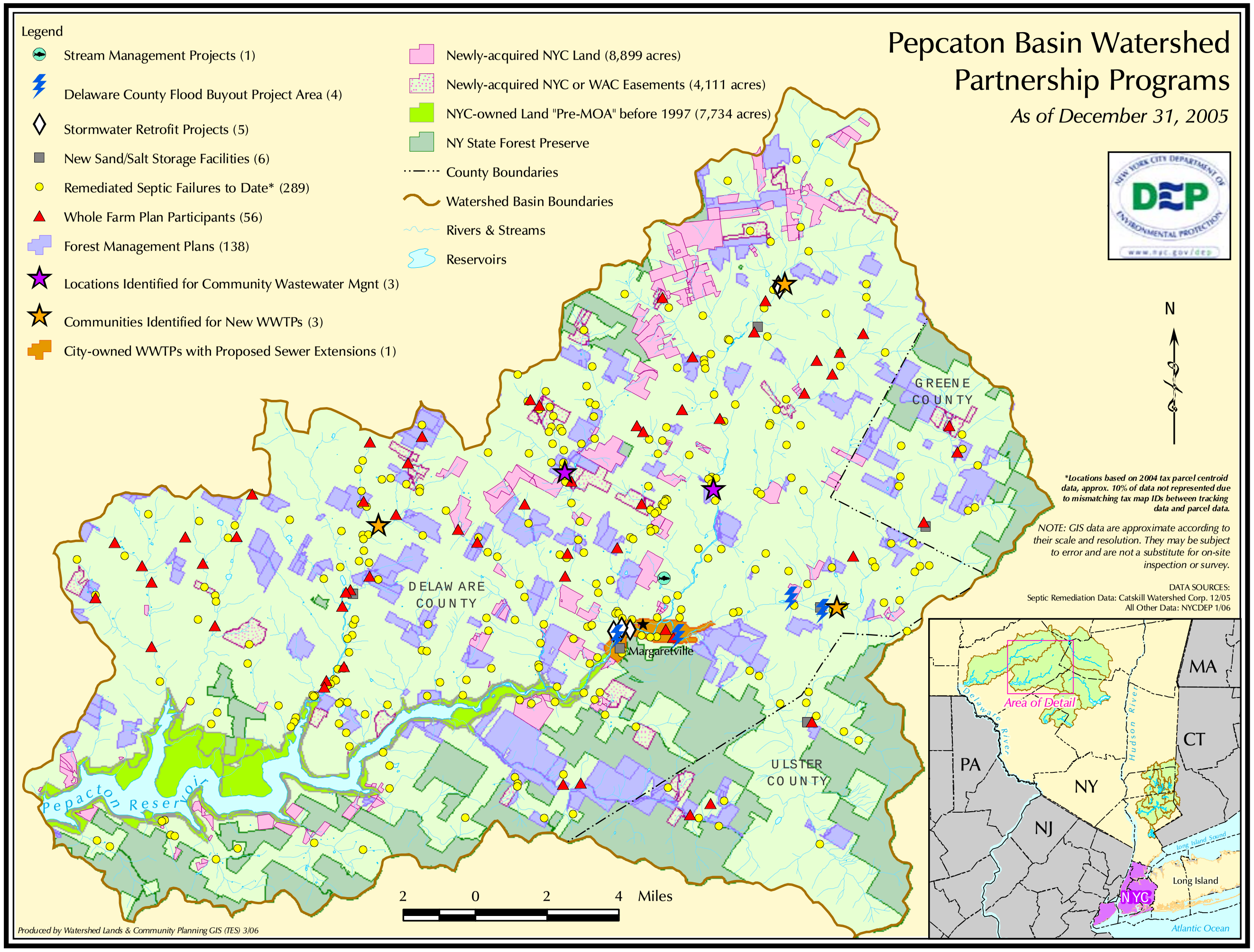


Figure 4.7 Pepacton basin Watershed Partnership Programs as of December 31, 2005.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Pepacton Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Pepacton Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging plants, including upgrade of the City-owned Margaretville plant, and also through the intervention and involvement of DEP's Regulatory Compliance and Inspection (RCI) Program. As illustrated in Figure 4.8, phosphorus (as Total Phosphorus) loads, considerably reduced from 1994 to 1999, remain low in 2004. The primary cause of the reduction was the upgrade of the largest plant, Margaretville. In addition, more effective pollutant removals at Roxbury Run resulted from DEP assistance. Table 4.2 highlights significant contributing events and accomplishments at some of the plants.

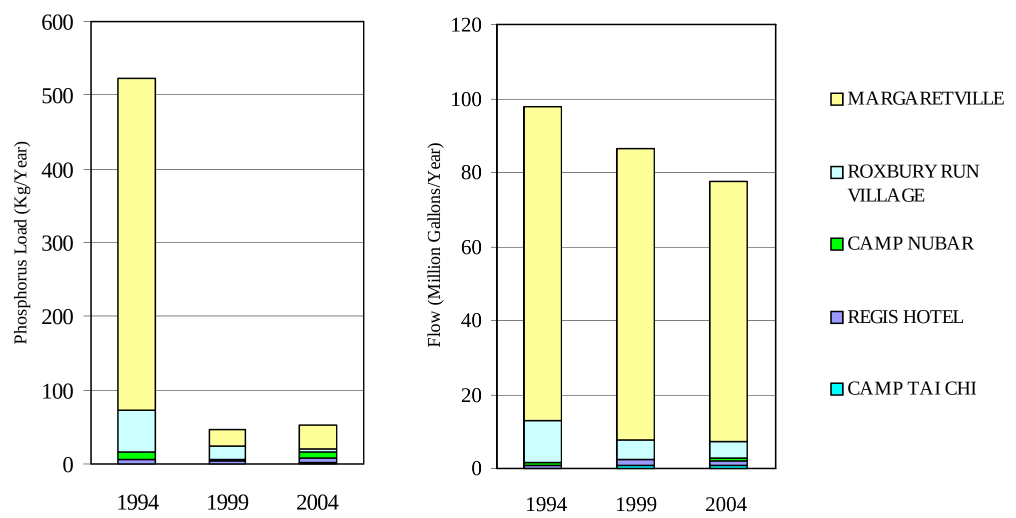


Figure 4.8 Total phosphorus loads and total volume of WWTP effluent flow to Pepacton Reservoir in 1994, 1999, and 2004.

Table 4.2. Significant events and accomplishments at WWTPs in the Pepacton Reservoir basin since 1994.

WWTP	COMMENTS *
Margaretville	Upgrade permit date Oct 1999
Roxbury Run Village	Plant improvements in 1995 and 1998 Upgrade permit date Feb 2005
Camp Nubar	-----
Regis Hotel	-----
Camp Tai Chi	Upgrade permit date Dec 2004

Table 4.2. Significant events and accomplishments at WWTPs in the Pepacton Reservoir basin since 1994.

WWTP	COMMENTS *

* The permit date referred to in this table is six months after plant upgrade is completed. Allowing for a start-up period, this is the date on which the requirements of each plant's final SPDES permit take effect.

Case Study
Wastewater Treatment Plant Effects on Water Quality in the Pepacton Basin

The benefits of the WWTP Regulatory and SPDES Upgrade Program can be demonstrated by examining the water quality of the receiving waters of the WWTP effluents. This has been accomplished visually by plotting the data and producing a LOWESS smoothing pattern (using a 30% smoothing factor) through the data. A vertical line on the plot shows when the upgraded SPDES permit went into effect for the WWTP, but it should be noted that WWTP upgrades and modifications were occurring prior to this date.

Figure 4.9 shows the total phosphorus concentrations and fecal coliform levels at sampling sites on the East Branch of the Delaware River above and below the Margaretville WWTP's discharge. Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were higher than those seen in the creek above the plant; however, the fecal coliform results were not quite as clear. The upstream fecal coliform levels (median value = 30 CFU 100 mL^{-1}) were often higher than the downstream site before the WWTP upgrades (median value = 20 CFU 100 mL^{-1}). This may have been due to agricultural activity in the watershed or issues with other WWTPs in the watershed. The median TP and fecal coliform levels in the river below the plant before the upgraded SPDES permit were 23 µg L^{-1} and 20 CFU 100 mL^{-1}, respectively, and were 14 µg L^{-1} and 22 CFU 100 mL^{-1}after the upgrade. Following the plant improvements and the upgraded SPDES permit, the upstream and downstream values for total phosphorus and fecal coliforms were similar.

The observed reduction in total phosphorus concentrations in the streams below the plants supports the findings of reduced phosphorus loads from the WWTPs as discussed in the WWTP Load Case Study for the Pepacton Basin.

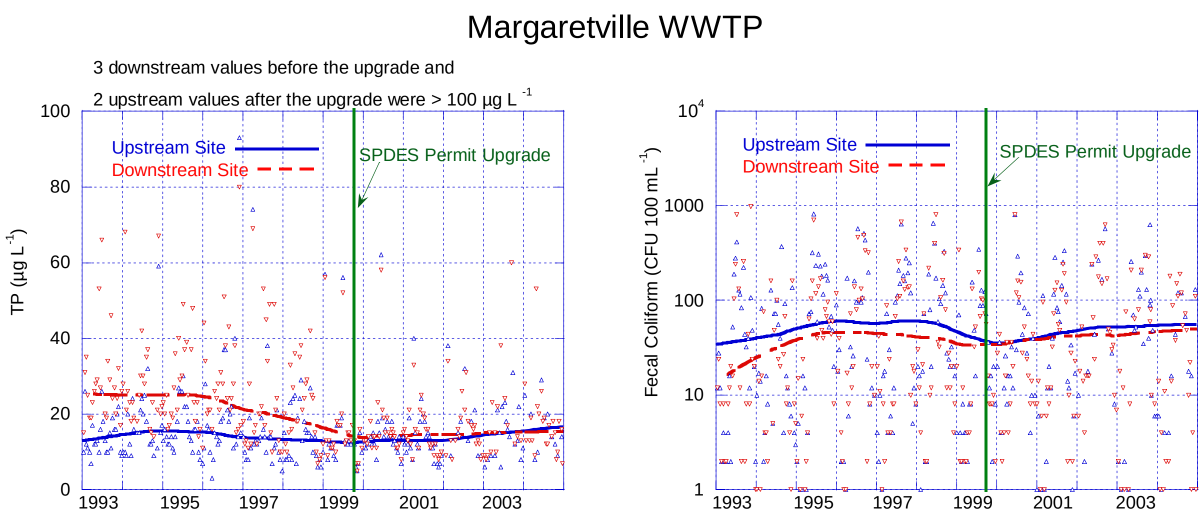


Figure 4.9 Total phosphorus and fecal coliform concentrations at stream sampling sites above and below the Margaretville WWTP (upstream site=PMSA, downstream site=PMSB) in the Pepacton Basin, 1993-2004. Lowess trend lines using a 30% smoothing coefficient are also plotted.

Case Study
Septic System Program/Watershed Agriculture Program

The Watershed Agriculture Program (see Section 2.3) and the Septic System Rehabilitation and Replacement Program (see Section 2.5.2) are designed to improve or maintain water quality in the NYC watershed. The Watershed Agricultural Program is a comprehensive effort to develop and implement pollution prevention plans on the commercial farms in the Catskill and Delaware watersheds. The program incorporates the economic and business needs of each participating farm into a Whole Farm Plan (WFP) to fully integrate the principles and goals of pollution prevention into the farm's operation. The plans are developed to protect water quality from farm-based pollution by tailoring Best Management Practices (BMPs) to each specific farm's circumstances.

Septic systems are used to treat wastewater from homes and small businesses that are not served by sewer systems and treatment plants. In a properly functioning septic system, pollutant concentrations found in raw sewage are reduced as biological activity and settling occurs in a septic tank and the remaining liquid passes through the septic tank. The water disperses in a tile field or soil absorption unit. Very old and failing systems threaten both groundwater and surface water quality by releasing ineffectively or untreated wastewater into the ground or, in the worst cases, directly on the surface. The Septic System Rehabilitation and Replacement Program has contributed funds to the Catskill Watershed Corporation (CWC) to repair or replace septic systems serving one- or two-family homes in the WOH watershed that are failing or likely to fail. In this case study, total phosphorus concentrations and fecal coliform levels in streams will be examined to see if the potential water quality benefits of these two programs can be detected at the sub-basin level.

The Tremper Kill sub-basin (84.5 km^2) of the Pepacton Reservoir watershed has had 21 septic failures remediated and has 12 participants in the Whole Farm Program. Figure 4.10 shows the total phosphorus concentrations and fecal coliform levels at the stream sampling site (site code P-13) on the Tremper Kill from 1993 - 2004. It should be noted that total phosphorus and fecal coliform values throughout this period are generally low with annual medians from this period ranging from 11 - 17 µg L^{-1} and 20 - 69 CFU $100mL^{-1}$, respectively. It should also be noted that beginning in 2002, the frequency of data collection for fecal coliforms was reduced from twice a month to monthly samples. While there does not appear to be any trend in these data, the annual median fecal coliform values in 2003 and 2004 (22 and 20 CFU 100 mL^{-1}, respectively) were the lowest annual medians for this period. Although 2003 and 2004 were relatively “wet” years, which typically lead to higher values of nonpoint source pollutants, it is possible that this characteristic was not observed because pollutant sources were somewhat mitigated by the FAD programs.

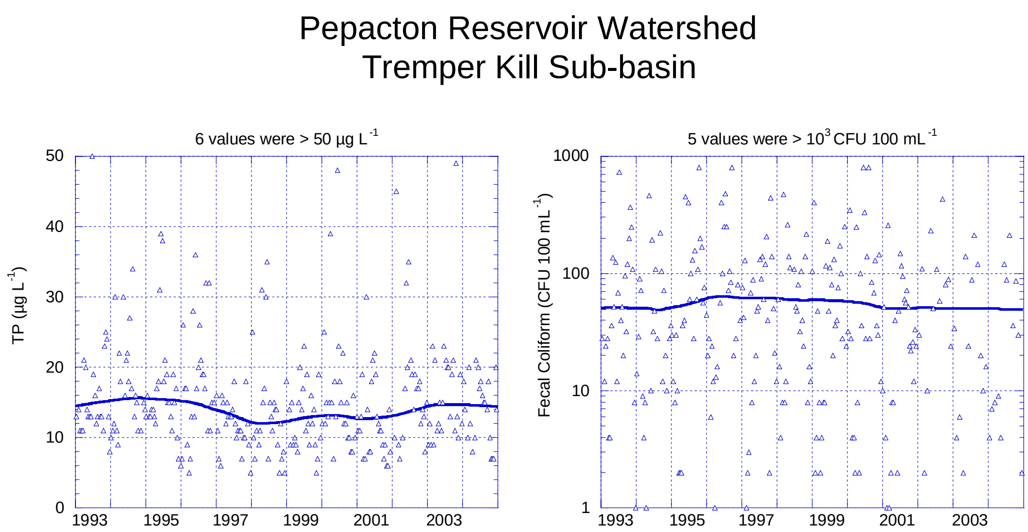


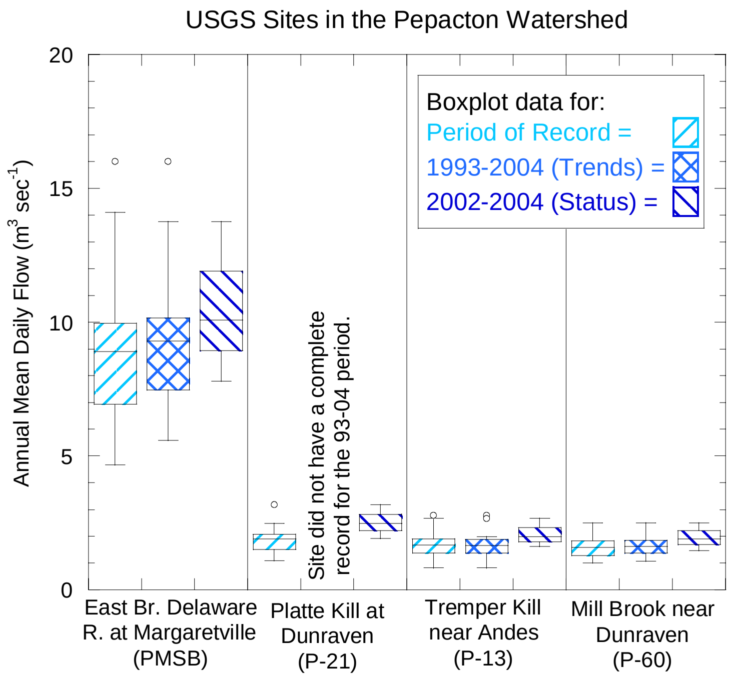
Figure 4.10 Total phosphorus and fecal coliform concentrations at the stream sampli
on the Tremper Kill (site code = P-13) in the Pepacton Basin, 1993-20
Lowess trend line using a 30% smoothing coefficient is also plotted.

Numerous factors besides failing septic systems and agricultural runoff can contribute to total phosphorus concentrations and fecal coliform levels in streams, e.g. stormwater runoff, lawn fertilizers, pets. Also, given that these are nonpoint sources of pollution, seasonal and annual variability in hydrology can affect the results. Finally, the objective of collecting water quality data at this site was not designed to specifically address the impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program, but was to examine long-term trends in water quality and provide loading information for use in water quality models. As such, the data may not have been collected at an appropriate resolution to isolate the water quality impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program. While the data do not indicate improvements in water quality, it should be noted that the relatively good water quality in this stream is being maintained with no signs of degradation.

4.2.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 4.11. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

The East Branch of the Delaware River at Margaretville is the primary inflow to Pepacton Reservoir. It drains 45% of the basin. The flow distributions (of the annual mean daily flows) show that the 12-year median representing the trends period was only slightly greater than the long-term median, and the 3-year median representing the status period was about 1 $m^3\ sec^{-1}$ greater than the long-term median and the overall distribution was slightly biased to higher flows. Therefore, flows in the status time period were higher than usual.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
PMSB	East Br. Delaware R. at Margaretville	44.5%	Feb. 1937 - present
P-21	Platte Kill at Dunraven	9.4%	Dec. 1996 - present; Oct. 1941 - Sept. 1962
P-13	Tremper Kill near Andes	8.8%	Feb. 1937 - present
P-60	Mill Brook near Dunraven	6.7%	Feb. 1937 - present

Figure 4.11 USGS stream gauge sites in the Pepacton watershed.

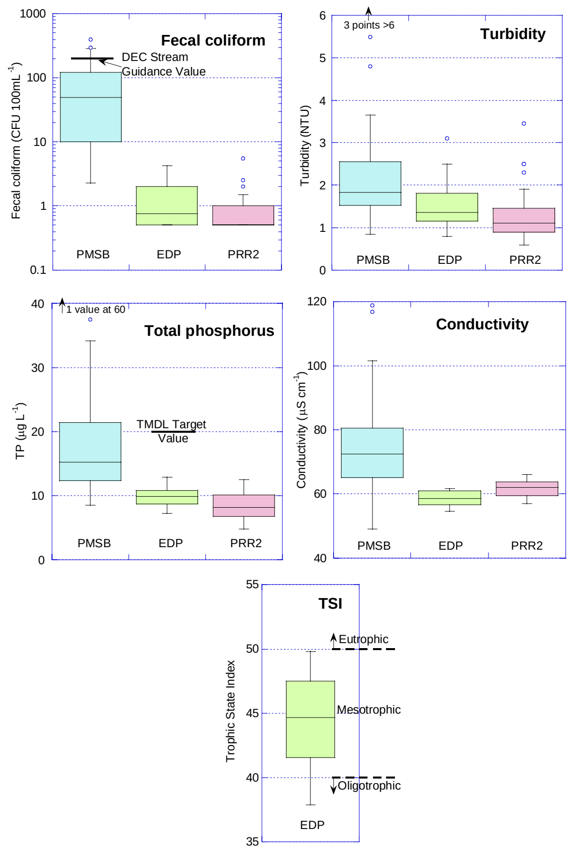


Figure 4.12 Water Quality status boxplots using 2002–2004 monthly data for the Pepacton basin for: the main stream input, the East Branch of the Delaware River at PMSB; the reservoir, EDP; and the effluent aqueduct keypoint, PRR2.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Status (Pepacton Basin)

Pepacton Reservoir's status evaluation is presented as a series of box plots in Figure 4.12. The input stream (PMSB), reservoir (EDP) and the output (PRR2) are included for comparison.

Fecal coliform values dropped dramatically between the input and the reservoir. Several values for the input stream exceeded the DEC Stream Guidance Value of 200 CFU 100 mL^{-1} during the 2002 – 2004 analysis period. In the reservoir and the output, many of the values were at or below the detection limit. By the time water from the stream input reaches the output in the reservoir, there is a significant attenuation of fecal coliform levels.

The turbidity values also show attenuation through the system. Both the variability and the medians decreased from the input to the reservoir and to the output. The median value at the output was 1.1 NTU for the three year period. Since the particulates associated with turbidity will settle with time, the attenuation of turbidity along a longitudinal transect is expected in a headwater reservoir.

Total phosphorus values resembled the pattern found with turbidity. The medians and variability were lower for the output and the reservoir as compared to the input stream. None of the values for Pepacton were above the TMDL target value of 20 µg L^{-1} in the reservoir.

The vast majority of trophic status index values for Pepacton Reservoir was well within the mesotrophic range.

There was more variability in the conductivity in the input stream as compared to the reservoir or the output of Pepacton. Stream conditions can be expected to fluctuate more than the reservoir, so this pattern was anticipated.

In summary, water quality was very good during the 2002 – 2004 analysis period in the Pepacton Reservoir. The data for the selected variables show that medians for fecal coliform were well below the established benchmarks.

Trends (Pepacton Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 4.13.

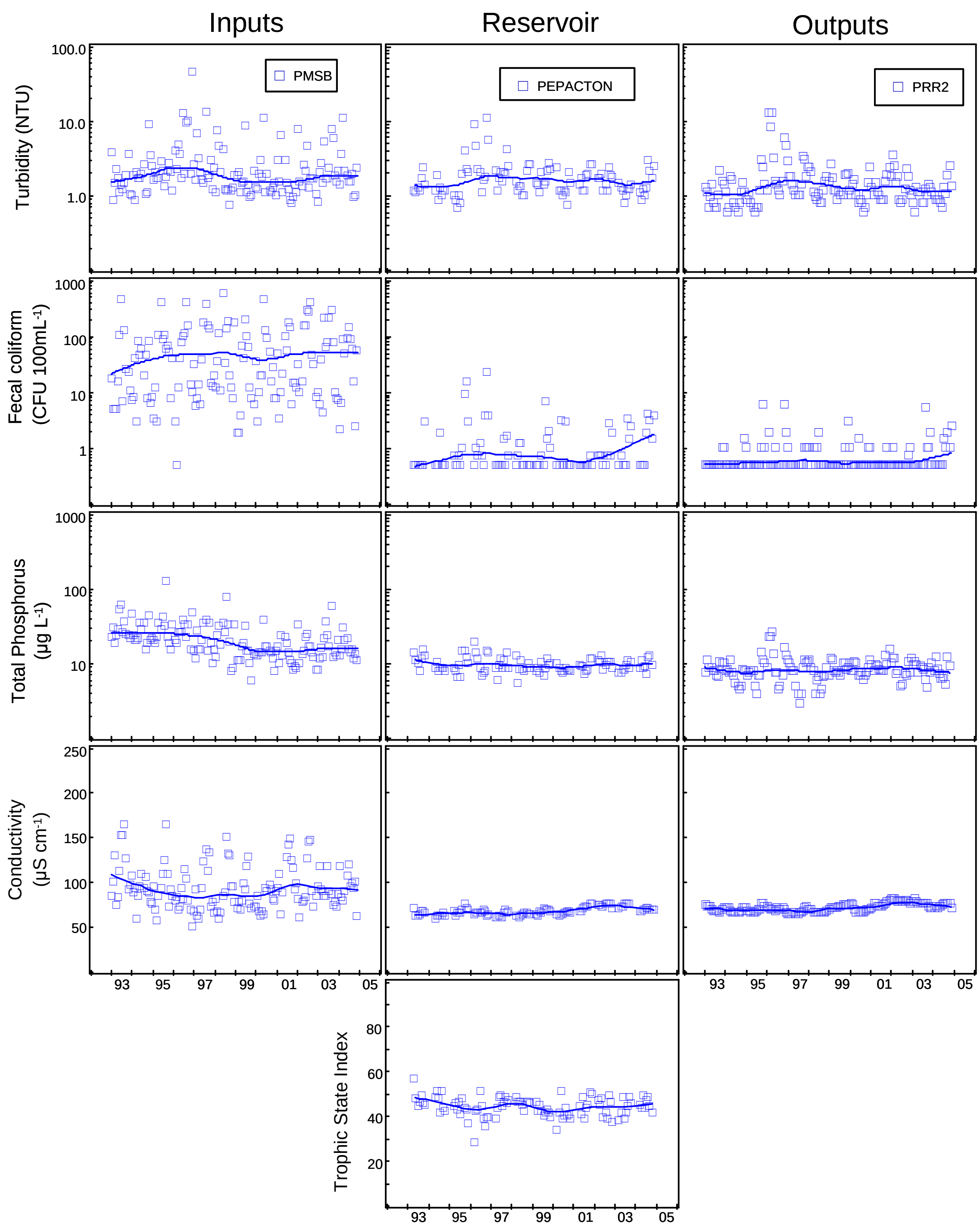


Figure 4.13 Water Quality trend plots for the Pepacton basin for: the main stream input, the East Branch of the Delaware River at PMSB; the reservoir, Pepacton; and the effluent aqueduct keypoint, PRR2.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Results of the Seasonal Kendall trend analysis are provided in Table 4.3.

Table 4.3. Pepacton Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[3]	*p*-value[2]	Change yr^{-1}
PMSB	Input	Turbidity	12	144	-0.01	NS	0.00
Pepacton	Reservoir	Turbidity	9	108	-0.03	NS	0.00
PRR2	Output	Turbidity	12	144	0.01	NS	0.00
PMSB	Input	Fecal coliform	12	144	0.05	NS	0.25
Pepacton	Reservoir	Fecal coliform	9	108	0.05	NS	0.00
PRR2	Output	Fecal coliform	12	144	0.03	NS	0.00
PMSB	Input	Total Phosphorus	12	144	-0.39	***	-1.24
Pepacton	Reservoir	Total Phosphorus	9	108	-0.07	NS	0.00
PRR2	Output	Total Phosphorus	12	144	0.03	NS	0.00
PMSB [1]	Input	Conductivity	12	144	0.11	**	0.33
Pepacton	Reservoir	Conductivity	9	108	0.46	***	0.67
PRR2	Output	Conductivity	12	144	0.37	***	0.56
Pepacton	Reservoir	Trophic State Index	9	108	-0.08	NS	-0.14

1. Data was adjusted for flow prior to trend analysis—see Appendix 3.
2. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
3. Tau refers to the Seasonal Kendall Test Tau statistic.

Long-term trends were not detected for turbidity, fecal coliform or trophic state index in Pepacton's input, output or in the reservoir itself. However, the LOWESS curve does indicate an upward trend for reservoir fecal coliforms and to a lesser extent, output coliforms (PRR2), during the last three years of the data record. Reasons are not clear but above average precipitation during the latter part of the data record may be a factor.

Trends in total phosphorus were not apparent in the reservoir or output although a significant decline (-1.24 $\mu g\ mL^{-1}\ yr^{-1}$) was observed in the input, PMSB, especially from 1996 through 1999. This period coincides with upgrades to the Margaretville Wastewater Treatment Plant which were completed in 1999. Part of the decline can also be attributed to recovery from flooding events in late 1995, early 1996. Terrestrial and reservoir modeling suggest that land use changes may also have played a part in this reduction.

Slight upward trends in conductivity were detected in the input (+0.33μS cm^{-1} yr^{-1}), reservoir (+0.67μS cm^{-1} yr^{-1}) and output (+0.56μS cm^{-1} yr^{-1}). Anthropogenic sources (e.g., road salt runoff) may be the cause. Chloride has steadily increased from a median of about 4.0 mg L^{-1} in 1997 to a median of about 6.0 mg L^{-1} in 2004.

Trends were not detected for Trophic State Index indicating that algal activity has been steady during the period of record.

In summary, a downward phosphorus trend was detected at PMSB and upward conductivity trends occurred at PMSB, the reservoir, and the output at PRR2. Treatment plant upgrades and recovery from flooding events are thought to be the main factors controlling the phosphorus decrease. The conductivity increase appears to have an anthropogenic source.

4.3 The Cannonsville Basin

The Cannonsville Reservoir is located at the western edge of Delaware County, southwest of the Village of Walton and about 120 miles northwest of New York City. The reservoir was formed by damming the West Branch of the Delaware River, which continues south and becomes part of the lower Delaware River, the border between New York and Pennsylvania. Placed into service in 1964, it holds 95.7 billion gallons at full capacity. Currently, Cannonsville supplies 86 million gallons per day (MGD), or roughly 7.1% of the total average daily consumption, to New York City and an additional one million upstate consumers.

Figure 4.14 Cannonsville Reservoir

The Cannonsville is one of four reservoirs in the City's Delaware system and the newest in New York City's water supply. Water drawn from the Cannonsville enters the West Delaware Tunnel and travels 44 miles to the upper end of the Rondout Reservoir. From there, it's carried in the 85 mile long Delaware Aqueduct under the Hudson River and ordinarily makes its way to the West Branch and Kensico Reservoirs for further settling. Leaving Kensico, where it also mixes with Catskill system water, it passes through two aqueducts to the Hillview Reservoir in Yonkers, where it enters New York City's water supply distribution system.

The Cannonsville watershed's drainage basin is 455 square miles, the largest basin in the City's system, and includes parts of 17 towns, all in Delaware County: Andes, Bovina, Delhi, Deposit, Franklin, Hamden, Harpersfield, Jefferson, Kortright, Masonville, Meredith, Middletown, Roxbury, Sidney, Stamford, Tompkins and Walton. Trout Creek and West Branch Delaware River are the two primary tributaries flowing into Cannonsville, the former providing approximately 4.5% and the latter approximately 77%. Presently there are seven wastewater treatment plants (WWTPs) sited in the Cannonsville watershed region producing an average flow of 2.43 MGD. As per the most recent SPDES permits, the plants are limited to a collective release of 3.06 MGD of flow.

Of the 291,084 acres of land in the Cannonsville watershed, 200,258 acres (85.2%) are forested, 10,036 acres (2.6%) are urban in nature, 4,158 acres (0.7%) are roads, 32,945 acres (5.5%) are brushland, and 28,930 acres (3.2%) are classified as grass land. Wetlands comprise 3,570 acres (1.6%) of the watershed, while 5,182 acres (0.8%) are under the reservoir. The remaining 6,004 acres (0.5%) are in agricultural use.

A portion of water not taken for the City's supply is released from Cannonsville Dam at the reservoir's west end and flows into the lower West Branch of the Delaware River. Under a 1954 U.S. Supreme Court ruling, New York City can take up to 800 million gallons a day from the Delaware River, provided it releases enough water to insure adequate flow in the lower Delaware for New Jersey and other downstream users. This process is overseen by the Delaware River Basin Commission (DRBC). The City also, in conjunction with the New York State Department of Environmental Conservation (DEC), releases water from Cannonsville and other Delaware system reservoirs to help maintain the fisheries of the lower West Branch Delaware River.

4.3.1 Program Implementation

DEP’s watershed protection efforts have resulted in remarkable improvement in water quality in the Cannonsville Reservoir. Over the past several years, WWTP upgrades have greatly reduced the amount of phosphorous entering the Reservoir. Presently there are seven wastewater treatment plants (WWTPs) in the Cannonsville basin producing an average flow of 2.434 MGD. As of December 31, 2005, five non-City-owned WWTPs in the Cannonsville basin had been upgraded – Walton, Delhi, Hobart, Stamford and DCMO BOCES. Additionally, two WWTPs and a another SPDES-permitted facility were consolidated into the new upgraded plants: Allen Residential Center was consolidated with Hobart WWTP and Ultra Dairy and DMV were consolidated with Delhi WWTP. There in one remaining non-City-owned WWTP in the basin that is either slated for an upgrade.

The Community Wastewater Management Program (CWMP) has been most active in the Cannonsville basin, as four of the original five towns named when the program was introduced are located in the Cannonsville watershed: Bovina, Delancey, Hamden, and Bloomville. CWMP has completed project installation in Bovina and is currently at the end of the study phase for the three remaining towns in the Cannonsville basin. DEP expects the towns Delancey, Hamden and Bloomville to go through a one-year design phase followed by a construction phase. Also of note are the ten new sand and salt storage facilities as well as nine stormwater retrofit projects.

Additional protection in has been provided by the Whole Farm Program: currently, there are 134 farms participating in the program in the Cannonsville Basin with 85 farms substantially implemented. DEP's Forest Management Program has also been active in the region, having developed close to 170 plans. The Stream Management Program installed a restoration project at Post Farm on Trout Creek.

Watershed protection programs in the Cannonsville watershed have been very successful in reducing the amount of phosphorous entering the Reservoir. The collective reduction of contaminants entering source waters in the region allowed for removal of Cannonsville Reservoir from the list of phosphorous restricted basins in the New York City watershed (NYC-DEP 2002a). Program activity in the Cannonsville basin up to December 31, 2005, is summarized in Figure 4.15.

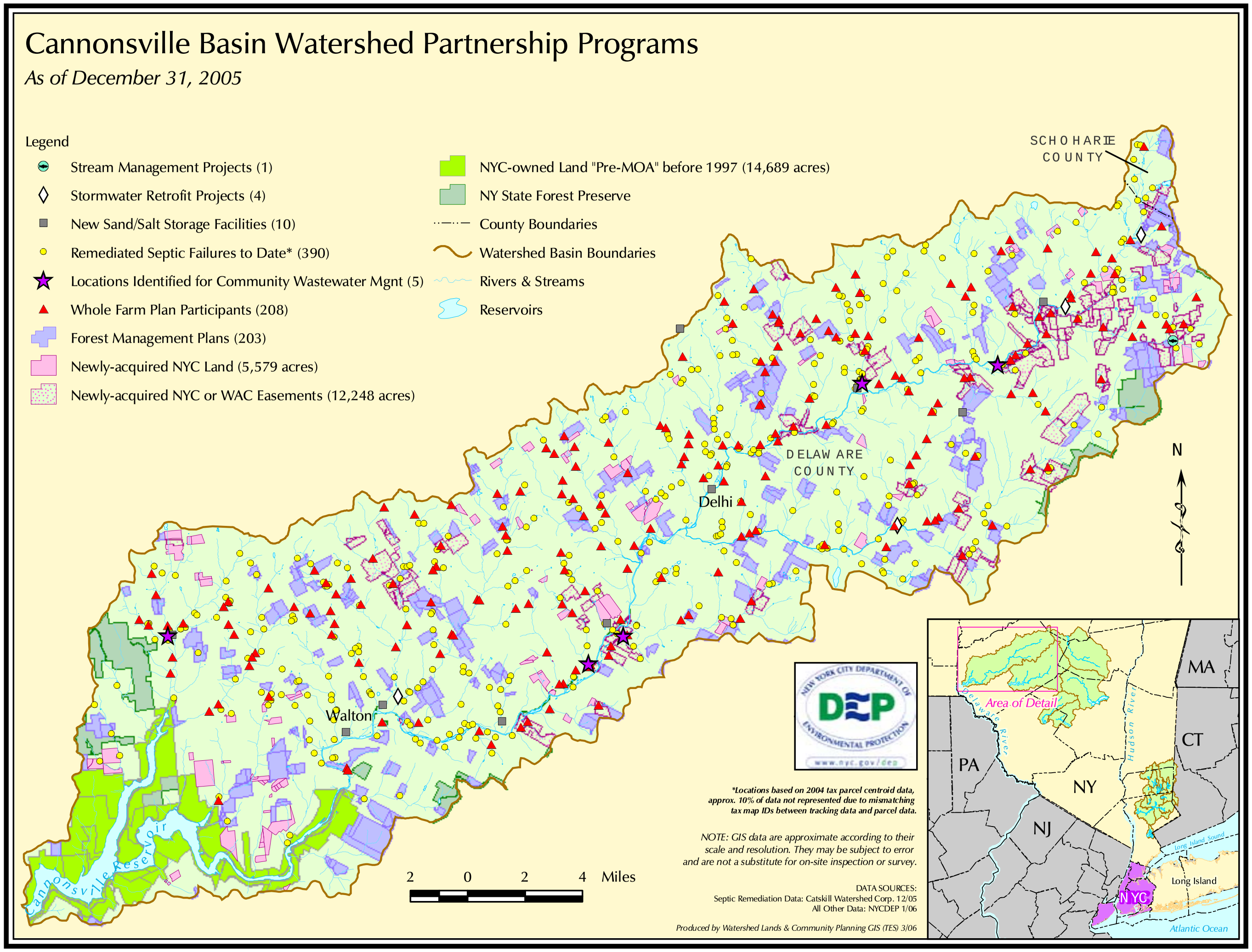


Figure 4.15 Cannonsville basin Watershed Partnership Programs as of December 31, 2005.

Case Study
Effectiveness of Whole Farm Planning in water quality improvement

Whole Farm Planning (WFP) was adopted by the NYC Watershed Agricultural Program (WAP), a voluntary incentive-based program, as the primary means of protecting NYC water supplies from farm-related nonpoint source pollution, as well as maintaining a viable agricultural community in the watershed. The study reported here is based on intensive monitoring (by DEC) of one farm, designated the R. Farm, from 1993 to the present with the objective of quantitatively evaluating the WFP approach for water quality protection and improvement.

The R. Farm, which is representative of upland agriculture in this hilly area, is located in the West Branch of the Delaware River (WBDR) watershed where most of the dairy agriculture of the entire NYC watershed occurs. It drains into Cannonsville reservoir. This Reservoir has had a long history of eutrophication problems due to excess loading of phosphorus from the WBDR associated primarily with dairy agriculture and point source discharges. Major sources of nonpoint phosphorus include land application of manure, barnyard runoff and overfertilization of cropland.

The project incorporates a modified paired watershed monitoring design, with the 160 ha R. Farm as the treatment watershed (improved pasture and hay 25%; corn rotation 7%; unimproved pasture 13%; deciduous forest 53%; and impermeable surface 2%) and a largely forested watershed (86 ha) as a control for inter-annual climate variability. Monitoring is conducted for a variety of analytes including phosphorus and nitrogen species. Stream flow and precipitation are also measured. In addition, records of farm activities before and after BMP implementation are being kept. Stream sampling is conducted during base flow and storm events at the outlet of each watershed.

The treatment and control sites were monitored for two years from June 1993 through May 1995, prior to implementation of near-barn and watershed scale BMPs at the treatment site in 1995–1996. Monitoring resumed in late 1996 and is expected to run for ten years. Additional improvements have taken place during this sampling period and are being evaluated through the monitoring.

DEC has thus far provided annual technical reports to the Watershed Agricultural Council on seven years of monitoring following BMP implementation. The results after four years of study following implementation were published in a peer-reviewed scientific paper (Bishop *et al.* 2005) and are reported below. A multivariate analysis of covariance (ANCOVA) provided estimates of both seasonal and overall load reductions. The results demonstrated overall load reductions during runoff events of 43% for total dissolved phosphorus (TDP) and 29% for particulate phosphorus (PP). Later, unpublished data support these results. Thus, changes in farm management practices and physical infrastructure clearly produced decreases in event P losses measurable at the small watershed scale.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Cannonsville Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Cannonsville Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging plants, and also through the efforts of DEP's Regulatory Compliance and Inspection (RCI) Program. As illustrated in Figure 4.16, phosphorus (as Total Phosphorus) loads were considerably reduced from 1994 to 1999. This was accomplished in large part through the intervention and assistance of DEP at Walton and at Walton's largest commercial contributor, Kraft. The substantial additional reductions in phosphorus loads realized after 1999 can be attributed to final upgrades of several plants and diversion of another. As a result, as of 2002 Cannonsville is no longer listed as a phosphorus-restricted basin. Table 4.4 highlights significant contributing events and accomplishments at the plants.

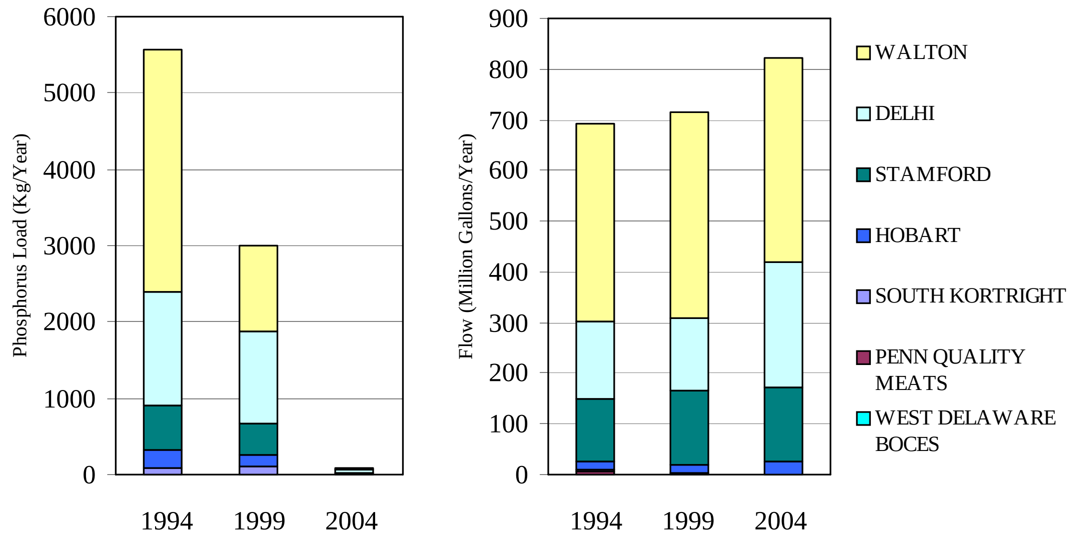


Figure 4.16 Total phosphorus loads and total volume of WWTP effluent flow to Cannonsville Reservoir in 1994, 1999, and 2004.

Table 4.4. Significant events and accomplishments at WWTPs in the Cannonsville Reservoir basin since 1994.

WWTP	COMMENTS *
Walton	Upgrade permit date Feb 2003
Delhi	Upgrade permit date Feb 2003
Stamford	Upgrade permit date Feb 2003
Hobart	Upgrade permit date Oct 2002
South Kortright	Connected to Hobart May 2002
Penn Quality Meats	Inactive
West Delaware Boces	Upgrade permit date Feb 2005

* The permit date referred to in this table is six months after plant upgrade is completed. Allowing for a start-up period, this is the date on which the requirements of each plant's final SPDES permit take effect.

Case Study
Wastewater Treatment Plant Effects on Water Quality in the Cannonsville Basin

The benefits of the WWTP Regulatory and SPDES Upgrade Program can be demonstrated by examining the water quality of the receiving waters of the WWTP effluents. This has been accomplished visually by plotting the data and producing a LOWESS smoothing pattern (using a 30% smoothing factor) through the data.

A vertical line on the plot shows when the upgraded SPDES permit went into effect for the WWTP, but it should be noted that WWTP upgrades and modifications were occurring prior to this date.

Figure 4.17a a shows the total phosphorus concentrations and fecal coliform levels at sampling sites on the West Branch of the Delaware River above and below the Stamford WWTP's discharge. It should be noted that in January 1996, the upstream site was relocated to better isolate the impacts of the WWTP effluent on the stream. Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were much higher than those seen in the creek above the plant. The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 119 µg L^{-1} and 12 CFU 100 mL^{-1}, respectively, and were 26 µg L^{-1} and 44 CFU 100 mL^{-1}after the upgrade. Following the plant improvements and the upgraded SPDES permit, the upstream and downstream values for total phosphorus and fecal coliforms were similar (The median TP and fecal coliform levels in the creek above the plant after the upgrade were 28 µg L^{-1} and 31 CFU 100 mL^{-1}, respectively).

Improvements were also seen for total phosphorus at the Hobart WWTP on the West Branch of the Delaware River (Figure 4.17b). The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 64 µg L^{-1} and 196 CFU 100 mL^{-1}, respectively, and were 30 µg L^{-1} and 59 CFU 100 mL^{-1} after the upgrade. The TP values upstream of the WWTP also dropped dramatically, probably as a result of the upgrade to the Stamford WWTP that is located upstream of Hobart. Following the plant improvements and the upgraded SPDES permits, the upstream and downstream values for total phosphorus and fecal coliforms were similar.

Water quality improvements below the Delhi WWTP on the West Branch of the Delaware River were also observed after the WWTP improvements and SPDES upgrade (Figure 4.17c). The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 49 µg L^{-1} and 30 CFU 100 mL^{-1}, respectively, and were 28 µg L^{-1} and 44 CFU 100 mL^{-1} after the upgrade. While the median fecal coliform level below the plant increased slightly after the upgrade, the median fecal coliform level above the plant also increased slightly after the upgrade; however, the LOWESS trend and observations suggests the fecal levels were decreasing somewhat and the upstream and downstream values were about the same.

The Walton WWTP is the largest plant in the Cannonsville watershed and is located downstream of the other plants on the West Branch of the Delaware River. The river downstream of this plant also showed improved water quality following the upgrades (Figure 4.17d). Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were much higher than those seen in the creek above the plant. Also, fecal coliform levels downstream of the plant were higher than the upstream levels. The median TP and fecal coliform levels in the creek below the plant before the upgraded SPDES permit were 57 µg L^{-1} and 30 CFU 100 mL^{-1}, respectively, and were 25 µg L^{-1} and 24 CFU 100 mL^{-1} after the upgrade. Following the plant improvements and the upgraded SPDES permit, the upstream and downstream values for total phosphorus and fecal coliform levels were very similar. (The median TP and fecal coliform levels in the creek above the plant after the upgrade were 24 µg L^{-1} and 28 CFU 100 mL^{-1}, respectively).

The observed reduction in total phosphorus concentrations in the streams below the plants supports the findings of reduced phosphorus loads from the WWTPs as discussed in the WWTP Load Case Study for the Cannonsville Basin.

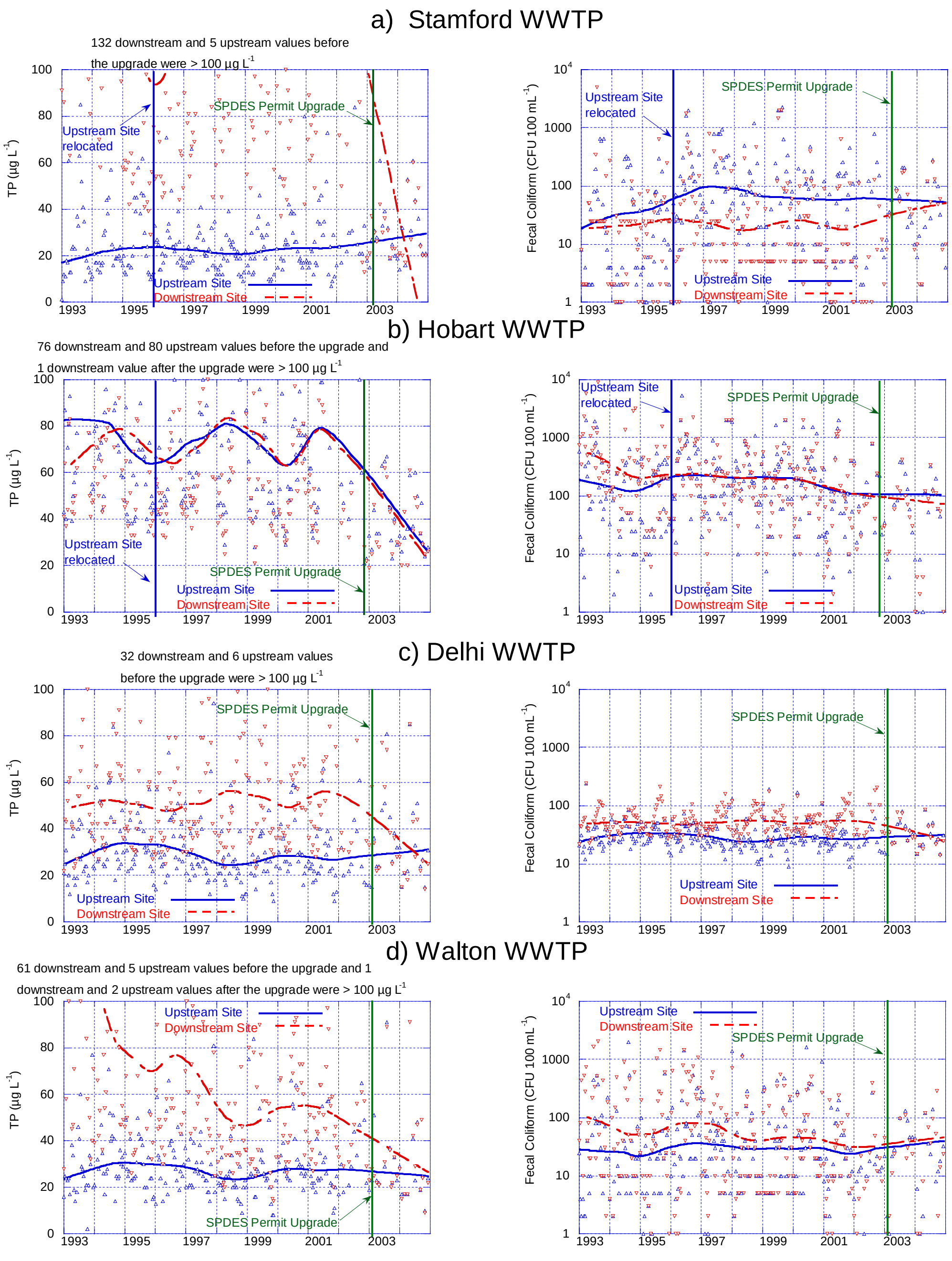


Figure 4.17 Total phosphorus and fecal coliform concentrations at stream sampling sites above and below wastewater plants in the Cannonsville Basin, 1993-2004.

Note: Lowess trend lines using a 30% smoothing coefficient are also plotted. a) Stamford WWTP (upstream site=WDSTA and WDSTM (after Jan. 1, 1996), downstream site=WDSTB), b) Hobart WWTP (upstream site= WDHOA and WDHOM (after Jan. 1, 1996), downstream site=WDHOB), c) Delhi WWTP (upstream site=DTPA, downstream site=DTPB), d) Walton WWTP (upstream site=WSPA, downstream site=WSPB).

Case Study
Septic System Program/Watershed Agriculture Program

The Watershed Agriculture Program (see Section 2.3) and the Septic System Rehabilitation and Replacement Program (see Section 2.5.2) are designed to improve or maintain water quality in the NYC watershed. The Watershed Agricultural Program is a comprehensive effort to develop and implement pollution prevention plans on the commercial farms in the Catskill and Delaware watersheds. The program incorporates the economic and business needs of each participating farm into a Whole Farm Plan (WFP) to fully integrate the principles and goals of pollution prevention into the farm's operation. The plans are developed to protect water quality from farm-based pollution by tailoring Best Management Practices (BMPs) to each specific farm's circumstances.

Septic systems are used to treat wastewater from homes and small businesses that are not served by sewer systems and treatment plants. In a properly functioning septic system, pollutant concentrations found in raw sewage are reduced as biological activity and settling occurs in a septic tank and the remaining liquid passes through the septic tank. The water disperses in a tile field or soil absorption unit. Very old and failing systems threaten both groundwater and surface water quality by releasing ineffectively or untreated wastewater into the ground or, in the worst cases, directly on the surface. The Septic System Rehabilitation and Replacement Program has contributed funds to the Catskill Watershed Corporation (CWC) to repair or replace septic systems serving one- or two-family homes in the WOH watershed that are failing or likely to fail. In this case study, total phosphorus concentrations and fecal coliform levels in streams will be examined to see if the potential water quality benefits of these two programs can be detected at the sub-basin level.

The Trout Creek sub-basin (52.9 km^2) of the Cannonsville Reservoir watershed has had 18 septic failures remediated and has 10 participants in the Whole Farm Program. Figure 4.18a shows the total phosphorus concentrations and fecal coliform levels at the stream sampling site (site code C-7) on Trout Creek from 1993 - 2004. Total phosphorus concentrations throughout this period are generally low with annual medians from this period ranging from 9 - 18 $\mu g\ L^{-1}$, and the fecal coliform values were mostly low to moderate with annual median values ranging from 20 - 160 CFU

100mL^{-1}. It should be noted that beginning in 2002, the frequency of data collection for fecal coliforms was reduced from twice a month to monthly samples. There does not appear to be any significant trend in these data, except for a small upturn for total phosphorus in 2003 and 2004 and a slight general increase in fecal coliform levels over the period. A comparison of 2002-2004 fecal coliform data from Trout Creek and Sherruck Brook, a small, unimpacted sub-basin in the Cannonsville watershed, also indicate an increase in coliform levels in Trout Creek in 2004. However, after May 2000, fecal coliform levels greater than 1,000 CFU 100 mL^{-1} were not observed, suggesting perhaps some attenuation of sources contributing to the occasional elevated levels of fecal coliforms.

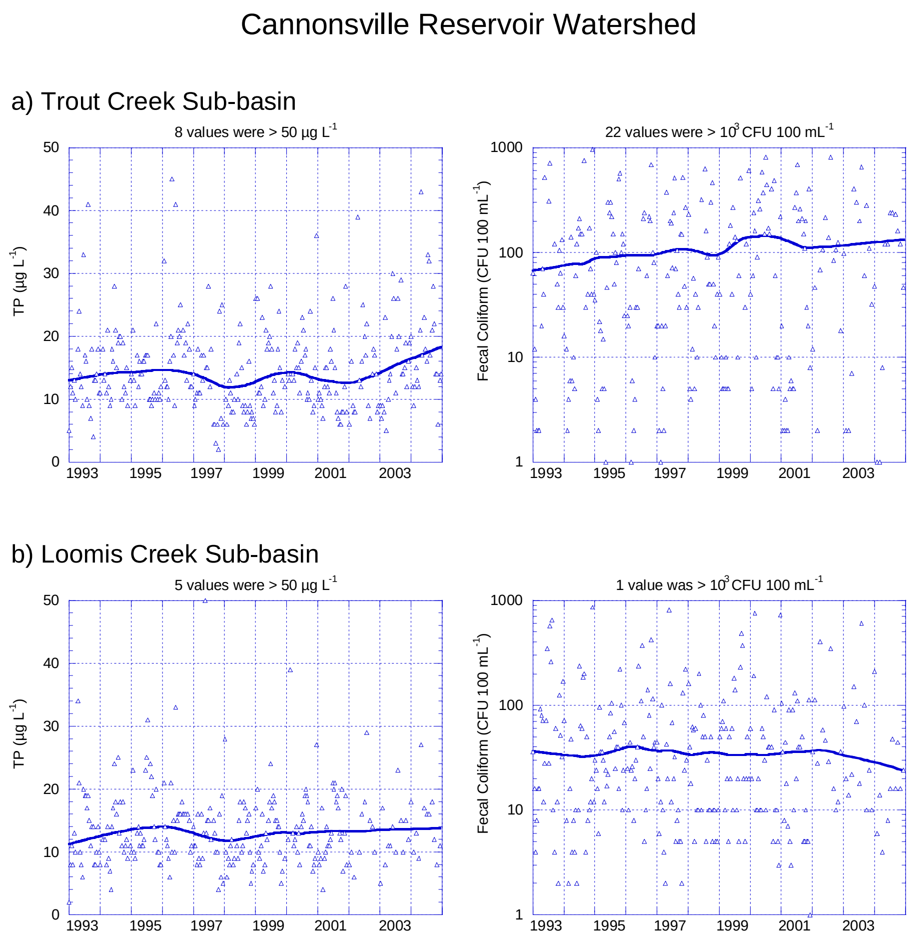


Figure 4.18 Total phosphorus and fecal coliform concentrations at stream sampling sites on: a) Trout Creek (site code = C-7) and b) Loomis Creek (site code = C-8) in the Cannonsville Basin, 1993-2004. Lowess trend lines using a 30% smoothing coefficient are also plotted.

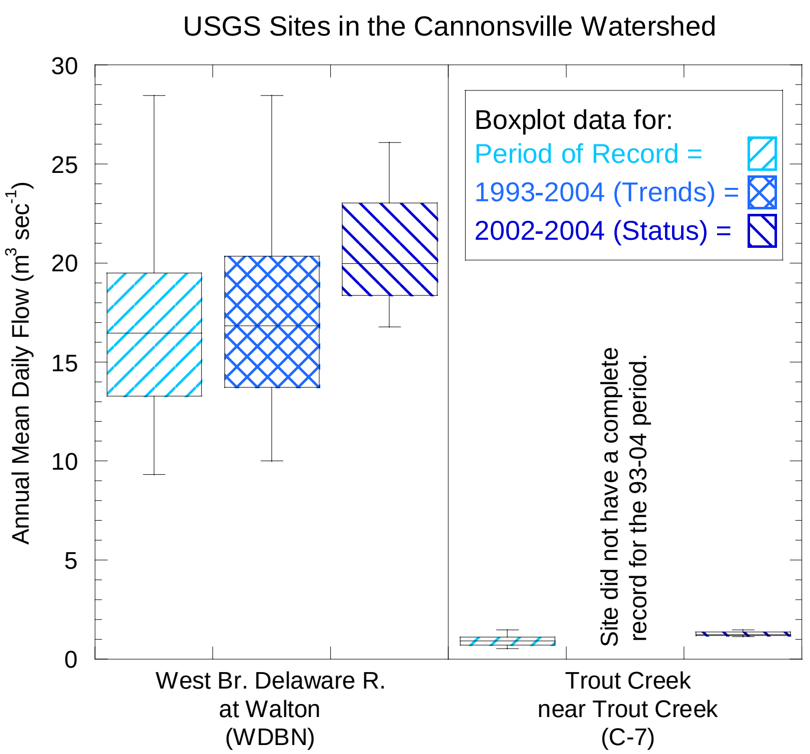
The Loomis Creek sub-basin (31.6 km^2) of the Cannonsville Reservoir watershed has had 11 septic failures remediated and has 8 participants in the Whole Farm Program. Figure 4.17b shows the total phosphorus concentrations and fecal coliform levels at the stream sampling site (site code C-8) on Loomis Creek from 1993 - 2004. It should be noted that total phosphorus and fecal coliform values throughout this period are generally low with annual medians from this period ranging from 11 - 15 µg L^{-1} and 12 - 50 CFU 100mL^{-1}, respectively. It should also be noted that beginning in 2002, the frequency of data collection for total phosphorus and fecal coliforms was reduced from twice a month to monthly samples. There does not appear to be any significant trend in these data, though the fecal coliform LOWESS line does show a decrease in 2003 and 2004. Although these were relatively “wet” years, which typically lead to higher values of nonpoint source pollutants, it is possible that this characteristic was not observed because pollutant sources were somewhat mitigated by the FAD programs. Also, a comparison of 2002-2004 TP data from Loomis Creek and Sherruck Brook, a small, un-impacted sub-basin in the Cannonsville watershed, shows that the TP concentrations in Loomis Creek are similar to those observed in an un-impacted watershed.

Numerous factors besides failing septic systems and agricultural runoff can contribute to total phosphorus concentrations and fecal coliform levels in streams, e.g. stormwater runoff, lawn fertilizers, pets. Also, given that these are nonpoint sources of pollution, seasonal and annual variability in hydrology can affect the results. Finally, the objective of collecting water quality data at this site was not designed to specifically address the impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program, but was to examine long-term trends in water quality. The Trout Creek site (C-7) also provides loading information for use in water quality models. As such, the data may not have been collected at an appropriate resolution to isolate the water quality impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program. While the data do not indicate improvements in water quality, the relatively good water quality in this stream appears to have been maintained with no signs of degradation.

4.3.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 4.19. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

The West Branch of the Delaware River at Walton is the primary inflow to Cannonsville Reservoir. It drains 77% of the basin. The flow distributions (of the annual mean daily flows) show that the 12-year median representing the trends period was very similar to the long-term median, and the 3-year median representing the status period was about 3 $m^3\ sec^{-1}$ greater than the long-term median and the overall distribution was somewhat biased to higher flows. Therefore, flows in the status time period were somewhat higher than usual.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
WDBN	West Br. Delaware R. at Walton	77.4%	Oct. 1950 - present
C-7	Trout Creek near Trout Creek	4.5%	Dec. 1996 - present; June 1952 - June 1967

Figure 4.19 USGS sites in the Cannonsville watershed.

Status (Cannonsville Basin)

Cannonsville Reservoir's status evaluation is presented as a series of box plots in Figure 4.20. The input stream (WDBN), reservoir (WDC) and the output (WDTO) are included for comparison.

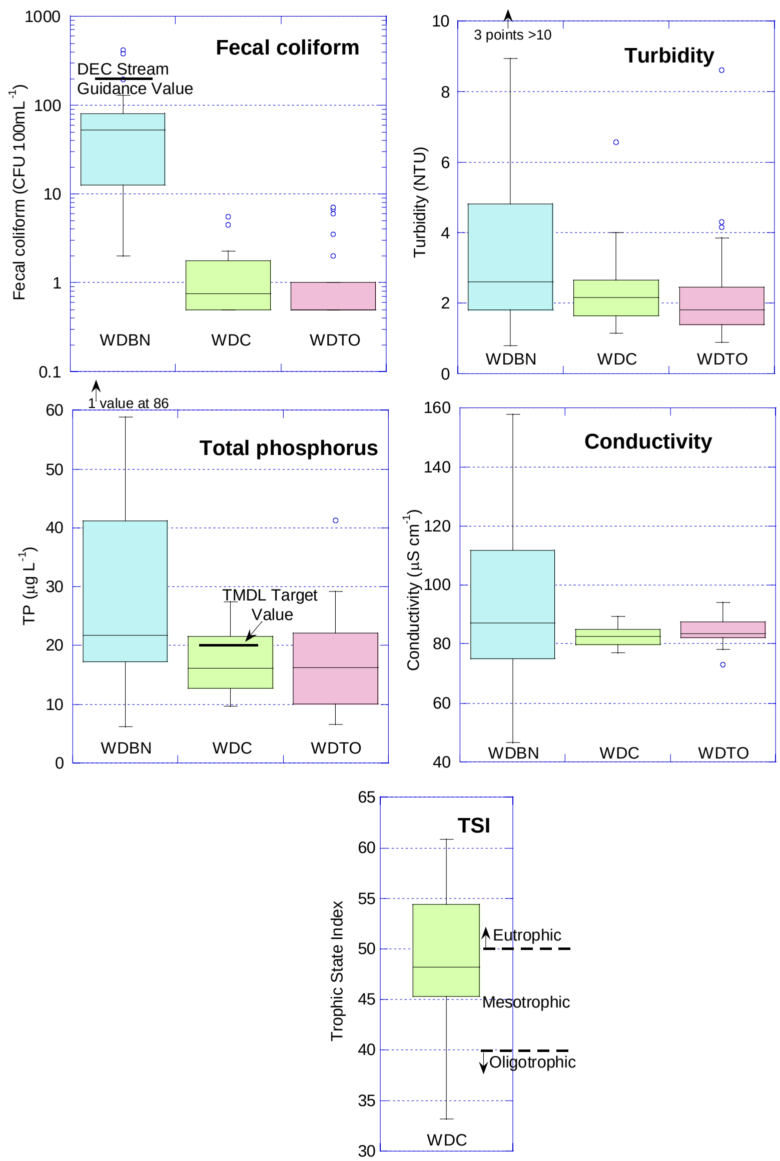


Figure 4.20 Water quality status boxplots using 2002–2004 monthly data for the Cannonsville basin for: the main stream input, the West Branch of the Delaware River at WDBN; the reservoir, WDC; and the effluent aqueduct keypoint, WDTO.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Fecal coliform values dropped by approximately two orders of magnitude between the input and the reservoir. This may be the result of settling and die-off of the coliform bacteria. In the reservoir and the output, the majority of the values were at or below the detection limit.

The turbidity values demonstrated that attenuation occurs through the system. Both the variability and the medians decreased as water traveled downstream from the input (median = 2.6 NTU), through the reservoir (median = 2.2 NTU) and to the output (median = 1.8 NTU).

Total phosphorus (TP) values resembled the pattern found with turbidity. The medians and variability were lower for the output and the reservoir as compared to the input stream. The boxplot above clearly demonstrates that the majority of the TP values in Cannonsville were well below the TMDL target value of 20 µg L-1 in the reservoir, and suggests that Cannonsville will remain categorized as "unrestricted" in the upcoming annual Phosphorus Restricted Basin Status assessment.

The trophic status index values for Cannonsville Reservoir ranged from mesotrophic to eutrophic, with the majority of the values falling in the mesotrophic range. Cannonsville typically has the highest trophic status amongst the Catskill and Delaware reservoirs, although with recent decreasing trends in phosphorus (see Trend section below), this is expected to change.

Conductivity was more variable in the input stream as compared to the reservoir or the output of Cannonsville, while their medians were broadly similar. During times of drought, such as early 2002, the conductivity in the input stream generally increases. Low conductivities generally occur during storm events and wet years, such as 2003 and 2004. These factors account for the greater variability that is shown in the input stream.

In summary, water quality was generally good during the 2002 – 2004 analysis period in the Cannonsville Reservoir. The data for the selected variables show that medians were well below the established benchmarks for the parameters presented.

Trends (Cannonsville Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 4.21.

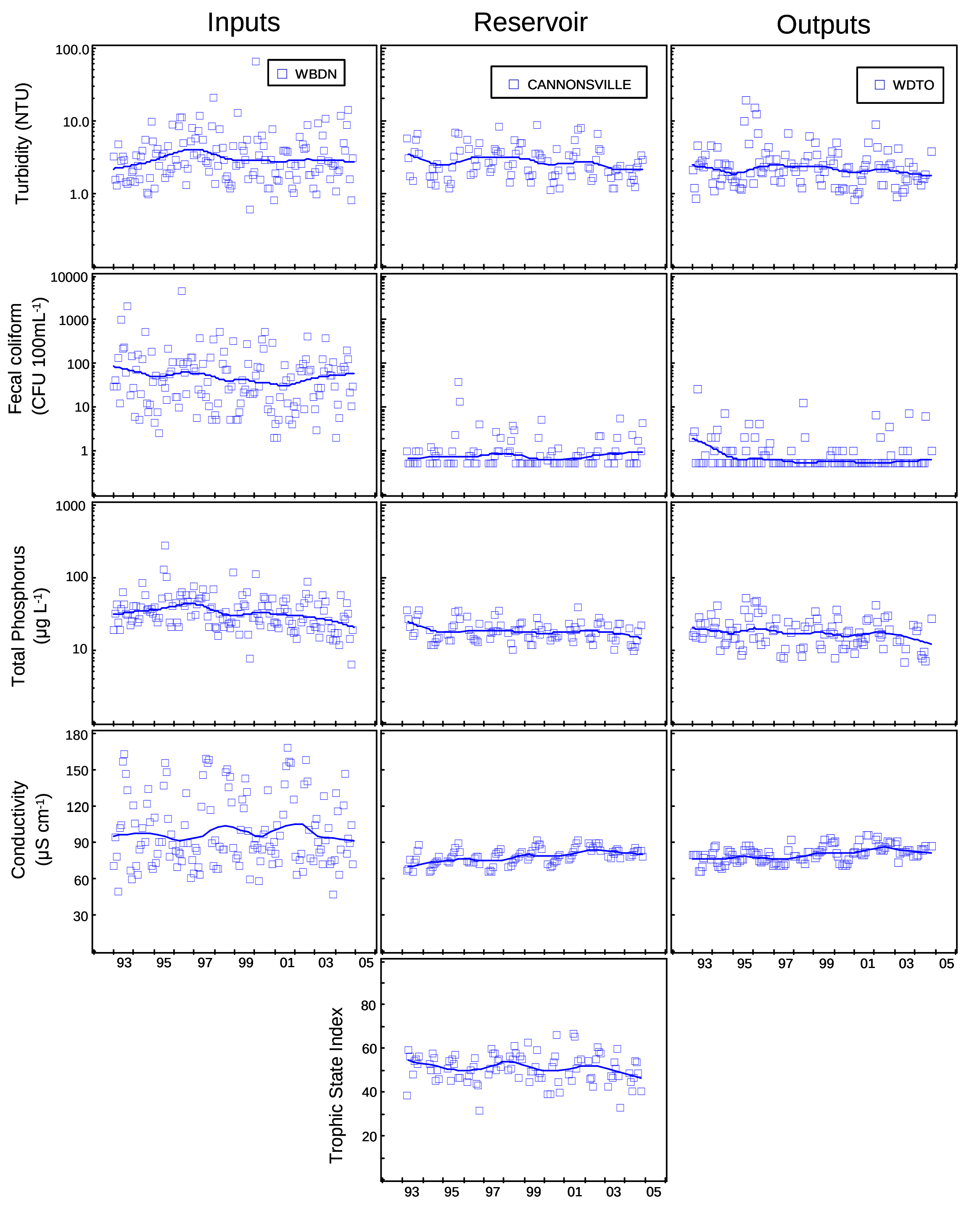


Figure 4.21 Water Quality trend plots for the Cannonsville basin for: the main stream input, the West Branch of the Delaware River at WDBN; the reservoir, Cannonsville; and the effluent aqueduct keypoint, WDTO.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Results of the Seasonal Kendall trend analysis are provided in Table 4.5.

Table 4.5. Cannonsville Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[3]	*p*-value[2]	Change yr^{-1}
WDBN [1.]	Input	Turbidity	12	144	0.03	NS	0.01
Cannonsville	Reservoir	Turbidity	8	96	-0.17	***	-0.05
WDTO	Output	Turbidity	10	120	-0.14	**	-0.04
WDBN	Input	Fecal coliform	12	144	-0.11	**	-1.00
Cannonsville	Reservoir	Fecal coliform	8	96	0.03	NS	0.00
WDTO	Output	Fecal coliform	10	120	-0.06	*	0.00
WDBN	Input	Total Phosphorus	12	144	-0.29	***	-1.29
Cannonsville	Reservoir	Total Phosphorus	8	96	-0.20	***	-0.33
WDTO	Output	Total Phosphorus	10	120	-0.17	***	-0.33
WDBN [1.]	Input	Conductivity	12	144	0.28	***	1.00
Cannonsville	Reservoir	Conductivity	8	96	0.38	***	0.89
WDTO	Output	Conductivity	10	120	0.38	***	1.00
Cannonsville	Reservoir	Trophic State Index	8	96	-0.07	NS	-0.19

1. Data was adjusted for flow prior to trend analysis—see Appendix 3.
2. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
3. Tau refers to the Seasonal Kendall Test Tau statistic.

Slight declines in turbidity are evident in both the reservoir and output (WDTO). Surprisingly, no trend was detected in the reservoir's primary input (WDBN). Note that input values at the end of the record (2003-04) were fairly high while reservoir turbidities were relatively low. Perhaps the stream samples are not an accurate representation of the input to the reservoir with monthly medians being overly influenced by short term rain events. Reasons for the decline detected in the reservoir and output are not clear. Certainly recovery from late 1995-early 1996 flood events is one factor. In addition, there is some evidence for algal declines in the latter part of the data record (Trophic State Index, Figure 4.21) which coincide with low reservoir (and output) turbidity, and decrease in TP concentrations.

For Total Phosphorus concentrations, trend analysis results indicate significant decreases in the input, reservoir and output. The LOWESS curve indicates that phosphorus peaked at the input in 1997 and except for a temporary increase in 1999 (Tropical Storm Floyd) it has been in decline through 2004. A portion of the decline may be explained by recovery from flooding events in late 1995 and early 1996, but the majority of the decline coincides with various WWTP upgrades and to load reductions from a food production plant located in Walton. Terrestrial and reservoir modeling suggest that land use changes may also have played a part in this reduction.

Increasing conductivity trends were detected in the input, the reservoir and in the output. The increases were not correlated with precipitation trends but do coincide with increases in chloride suggesting an anthropogenic source.

Although, no over all trend was detected for trophic state index, there does appear to be a short-term decrease over the last three years of the data record. Reasons for the decrease are not clear, though the continuing decrease in phosphorus may be an important factor.

In summary, downward trends were detected for turbidity and phosphorus while slight upward trends were detected for conductivity. The decreases in turbidity may be linked to recovery from flooding events in 1995-96 and perhaps from declines in algal populations in latter years. Recovery from 1995-96 flooding events may also contribute to the declines in phosphorus but load reductions from wastewater treatment plants and food manufacturing maybe the primary cause. The conductivity increases are thought to be caused by increases from anthropogenic sources (*e.g.* road salt).

4.4 The Rondout Basin

Figure 4.22 Rondout Reservoir.

The Rondout reservoir straddles the Ulster/Sullivan County border along the southern edge of the Catskill Park, approximately 6 miles northwest of the Village of Ellenville and more than 65 miles northwest of New York City. Placed into service in 1950, it was formed by the damming of Rondout Creek, which continues northeastward and eventually drains into the Hudson River at Kingston. The reservoir consists of one basin, almost 6.5 miles long, which holds 49.6 billion gallons at full capacity. Currently, Rondout supplies 160 million gallons per day (MGD) or roughly 13.2% of the total average daily consumption to New York City and an additional one million upstate consumers.

The Rondout is one of four reservoirs in the City's Delaware system. It serves as the central collecting reservoir for the Delaware system, receiving water from the Pepacton, Cannonsville and Neversink Reservoirs. Since the Delaware system supplies approximately 50% of New

York City's water, the Rondout plays a critical role in the City's overall water supply system. The Rondout also receives water from its own watershed. Water from the Rondout heads southeast in the 85-mile long Delaware Aqueduct, which tunnels below the Hudson River. Rondout water ordinarily makes its way to the West Branch and then the Kensico Reservoir for further settling. After mixing with Catskill system water, it leaves Kensico through aqueducts to reach the Hillview Reservoir in Yonkers, at the City's northern boundary, where it enters the water supply distribution system.

The Rondout's watershed drainage basin is 95 square miles and takes in parts of seven towns. Four main tributaries flow into Rondout, with Rondout Creek supplying 40% of flow while Chestnut Creek provides 22%. Sugarloaf Brook delivers another 8.4% and Sawkill Brook an additional 6.6% of flow. Presently there is one wastewater treatment plants (WWTPs) sited in the Rondout watershed region producing an average flow of 0.062 MGD. As per the most recent SPDES permits, the plants are limited to a collective release of 0.180 MGD of flow.

Of the 61,103 acres of land in the Rondout watershed, 54,466 acres (89.2%) are forested, 1,113 acres (1.8%) are urban in nature, 253 acres (0.4%) are roads, 1,509 acres (2.5%) are brushland, and 999 acres (1.6%) are classified as grass land. Wetlands comprise 544 acres (0.9%) of the watershed, while 2,102 acres (3.4%) are under the reservoir. The remaining 48 acres (0.1%) are in agricultural use.

4.4.1 Program Implementation

DEP has taken great steps to ensure the high quality of water in the Rondout Reservoir basin. Program activity in the Rondout basin up to December 31, 2005, is summarized in Figure 4.2. Of particular significance has been the extensive protection effort extended by Septic Remediation Program, which has repaired or replaced 214 failing septic systems as of the end of 2004. Presently there is one wastewater treatment plant (WWTP) in the Rondout basin, producing an average flow of 0.062 MGD. The City-owned Grahamsville WWTP was upgraded to state-of-the-art tertiary treatment in the late 1990s.

Additional protection has been provided by the Whole Farm Program; currently, there are five farms participating in the program in the Rondout Basin with four farms substantially implemented. Also, the Stream Management Program installed a restoration project at Post Farm on Trout Creek.

Also of note in the Rondout basin has been DEP’s Land Acquisition Program. The Rondout basin land area contains 59,008 acres, all categorized as Priority 1A or 1B.

As of 1997, DEP owned 1,063 acres of reservoir buffer land, or 1.8 % of the basin, with another 20,049 acres (34%) protected by non-City entities. Since that time DEP has protected 5,801 acres in fee or easement. This land represents 9.8% of the basin land area and more than a five-fold increase in the amount of City-controlled land in this basin. Total land protected by City and non-City entities is 26,913 acres, or 45.6 % of the basin land area.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Rondout Basin

Inputs of phosphorus, as well as other pollutants, to Rondout Reservoir have been considerably reduced as a result of the upgrade of the City-owned Grahamsville plant, the only WWTP discharging in the Rondout Reservoir basin. As illustrated in Figure 4.23, phosphorus (as Total Phosphorus) loads were considerably reduced from 1994 to 1999, and remain low in 2004. Table 4.6 highlights the date of the plant's upgrade, the most significant contributing accomplishment at the plant.

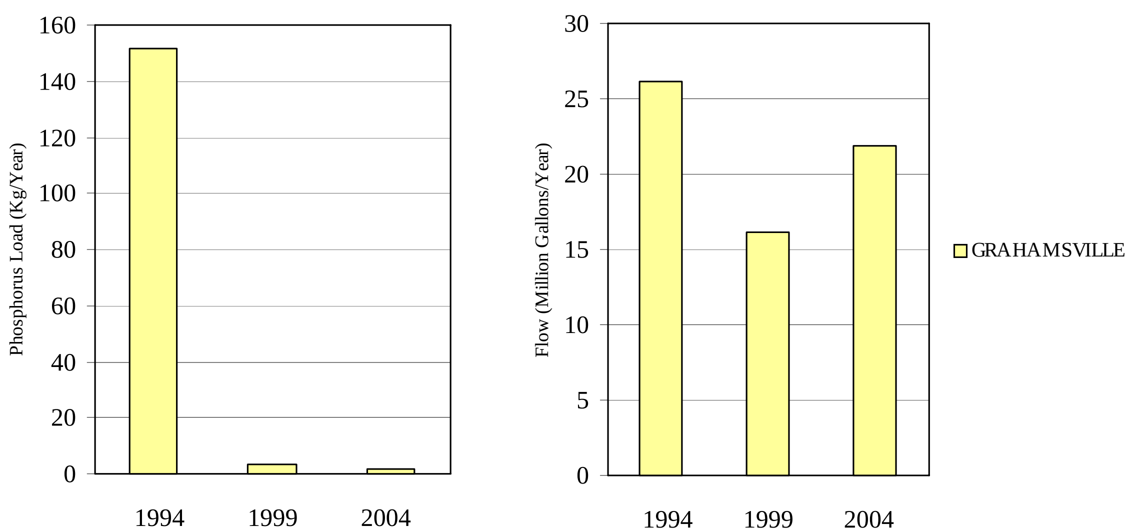


Figure 4.23 Total phosphorus loads and total volume of WWTP effluent flow to Rondout Reservoir in 1994, 1999, and 2004.

Table 4.6. Significant events and accomplishments at Grahamsville, the only WWTP in the Rondout Reservoir basin.

WWTP	COMMENTS *
Grahamsville	Upgrade permit date Apr 1998

Case Study
Wastewater Treatment Plant Effects on Water Quality in the Rondout Basin

The benefits of the WWTP Regulatory and SPDES Upgrade Program can be demonstrated by examining the water quality of the receiving waters of the WWTP effluents. This has been accomplished visually by plotting the data and producing a LOWESS smoothing pattern (using a 30% smoothing factor) through the data. A vertical line on the plot shows when the upgraded SPDES permit went into effect for the WWTP, but it should be noted that WWTP upgrades and modifications were occurring prior to this date.

Figure 4.24 shows the total phosphorus concentrations and fecal coliform levels at sampling sites on the Rondout Creek above and below the Grahamsville WWTP's discharge. Prior to the upgrade of the plant, the total phosphorus concentrations downstream of the plant were higher than those seen in the creek above the plant; however, the fecal coliform results were not quite as clear. The upstream fecal coliform levels (median value = 28 CFU 100 mL^{-1}) were about the same as the downstream site before the WWTP upgrades (median value = 26 CFU 100 mL^{-1}). The median TP and fecal coliform levels in the river below the plant before the upgraded SPDES permit were 19 µg L^{-1} and 26 CFU 100 mL^{-1}, respectively, and were 12 µg L^{-1} and 14 CFU 100 mL^{-1}after the upgrade. Following the plant improvements and the upgraded SPDES permit, the upstream and downstream values for total phosphorus and fecal coliforms were very similar. However, the decline in fecal coliform levels was also observed in the upstream location, indicating the decline in fecal coliforms was due to something other than the WWTP.

The observed reduction in total phosphorus concentrations in the streams below the plants supports the findings of reduced phosphorus loads from the WWTPs as discussed in the WWTP Load Case Study for the Rondout Basin.

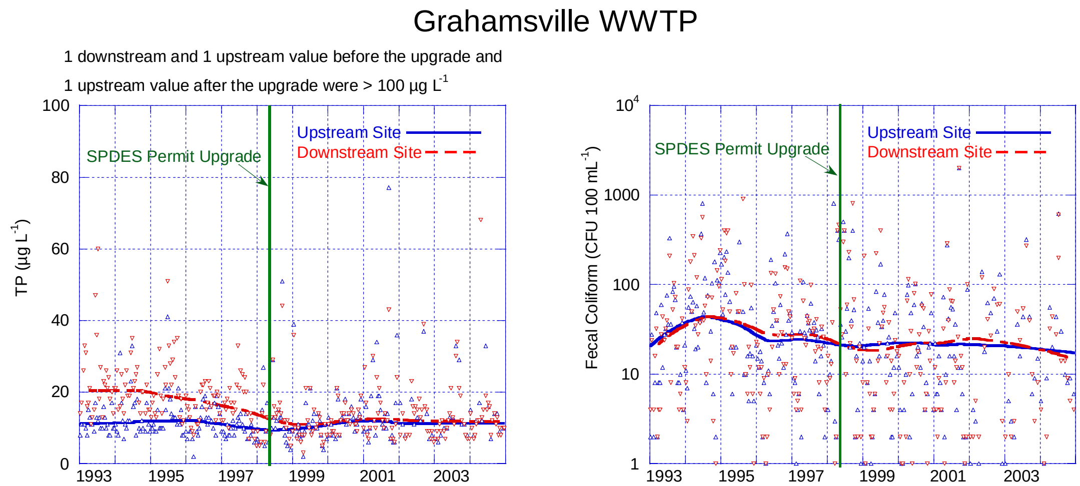


Figure 4.24 Total phosphorus and fecal coliform concentrations at stream sampling sites above and below the Grahamsville WWTP (upstream site=RGA, downstream site=RGB) in the Rondout, 1993-2004.

Note: Lowess trend lines using a 30% smoothing coefficient are also plotted.

Case Study
Septic System Program/Watershed Agriculture Program

The Watershed Agriculture Program (see Section 2.3) and the Septic System Rehabilitation and Replacement Program (see Section 2.5.2) are designed to improve or maintain water quality in the NYC watershed. The Watershed Agricultural Program is a comprehensive effort to develop and implement pollution prevention plans on the commercial farms in the Catskill and Delaware watersheds. The program incorporates the economic and business needs of each participating farm into a Whole Farm Plan (WFP) to fully integrate the principles and goals of pollution prevention into the farm's operation. The plans are developed to protect water quality from farm-based pollution by tailoring Best Management Practices (BMPs) to each specific farm's circumstances.

Septic systems are used to treat wastewater from homes and small businesses that are not served by sewer systems and treatment plants. In a properly functioning septic system, pollutant concentrations found in raw sewage are reduced as biological activity and settling occurs in a septic tank and the remaining liquid passes through the septic tank. The water disperses in a tile field or soil absorption unit. Very old and failing systems threaten both groundwater and surface water quality by releasing ineffectively or untreated wastewater into the ground or, in the worst cases, directly on the surface. The Septic System Rehabilitation and Replacement Program has contributed funds to the Catskill Watershed Corporation (CWC) to repair or replace septic systems serving one- or two-family homes in the WOH watershed that are failing or likely to fail. In this case study, total phosphorus concentrations and fecal coliform levels in streams will be examined to see if the potential water quality benefits of these two programs can be detected at the sub-basin level.

The Chestnut Creek sub-basin (54.5 km^2) of the Rondout Reservoir watershed has had 69 septic failures remediated and has 6 participants in the Whole Farm Program. Figure 4.25 shows the total phosphorus concentrations and fecal coliform levels at the stream sampling site (site code RGA) on Chestnut Creek above the Grahamsville WWTP from 1993 - 2004. Total phosphorus and fecal coliform values throughout this period are generally low with annual medians from this period ranging from 9 - 13 µg L^{-1} and 10 - 56 CFU 100mL^{-1}, respectively. It should be noted that beginning in 2002, the frequency of data collection was reduced from twice a month to monthly samples. While there does not appear to be any trend in these data, the annual median fecal coliform values in 2003 and 2004 (12 and 10 CFU 100 mL^{-1}, respectively) were the lowest annual medians for this period (although the annual median for 2001 was also 12 CFU 100 mL^{-1}). Although 2003 and 2004 were relatively "wet" years, which typically lead to higher values of non-point source pollutants, it is possible that this characteristic was not observed because pollutant sources were somewhat mitigated by the FAD programs.

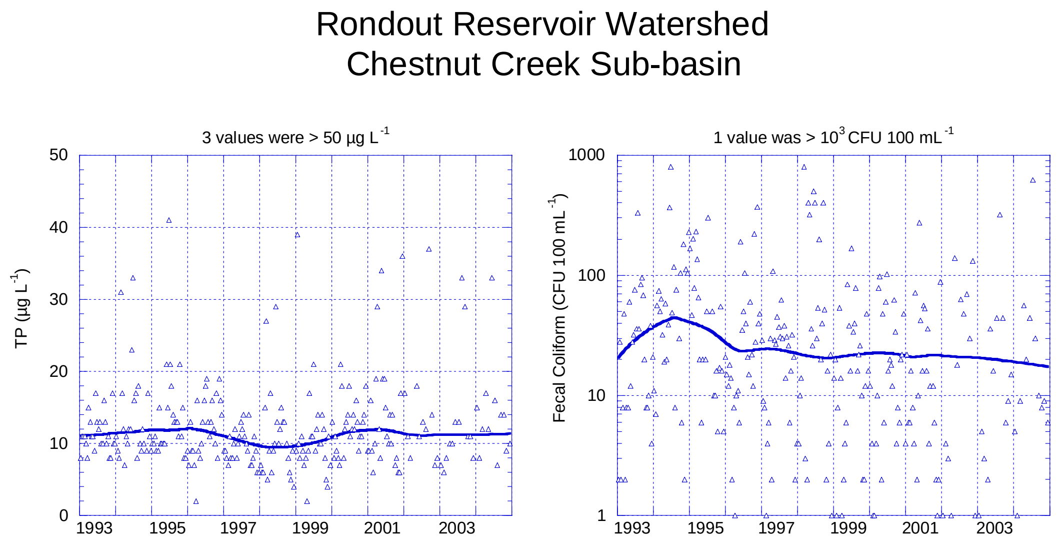


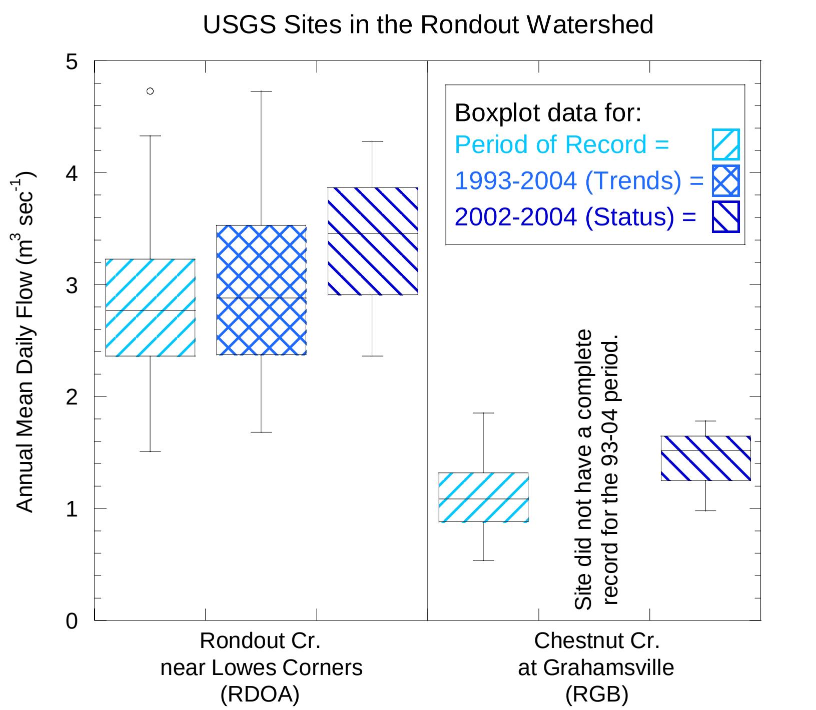
Figure 4.25 Total phosphorus and fecal coliform concentrations at the stream sampling on Chestnut Creek above the Grahamsville WWTP (site code =RGA) in the Rondout Basin, 1993-2004. Lowess trend line using a 30% smoothing coefficient is also plotted.

Numerous factors besides failing septic systems and agricultural runoff can contribute to total phosphorus concentrations and fecal coliform levels in streams, e.g. stormwater runoff, lawn fertilizers, pets. Also, given that these are nonpoint sources of pollution, seasonal and annual variability in hydrology can affect the results. Finally, the objective of collecting water quality data at this site was not designed to specifically address the impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program, but was to assist in the assessment of the Grahamsville WWTP's impact on the water quality of Chestnut Creek. As such, the data may not have been collected at an appropriate resolution to isolate the water quality impacts of the Watershed Agriculture Program or the Septic System Rehabilitation Program. While the data do not indicate improvements in water quality, it should be noted that the relatively good water quality in this stream is being maintained with no signs of degradation.

4.4.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 4.26. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

Rondout Creek near Lowes Corners is the primary stream inflow to Rondout Reservoir. It drains 40% of the basin. The flow distributions (of the annual mean daily flows) show that the 12-year median representing the trends period was very similar to the long-term median, and the 3-year median representing the status period was about 0.7 m^3 sec^{-1} greater than the long-term median.and the overall distribution is slightly biased to higher flows. Therefore, flows in the status time period were higher than usual.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
RDOA	Rondout Cr. near Lowes Corners	40.3	Feb. 1937 - present
RGB	Chestnut Cr. at Grahamsville	22.1%	Oct. 1998 - present; Oct. 1938 - Mar. 1987

Figure 4.26 USGS sites in the Rondout watershed.

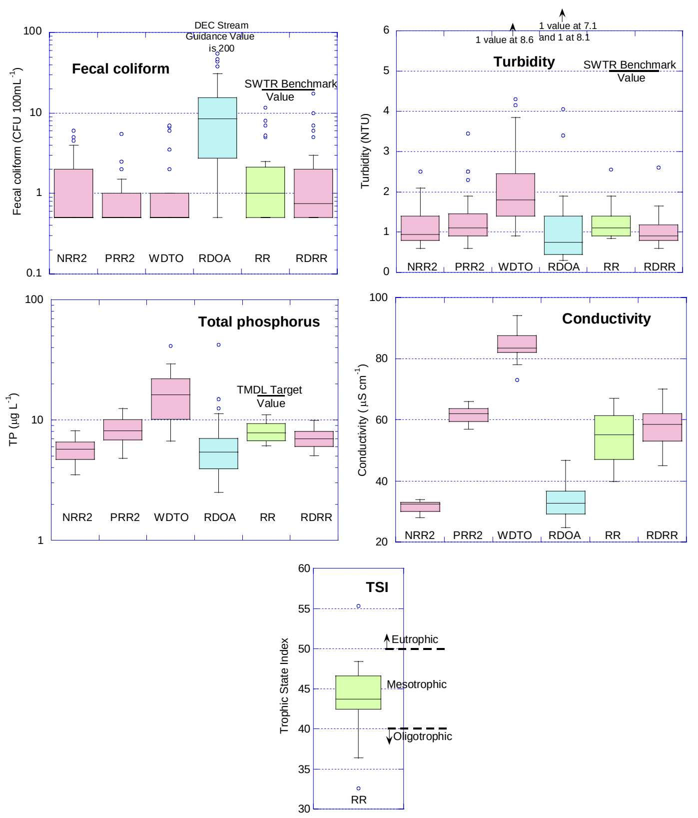


Figure 4.27 Water quality status boxplots using 2002–2004 monthly data for the Rondout basin for: the three aqueduct inputs keypoints, NRR2, PRR2, and WDTO; the main stream input, the Rondout Creek at RDOA; the reservoir, RR; and the effluent aqueduct keypoint, RDRR.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Status (Rondout Basin)

Rondout basin's status evaluation is presented as a series of box plots in Figure 4.27. The inputs include water diverted from Neversink Reservoir (NRR2), Pepacton Reservoir (PRR2), Cannonsville Reservoir (WDTO) and Rondout Creek (RDOA). The reservoir is designated as RR and the output is RDRR.

Fecal coliform values were very low for three reservoir inputs and noticeably higher for the stream input from Rondout Creek. None of the values exceeded the 200 CFU 100 mL^{-1} DEC Stream Guidance Value. The reservoir and the output had coliform values that were below the SWTR benchmark of 20 CFU 100 mL^{-1} used for source waters. Rondout Reservoir can be source water when Kensico and West Branch Reservoirs are by-passed.

The turbidity values were similar for two of the inputs, NRR2 and PRR2. WDTO had the most variability of the reservoir inputs, probably due to turbidity contributed by primary production in Cannonsville Reservoir. Another potential source is turbidity caused by a nepheloid layer at the bottom of the reservoir during times of anoxia. High flows during these conditions can entrain this turbid water. Interestingly, the box plot for the stream input, RDOA, was roughly similar to the other inputs for turbidity as compared to the contrast found in the fecal coliform plot. One would expect higher values of turbidity in the stream due to less settling. None of the values for the reservoir or the output from Rondout were above the 5 NTU SWTR benchmark value for source waters.

Total phosphorus values varied amongst the inputs to Rondout Reservoir. WDTO had the highest median and the most variability, while RDOA had the lowest median of the four inputs. The reservoir and its output had similar TP values, and none of the values were above the TMDL target value of 15 µg L^{-1} in the reservoir.

The trophic state index clearly indicates that Rondout was mesotrophic over the three year study period.

The conductivity varied widely among the inputs, reflecting the differing water quality in each of these sources. The Cannonsville input had the highest conductivity in the Delaware system as compared to Neversink, which had the lowest. RDOA, also had low conductivity levels, but this stream source only contributes a small percentage to the total inflow. The operational changes that result in the mixing of these sources determine the resultant conductivity in the reservoir. As a result, the variability in the reservoir was greater than most of the inputs and the outflow.

Water quality was very good during the 2002 – 2004 analysis period in Rondout Reservoir. The data for the selected variables show that none of the variables had values that exceeded the established benchmarks.

Trends (Rondout Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 4.28. Results of the Seasonal Kendall trend analysis are provided in Table 4.7.

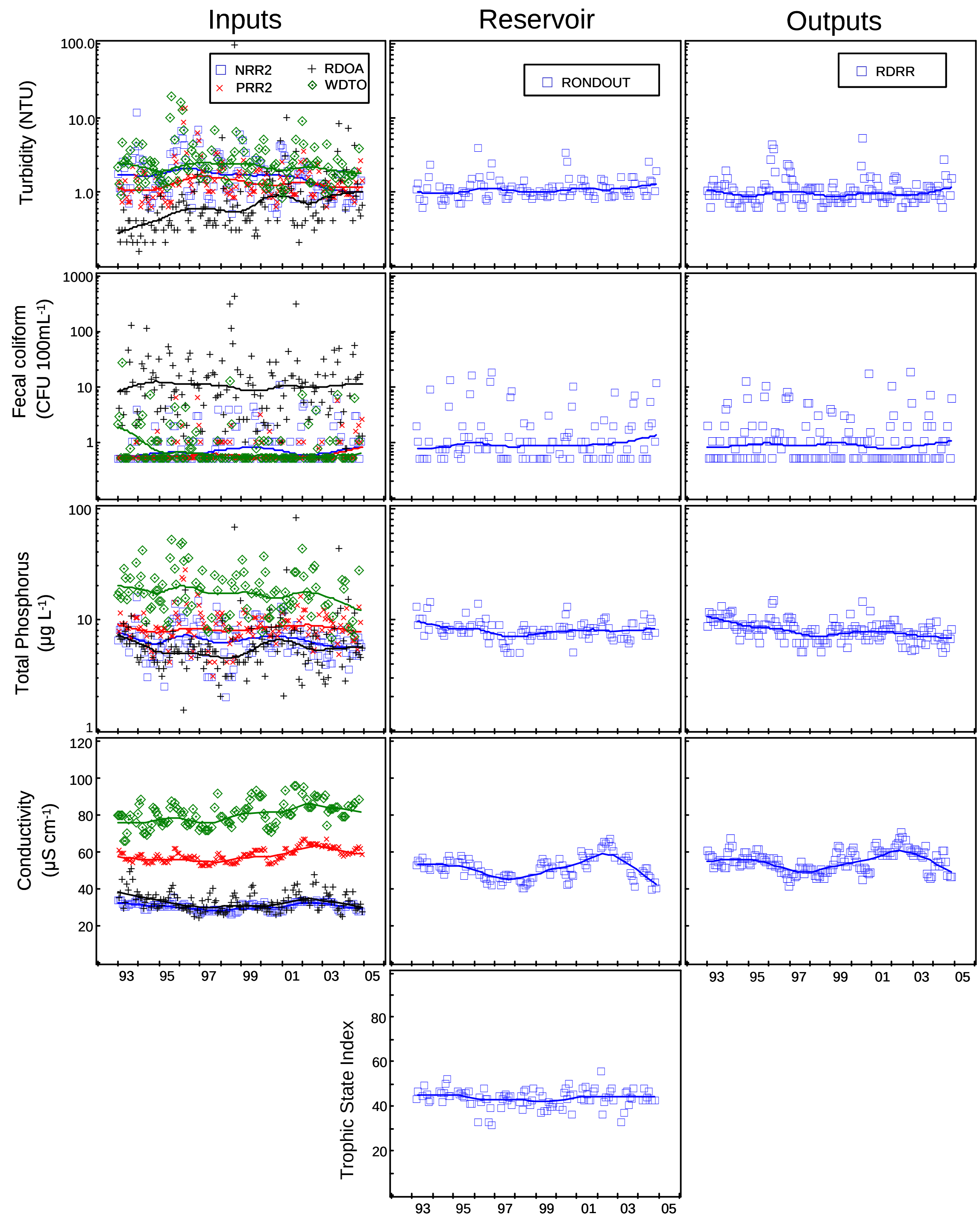


Figure 4.28 Water Quality trend plots for the Rondout basin for: the three aqueduct inputs keypoints, NRR2, PRR2, and WDTO; the main stream input, the Rondout Creek at RDOA; the reservoir, Rondout; and the effluent aqueduct keypoint, RDRR.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 4.7. Rondout Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
NRR2	Input	Turbidity	12	144	-0.21	***	-0.03
PRR2	Input	Turbidity	12	144	0.01	NS	0.00
WDTO	Input	Turbidity	10	120	-0.14	**	-0.04
RDOA	Input	Turbidity	12	144	0.37	***	0.05
Rondout	Reservoir	Turbidity	9	108	0.12	*	0.01
RDRR	Output	Turbidity	12	144	0.02	NS	0.00
NRR2	Input	Fecal coliform	12	144	0.05	NS	0.00
PRR2	Input	Fecal coliform	12	144	0.03	NS	0.00
WDTO	Input	Fecal coliform	10	120	-0.06	*	0.00
RDOA	Input	Fecal coliform	12	144	-0.10	*	-0.25
Rondout	Reservoir	Fecal coliform	9	108	0.02	NS	0.00
RDRR	Output	Fecal coliform	12	144	-0.02	NS	0.00
NRR2	Input	Total Phosphorus	12	144	-0.12	**	0.00
PRR2	Input	Total Phosphorus	12	144	0.03	NS	0.00
WDTO	Input	Total Phosphorus	10	120	-0.17	***	-0.33
RDOA	Input	Total Phosphorus	12	144	-0.01	NS	0.00
Rondout	Reservoir	Total Phosphorus	9	108	-0.09	NS	0.00
RDRR	Output	Total Phosphorus	12	144	-0.35	***	-0.22
NRR2	Input	Conductivity	12	144	0.04	NS	0.00
PRR2	Input	Conductivity	12	144	0.37	***	0.56
WDTO	Input	Conductivity	10	120	0.38	***	1.00
RDOA	Input	Conductivity	12	144	-0.07	NS	-0.12
Rondout	Reservoir	Conductivity	9	108	0.02	NS	0.00
RDRR	Output	Conductivity	12	144	0.06	NS	0.14
Rondout	Reservoir	Trophic State Index	12	144	-0.07	NS	0.00

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
2. Tau refers to the Seasonal Kendall Test Tau statistic.

A very small turbidity increase (+0.01 NTU yr^{-1}) was detected in Rondout Reservoir and much greater turbidity decreases were observed in two of its major inputs, –0.03 NTU yr^{-1} at the Neversink Diversion (NRR2) and –0.04 NTU yr^{-1} at the Cannonsville Diversion (WDTO). Turbidity trends at the third major input, the Pepacton Diversion (PRR2), were not apparent. The largest stream input (on average accounting for about 11% of the total flow into the reservoir), Rondout Creek (RDOA), did display the greatest change (+0.05 NTU yr^{-1}) and is probably responsible for the very slight turbidity increase in the reservoir. The increased turbidity was caused by flooding events in recent years causing stream banks to become becoming more susceptible to erosion. Despite the slight increase in the reservoir, turbidity increases were not detected in the output, RRDR.

Trends in fecal coliforms were not apparent in the reservoir, its outputs or in most of its inputs. The input, Rondout Creek, did display a slight decrease (-0.25 CFU 100 mL^{-1} yr^{-1}) although the cause is not clear.

Trends in total phosphorus were not detected in Rondout Reservoir despite a significant decrease (-0.33 µg L^{-1} yr^{-1}) from a major input, Cannonsville Diversion (WDTO). The decrease at WDTO is especially significant since this input generally has the highest phosphorus concentrations. Trends were not apparent in the other inputs. Despite the lack of a trend in the reservoir, decreases were apparent in the output, RDRR. Notably, the absence of winter data collected from the reservoir may mask a total phosphorus decline in Rondout. The decreasing phosphorus trends in RDRR may be due to upgrades at wastewater treatment plants (and food manufacturing plants) within the Cannonsville basin. Some portion of the decrease may also simply be recovery from high inputs caused by flooding in 1995-96.

No conductivity trends were detected in the reservoir despite increases detected in some of its inputs (1 µS cm^{-1} yr^{-1} for WDTO, 0.56 µS cm^{-1} yr^{-1} for PRR2). Conductivity trends appear to be controlled by precipitation patterns. In wet years (e.g. 2003, 2004) (2002 started off as a drought year) dilution caused conductivity to decrease. During drier periods (e.g., 1998-2001) more conductive base flow becomes more prominent causing conductivity to increase. The lack of trend in the reservoir is not unexpected since the aforementioned increases were very slight and because the absence of winter reservoir data makes detection of trends more difficult.

Trends were not detected in the Trophic State Index of the reservoir suggesting that algal populations were relatively steady during the period of record.

In summary, both upward and downward trends were detected for turbidity at different sites in the Rondout Basin. Downward trends were also detected for fecal coliforms and phosphorus while upward trends were indicated for conductivity. The increase in turbidity was probably caused by increased stream bank erosion at Rondout Creek. Reasons for the decrease in fecal coliforms at Rondout Creek are not readily apparent. Phosphorus declines maybe linked to a combination of wastewater treatment and food manufacturing plant upgrades in the Cannonsville basin and from recovery following flooding events in 1995-96. Increases in conductivity were very small and appear to be controlled by precipitation patterns.

4.5 Water Quality Summary for the Delaware System

As watershed hydrology plays an important role in determining water quality status and trends in the Delaware System it is crucial to note that major runoff events occurred in 1996 (event of record in many watershed areas), 1999, and 2000 and that drought conditions were present in 2001 and 2002. This was followed up with persistent wet period (2003 and 2004). These extreme circumstances largely controlled water quality.

Since the implementation of the MOA the DEP has made tremendous improvements in watershed protection. Wastewater treatment plants in the Delaware System, have been substantially enhanced, and have resulted in significant reductions in phosphorus loading to the watershed streams. In Cannonsville watershed, for example, the phosphorus load discharged from seven WWTPs to the West Branch of the Delaware River declined from greater than 5000 Kg yr^{-1} (1994) to less than 100 Kg yr^{-1} (2004) Land acquisition and conservation easement purchases have protected more than 31,000 acres of land from potential development across the four Delaware watersheds; and the Septic System Rehabilitation and Replacement Program have remediated over 900 septic systems within in the Delaware System.

An in-depth examination of the effects of wastewater treatment plant on stream water quality in the Delaware System revealed that phosphorus concentrations immediately downstream of the plants in Cannonsville, Pepacton, and Rondout watersheds have been significantly reduced as a result of the plant improvements. These observations support the phosphorus loading reductions discharged from watershed WWTPs as described in the Program Implementation sections of this chapter. Fecal coliform bacterial levels remained low following the WWTP improvements, as adequate disinfection treatment was present prior to the upgrades. Additional case studies examining the effects of the implementation of the Septic System Rehabilitation and Replacement Program on stream water quality did not detect any improvements. This may have been due to other confounding factors (e.g., other sources of phosphorus and coliforms, hydrology, and study design). Although the data did not indicate improvements in water quality the relatively good water quality in the streams appears to have been maintained through the period with no signs of degradation.

The water quality status of all four Delaware System basins is currently very good. Recent data (2002-2004) for all selected variables (i.e., phosphorus, turbidity, conductivity, fecal coliforms, and trophic state) show that median values of these constituents are well below established benchmarks.

Some improvements in water quality were observed throughout the Delaware System over the study period (1993-2004). Downward trends in the concentrations of phosphorus, for example, were detected in Neversink Reservoir (0.17 $\mu g L^{-1} yr^{-1}$), as well as in the outputs (diversions) from Cannonsville (0.33 $\mu g L^{-1} yr^{-1}$) and Rondout (0.22 $\mu g L^{-1} yr^{-1}$) reservoirs. The decrease in phosphorus concentration within Cannonsville Reservoir is particularly significant as the reductions have allowed Cannonsville to be taken off the phosphorus-restricted status list (NYC-DEP 2004).

Turbidity levels also declined over the study period in Neversink's and Cannonsville's reservoir outputs (0.03 NTU yr^{-1} and 0.04 NTU yr^{-1}, respectively). Treatment plant upgrades, land use changes, and recovery from flooding events (1995-96) are thought to be the main factors controlling the observed decreases in phosphorus and turbidity.

Minor rises in conductivity were observed in Pepacton (0.65 µS $cm^{-1}yr^{-1}$) and Cannonsville (1 µS $cm^{-1}yr^{-1}$) watersheds. The conductivity increases are thought to be caused by increases from anthropogenic sources (e.g. road salt). Despite the increases in the output from these basins, no detectable changes in conductivity were found in Rondout Reservoir. This may be due to the greater than normal precipitation in the basins in the later years providing a dilution effect.

Fecal coliform levels exhibited little or no change throughout the watershed reservoirs during the time period. Levels of these bacteria are generally very low (~1 CFU 100 ml^{-1}) and trends at these low levels are of no practical significance.

5. East of Hudson Catskill/Delaware Basins

5.1 The West Branch Basin

The West Branch Reservoir is located in Putnam County in the Towns of Kent and Carmel, approximately 35 miles from New York City. It was formed by the damming of the West Branch of the Croton River, which continues south to the Croton Falls Reservoir and consists of two basins, separated by Route 301. The reservoir holds 8 billion gallons at full capacity, and was placed into service in 1895 as part of the City's Croton water supply system.

Figure 5.1 West Branch Reservoir.

Today, however, the West Branch functions primarily as part of the Delaware water supply system, serving as a supplementary settling basin for the water which arrives from the Rondout Reservoir, west of the Hudson River, via the Delaware Aqueduct. The West Branch Reservoir also receives water from its own small watershed and the Boyds Corner Reservoir. 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. Water withdrawn from the West Branch ordinarily flows via the Delaware Aqueduct into the Kensico Reservoir in Westchester County for further settling. There it mixes with Catskill system water before entering aqueducts that carry it to the Hillview Reservoir in Yonkers, at the City's northern boundary, where it enters the water supply distribution system.

The West Branch watershed's drainage basin is 20 square miles, and includes portions of the Towns of Kent and Carmel.

The Boyds Corner Reservoir is located in Putnam County in the Town of Kent, almost 40 miles from New York City. It was formed by damming the West Branch of the Croton River, which continues southeast to the West Branch Reservoir. The reservoir consists of one basin, 1.5 miles in length and holds 1.7 billion gallons at full capacity. First placed into service in 1873, the dam, spillway and outlet works were rebuilt in 1990 as part of the City's complete overhaul and modernization of the 19 reservoirs in its water supply system.

Originally constructed as part of the City's Croton system, Boyd Corners today serves mainly as part of the Delaware system. Water from Boyd Corners flows briefly into the Croton River and then enters the City's West Branch Reservoir, where it mixes with water carried from the Rondout Reservoir, west of the Hudson, through the Delaware Aqueduct. From the West Branch, it ordinarily flows into the Kensico Reservoir, which also receives water from the Catskill system through the Catskill Aqueduct. After settling at Kensico, the water flows through two aqueducts to the Hillview Reservoir in Yonkers, were it enters the City's distribution system.

The Boyd Corners watershed drainage basin is 22 square miles, and includes portions of the Towns of Carmel and Putnam Valley in Putnam County, and East Fishkill in Dutchess County.

5.1.1 Program Implementation

DEP’s watershed protection programs have been very active in the West Branch and Boyd Corners Reservoir basins. DEP’s Land Acquisition has been one of the more active programs in the West Branch/ Boyd Corners basins. As of 1997, DEP owned only 680 acres or 2.6% of basin land area with another 1,170 acres 4.5% protected by non-City entities. Currently, over 10,000 acres or 39.1% of the basin land area is protected by both DEP and other non-City entities

Under the Stormwater Infrastructure Mapping and Inspection Program, 49,560 linear feet of piping were digitally mapped in the West Branch watershed and 3,450 were mapped at Boyd Corners. Additionally, 11,275 linear feet of ditch and 427 structures (manholes and stormwater outfalls) were mapped at Boyd Corners. At West Branch, 18,279 linear feet of ditch and 1,064 structures were mapped as well.

DEP designed and constructed two large stormwater retrofit/remediation projects in the West Branch Basin. Three additional projects are scheduled to be installed in the near future.

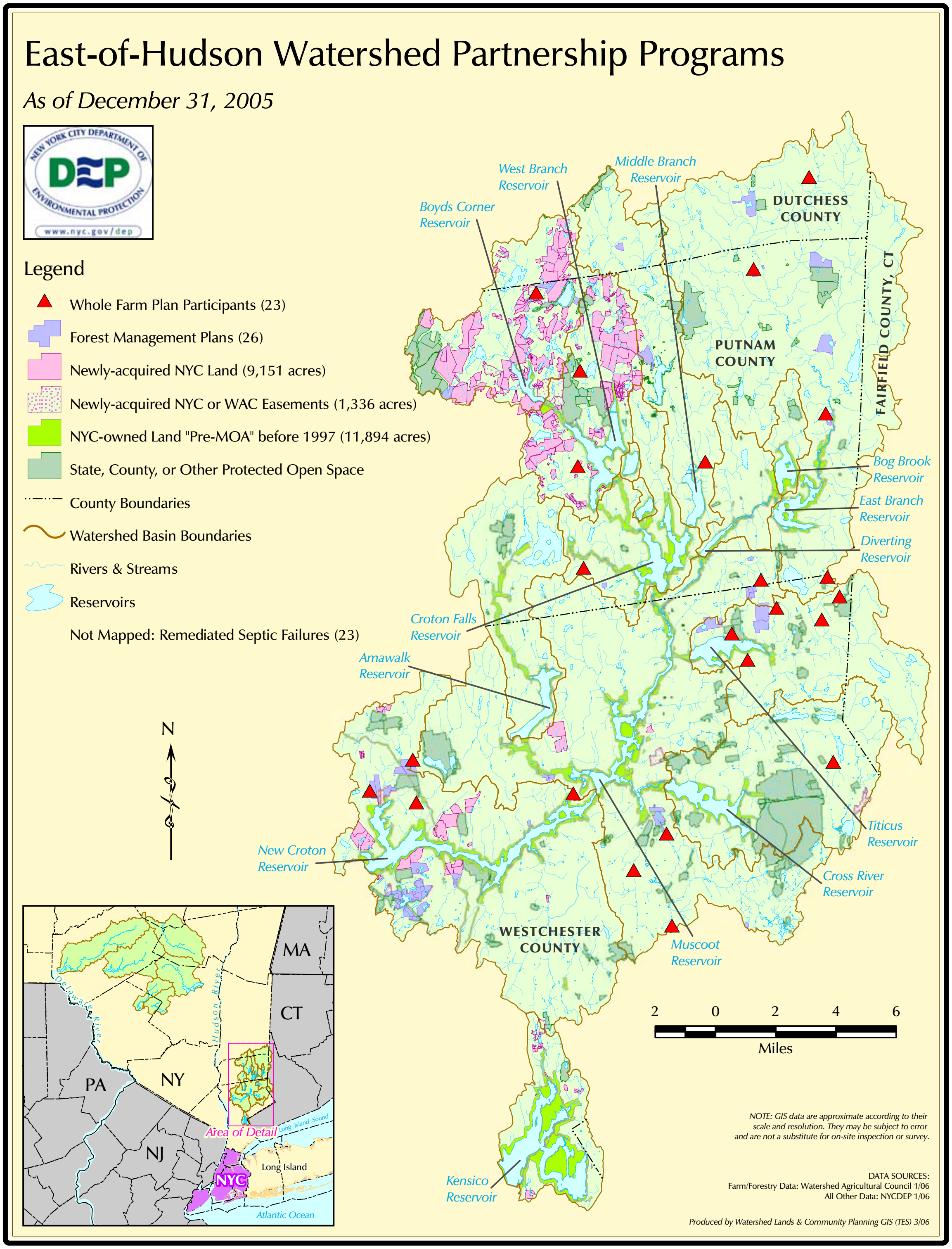


Figure 5.2 East of Hudson Watershed Partnership Programs as of December 31, 2005.

Wastewater Treatment Plants and Phosphorus Load Reductions in the West Branch Basin

As illustrated in Figure 5.3, phosphorus (as Total Phosphorus) loads to West Branch Reservoir from the basin's only WWTP, Clear Pool Camp, have increased since 1995 (the first full year of data), as has flow. The plant has been upgraded as part of DEP's effort to upgrade all surface-discharging WWTPs. This will significantly reduce the plant's inputs of phosphorus, as well as other pollutants, to West Branch Reservoir. It should be noted that loads and flows from this plant are extremely small.

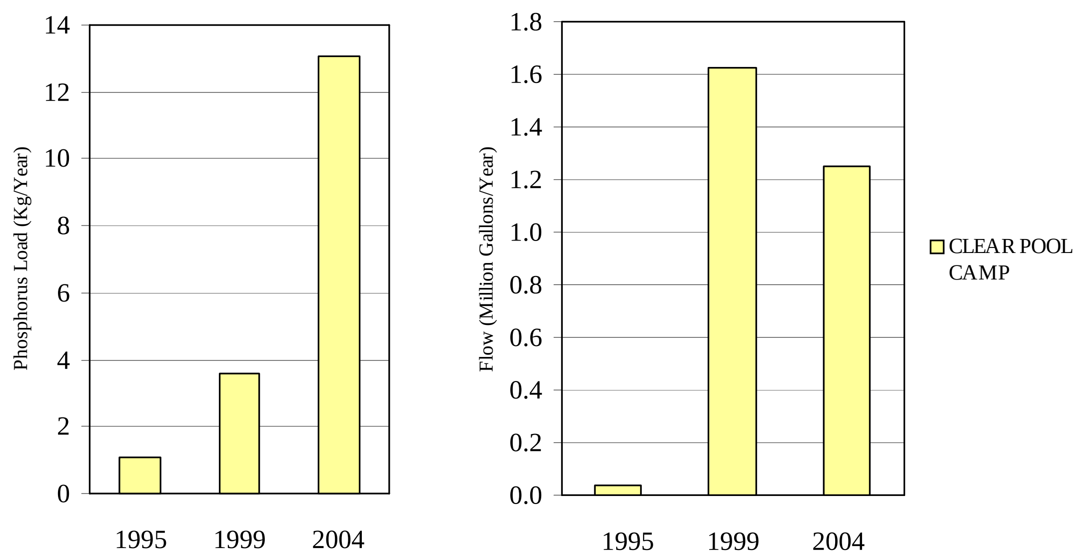


Figure 5.3 Total phosphorus loads and total volume of WWTP effluent flow to West Branch Reservoir in 1995, 1999, and 2004.

Table 5.1. Significant events and accomplishments at the only WWTP in the West Branch Reservoir basin.

WWTP	COMMENTS *
Clear Pool Camp	Upgrade permit date Feb 2005

Case Study
Modeling the Effect of Land Acquisition Program on Dissolved Phosphorus in Runoff at Horse Pound Brook.

The Land Acquisition Program can have an effect on water quality in NYC Reservoirs by controlling land development. We evaluated the effect of controlling development by land acquisition on dissolved phosphorus loads in the Horse Pound Brook watershed, using DEP's GWLF watershed water quality model (see section 7.1.1). The watershed model is an effective tool for this type of analysis, as the model can be used to simulate dissolved nutrient loads for different land use scenarios.

The Horse Pound Brook watershed, illustrated in Figure 5.4, is located within the eastern portion of the West Branch Reservoir Watershed in Putnam and Dutchess Counties, NY. This area of the watershed has been a highly active area for DEP's Land Acquisition Program. A large number of acquired lands, representing 36.7% of the Horse Pound Brook watershed area, were in various stages of proposed development at the time they were acquired by DEP. In all, planned development prior to DEP's land acquisition included 655 single family residential units, 401 condominiums and apartments, and one church. Figure 5.4 shows all city owned land and the acquired land that was slated for development.

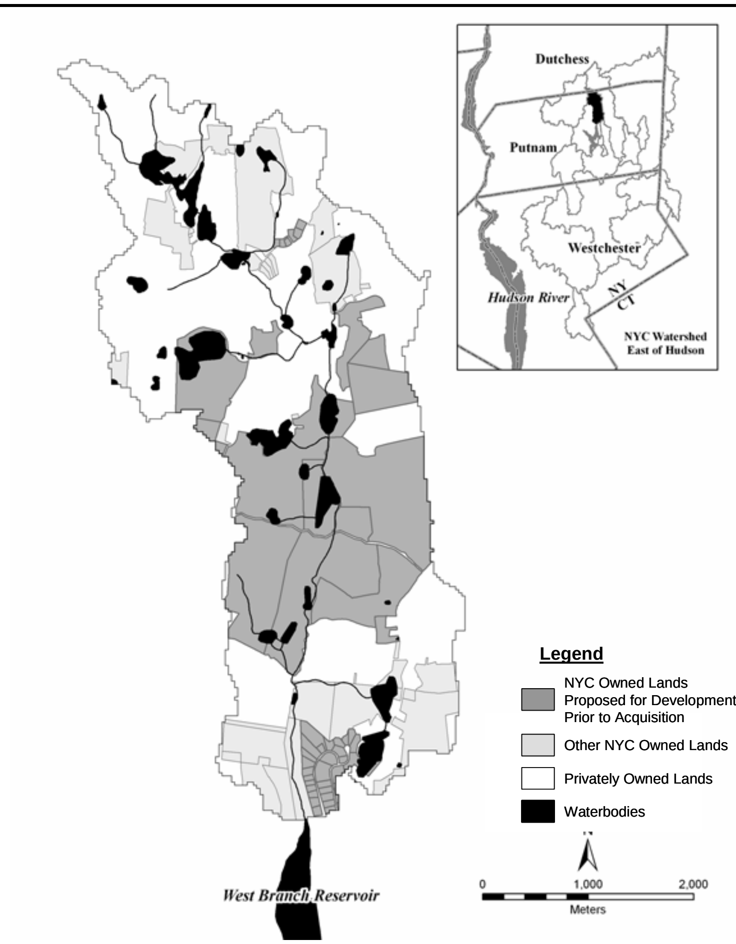


Figure 5.4 Location map of Horse Pound Brook watershed showing NYC owned lands.

Two scenarios were evaluated using the watershed model. In the *land acquisition* scenario, all planned development in the acquired area is precluded, and the land uses of the acquired areas are maintained at the existing land use, based on 2001 satellite derived land use data (DEP, 2006a). The *development* scenario assumes that acquisition of lands with planned development did not transpire, and that all the planned development occurs, with concomitant conversion of existing undeveloped land to residential and commercial/industrial land uses. To obtain reasonable estimates of pervious and impervious areas associated with proposed developments, an analysis of existing development within the Horse Pound Brook basin was performed. This analysis revealed that the average parcel size for single family residential development was 0.43 ha., with 14.5% consisting of impervious surface, 48.8% consisting of undeveloped forest or brushland, and the remaining 36.7% encompassing residential pervious areas such as managed lawns. From this analysis, the 655 proposed single family units were translated into additional residential impervious and pervious land areas that replace undeveloped land uses. For the proposed condominium/apartments and church, impervious surface coverage was assumed to be 65% based on average impervious areas for these types of developments applied in the TR-55 urban watershed model (USDA, 1986). The final land use areas for the *land acquisition* and *development* scenarios are shown in Table 5.2, with development converting approximately160 ha of existing undeveloped land to residential impervious, residential pervious, commercial/industrial impervious and commercial/industrial impervious land use categories. Meteorological inputs (precipitation and temperature) for the model scenario runs were obtained from cooperator stations recognized by the National Climate Data Center and detailed in DEP (2006b).

Table 5.2. Land use areas (ha) in Horse Pound Brook Watershed for *land acquisition* and *development* scenarios.

	Horse Pound Brook Watershed		
Land Use Category	land acquisition	development	difference
Deciduous Forest	1057.7	905.0	-152.7
Coniferous Forest	84.7	83.0	-1.7
Mixed Forest	28.8	27.3	-1.5
Brushland	32.6	30.7	-1.9
Cropland	0.3	0.3	0
Hayland	0.0	0.0	0
Pasture	2.1	2.0	-0.1

Table 5.2. Land use areas (ha) in Horse Pound Brook Watershed for *land acquisition* and *development* scenarios.

	Horse Pound Brook Watershed		
Land Use Category	land acquisition	development	difference
Barnyard	0.0	0.0	0
Non-Agricultural Turf	49.4	48.0	-1.4
Residential Pervious	89.7	197.1	+107.4
Residential Impervious	29.7	78.9	+49.2
Commercial/Industrial Pervious	5.9	6.9	+1.0
Commercial/Industrial Impervious	3.0	4.8	+1.8
Rural Roads	13.1	13.1	0
Wetland	53.3	53.3	0
Water	32.5	32.5	0

Results of the model scenario simulations showed a 39% increase in dissolved phosphorus load due to development in the absence of land acquisition, with dissolved phosphorus loads under the *land acquisition* scenario conditions for 1996-2004 averaging 55.7 $kg \cdot yr^{-1}$ vs. 77.5 $kg \cdot yr^{-1}$ for the *development* scenario. Figure 5.5 shows that the simulated increase in annual dissolved phosphorus load is consistent for each year of the meteorological record.

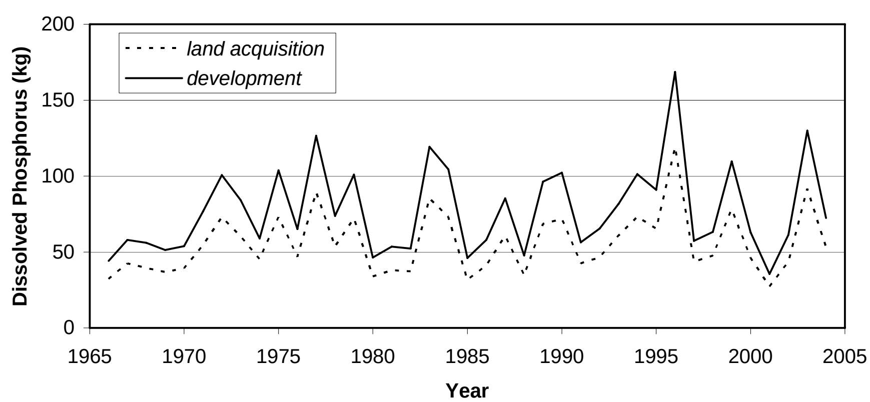


Figure 5.5 Annual simulated dissolved phosphorus load ($kg \cdot yr^{-1}$) at Horse Pound Brook for the land acquisition (dashed) and the development (solid) scenarios.

The average streamflow (Figure 5.6a) is essentially unchanged for the two scenarios (55.5 cm·yr^{-1} for *land acquisition* and 56.6 cm·yr^{-1} for the *development* scenario. However the direct runoff (Figure 5.6b) for the *development* scenario is 17.2 cm·yr^{-1} which is 16% greater than the *land acquisition* scenario average direct runoff of 14.8 cm·yr^{-1}.

The increase in dissolved phosphorus load under the *development* scenario is due to a combination of increased runoff concentrations for urban land uses and an increase in the fraction of direct runoff in streamflow. The average concentration of dissolved phosphorus in runoff increased from 6.8 µg·L^{-1} in the *land acquisition* scenario to 9.2 µg·L^{-1} in the *development* scenario.

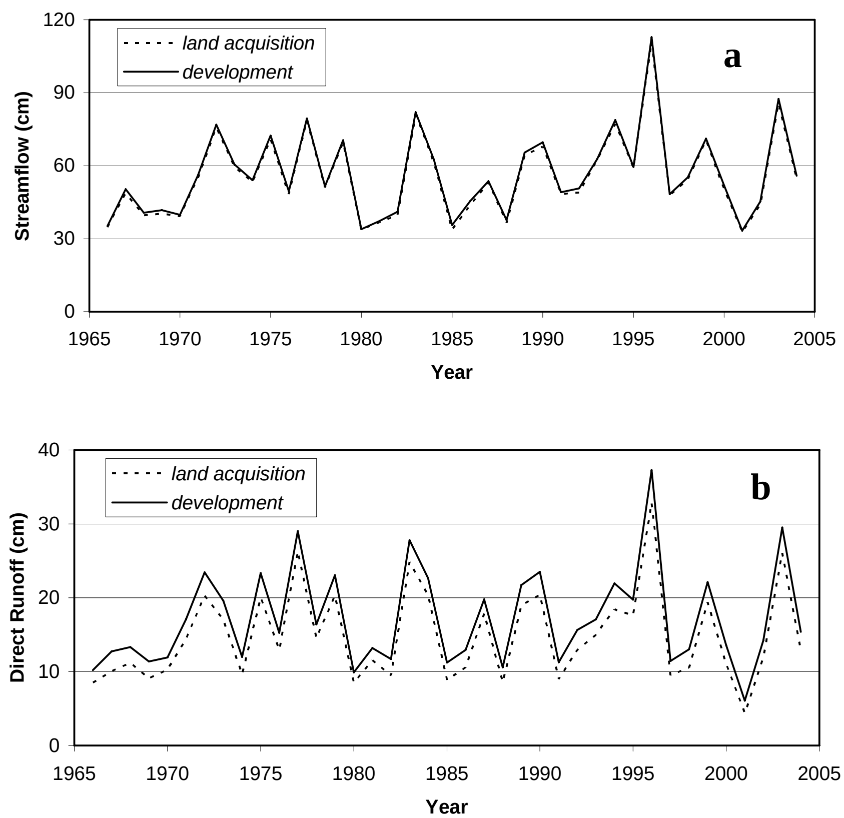


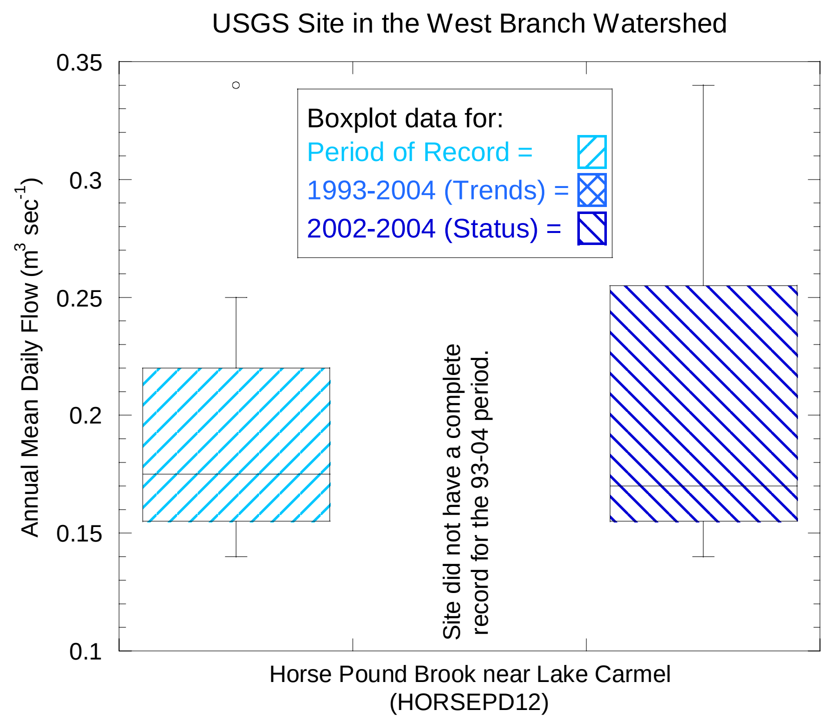
Figure 5.6 Annual simulated (a) streamflow and (b) runoff (cm·yr^{-1}) at Horse Pound Brook for the land acquisition (dashed) and the development (solid) scenarios.

This case study presents an example of how the Land Acquisition Program helps to maintain high quality water in NYC watersheds. By controlling development, the increases in dissolved phosphorus loads due to increased runoff and dissolved phosphorus concentrations that occur when undeveloped land is converted to urban land uses are averted. The Horse Pound Brook example may be considered an extreme case, as the program has acquired a large percentage of land in the watershed with plans for development. Where development is not as prevalent, the results will not be as dramatic as shown here.

5.1.2 Water Quality Status and Trends

Water quality is dependent on the flow characteristics of streams, and subsequently the flushing rates of the receiving reservoirs. In order to gain perspective on the flow characteristics for the different time periods represented in the water quality descriptions, flow distributions are presented in Figure 5.7. Three time periods are represented for each site: i) the full period of record, ii) the 12-year period used in discussing the trend over the period of FAD program implementation, and iii) the 3-year period (2002 to 2004) to represent the most recent status of water quality. High flows typically transport greater loads from the landscape than small flows, and increase flushing rates of reservoirs. High flushing rates are usually associated with high water quality, whereas low flushing rates (such as times of drought) may be associated with low water quality.

Horse Pound Brook near Lake Carmel is the primary stream inflow to West Branch Reservoir. It drains 20% of the basin. The flow distributions (of the annual mean daily flows) show the 3-year median representing the status period was very similar to the long-term median, although the overall distribution was slightly biased to higher flows.



DEP Site Code	Site Description	Sample Site Drainage Area to Reservoir Drainage Area	Period of Record
HORSEPD12	Horse Pound Brook near Lake Carmel	19.6%	Aug. 1996 - present

Figure 5.7 USGS stream gauge site in the West Branch watershed.

Status (West Branch Basin)

West Branch basin's status evaluation is presented as a series of box plots in Figure 5.8. The inputs include water diverted from Rondout Reservoir (DEL9), Boyd Corners release (BOYDR), and Horse Pound Brook (HORSEPD12). The reservoir is designated as CWB and the output is DEL10.

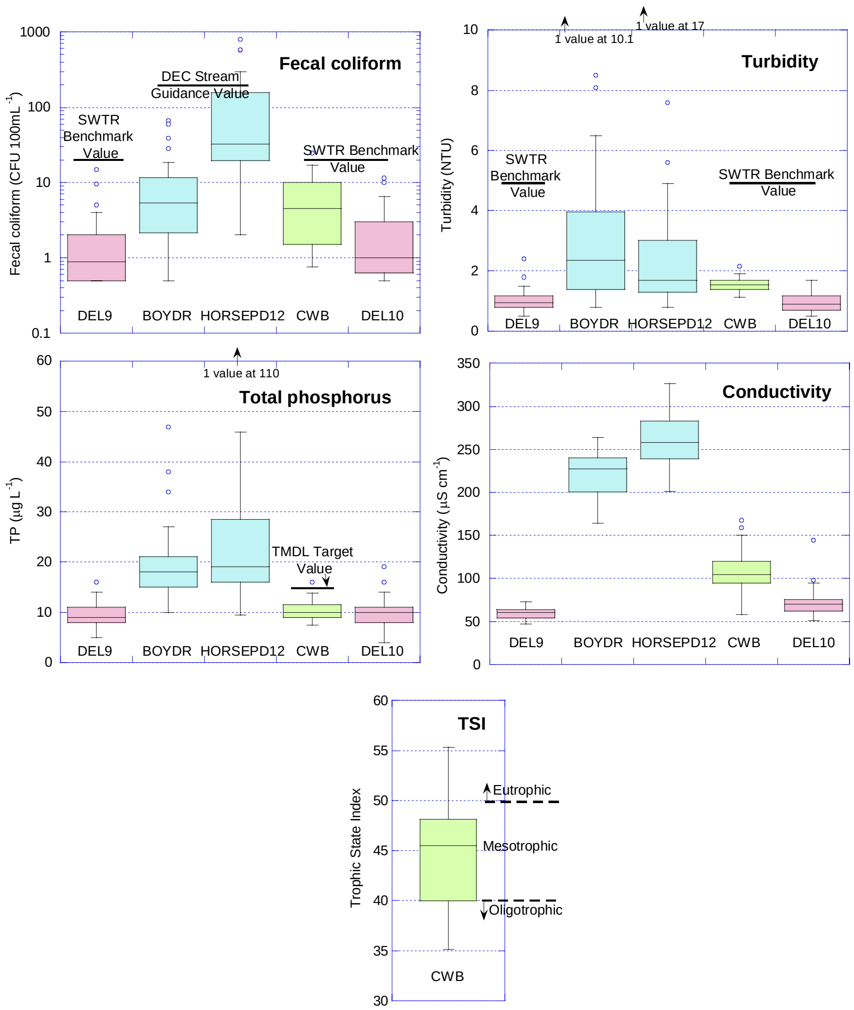


Figure 5.8 Water quality status boxplots using 2002–2004 monthly data for the West Branch basin for: the aqueduct input keypoint, DEL9; the main stream inputs, the Boyd Corners release at BOYDR and the Horsepound Creek at HORSEPD12; the reservoir, CWB; and the effluent aqueduct keypoint, DEL10.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Fecal coliform values were the lowest for DEL9 and highest for HORSEPD12, which is a stream input from the local watershed, and illustrates the sharp contrast between water quality from Rondout Reservoir as compared to local inputs. The reservoir and the output had median coliform values (4.5 and 1 CFU 100 mL^{-1}, respectively) that were well below the SWTR benchmark of 20 CFU 100 mL^{-1} used for source waters. DEL10 had a lower median for fecal coliform than the reservoir because on many occasions, the bulk of the water from the Delaware Aqueduct does not go through the reservoir; frequently West Branch is in “float mode” so the reservoir contributes a minor portion to the aqueduct flow.

The turbidity values were higher in the two local inputs, BOYDR and HORSEPD12, than from DEL9. BOYDR had the widest variability among the inputs. Both the reservoir and DEL10 had low median turbidity values. The reservoir values tended to be slightly higher than DEL10 due to operation in float mode as stated above. None of the values for the reservoir or the output from West Branch were above the 5 NTU SWTR benchmark value for source waters; the median values were 1.55 and 0.9 NTU, respectively. West Branch can become a source water for the Delaware system if Kensico is on by-pass.

Total phosphorus values for the inputs were also higher in the local inputs than the aqueduct inflow from Rondout. The highest variability was found in HORSEPD12. The reservoir and its output had similar TP values, and the median for the reservoir (10 µg L^{-1}) was well below the TMDL target value of 15 µg L^{-1} in the reservoir.

The trophic status index value for West Branch Reservoir was well within the mesotrophic range for the three year period. Since the majority of the inflow comes from Rondout Reservoir, the trophic status was driven by the input from this impoundment.

As with the other analytes, the conductivity varied among the inputs than the aqueduct inflow from Rondout. HORSEPD12 had the highest conductivity, which was reflective of values found in the Croton system. Both HORSEPD12 and BOYDR were significantly higher than the contrasting conductivity of the inflow from DEL9. West Branch Reservoir was higher than DEL10, again because of the frequent operation of this reservoir in float mode.

Water quality was good during the 2002 – 2004 analysis period in West Branch Reservoir. The important qualifier for this statement is that operational changes largely determine the characteristics of the reservoir, which is driven by the inflow from DEL9. The data for the selected variables show that medians are all well below the established benchmarks for fecal coliforms, turbidity, and total phosphorus.

Trends (West Branch Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 5.9. Results of the Seasonal Kendall trend analysis are provided in Table 5.3.

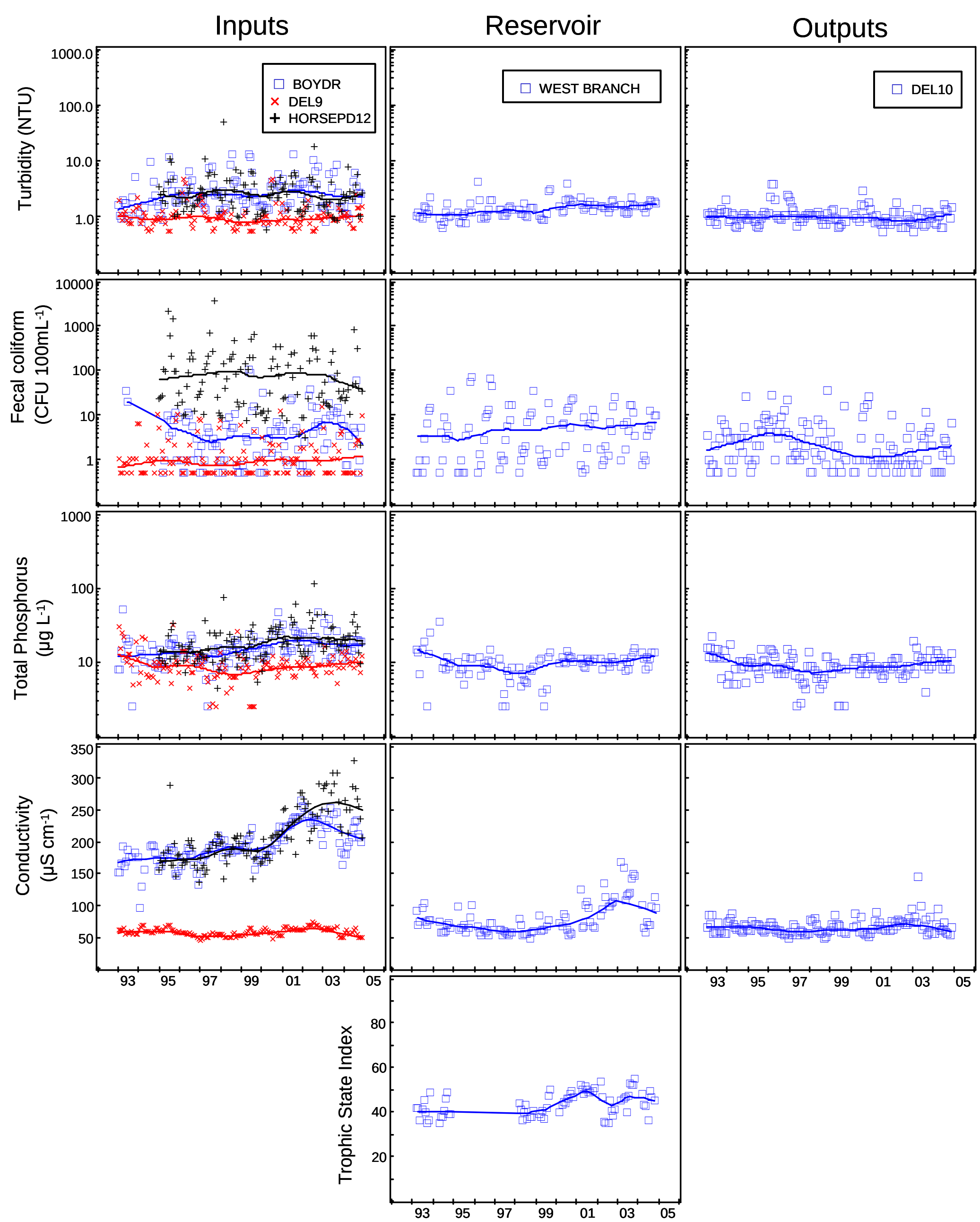


Figure 5.9 Water Quality trend plots for the West Branch basin for: the aqueduct input keypoint, DEL9; the main stream inputs, the Boyd Corners release at BOYDR and the Horse Pound Creek at HORSEPD12; the reservoir, West Branch; and the effluent aqueduct keypoint, DEL10.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3

Table 5.3. West Branch Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
BOYDR	Input	Turbidity	12	144	0.04	NS	0.01
DEL9	Input	Turbidity	12	144	-0.03	NS	0.00
HORSEPD12	Input	Turbidity	12	120	-0.07	NS	-0.04
West Branch	Reservoir	Turbidity	9	108	0.38	***	0.05
DEL10	Output	Turbidity	12	144	-0.15	***	-0.01
BOYDR	Input	Fecal coliform	12	144	0.17	***	0.06
DEL9	Input	Fecal coliform	12	144	0.04	NS	0.00
HORSEPD12	Input	Fecal coliform	12	120	-0.14	***	-1.57
West Branch	Reservoir	Fecal coliform	9	108	0.11	*	0.00
DEL10	Output	Fecal coliform	12	144	-0.13	***	0.00
BOYDR	Input	Total Phosphorus	12	144	0.28	***	0.57
DEL9	Input	Total Phosphorus	12	144	-0.05	NS	0.00
HORSEPD12	Input	Total Phosphorus	12	120	0.40	***	1.00
West Branch	Reservoir	Total Phosphorus	9	108	0.10	*	0.09
DEL10	Output	Total Phosphorus	12	144	-0.01	NS	0.00
BOYDR	Input	Conductivity	12	144	0.55	***	5.60
DEL9	Input	Conductivity	12	144	0.05	NS	0.12
HORSEPD12	Input	Conductivity	12	120	0.59	***	10.33
West Branch	Reservoir	Conductivity	9	108	0.26	***	2.00
DEL10	Output	Conductivity	12	144	0.10	*	0.25
West Branch	Reservoir	Trophic State Index	9	108	0.28	***	0.60

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
2. Tau refers to the Seasonal Kendall Test Tau statistic.

In general West Branch Reservoir receives the vast majority of its water from Rondout Reservoir via the Delaware Aqueduct (DEL9) so water quality patterns should be similar to Rondout. Exceptions occur when operational changes decrease or prevent the input from Rondout allowing local inputs, Boyds Corner Reservoir release (BOYDR) and Horse Pound Brook (HORSEPD12) to have greater influence over the water quality of West Branch Reservoir. Operational changes are initiated primarily to satisfy volume requirements in the City or if there is some water quality issue at West Branch. As discussed below these operational changes cause fluctuations in water quality, which perhaps are misleadingly detected as long-term trends.

From 1993 to 1998, West Branch was operated in "reservoir" mode at least 66% of the time. In reservoir mode water from the Delaware Aqueduct is totally diverted into the Reservoir and exits through DEL10. In this scenario residence time is extremely short (11 to 18 days) and Rondout water accounts for 90% of the inputs into West Branch. During 1999 and 2000 the reservoir was operated in roughly 50% "reservoir" mode, 50% "float" mode and in 2001 and 2002 it was almost exclusively "float" mode (95%). In "float" mode Rondout water is not allowed to enter West Branch at DEL9 while DEL10 is kept open allowing water from West Branch to enter the Delaware Aqueduct at a very slow rate. Usually, more time spent in "float" mode means a longer residence time and more contributions from local streams. During 2003, time in "reservoir" mode was increased to about 44%, time in "float" mode reduced to 40% and time in "by-pass" mode increased to 16%. In "by-pass" mode West Branch is totally isolated (no input, no outputs) from the Delaware Aqueduct and again local streams become the exclusive source of water to the reservoir.

During the first five years of the data record West Branch was essentially operated as an extension of the Delaware Aqueduct thus minimizing inputs from local sources. During the next 5 years West Branch was operated in such a way that progressively increased the relative contributions of local inputs. The effect on water quality is best described by examining the long-term trend in reservoir conductivity. From 1999 to 2003 conductivity increases as the time in float/by-pass mode increases. An upward "trend" is imparted because more conductive local waters comprise a greater percentage of the reservoir volume. Note the large increase in the local conductivity for the inputs (BOYDR, HORSEPD12) starting in 2000. This increase is likely a result of extremely dry conditions prevalent in this watershed from 2000 through 2001. A very small increase in conductivity is observed in the output (DEL 10) as well. It is not as large as the reservoir trend because during the times of elevated conductivity in the reservoir, the reservoir was in "float" or "by-pass" mode and therefore, not open to the Delaware Aqueduct.

In similar fashion, these historic operational changes are largely responsible for the upward turbidity and phosphorus trends in the reservoir as well as the downward turbidity trend and lack of phosphorus trend in the output. Not only was the relative contribution of local streams (BOYDR, HORSEPD12) increased in more recent years, we also detected upward phosphorus trends in both of these streams. The LOWESS curves in Figure 5.9 indicates that the increase occurred primarily from 1998-2000. We are unclear as to the reason for this increase.

The increasing trend in Trophic State index values can also be ascribed to these same operational changes that increased the contribution of local sources during the latter part of the data record.

Fecal coliform trends were detected statistically in the West Branch Reservoir and output. However, the Seasonal Kendall trend slopes are calculated to be zero; this is a consequence of numerous tied values in the data (see Appendix 3). The LOWESS curves suggest an upward trend in the reservoir and a downward trend in the output; these are supported by the signs of the trend tests. There is a “disconnect” between the output and the reservoir at times. Depending upon operational status, DEL 10 reflects either the reservoir input, or primarily, the Delaware Aqueduct. During “float mode” DEL 10 is primarily influenced by water quality from Rondout while the reservoir is more typical of the Croton System. Local input, BOYDR, does show an upward trend in fecal coliform while the other, HORSEPD12, shows a declining trend. The increase at BOYDR appears to be correlated to an increase in runoff events starting in May 2002. Reasons for the decline at HORSEPD12 are not clear.

In summary, an increasing turbidity trend was detected in the reservoir while the output showed a decrease. One local stream input and the reservoir showed increases in fecal coliform while another local stream input and the output showed a decrease. Both local stream inputs and the reservoir showed increases in phosphorus. Conductivity increases were noted in the local streams, the reservoir and output. Production increases were detected in the reservoir as well. All trends associated with the reservoir and output are thought to be related to changes in reservoir operations. Causes of local stream input trends are complex and in some cases not clear but likely related to weather patterns and development within the watershed.

5.2 The Kensico Basin

The Kensico Reservoir is located in Westchester County, about 3 miles north of White Plains and 15 miles north of New York City. Although formed by the damming of the Bronx River, it receives most of its water from the City's west of Hudson reservoirs through the Catskill and Delaware aqueducts. Kensico consists of a western main basin and an eastern Rye Lake portion, with water passing freely between the two. It holds 30.6 billion gallons at full capacity and was placed into service in 1915.

Figure 5.10 Kensico Reservoir.

The major function of the Kensico Reservoir is to receive water from all six Catskill and Delaware system reservoirs via two aqueducts, 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 the effluent segments of the 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, Kensico is called a source water, rather than a collecting reservoir. Under normal operations, waters 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 the Kensico Reservoir. (Delaware water usually passes through the West Branch Reservoir before reaching Kensico.) Kensico also has its own watershed, which supplies just 2% or less of the total water volume entering the reservoir. As the final reservoir in the Catskill/Delaware system before water enters the distribution network, the Kensico Reservoir is subject to federal water quality standards for coliforms and turbidity.

The Kensico watershed's drainage basin is 13 square miles and includes portions of the Towns of Harrison, Mount Pleasant, North Castle and a small part of Fairfield County, Connecticut.

5.2.1 Program Implementation

DEP watershed protection programs have been effective in preserving the high quality of the water in the Kensico Reservoir. More than 97% of the water in the Reservoir is delivered via the Catskill or Delaware aqueduct. Kensico was one of the earliest focuses of DEP's watershed protection activities and is certainly the most intensely studied basin in the system. Those study efforts have led to implementation of targeted controls to address localized threats to water quality.

A total of 45 stormwater and erosion abatement facilities have been installed in the Kensico basin, significantly reducing in the possibility of turbidity and fecal coliforms entering the Reservoir. A maintenance program to ensure the continued effectiveness of the practices is in place. Additionally, a Spill Containment Plan has improved DEP's ability to respond to and clean up spills around Kensico Reservoir. A series of permanently-anchored containment booms were installed to prevent movement of contaminants in the event of a spill. Thirty-nine spill containment facilities have been installed.

To address turbidity entering Kensico from two streams near the Catskill Effluent Chamber, DEP installed a turbidity curtain in 1995. Since that time, DEP has been actively monitoring the effectiveness of the curtain and has been able to confirm that the curtain does deflects runoff from Catskill Upper Effluent Chamber, allowing for mixing and settling in the basin. The curtain was repaired in 2002, replaced in 2003 and extended by 300 feet in 2004. Additionally, with the installation of animal deterrent gates at the stormwater outfalls at Malcolm Brook, DEP has reduced the chance of fecal coliforms entering Kensico.

Also of note is DEP's Sanitary Infrastructure Inspection Program. Video inspection and digital mapping was performed on those portions of sewers in the Kensico watershed that had not been previously mapped by DEP. The entire length of a Westchester County sewer line - approximately 21,864 linear feet and 120 manholes - bordering the western shore of the Reservoir was inspected and was found to be free of any defects that might cause exfiltration.

Case Study
Kensico Reservoir Extended Detention Basins for Stormwater Treatment

DEP has developed a comprehensive stormwater management plan for the Kensico Reservoir watershed. Part of that plan required the construction of extended detention basin best management practices (BMPs) on several streams draining into the reservoir, to reduce fecal coliform bacteria and turbidity. The first extended detention basin constructed (on the closest stream to the Catskill Effluent Chamber) was Best Management Practice Facility 12, located on Malcolm Brook (Figure 5.11).

Monitoring of 12 storms was carried out at this BMP in 2000 and 2001 to determine its efficiency at reducing loads and peak values of fecal coliform, and turbidity (quasi-load) discharged to Kensico Reservoir.

For each storm, an average of 12 discrete samples were collected at each monitoring location to calculate storm loads and to identify peak analyte levels. A regression of loads analysis technique was used to determine the BMP's load reduction efficiency. Using this technique, DEP estimates that this BMP has reduced stream loads by an average of 37% for fecal coliform and 49% for turbidity (quasi-load). Additionally, because of the additional time for settling of solids, storm peak concentrations of fecal coliform bacteria have been reduced by an average of 60%, and peak turbidity has been reduced by an average of 79%. Peak flows have been attenuated by around 74% thereby further reducing the peak instantaneous loads to the reservoir.

Another Extended Detention Basin (Facility 37 at stream N5-1), the monitoring of which took place between 2002 and 2004, has shown similar reductions.

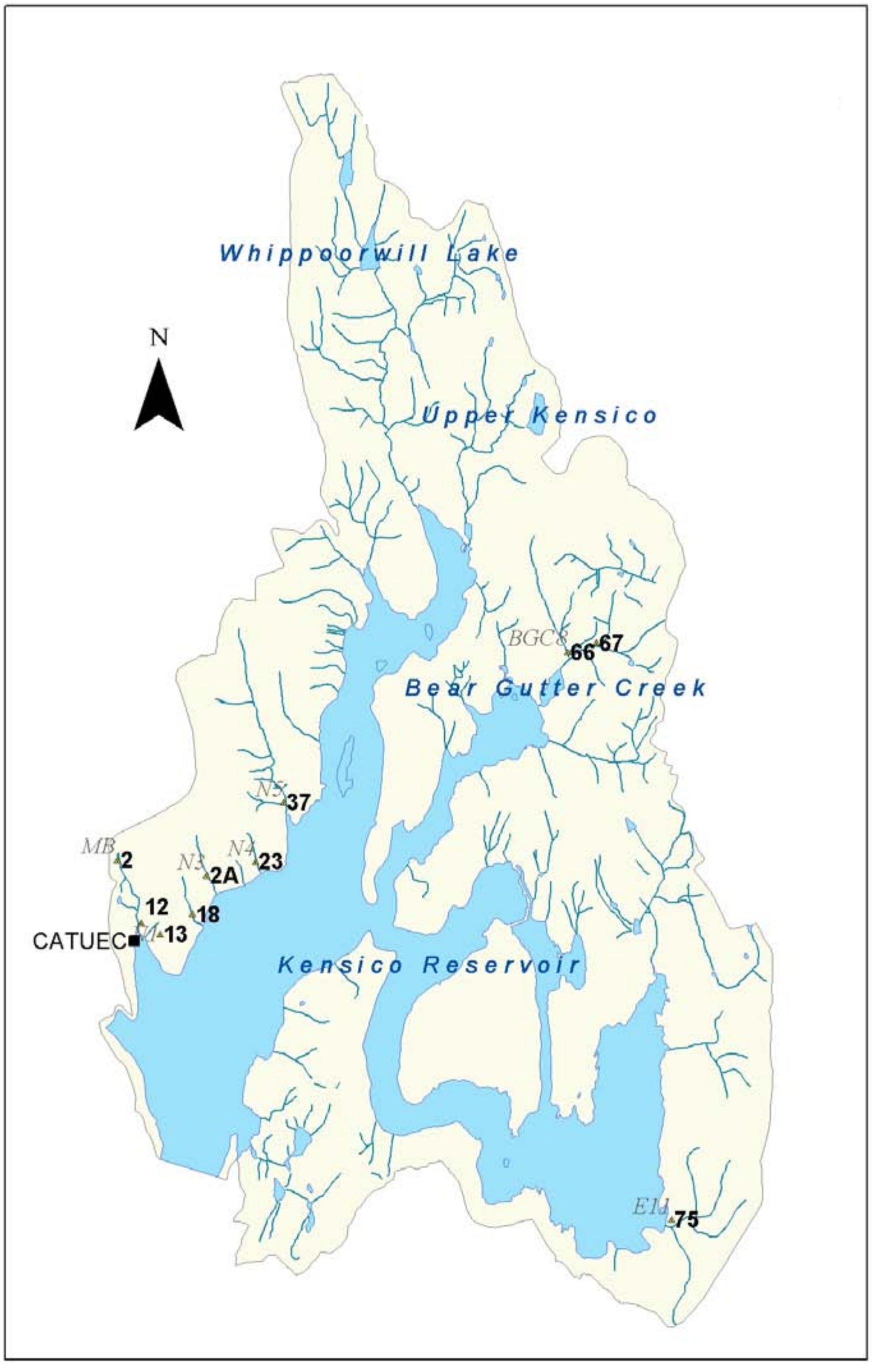


Figure 5.11 Kensico Reservoir watershed showing locations and facility numbers of extended detention basin BMPs. The Catskill Upper Effluent Chamber is marked as CATUEC.

Case Study
The Water Quality Effects, at the Catskill Effluent Chamber, of the Kensico Reservoir Turbidity Curtain, and the Malcolm Brook and Stream N1 Extended Detention Basin Best Management Practices

DEP has evaluated the effects of the Malcolm Brook cove turbidity curtain, plus the Malcolm Brook and N1 stream extended detention basin best management practices (BMPs) on the waters leaving Kensico Reservoir using daily data obtained from the Catskill effluent chamber (CATLEFF) (see Figure 5.12).

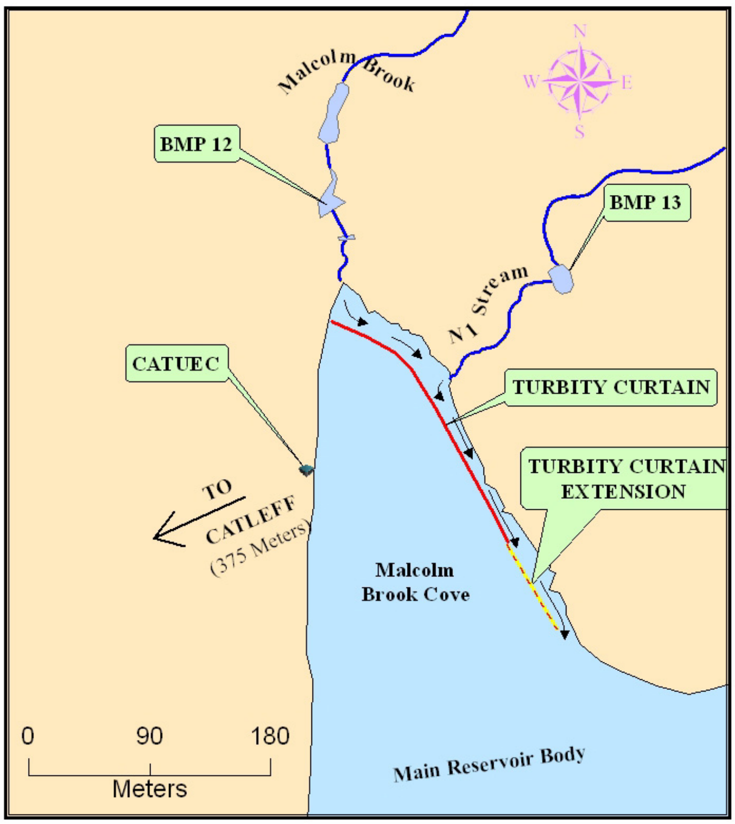


Figure 5.12 The Malcolm Brook cove of Kensico Reservoir showing the positioning of CATUEC and CATLEFF effluent chambers, the turbidity curtain(s), and the location of the extended detention basin BMPs

The original turbidity curtain was installed in the summer of 1994 principally to divert stormwater from Malcolm Brook and stream N1 away from the adjacent effluent chamber intake at CATUEC with the intention of reducing the peak values of turbidity and fecal coliform concentrations during storm events. Short-circuiting of waters from these streams to CATUEC within the cove would therefore be avoided because these waters would be diverted towards the main basin of Kensico Reservoir where greater dilution of the stormwater would be expected to occur. The main target for water diversion was from Malcolm Brook because its watershed is somewhat developed and is about four times the area of the N1 stream. The curtain was replaced in June 2003 and extended in October 2004.

Figure 5.13 The turbidity curtain showing noticably turbid stormwater being diverted away from the CATUEC effluent chamber.

The periods of construction (March through November 1999) of the primary BMPs on both streams are approximately the same so the benefits at the effluent chamber of just one of the BMPs cannot be assessed. In the summer and autumn of the following year, an additional BMP was constructed near the headwaters of Malcolm Brook (completion date November 2000). Effects of this smaller, secondary BMP on water quality at CATLEFF during and after its construction are assumed here to have been minimized by the primary BMP already in place downstream. Therefore the benefits of this upstream BMP were not assessed for this study, but were assumed to have been integrated into the effects of the primary BMP.

The data used in this analysis were from the daily turbidity and fecal coliform grab samples taken at approximately 08:00 at CATLEFF. These data are shown graphically in Figures 5.14 and 5.15, respectively, with a locally weighted smoothing curve (LOWESS) plotted on each graph to depict the general trending over the whole time period considered here (January 1990 through February 2005).

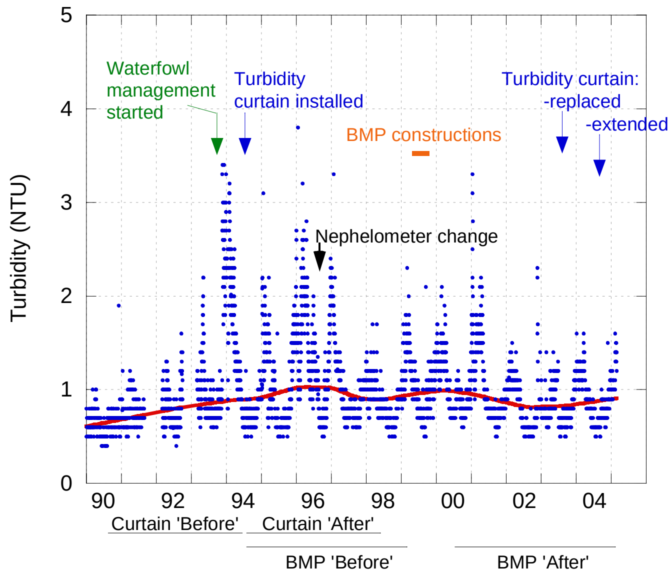


Figure 5.14 Daily turbidity data for the period January 1990 through February 2005 from the CATLEFF effluent chamber. Data are not included when Catskill system was on bypass. The curve is a LOWESS weighted curve fit with a 25% smoothing factor.

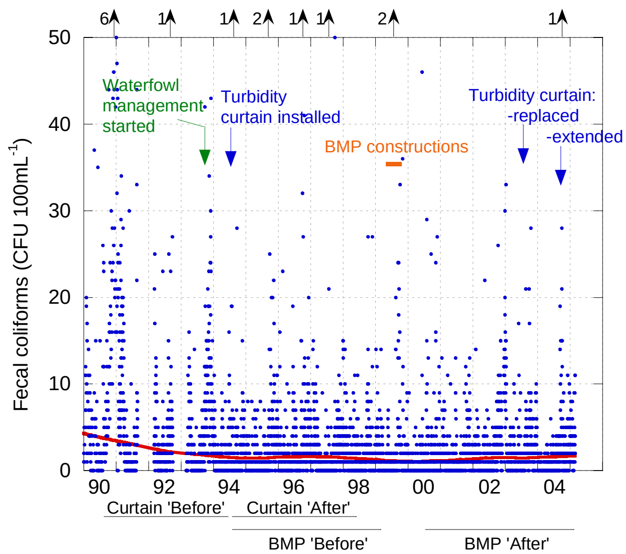


Figure 5.15 Daily fecal coliform data for the period January 1990 through February 2005 from the CATLEFF effluent chamber.

Note: Data are not included when Catskill system was on bypass. Data < detection limit (normally 1 100mL^{-1}) are plotted here as zero. The up-pointing arrows at the top of the graph indicate approximately where there are values (number indicated) > 50 100mL^{-1}. The curve is a LOWESS weighted curve fit with a 25% smoothing factor.

The Effects of the Turbidity Curtain

The period of analysis was chosen to avoid interference by the construction of the stream BMPs and to ensure that comparable times of the year before and after the initial installation of the curtain were achieved; it is also preferable that both data sets are similar in length (see Figure 5.14). This temporal comparability is essential because of the annually cyclic nature of the data. The periods July 1990 through June 1994 (the 'before' period) and July 1994 through June 1998 (the 'after' period) were therefore selected. Because the Waterfowl Management Program (WMP), which commenced in October 1993 (less than a year before the installation of the turbidity curtain), is designed to reduce fecal coliform concentrations in the reservoir, this analyte cannot be studied here because the commencement of the WMP confounds the 'before' data. There is an assumption here that the change in nephelometer in 1996 caused no bias in the turbidity data.

There is no statistical difference whatsoever in rainfall for the 'before' and 'after' periods—this is for all days in the selected periods, and for days when there were storm events (defined as rainfall $\geq$ 0.5" and $\geq$ 1.0"). Additionally, the number of days of rain (including storm events) was very similar for both time periods.

Because this study involves a potential data step-trend, a linear trend analysis is inappropriate, therefore the distribution-free Wilcoxon-Mann-Whitney Rank Sum Test has been used to compare the 'before' and 'after' data.

Using all data points available (except for days when the Catskill system was on bypass, and days when alum treatment was employed) there is no statistically significant difference in turbidity 'before' to 'after' (means 1.01 and 0.94NTU, medians 0.80 and 0.80NTU, respectively: $p = 0.37$, n ~950 for each group). However, the curtain was designed to reduce the effects of storm events, and when the data are examined when turbidity was $\geq$1.5NTU (this normally occurs following local storms) there is a different picture. Now, there is a significant reduction 'before' to 'after' (means 2.23 and 1.89NTU, medians 2.20 and 1.80NTU, respectively: $p = 0.0001$, n ~160 for each group). Further, when values $\geq$ 3NTU are examined, the number of observations drops from 8 'before' to 2 'after'.

In conclusion, the turbidity curtain appears to have had a small but statistically significant effect on peak turbidity values obtained during storm events. The overall effects of the curtain can be seen graphically in the LOWESS curve in Figure 5.14 where, up to the time when the initial curtain was installed, there seems to have been a steady rise in turbidity. This ceased once the curtain was in place.

The Effects of the Malcolm Brook and N1 Stream Extended Detention Basin BMPs

The periods of analysis chosen followed the initial installation of the turbidity curtain to avoid any possible confounding effects. The 'before' and 'after' BMP construction periods preferably need to be similar in length and encompass equivalent times of the year to avoid biasing the data because both fecal coliform concentrations and turbidity exhibit strong annual periodicity. The chosen periods also need to avoid the time when the BMPs were under construction. To provide as long a period as possible, the analyses have been performed for the time periods July 1994 through February 1999 ('before') and July 2000 through February 2005 ('after') assuming that the turbidity curtain replacement and extension created no confounding influences (see Figures 5.14 and 5.15 for turbidity and fecal coliform, respectively). There is an assumption here that the change in nephelometer in 1996 caused no bias in the turbidity data.

There is no statistical difference whatsoever in rainfall for the 'before' and 'after' periods-this is for all days in the selected periods, and for days when there were storm events (defined as rainfall $\geq$ 0.5" and $\geq$ 1.0"). Additionally, the number of days of rain (including storm events) was very similar for both time periods.

Because this study involves a potential data step-trend, a linear trend analysis is inappropriate, therefore the distribution-free Wilcoxon-Mann-Whitney Rank Sum Test has been used to compare the 'before' and 'after' data.

For turbidity, using all data points available (except for days when the Catskill system was on bypass, and days when alum treatment was employed) there is a small but statistically significant reduction in 'before' to 'after' data (means 0.96 and 0.89NTU, medians 0.90 and 0.80NTU, respectively: $p \leq 0.0001$, n ~1600 for each group). However, as with the turbidity curtain, the BMPs are designed to reduce the impact of storm events; after BMP construction, the number of days when the turbidity is $\geq$1.5NTU is considerably reduced (257 to 101) with a corresponding statistically significant reduction in means and medians (means 1.88 and 1.71NTU, medians 1.80 and 1.60NTU, respectively: $p \leq 0.0001$).

For fecal coliforms, as with turbidity, using all data points available (except for bypass days and days when alum treatment was employed) and setting all <1 (the detection limit) values to zero, there is a statistically significant reduction in 'before' to 'after' data (means 2.78 and 2.45 $100mL^{-1}$, medians 1.00 and 1.00 $100mL^{-1}$, respectively: $p = 0.069$, n ~1600 for each group) although the two median values are identical. However, there is a different picture when the high values that the BMPs are meant to reduce are examined. For fecal coliform concentrations $\geq$ 20 $100mL^{-1}$, although the number of exceedances are similar between the two groups (16 and 14, respectively) the mean values of these exceedances are considerably reduced (46.9 to 27.9 $100mL^{-1}$; the medians are 30.0 and 26.5 $100mL^{-1}$, respectively; $p = 0.084$).

Summarizing, the BMPs are having a small but statistically significant effect on peak turbidity and fecal coliform concentrations obtained during storm events. The overall effects of the curtain can just be seen graphically in the LOWESS curve in Figure 5.14 where there seems to have been a small lowering in turbidity after the BMPs were put in place.

Case Study
Waterfowl Management Program on Kensico Reservoir

DEP's Waterfowl Management Program (WMP) is a comprehensive strategy to manage waterbird[1] species that inhabit New York City reservoirs, of which six are intensively monitored for avian activity to detect population changes that may elevate reservoir fecal coliform bacteria levels. This program has been in continuous operation on Kensico Reservoir since 1993 and as a result it has effectively reduced waterbird populations (Figure 5.16a) and, as a consequence, kept fecal coliform bacteria concentrations below the required value specified in the Surface Water Treatment Rule (SWTR) regulations (Figure 5.16b). The WMP was more recently expanded to include five additional reservoirs on a criteria-based "as needed" program under the November 2002 FAD. The program involves population monitoring and bird dispersal techniques of local and migratory waterbirds. Waterbird numbers have been dramatically reduced through non-lethal techniques designed to remove birds from the reservoirs while minimizing other environmental and ecological effects to non-targeted species. The success can be attributed directly to the seasonal bird hazing activity which deploys a variety of bird dispersal techniques. When these dispersal tools (motorboats, Husky Airboats, and pyrotechnics) are used in concert, they result in the most effective means for bird reduction over large open areas of drinking water. As a direct consequence of the WMP, there has been a dramatic reduction in the fecal coliform bacterial threat to the New York City drinking water supply.

1. Waterbird – Includes Canada Geese, gulls, cormorants, swans, coots, grebes, loons, and all North American species of duck.

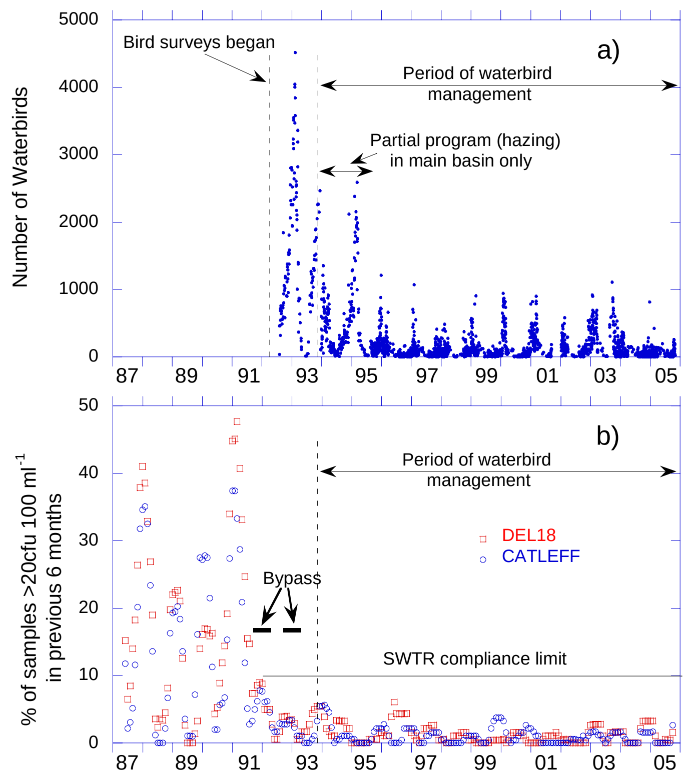


Figure 5.16 a) Kensico Reservoir waterbird population 1992–2005. b) Kensico Reservoir fecal coliform bacteria levels and Surface Water Treatment Rule Compliance 1987–2005.

5.2.2 Water Quality Status and Trends

Status (Kensico Basin)

Kensico Reservoir's status evaluation is presented as a series of box plots in Figure 5.17. The inputs include water diverted from Rondout Reservoir via West Branch (DEL17), the diversion from Ashokan Reservoir (CATALUM), and a local stream (WHIP). The reservoir is designated as BRK and the outputs are DEL17 and CATLEFF.

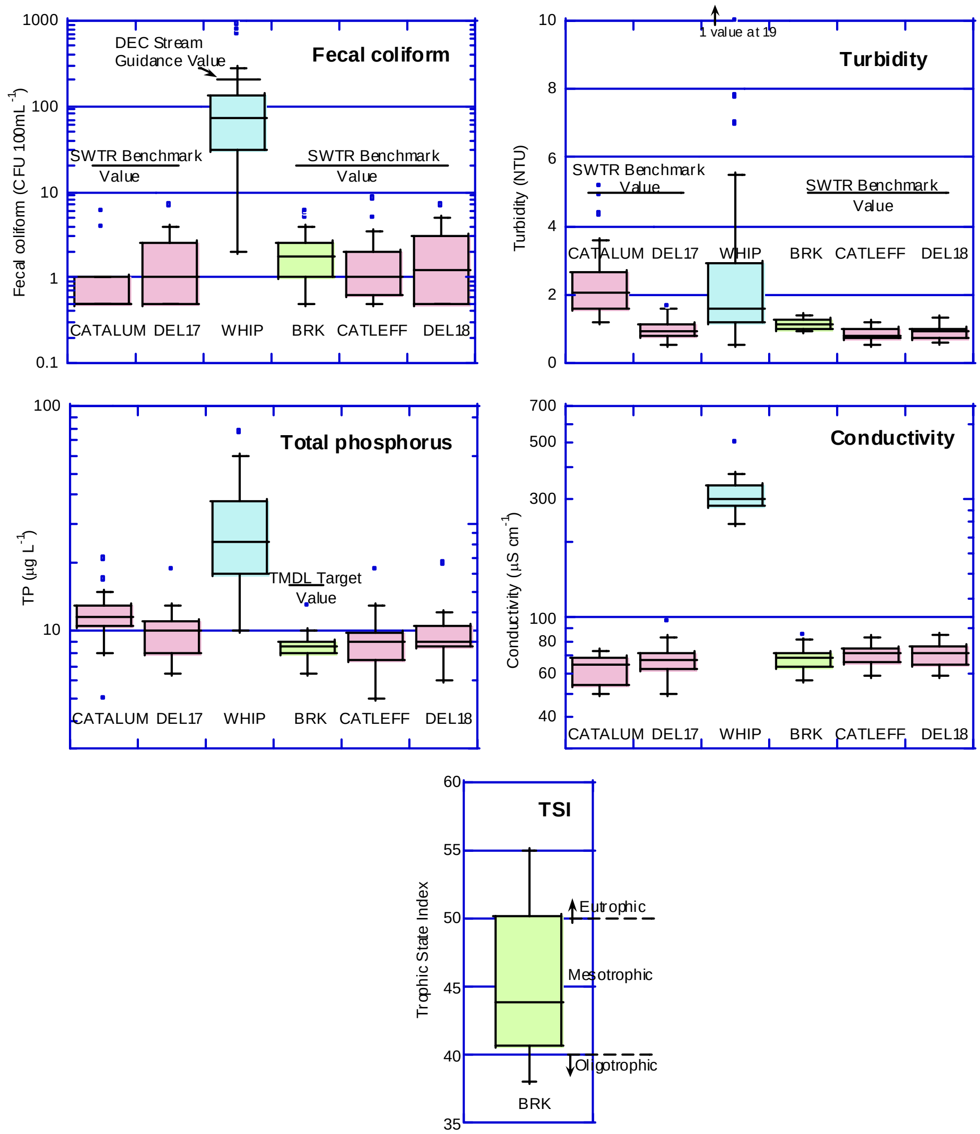


Figure 5.17 Water Quality status boxplots using 2002–2004 monthly data for the Kensico basin for: the aqueduct input keypoints, CATALUM and DEL17; the main stream input, Whippoorwill Creek at WHIP; the reservoir, BRK; and the effluent aqueduct keypoints, CATLEFF and DEL18.

Note: For methodology details and boxplot interpretation, see Appendix 3.

Fecal coliform values were low for both CATALUM and DEL17, with DEL17 having more variability over the three year period. WHIP had the highest levels of fecal coliform of the three inputs. As a local stream from a developed watershed, WHIP was expected to have higher fecal coliform concentrations compared to the two inputs from upstream reservoir sources. Medians were well below the 200 CFU 100 mL^{-1} DEC Stream Guidance Value. The reservoir and the two outputs had coliform values that were also well below the SWTR benchmark of 20 CFU 100 mL^{-1} used for source waters. Only minor differences occurred between the reservoir and its outputs.

The turbidity values for the inputs were lowest in DEL17. WHIP is subject to local storms with a resultant increase in turbidity, however, the flow contribution to Kensico is minimal. CATALUM provides water from Ashokan Reservoir which is impacted by turbidity events in the Catskills. Kensico Reservoir can attenuate the various sources of turbidity to some degree, and for that reason lower median turbidity values in the two outflows are observed. None of the values in the box plots exceeded the 5 NTU SWTR benchmark in the reservoir or the outputs; median values are well below this benchmark.

Total phosphorus values exhibited a pattern similar to turbidity. WHIP had the highest values and variability for TP in the inputs. In Kensico Reservoir, the median TP value (8.5 µg L^{-1}) was well below the TMDL target value of 15 µg L^{-1}.

The trophic status index value for Kensico Reservoir was generally within the mesotrophic range for the three year period. The trophic status was driven by the major inputs from Ashokan and Rondout reservoirs.

The conductivity was broadly similar in the two major inputs, the reservoir and the two outputs. The local watershed was significantly higher, yet the lack of an increase in conductivity in the reservoir demonstrates the minimal effect of the inflow from WHIP. The change in scale caused by the inclusion of WHIP diminishes the amplitude of the differences amongst all the other sites. Although some differences exist, the medians are similar.

In summary, water quality was excellent during the 2002 – 2004 analysis period in Kensico Reservoir. The data for the selected variables show that none of the monthly values exceeded the established benchmarks in the reservoir or the outputs, with median values falling well below the benchmarks. .

Trends (Kensico Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 5.18. Results of the Seasonal Kendall trend analysis are provided in Table 5.4.

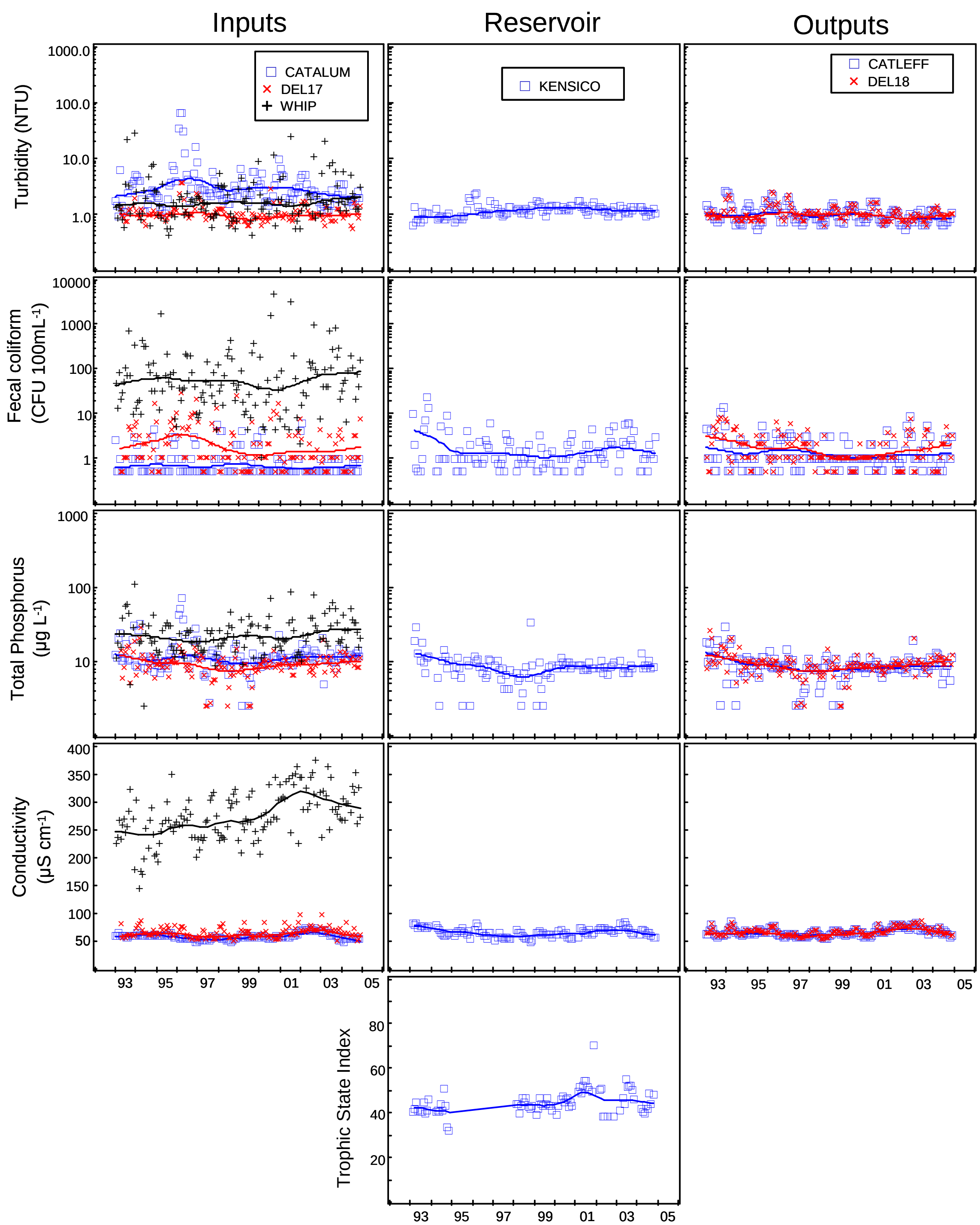


Figure 5.18 Water Quality trend plots for the Kensico basin for: the aqueduct input keypoints, CATALUM and DEL17; the main stream input, Whippoorwill Creek at WHIP; the reservoir, Kensico; and the effluent aqueduct keypoints, CATLEFF and DEL18.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 5.4. Kensico Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
CATALUM	Input	Turbidity	12	144	-0.08	NS	-0.04
DEL17	Input	Turbidity	12	144	-0.14	***	-0.01
WHIP	Input	Turbidity	12	144	0.13	***	0.03
Kensico	Reservoir	Turbidity	10	120	0.24	***	0.02
CATLEFF	Output	Turbidity	12	144	-0.25	***	-0.01
DEL18	Output	Turbidity	12	144	-0.11	**	0.00
CATALUM	Input	Fecal coliform	12	144	-0.09	***	0.00
DEL17	Input	Fecal coliform	12	144	-0.15	***	0.00
WHIP	Input	Fecal coliform	12	144	0.04	NS	0.56
Kensico	Reservoir	Fecal coliform	10	120	-0.03	NS	0.00
CATLEFF	Output	Fecal coliform	12	144	-0.08	**	0.00
DEL18	Output	Fecal coliform	12	144	-0.15	***	0.00
CATALUM	Input	Total Phosphorus	12	144	0.06	NS	0.00
DEL17	Input	Total Phosphorus	12	144	0.01	NS	0.00
WHIP	Input	Total Phosphorus	12	144	0.22	***	0.60
Kensico	Reservoir	Total Phosphorus	10	120	-0.06	NS	0.00
CATLEFF	Output	Total Phosphorus	12	144	-0.04	NS	0.00
DEL18	Output	Total Phosphorus	12	144	0.03	NS	0.00
CATALUM	Input	Conductivity	12	144	0.02	NS	0.00
DEL17	Input	Conductivity	12	144	0.04	NS	0.00
WHIP	Input	Conductivity	12	144	0.42	***	6.67
Kensico	Reservoir	Conductivity	10	120	-0.02	NS	0.00
CATLEFF	Output	Conductivity	12	144	0.20	***	0.50
DEL18	Outputs	Conductivity	12	144	0.18	***	0.39
Kensico	Reservoir	Trophic State Index	10	90	0.29	***	0.67

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).

2. Tau refers to the Seasonal Kendall Test Tau statistic.

A *very* slight increase in turbidity (+0.02 NTU yr^{-1}) was detected in Kensico Reservoir. This is surprising since the major inputs show either no statistically significant trend (CATALUM—although the Seasonal Kendall Tau statistic and the Seasonal Kendall trend slope are both negative) or a slight downward trend (DEL17). This very small increase may be the result of increasing the diversion from the more turbid Catskill System relative to the Delaware System in 1998 and 1999. A very slight downward trend (-0.01 NTU yr^{-1}) was detected in the Catskill output, CATLEFF, despite the trend of increased turbidity in the reservoir. The decrease seems to be a consequence of the construction of a detention basin on Malcolm Brook, a turbid local stream that flows into the reservoir very near CATLEFF and a turbidity curtain designed to deflect water from this brook into the main reservoir basin. Additional details are provided in the Case Study of these constructions. A small local stream, Whippoorwill Creek (WHIP), did show a small increase of 0.03 NTU yr^{-1} but its impact is probably negligible due to its small flow compared to the other inputs.

Downward trends were detected statistically for fecal coliform in the aqueduct inputs (CATALUM, DEL17) and outputs (CATLEFF, DEL18). However, the Seasonal Kendall trend slopes are calculated to be zero; this is a consequence of numerous tied values in the data (see Appendix 3). The signs of the trend test support these downward trends and this is further supported by the LOWESS curves for DEL 17 and DEL 18 Although a downward trend was not detected for the reservoir, monthly values remained consistently low in the reservoir and in its outputs, especially after 1994. The consistently low counts are attributed to the success of the Kensico Waterfowl Management Program, ongoing since 1995 (see Case Study).

Phosphorus trends were not discernible in the reservoir, outputs or major inputs although an increasing trend was detected in the small local input, WHIP. The increase may be due to increased runoff during abnormally wet years, 2003 and 2004. An upward conductivity trend was also apparent in this input, especially noticeable during drought years, 2000 and 2001. Road salting and other activities associated with development probably contributed to the increase in conductivity as well. Although no trend was detected in the reservoir, very slight upward trends in conductivity were detected in both outputs.

There is a small increasing trend in Trophic State Index values in Kensico Reservoir. This is not unexpected since production increases have been noted in all Catskill Reservoirs and the Catskill System accounts for approximately 40% of the flow to Kensico.

In summary, both upward and downward turbidity trends were detected in the inputs to Kensico Reservoir. The reservoir itself showed a very slight increase attributed to operational changes in the late 1990s. Output turbidity appears to be decreasing perhaps due to the construction of a detention basin on a local stream located near the output. Fecal coliform concentrations were consistently low and appear to be decreasing slightly largely through the efforts of the Kensico Waterfowl Management Project. For the most part, total phosphorus concentrations remain low with almost no trends detected. One exception was a small local stream, Whippoorwill Creek, which showed an increasing trend associated with increases in precipitation in 2003 and 2004. An upward conductivity trend was detected for this input and in the outputs as well. The 2001 drought and anthropogenic sources are likely causes for the noted increase. Primary production increases in Kensico Reservoir may be associated with production increases experienced by all reservoirs in the Catskill System, but this has not been confirmed.

5.3 Water Quality Summary for the East of Hudson Catskill/Delaware System

DEP has continued enhancing watershed protection in the West Branch and Kensico basins. Additional land has been purchased, with land owned by the City and non-City entities (see Section 2.2) now comprising 39% and 37% of West Branch and Kensico basins, respectively. In the West Branch basin, two large and several small stormwater remediation sites have been constructed. In the Kensico basin, there has been a multiplicity of engineering programs with, for example, construction of 45 stormwater management and erosion abatement facilities. The Malcolm Brook Cove turbidity curtain has been repaired (2002), replaced (2003), and extended (2004) to ensure that it continues to divert stormwater away from the Catskill Effluent Chamber. The Waterfowl Management Program continues its activities on and around Kensico reservoir to reduce the population of waterbirds.

Water quality was excellent during the 2002 – 2004 analysis period in West Branch and Kensico reservoirs with median values (of the monthly reservoir-wide medians) all well below the established benchmarks for fecal coliforms (benchmark 20 CFU $100ml^{-1}$), turbidity (5 NTU), and total phosphorus (15 $\mu g\ L^{-1}$). The only exceedances of the benchmarks were for TP with one for each reservoir. Conductivity was relatively low in both reservoirs with median values of 104 and 70 $\mu S\ cm^{-1}$ for West Branch and Kensico, respectively. Both reservoirs are mesotrophic.

For Kensico, especially, it is important to also consider water quality at the effluent chambers (CATLEFF and DEL18) because Kensico is the main source water for the City. The water quality at these chambers largely reflects that of the reservoir's main basin. However, median values for fecal coliform and turbidity are somewhat lower than those reservoir-wide at around 1 CFU $100ml^{-1}$ and 1 NTU, respectively for both analytes, at both effluent chambers.

For West Branch, very small, but increasing, trends were detected for all analytes studied: turbidity (0.05 NTU yr^{-1}), fecal coliform (0.00 CFU $100ml^{-1}\ yr^{-1}$), total phosphorus (0.09 $\mu g\ L^{-1}\ yr^{-1}$), conductivity (2 $\mu S\ cm^{-1}\ yr^{-1}$ and Trophic State Index (0.6 yr^{-1}). This is, in part, a consequence of the sensitivity of the trends analysis.

For Kensico Reservoir, there were extremely small upward trends detected for turbidity (0.02 NTU yr^{-1}) and Trophic State Index (0.7 yr^{-1}), although the latter is not reflected in a TP trend (where there is actually a negligible downtrend). The outputs from Kensico (at the effluent chambers CATLEFF and DEL18) showed negligible downward trends for turbidity and fecal coliform. There were very small upward trends at both sites for conductivity (0.39 and 0.67 $\mu S\ cm^{-1}\ yr^{-1}$, respectively).

DEP's Waterfowl Management Program efforts on Kensico Reservoir have had a major effect on reducing the bird population on and around the reservoir, the upshot of this being a dramatic reduction, starting in the early 90s, in fecal coliform concentrations in the water being delivered to the City. That this water is of excellent , i.e., low in bacteria, quality is in very large part a consequence of this program.

DEP has installed a series of Extended Detention Basins for stream stormwater pollutant load reduction Kensico Reservoir. The facility at Malcolm Brook has been shown to reduce stream storm loads by an average of 37% for fecal coliform and 49% for turbidity (quasi-load). Further, because of the additional time for settling of solids, storm peak concentrations of fecal coliform bacteria have been reduced by an average of 60%, and peak turbidity has been reduced by an average of 79%. Peak flows have been attenuated by around 74% thereby further reducing the peak instantaneous loads to the reservoir. A more recently installed extended detention basin (at stream N5-1), has shown similar reductions.

The Malcolm Brook Extended Detention has been shown to have a small but statistically significant effect on peak turbidity and fecal coliform concentrations at the Catskill Lower Effluent Chamber following storm events.

A turbidity curtain was installed in 1994 in the Malcolm Brook Cove in Kensico Reservoir with the intention of reducing turbidity in the Catskill Effluent Chamber following storm events in an adjacent stream, Malcolm Brook. A statistical analysis of data has shown a small, but statistically significant, effect of the curtain on reducing peak turbidity values at CATLEFF following storm events.

6. East of Hudson Potential Delaware System Basins

6.1 Cross River Basin

Located in northeastern Westchester County, about a mile east of the Village of Katonah, and more than 25 miles from New York City, the Cross River Reservoir was formed by the damming of the Cross River, which then continues west and drains into the Muscoot Reservoir. It was placed into service in 1908. The reservoir consists of one basin, approximately 3.2 miles in length. It holds 10.3 billion gallons at full capacity.

Figure 6.1 Cross River Reservoir.

Cross River is one of 12 reservoirs in the City's Croton system. Water withdrawn from the reservoir's western tip flows into the continuation of Cross River, empties into the Muscoot Reservoir, and from there flows to the New Croton Reservoir for further settling. After travelling through the 24-mile New Croton Aqueduct, the water reaches the Jerome Park Reservoir in the Bronx, where it enters New York City's distribution system.

Cross River Reservoir watershed's drainage basin is 30 square miles and includes portions of the Towns of Bedford, Lewisboro and Pound Ridge in Westchester County, and a small part of Fairfield County, Connecticut. Currently there are four WWTP's located in the Cross River watershed basin, which collectively produce approximately 0.064 MGD of flow. As per the most recent SPDES permits, the plants are limited to a combined release of 0.137 MGD of flow.

Cross River Reservoir has a pump station that enables DEP to pump water to the lower portion of the Delaware Aqueduct. The pump station is not frequently used, but has been operated during times of drought. The Cross River pump station was last used in 1995. DEP plans to rehabilitate and upgrade the pump station to increase its capacity to improve reliability during drought or other water shortages.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Cross River Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Cross River Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging WWTPs, and also through the intervention and involvement of the Division of Engineering's Regulatory Compliance and Inspection (RCI) group. As illustrated in Figure 6.2, phosphorus (as Total Phosphorus) loads were considerably reduced at The Meadows at Cross River, and at Michelle Estates, which began operations in 1995. Table 6.1 highlights significant contributing events and accomplishments at those plants.

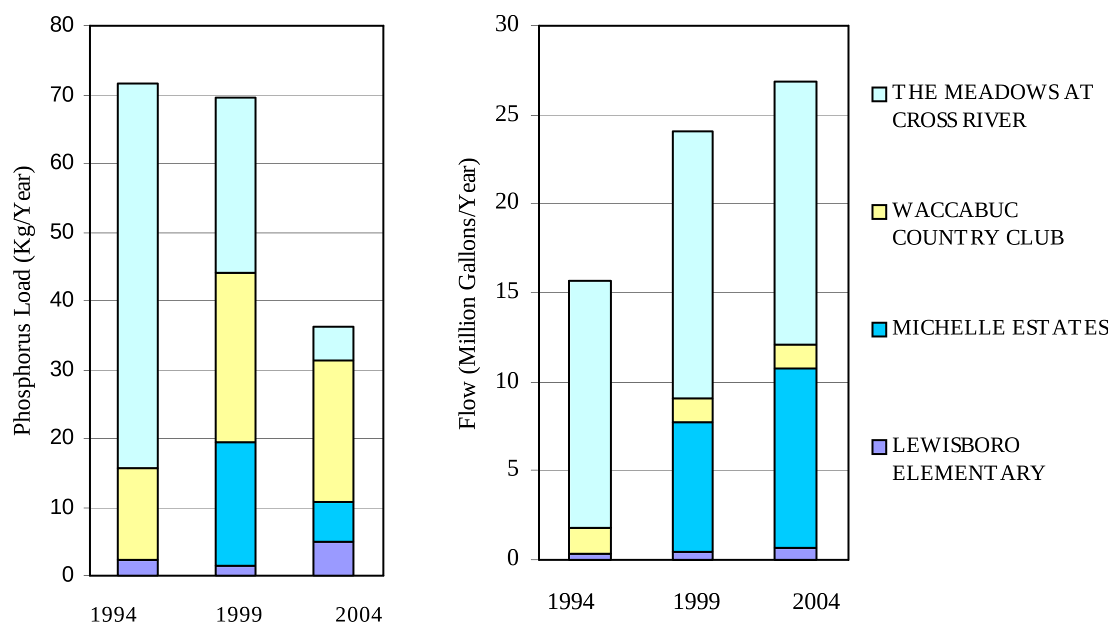


Figure 6.2 Total phosphorus loads and total volume of WWTP effluent flow to Cross River Reservoir in 1994, 1999, and 2004.

Table 6.1. Significant events and accomplishments at WWTPs in the Cross River Reservoir basin since 1994.

WWTP	COMMENTS
The Meadows at Cross River	Phosphorus removal enhanced Mar 1995
Waccabuc Country Club	-----
Michelle Estates	Began operations Dec 1995
Lewisboro Elementary	-----

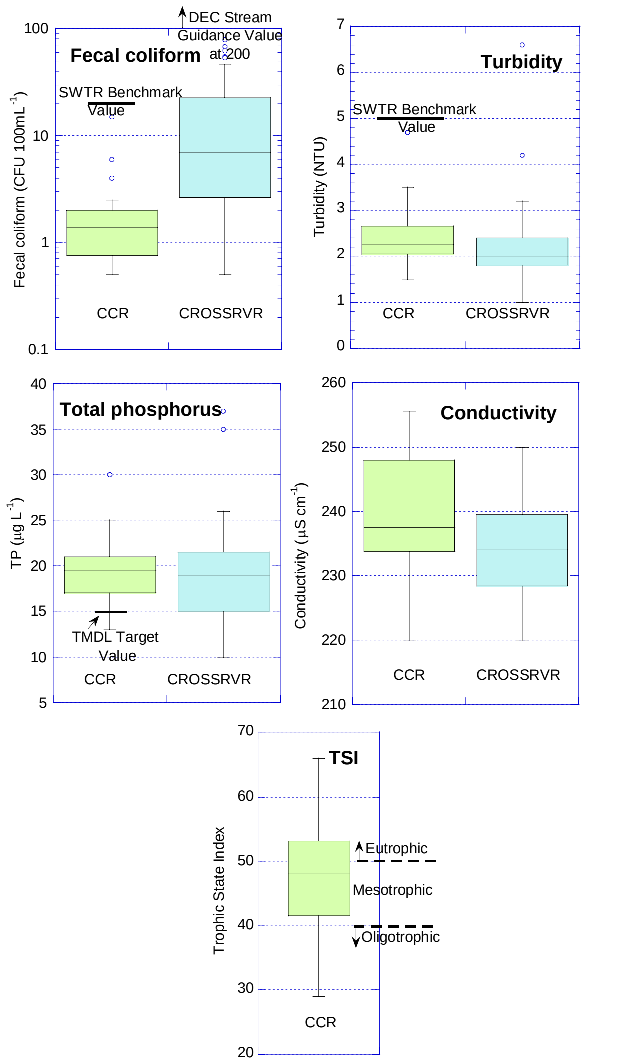


Figure 6.3 Water Quality status boxplots using 2002–2004 monthly data for the Cross River basin for: the reservoir, CCR; and the Cross River release at CROSSRVR.

Note: For methodology details and boxplot interpretation, see Appendix 3.

6.1.1 Quality Status and Trends

Status (Cross River Basin)

The status evaluation for the Cross River Reservoir basin is presented as a series of box plots in Figure 6.3. Cross River Reservoir was added to the FAD in 2002 and no new protection efforts have been added in this basin. Therefore, since there are no expected effects on streams, no stream inputs sites have been included in this analysis. Water from Cross River Reservoir (CCR) can be diverted to the Delaware Aqueduct via a pump station (CROSSRVR) in times of need, although the diversion rate is minimal. (The status of the main Cross River inflow is reported each year in DWQC's Annual Watershed Water Quality Report.)

The median fecal coliform value in the reservoir (1.4 CFU 100 mL^{-1}) was well below the SWTR benchmark of 20 CFU 100 mL^{-1} used for source waters. Cross River can be considered source water when the pump station is operational, and the Delaware Aqueduct is by-passing Kensico. Coliform levels in the release (CROSSRVR) were higher and more variable than the reservoir. One potential explanation for this difference is that the release site is sampled throughout the year, so that the higher values may occur during times when the reservoir is not sampled. Despite the slightly higher levels of fecal coliform in the release, none of the values exceeded the 200 CFU 100 mL^{-1} DEC Stream Guidance Value.

The turbidity values for the reservoir and the release were similar. None of the monthly values for the reservoir exceeded the 5 NTU SWTR benchmark for source water; the median value was 2.2 NTU.

Total phosphorus median values (around 19 mg L^{-1}) were similar in the reservoir and the release, but had more variability in the release. Since there are times when the release can come from anoxic hypolimnetic water, fluctuations in TP may be greater in the release water than the reservoir as a whole. The majority of the monthly values in the reservoir were above the source water and terminal basin TMDL target value of 15 µg L^{-1}, but below the 20 mg L^{-1} target value used for all other reservoirs.

The trophic status index value for Cross River Reservoir ranged between mesotrophic and eutrophic for the three year period. The box plot shows that there was some variability with several occurrences of higher and lower trophic status indices.

The conductivity in the reservoir was slightly higher and more variable than the release. Since the reservoir median is from two sites and several depths, increased variability as compared to the release site can be expected. The reservoir would also be more reflective of changes induced by its inputs.

In summary, water quality was good during the 2002 – 2004 analysis period in Cross River Reservoir, with only TP in the reservoir exceeding the established benchmark of 20 µg L^{-1} : the median TP was 19.5 µg L^{-1}.

Trends (Cross River Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 6.4. Results of the Seasonal Kendall trend analysis are provided in Table 6.2.

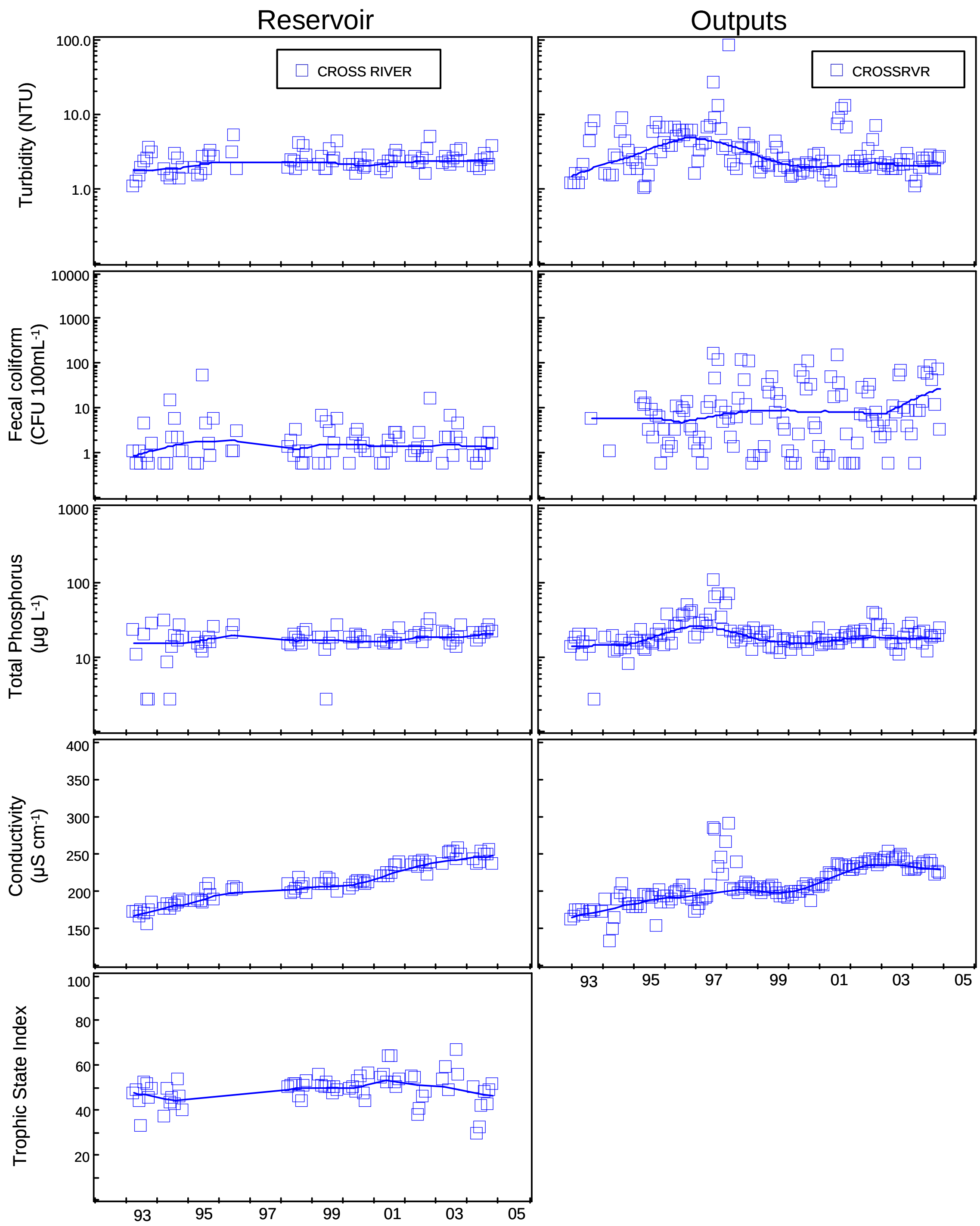


Figure 6.4 Water Quality trend plots for the Cross River basin for: the reservoir, Cross River; and the Cross River release at CROSSRVR.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Table 6.2. Cross River Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* Obs	Tau[2]	*p*-value[1]	Change yr^{-1}
Cross River	Reservoir	Turbidity	8	96	0.24	***	0.04
CROSSRVR	Output	Turbidity	12	144	-0.18	***	-0.09
Cross River	Reservoir	Fecal coliform	8	96	0.04	NS	0.00
CROSSRVR	Output	Fecal coliform	12	144	0.15	***	0.00
Cross River	Reservoir	Total Phosphorus	8	96	0.18	***	0.33
CROSSRVR	Output	Total Phosphorus	12	144	0.06	NS	0.00
Cross River	Reservoir	Conductivity	8	96	0.88	***	6.76
CROSSRVR	Output	Conductivity	12	144	0.67	***	5.83
Cross River	Reservoir	Trophic State Index	8	72	0.16	**	0.50

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).

2. Tau refers to the Seasonal Kendall Test Tau statistic.

Trends of increasing turbidity and phosphorus were detected for the reservoir. However, output trend results reveal a strong decrease in turbidity and no change in phosphorus. These seemingly contrary results are explained by sampling differences between the reservoir and output. Reconstruction of the Cross River Dam occurred in 1996 and 1997 and is reflected in the elevated turbidity and phosphorus results of the output during this time. The downward turbidity (and phosphorus) trend detected for the output reflects the recovery of the reservoir since the reconstruction project. During the reconstruction period, reservoir samples were not available so the high turbidity and phosphorus associated with reconstruction do not appear on the reservoir plots and could not be used in the trend analysis. Hence, the increasing turbidity and phosphorus trends in the reservoir are not due to the dam reconstruction project and are likely associated with the overall greater runoff that occurred in the latter half of the data record.

A statistically significant trend was detected for fecal coliforms in the output However, the Seasonal Kendall trend slope is calculated to be zero; this is a consequence of numerous tied values in the data (see Appendix 3). The LOWESS curve suggests an upward trend in the output in 2003–2004 ; this is supported by the sign of the trend test. The reasons are not clear but the increase could be due to above average precipitation during 2003–2004.Although one would expect reservoir and output fecal levels to be similar, clearly this is not the case since the output levels are approximately an order of magnitude higher.

Strong upward conductivity trends were detected for the reservoir and output. The cause is likely related to development activity in the basin, with road salt, especially, and discharges from domestic water softeners accounting for the main sources.

A slight upward trend in trophic state was detected for the reservoir although the LOWESS curve indicates a downturn since 2001. Possibly, the increase was a temporary response to refilling the reservoir in 1998.

In summary, upward turbidity and phosphorus trends were detected for Cross River Reservoir. Reasons are not clear but likely due to increases in precipitation during the second half of the data record. The downward turbidity trend detected for the output represents recovery from a dam rehabilitation project in 1996-97. A fecal coliform increase was also detected for the output and is likely related to precipitation increases in 2003-04. Upward conductivity trends were detected for the reservoir and output which was likely caused by antropogenic activity in the basin. Primary production increases were also detected in the reservoir. Reasons for the increase are not clear but perhaps are associated with the dam rehabilitation project.

6.2 The Croton Falls Basin

Located in Putnam County in the Towns of Carmel and Southeast, more than 30 miles north of New York City, the Croton Falls reservoir was formed by the damming of the West and Middle Branches of the Croton River, which continue south and drain into the Muscoot Reservoir.

Figure 6.5 Photo of the launch site at Croton Falls Reservoir.

The reservoir consists of three basins, separated by the Route 35 and Route 36 causeways; the water flows between basins through culverts under the roadways. Croton Falls Reservoir holds 14.2 billion gallons at full capacity and was placed into service in 1911.

The Croton Falls watershed's drainage basin is 16 square miles and includes portions of the Towns of Carmel and Southeast. Currently there are five WWTPs in the Croton Falls watershed basin, which collectively to release approximately 0.823 MGD of flow. As per the most recent SPDES permits, the plants are limited to a combined release of 1.206 MGD of flow.

The Croton Falls Reservoir has a pump station that currently enables DEP to pump up to 60 mgd from Croton Falls to the lower portion of the Delaware Aqueduct. The pump station is not frequently used, but has been operated during times of drought. The Croton Falls pump station was last in use from November 2001 until May 2002, while the region was experiencing the 2001-2002 Drought. DEP plans to rehabilitate and upgrade the pump station to increase its capacity to improve reliability during drought or other water shortages.

Wastewater Treatment Plants and Phosphorus Load Reductions in the Croton Falls Basin

Inputs of phosphorus, as well as other pollutants, from WWTPs to Croton Falls Reservoir continue to be reduced as a result of DEP's effort to upgrade all surface-discharging WWTPs, including upgrade of the City-owned Mahopac plant, and also through the intervention and involvement of the Division of Engineering's Regulatory Compliance and Inspection (RCI) group. As illustrated in Figure 6.6, phosphorus (as Total Phosphorus) loads, considerably reduced from 1994 to 1999, remain low in 2004. Table 6.3 highlights significant contributing events and accomplishments at several of the plants.

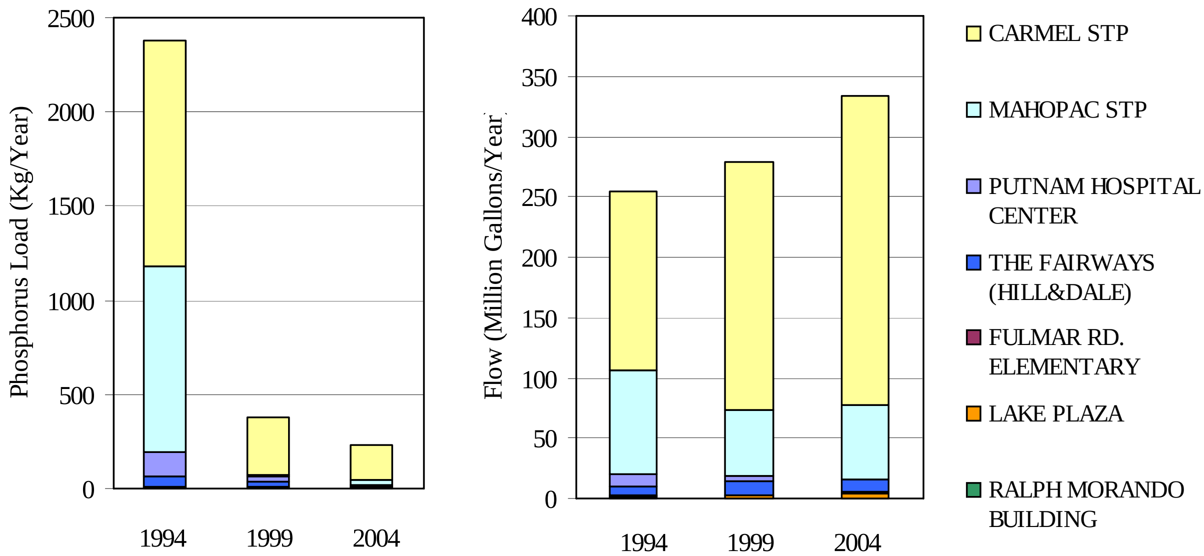


Figure 6.6 Total phosphorus loads and total volume of WWTP effluent flow to Croton Falls Reservoir in 1994, 1999, and 2004.

Table 6.3. Significant events and accomplishments at WWTPs in the Croton Falls Reservoir basin since 1994.

WWTP	COMMENTS *
Carmel	Plant upgrade 1996-1997 Final upgrade 2006
Mahopac	Plant upgrade 1995-1996 Final upgrade permit date Dec 2002
Putnam Hospital	Connected to Carmel Aug 1999
The Fairways	-----
Fulmar Rd. Elementary	-----
Lake Plaza	-----
Ralph Morando Bldg	Connected to Lake Plaza Sep 1997

* The permit date referred to in this table is six months after plant upgrade is completed. Allowing for a start-up period, this is the date on which the requirements of each plant's final SPDES permit take effect.

6.2.1 Quality Status and Trends

Status (Croton Falls Basin)

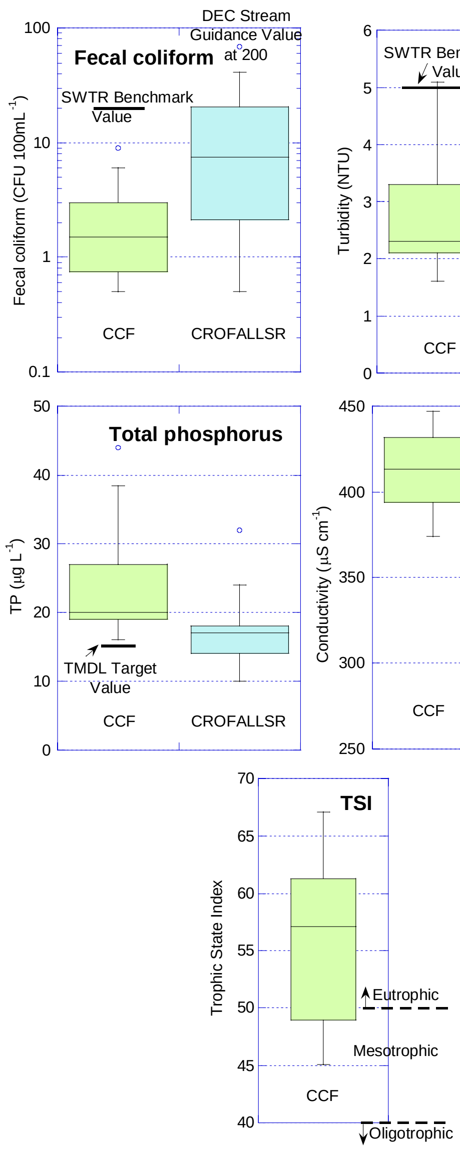


Figure 6.7 Water Quality status boxplots using 2002–2004 monthly data for the Croton Falls basin for: the reservoir, CCF; and the Croton Falls release at CROFALLSR.

Note: For methodology details, see Appendix 3.

The status evaluation for the Croton Falls Reservoir basin is presented as a series of box plots in Figure 6.7. Croton Falls Reservoir was added to the FAD in 2002 and no new protection efforts have been added in this basin. Therefore, since there are no expected effects on streams, no stream inputs sites have been included in this analysis. Water from Croton Falls Reservoir (CCF) can be diverted to the Delaware Aqueduct via a pump station (CROFALLSR) in times of need, although the diversion rate is minimal.

Fecal coliform values in the reservoir did not exceed the SWTR benchmark of 20 CFU 100 mL^{-1} used for source waters. Croton Falls Reservoir can be considered source water when the pump station is operational, and the Delaware Aqueduct is by-passing Kensico. Coliform levels in the release were higher and more variable than the reservoir. One potential explanation for this difference is that there may be a localized source of fecal coliform near the release. Waterfowl have been known to roost in the main basin just above the dam. This could increase the coliform in the release relative to the reservoir, which has a median comprised of five stations and several depths. Another factor may be that the release site is sampled throughout the year, so that the higher values may occur during times when the reservoir is not sampled. Despite the slightly higher levels of fecal coliform in the release, none of the values exceeded the 200 CFU 100 mL^{-1} DEC Stream Guidance Value.

The turbidity values were slightly lower in the release than in the reservoir. The release had lower turbidity values, because the reservoir values are representative of sites from multiple basins. A few of the values in the reservoir exceeded the 5 NTU SWTR benchmark for source water, but the medians for both the reservoir and release are well below this benchmark.

Total phosphorus levels were slightly lower in the release as compared to the reservoir. Since the TP levels can vary dramatically between the basins, the reservoir-wide median values used for the box plot capture the higher TP levels and greater variability found in the impoundment. All of the values in the reservoir were above the TMDL target value of 15 µg L^{-1} for source waters, and the median is equivalent to 20 mg L^{-1} used for other basins.

The trophic status index value for Croton Falls Reservoir was within the eutrophic range for the three year period. Only a few values fell below the TSI threshold of 50 for eutrophic waters.

The conductivity in the reservoir was much higher than the release. Water in the main basin is primarily affected by the release from West Branch Reservoir. Delaware Aqueduct water in West Branch causes lower conductivities in Croton Falls' main basin and release. The two other basins in Croton Falls are heavily impacted by increasing chloride levels from the surrounding watershed and upstream reservoirs. Middle Branch Reservoir, which feeds into Croton Falls, has a long-term rising trend in conductivity and some of the highest levels of all the reservoirs. High-conductivities from Middle Branch flow through the main basin, affecting the Croton Falls release, and can be detected as far downstream as New Croton Reservoir.

In summary, water quality was acceptable during the 2002 – 2004 analysis period in Croton Falls Reservoir. The data for the selected variables show that the TP in the reservoir exceeded the established TMDL benchmark, and a few values exceeded the SWTR benchmark for turbidity.

Trends (Croton Falls Basin)

Trends are examined in two ways, firstly by fitting a smoothing function (LOWESS) through all the raw data, and secondly by performing the non-parametric Seasonal Kendall Trend Test (Tau statistic) and its associated Seasonal Kendall Slope. The former seeks to place a best-fit smooth curve through the data and is relatively insensitive to outliers. The latter addresses statistical significance and fits a monotonic trend plot though the data. See Appendix 3 for a more detailed description of the data manipulation and statistical methods used.

The LOWESS smoother plots are presented in Figure 6.8.

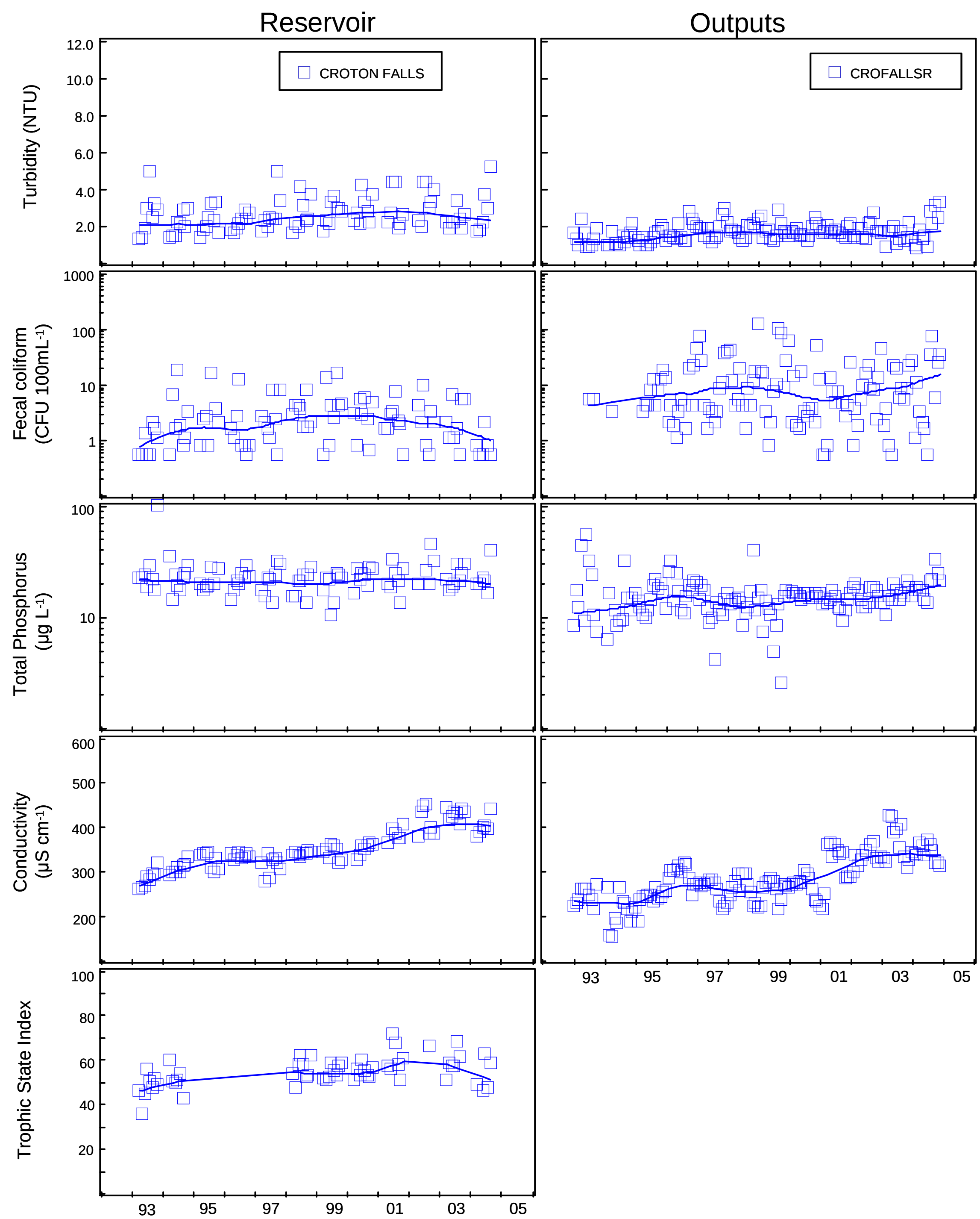


Figure 6.8 Water Quality trend plots for the Croton Falls basin for: the reservoir, Croton Falls; and the Croton Falls release at CROFALLSR.

Note: For each site the central tendency of the data over time is represented by a LOWESS curve with a smooth factor 30%. For methodology details, see Appendix 3.

Results of the Seasonal Kendall trend analysis are provided in Table 6.4. Like the Cross River Basin, inputs are not discussed here because FAD programs were not in place in this basin.

Table 6.4. Croton Falls Basin trend results.

Site	Description	Analyte	Months yr^{-1}	*N* obs	Tau[2]	*p*-value[1]	Change yr^{-1}
Croton Falls	Reservoir	Turbidity	8	96	0.28	***	0.05
CROFALLSR	Output	Turbidity	12	144	0.20	***	0.03
Croton Falls	Reservoir	Fecal coliform	8	96	0.05	NS	0.00
CROFALLSR	Output	Fecal coliform	12	144	-0.04	NS	0.00
Croton Falls	Reservoir	Total Phosphorus	8	96	0.04	NS	0.00
CROFALLSR	Output	Total Phosphorus	12	144	0.16	***	0.33
Croton Falls	Reservoir	Conductivity	8	96	0.75	***	11.40
CROFALLSR	Output	Conductivity	12	144	0.60	***	11.40
Croton Falls	Reservoir	Trophic State Index	8	72	0.50	***	1.00

1. The *p*-values for each trend test are symbolized as follows: $p = 0.20$ (NS—Not Significant); $p < 0.20$ (*); $p < 0.10$ (**); and $p < 0.05$ (***).
2. Tau refers to the Seasonal Kendall Test Tau statistic.

A slight increasing turbidity trend was detected in the Croton Falls Reservoir and its output, CROFALLSR. The increase may be associated with inputs from West Branch Reservoir, which experienced increased turbidity as per operational changes in 2000-2003. Detected upward trends in phosphorus and in trophic state may also be associated with these operational changes.

No statistically significant trends were detected for fecal coliforms. However, it is interesting to note that output fecal concentrations are around an order of magnitude higher than concentrations observed in the reservoir. Also, the LOWESS plots show that the reservoir values have decreased from the beginning of 2001 whereas the output concentrations have increased. Croton Falls has had a history of increased waterfowl activity during late fall and early winter. Our reservoir sampling does not fully capture this time frame (ending in early November), whereas the release samples are probably more representative. The reservoir median is also comprised of coliform samples from throughout the three basins which may decrease the reservoir median compared to the release.

A steep increase in conductivity was detected in both the reservoir and outputs especially from 2001 to 2003. Much of the initial increase is associated with snowmelt in late March, early April 2001. The cause is likely related to development activity in the basin, with road salt, especially, and discharges from domestic water softeners accounting for the main sources.

In summary, upward trends were detected for turbidity, total phosphorus, conductivity and Trophic State Index in the Croton Falls Basin. The increase in turbidity, phosphorus and Trophic State may be due to operational changes at West Branch Reservoir, an input to Croton Falls. The conductivity increase is likely due to anthropogenic activity.

6.3 Water Quality Summary for the Potential Delaware System Basins

Water quality was generally good during the 2002 – 2004 status analysis time frame for Cross River and Croton Falls reservoirs. The fecal coliform benchmark value (20 CFU $100ml^{-1}$), was not exceeded in both reservoirs; the median values were 1.4 and 1.5 CFU $100ml^{-1}$, respectively. Croton Falls had just one turbidity value (5.1 NTU) above the benchmark 5 NTU although its median value was just 2.3 NTU, the same as that of Cross River. However, both reservoirs are very close to the TP guideline value of 20 $\mu g\ L^{-1}$; median values were 19.5 and 20 for Cross River and Croton Falls, respectively. Conductivity was relatively high in both reservoirs. Cross River Reservoir is mesotrophic, on average, whereas Croton Falls is eutrophic.

Upward trends for turbidity (0.04 NTU yr^{-1}) and total phosphorus (0.33 $\mu g\ L^{-1}\ yr^{-1}$) were detected for Cross River Reservoir during the study period 1993-2004. Reasons are not clear but they are likely due to increases in precipitation during the second half of the data record. The turbidity decrease for the Cross River Reservoir output over the period (0.09 NTU yr^{-1}) probably represents recovery from a dam rehabilitation project in 1996-97. There was an upward turbidity trend for Croton Falls (0.05 NTU yr^{-1}).

Upward conductivity trends were detected for both reservoirs: 6.8 $\mu S\ cm^{-1}\ yr^{-1}$ at Cross River and 11.4 $\mu S\ cm^{-1}\ yr^{-1}$ at Croton Falls; these were likely caused by development activity in the basin. Small productivity increases (as Trophic State Index) were detected in both reservoirs: 0.5 yr^{-1} in Cross River and 1 yr^{-1} in Croton Falls.

It should be noted that Cross River and Croton Falls Reservoirs were added to the FAD in 2002 due to the ability to pump water from these Croton System reservoirs into the Catskill/Delaware system during times of drought. Therefore, because many of the protection programs for these basins are still in the early stages of implementation, they are unlikely to have achieved any impact on water quality thus far.

7. Modeling Evaluation of Program Effects in Cannonsville and Pepacton Watersheds

The effects of land use change and best management practices (BMPs) implemented by watershed management programs can be evaluated using models. Modeling integrates watershed and reservoir data collected through DEP's extensive monitoring programs along with processes governing the transport and fate of nutrients to obtain water quality predictions. Through model application, inferences are made about the simultaneous effects of population growth, land use change, and watershed management programs designed to improve water quality. Model application also allows DEP to make a quantitative comparison of the effects of individual programs so that the most effective ones can be identified.

DEP has developed a eutrophication modeling system, consisting of the GWLF watershed loading model linked to a reservoir receiving water model, to evaluate the relationship of nutrient loading changes to reservoir trophic state changes. GWLF model simulations generate time series of loads for baseline versus land use and management scenarios which are then input to the reservoir model. Output from the reservoir model includes probability frequency distributions for water quality parameters that describe the trophic state of the reservoir for different watershed scenarios.

The eutrophication modeling system was applied to evaluate land use change and watershed management that occurred in Cannonsville and Pepacton watersheds from 1990 through 2004. The changes in agricultural activity and human population in these two basins during the period were evaluated as a land use change that occurred independent of watershed management. Watershed management programs (and associated BMPs) that were evaluated include:

- Watershed Agricultural Program
- Urban Stormwater Retrofit Program
- Septic Remediation and Replacement Program
- Wastewater Treatment Plant (WWTP) Upgrade Program.

Scenario results were compared with nutrient data for Cannonsville watershed collected in 2000 - 2004 (after land use changes and BMP implementation occurred) to test the validity of the scenario predictions.

7.1 Eutrophication Modeling System

7.1.1 GWLF Watershed Model

The GWLF watershed loading model is a lumped-parameter model that simulates daily water, nutrients, and sediment loads from non-point and point sources. GWLF was originally developed at Cornell University by Dr. Douglas Haith and associates (Haith and Shoemaker, 1987; Haith *et al*., 1992) as “an engineering compromise between the empiricism of export coefficients and the complexity of chemical simulation models”. GWLF treats the watershed as a system of different land areas (Hydrologic Response units or HRUs) that produce runoff, and a single groundwater reservoir that supplies baseflow. Dissolved and suspended substances (e.g. nutrients and sediment) in streamflow are estimated at the watershed outlet by loading functions that empirically relate substance concentrations in runoff and baseflow to watershed and HRU-specific characteristics.

The current version of GWLF that DEP uses has been developed by DEP, with modifications as described in Schneiderman et al. (2002), DEP (2005e; 2006a). A major model modification is the incorporation of saturation-excess runoff on Variable Source Areas (VSAs), which is considered the primary runoff generation mechanism in NYC watersheds. The revised GWLF model simulates runoff volumes using the SCS Curve Number (CN) Method, similarly as in the standard GWLF model, but spatially-distributes the runoff response according to a soil wetness index. The spatial distribution of runoff by soil wetness index provides a more realistic identification of runoff generating areas in the NYC watersheds, with important consequences for simulation of pollutants that are typically transported by runoff.

Other model modifications include use of Priestley-Taylor method for estimating potential evapo-transpiration; incorporation of a sediment rating curve into the sediment yield algorithm; and incorporation of concentration: flow relationships that vary nutrient concentrations as a function of runoff volume. The latest version of the GWLF model has been calibrated and validated for Cannonsville (Appendix 4) and Pepacton (DEP, 2006b) watersheds with updated land use, soils, meteorology, streamflow, and water quality monitoring data.

GWLF generates the following daily time series which subsequently can be input to the reservoir receiving water model:

- streamflow,
- dissolved phosphorus (P) and nitrogen (N) from non-point and point sources,
- particulate phosphorus from non-point and point sources,
- dissolved organic carbon (C) from non-point sources,
- total suspended solids (TSS)

Loads in surface runoff from different land uses, in sub-surface flows, from septic systems and from point sources are explicitly tracked in GWLF and summed to provide total loads delivered to the reservoir. The explicit tracking of loads from different sources is the key to evaluating the effects of watershed management on nutrient loading. Non-point source watershed management entails application of BMPs which typically focus on removing nutrients from specific sources. A significant and growing literature exists which documents nutrient removal rates for BMPs applied to specific nutrient sources. Applying BMP efficiency data and implementation rates to loading estimates from different sources provides a means for quantifying nutrient reductions from BMPs on a watershed scale.

The effects of BMPs on nutrient loads are applied in the model by land use-specific BMP reduction factors which adjust dissolved and particulate nutrient time-series as generated by the model. Loading reductions due to septic system upgrades are implemented in GWLF by revising the percentages of failing systems and unsewered population sizes which are input to the model. Loading reductions due to WWTP upgrades are implemented in GWLF by revising the daily WWTP effluent loading estimates that are input to the model.

7.1.2 Reservoir Water Quality Model

DEP has developed one dimensional (1D) reservoir water quality models for all West of Hudson (WOH) reservoirs. The purpose of these models has been to provide a credible quantitative framework that can be used to evaluate watershed management programs, and to predict water quality features related to eutrophication. These models consist of three components:

1) a hydrothermal sub-model
2) nutrient sub-models
3) a phytoplankton sub-model

The hydrothermal model simulates the vertical dynamics of reservoir thermal stratification and related hydrodynamics/transport regimes, based on changes in such critical (state) variables as meteorological, hydrological and operational conditions. The hydrothermal models function as the physical/mass transport frameworks of the water quality models.

The nutrient sub model describes the transformation and fate of the nutrient loads (total dissolved phosphorus, total dissolved nitrogen, and particulate phosphorus) that are simulated to enter the reservoir by the GWLF model. The reservoir model distributes nutrients vertically through the water column based on vertical mixing coefficients derived from the hydrothermal sub-model, and the nutrient inputs are partitioned into different forms based on model coefficients. Nutrient transformations occur within the model, which affect the form and bioavailability of the nutrient. Ultimately nutrients remain within the water, are taken up by the phytoplankton, or are lost from the reservoir in outflows or by sedimentation.

Phytoplankton biomass is predicted in terms of algal carbon and is a balance between growth (photosynthesis), and losses due to respiration, grazing, sedimentation and outflow. Growth is a function of light, temperature and nutrients. Phosphorus is the nutrient that predominately limits growth in the Cannonsville and Pepacton reservoirs. Thus, the most important and manageable input condition or factor affecting primary production and phytoplankton biomass addressed with these models is the external phosphorus loads. Chlorophyll *a*, the most widely used measure of phytoplankton biomass, is calculated from the algal carbon based on system-specific stoichiometric relationships.

Since DEP last used the eutrophication modeling system to evaluate FAD watershed management programs (DEP 2001) the Cannonsville water quality model has been modified to better account for the effects of sediment resuspension on phosphorus availability (UFI 2003). The upgraded model includes an inorganic particle sub-model, and adds inorganic suspended solids as a model state variable. This sub-model has three components: (1) a wave sub-model that simulates waves and associated energy from wind conditions and reservoir morphometry, (2) a sediment resuspension sub-model that simulates fluxes of resuspended sediment from the near-shore zone associated with wave energy delivered and sediment characteristics, and (3) a sediment mass balance model that simulates the mass or thickness of sediments available for resuspension. In accordance with the improved capability to simulate sediment resuspension, the phosphorus sub-model has been modified to accommodate the effects of phosphorus sorption/desorption associated with resuspended inorganic material. Mass balance calculations are conducted on a new state variable in this sub-model, total reactive phosphorus, that includes both soluble reactive and particulate reactive (subject to sorption/desorption transformations) components. The effect of resuspended particulate material on light attenuation is also included in the upgraded model.

The reservoir component of the eutrophication modeling system used for the simulations in this report are the most recent version of the 1D eutrophication models developed for the Pepacton and Cannonsville reservoirs. For Cannonsville this is the model that mechanistically describes the effects of resuspension on phosphorus and light availability as summarized above. For Pepacton the same model is used as in the last FAD program evaluation (DEP 2001). In this version of the model, resuspension is simulated empirically based on a relationship between reservoir water elevation and resuspended particulate phosphorus. Both of these versions of the 1D reservoir model have been extensively calibrated and model performance has been verified using data sets independent of that used for calibration (UFI 2001; 2003). For all simulations done in this report we have updated the reservoir model driving data up to the end of 2004, so that continuous simulations can be made for the 39 year period beginning in 1966 and ending in 2004.

7.1.3 Eutrophication Modeling System Simulation Strategy

The purpose of the simulations presented here was to examine the effects of changes in land use that occurred in the Cannonsville and Pepacton Reservoir watersheds, and the effects of the FAD programs implemented in these watersheds on the quality of water within these reservoirs. As these changes are expected and/or designed to influence nutrient delivery, the predicted effect is on reservoir trophic status. There are always difficulties associated with assessing the effects of long term changes in nutrient delivery on reservoir water quality, because reservoir water quality varies greatly from year to year as a result of natural variations in climate and the manifestation of climatic variations on nutrient delivery and phytoplankton growth. Through the use of modeling it is possible to separate the effects of FAD program induced changes in nutrient delivery from the year to year variations due to climate, in a way that can not be achieved by analyzing actual water quality measurements.

The strategy used here is to make multiple runs of the linked watershed and reservoir water quality models using a long term record (1966-2004) of meteorological, and operational data. The long-term meteorologic data time series, along with model parameters that reflect watershed land use, population and watershed management conditions, are input to the GWLF model to generate a scenario. The same (1966-2004) meteorological record is used to drive all scenario simulations to control for climate-related temporal variability. Running the watershed model produces a time series of predicted streamflow, particulate phosphorus, dissolved phosphorus and nitrogen nutrient loads to the reservoir. This long-term time series of reservoir loads is combined with historical meteorology and reservoir operations as input to the 1D reservoir water quality model. The reservoir model, in turn, produces a time series of reservoir water quality results (Figure 7.1). Simulations run in this manner predict changes in reservoir trophic status over the full range of recorded variability.

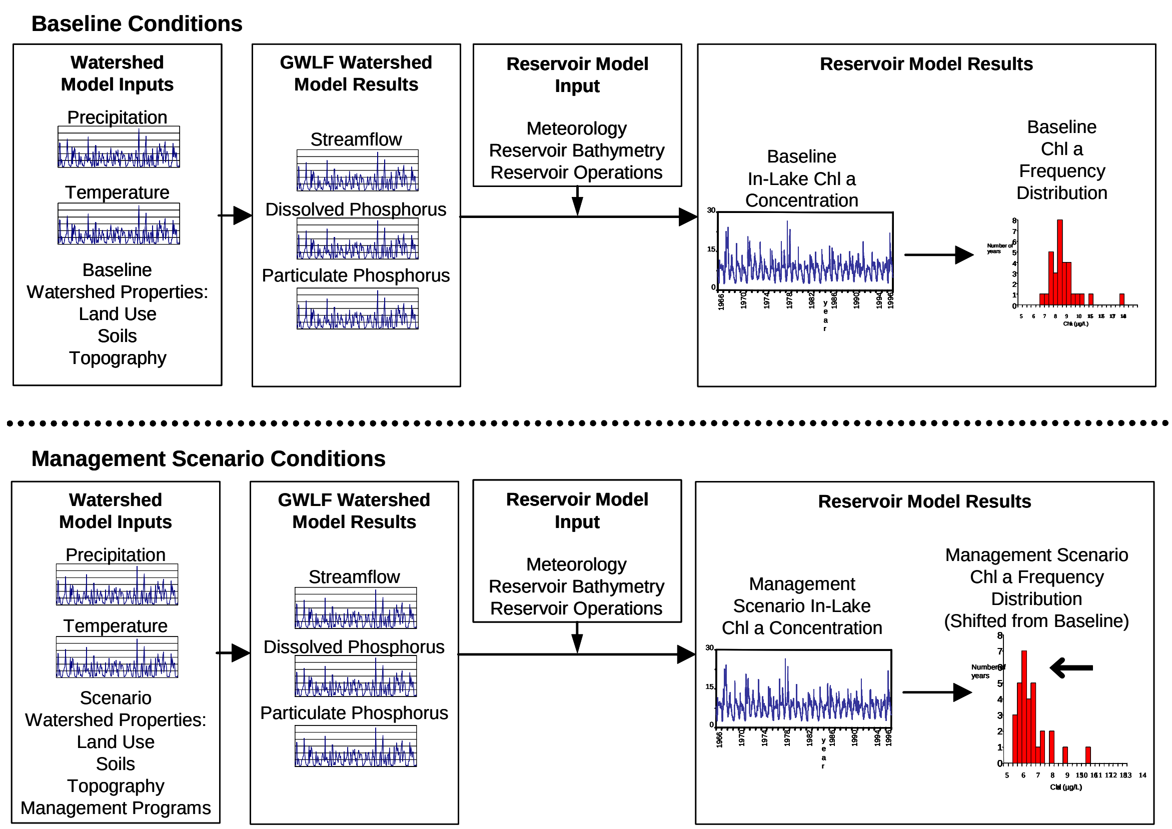


Figure 7.1 Schematic Eutrophication Modeling System.

7.2 Modeling Scenarios

Model scenarios were run and compared to analyze the separate and combined effects of land use and watershed management programs on levels of nutrient loading and the trophic status of Cannonsville and Pepacton Reservoir. Scenarios were developed with different combinations of land use change, BMPs for non-point source management, and point source management (WWTP upgrades). The scenario names are signified by abbreviations "*LU*" for land use changes, "*BMP*" for non-point source watershed management, and "*PS*" for point source management. The five scenarios used for this analysis are:

1. *BASELINE* Scenario – land use and population conditions representative of conditions prior to implementation of BMPs or Point Source Upgrades,
2. *LU* Scenario – post-2000 land use and population; without BMPs or Point Source Upgrades
3. *LU-BMP-PS* Scenario - post-2000 land use and population; with BMPs and Point Source Upgrades
4. *LU-BMP* Scenario - post-2000 land use and population; with BMPs
5. *LU-PS* Scenario - post-2000 land use and population; with Point Source Upgrades

Each scenario assumes one of two alternative land use and population conditions. The post-2000 land use and population condition has land use areas from analysis of 2001 remotely-sensed imagery (DEP 2006a), average farm animal density for 2003 based on Watershed Agricultural Program data, and population density from 2000 census data. The *BASELINE* land use and population condition is based on the same 2000-2001 land use data but with agricultural areas increased to account for farms that were active prior to 1993 but subsequently became inactive, average farm animal density for 1997, and population density from 1990 census data.

The *BASELINE* scenario represents watershed conditions prior to or at the initial stages of non-point source management, point source upgrades, and the recent decline in farming. The GWLF models were calibrated and validated for the *BASELINE* conditions (Appendix 4). *BASELINE* land use in Cannonsville watershed (Table 7.1) included significant agriculture (~14% of land area); ~3% urban areas including residential, commercial/industrial areas and rural roads; , ~7% non-agricultural grass areas such as open fields, parks and recreation areas; ~73% undeveloped forested and brushland areas, and ~3% water and wetland areas. The estimated year-round population was 9,674 and the seasonal unsewered population was estimated to be 13,527, based on 1990 census data. For Pepacton, *BASELINE* land use (Table 7.1) consisted of ~3% agricultural areas, ~2% urban, ~4% non-agricultural grass, ~90% undeveloped and ~1% water and wetlands. Unsewered population for Pepacton was 5,821 year-round and 8,149 seasonal based on 1990 census data.

The "*LU*" scenarios differ from the *BASELINE*, with less active farmland, lower farm animal density, and increased census population. Changes in farm activity have taken a number of forms including the ending of operations for some farms and changes in operations, such as a switch from dairy production to heifers, for other farms. These changes are independent of, and treated separately from, the effects of any land use changes associated with watershed management. Agricultural land use area (including cropland, hayland, pasture and barnyard) was reduced by 11.4% for Cannonsville and by 7.7% for Pepacton in the *LU* vs. the *BASELINE* scenario. Unsewered population size increased by about 9.2 % for both year-round (to 14,771) and seasonal (to 10,562) residents in Cannonsville, and by about 16.2% for year-round (to 9,402) and 15.4% for seasonal (to 6,766) for Pepacton.

The *LU* scenarios include adjustments made to agricultural runoff nutrient concentrations and baseflow nutrient concentrations due to a reduction of intensity in farm operations. During the last decade, the number of animal units using the farmed area has decreased, thus creating fewer animals per farmed hectare. Based on data from the Watershed Agricultural Program, the number of animal units for WOH watersheds has decreased from 23,747 animal units to 16,750 animal units (Table 7.2), or a reduction of about 29.5% over the last decade. It is assumed that the reduction in animal units translates directly into reduction in nutrient enrichment within the watershed and this leads to a corresponding reduction in nutrient concentrations in runoff and baseflow. Section 7.3.2 discusses nutrient loading data collected for Cannonsville watershed that supports this assumption.

Table 7.1. Land use areas (ha) for *BASELINE*, *LU* and *LU-BMP* Scenarios for Cannonsville and Pepacton watersheds.

	Cannonsville Watershed			**Pepacton Watershed**		
Land Use Category	***BASELINE***	***LU***	***LU-BMP***	***BASELINE***	***LU***	***LU-BMP***
Deciduous Forest	63,961	65,785	66,328	62,984	63,218	63,283
Coniferous Forest	11,324	11,324	11,324	11,299	11,299	11,299
Mixed Forest	4,398	4,398	4,398	4,389	4,389	4,389
Brushland	6,328	6,328	6,328	5,354	5,354	5,354
Cropland	4,874	4,579	4,436	538	507	492
Hayland	5,267	4,480	4,589	1,273	1,205	1,215
Pasture	5,754	5,013	4,504	1,213	1,078	1,019
Barnyard	42	42	42	12	12	12
Non-Agricultural Turf	8,701	8,701	8,701	3,551	3,551	3,551
Residential Pervious	1,837	1,837	1,837	1,318	1,318	1,318
Residential Impervious	564	564	564	348	348	348
Commercial/Industrial Pervious	219	219	219	98	98	98
Commercial/Industrial Impervious	171	171	171	64	64	64
Rural Roads	649	649	649	455	455	455
Wetland	869	869	869	433	433	433
Water	2,759	2,759	2,759	588	588	588

Table 7.2. Change in animal units from 1997 (*BASELINE*) to 2003 (post-2000) for WOH watersheds based on WAC Program Data. (DEP, 2004b).

		1997		2003	
Animal Type	**Animal Units per Animal***	**No. of Animals**	**Animal Units**	**No. of Animals**	**Animal Units**
Mature Dairy	1.2	12,636	15,163	7,848	9418
Dairy Heifers	0.7	8,758	6,131	6,985	4890
Veal	0.2	790	158	762	152
Beef	1.0	1,566	1,566	1,413	1413
Sheep	0.1	569	57	544	54
Goats	0.1	78	8	250	25
Pigs	0.3	68	20	199	60
Horses	1.0	565	565	604	604
Chickens	0.004	2,655	11	21,129	85
Pheasants	0.005	250	1	250	1
Rabbits	0.018	25	0	50	1
Emus	0.15	0	0	26	4
Ostrich	0.15	18	3	57	9
Llama	0.15	55	8	82	12
Deer	0.15	375	56	154	23
Total			23,747		16,750

*Minnesota Department of Agriculture (2006)

BMP Scenarios (Non-Point Source Management)

Agricultural BMPs

BMPs are implemented in GWLF by applying phosphorus reduction factors that account for the cumulative effects of BMPs on phosphorus loads from different land uses. Seven agricultural BMPs which are applied regularly in farm plans developed by the Watershed Agricultural Program were considered: Conservation Tillage, Contour Strip Cropping, Crop Rotation, Grass Filter Strips, Nutrient Management Plans, Barnyard Runoff Management, and Riparian Forest Buffers. Dissolved and particulate phosphorus removal rates for these BMPs (Table 7.3) were estimated based on literature review by the USDA Pasture Systems Lab BMP database project (Gitau *et al*., 2005).

BMP reduction factors were calculated for dissolved and particulate phosphorus by land use (Tables 7.4 and 7.5). For each agricultural land use (cropland, hayland, pasture, and barnyard), a BMP-specific phosphorus reduction factor was calculated by multiplying the mean BMP phosphorus removal rate by the BMP implementation rate (the fraction of the land use affected by a BMP). BMP implementation rates were determined by analysis of whole farm plans for participants in the NYC Watershed Agricultural Program. The total reduction factor for an individual land use was determined by compounding the effects of the individual BMPs applied. Compounding is used because it is assumed that multiple BMPs are applied to the same fields. A similar approach was followed by Palace *et al*. (1998) for analyzing agricultural non-point BMPs for the Chesapeake Bay watershed using the HSPF model.

In addition to BMP effects which operate by effectively reducing loads from particular land uses, several agricultural BMPs – Riparian Forest Buffers and Conversion of Cropland to Hayland – also effectively change the distribution of land use areas in the watershed. Land use area changes for Cannonsville amounted to reduction in cropland and pasture 143 ha and 509 ha, respectively with a corresponding increase in hayland and forest of 110 ha and 542 ha. For Pepacton, cropland decreased by 16 ha, pasture decreased by 59 ha, hayland increased by 10 ha and forest increased by 65 ha.

Table 7.3. Dissolved and particulate phosphorus removal rates for Agricultural BMPs.

		Dissolved Phosphorus Removal Rate			**Particulate Phosphorus Removal Rate**		
BMP	**BMP Description**	**mean**	**min**	**max**	**mean**	**min**	**max**
Barnyard Runoff Management	Exclusion of clean water runoff from the barnyard disposal of the remaining barnyard runoff to minimize pollution potential.	30%	5%	81%	33%	33%	33%
Conservation Tillage	Tillage and planting system that leaves a minimum of 30% of the soil surface covered with plant residue after the operation (i.e. reduced-till, no-till etc.)	-167%	-889%	73%	63%	15%	92%
Contour Strip Crop	Alternating strips of a row crop with a small grain or forage, planted on the contour.	45%	20%	93%	60%	43%	76%
Crop Rotation	A planned sequence of annual and/or perennial crops.	50%	30%	75%	65%	60%	70%
Grass Filter Strips	A strip of perennial grasses, planted across the slope, established adjacent to areas of high pollutant potential	26%	-56%	59%	41%	38%	43%
Nutrient Management Plan	Managing the rate, timing, and placement of fertilizers, manures and other nutrient sources to encourage maximum nutrient recycling and minimize nutrient runoff and leaching.	26%	-66%	94%	46%	42%	50%

Table 7.3. Dissolved and particulate phosphorus removal rates for Agricultural BMPs.

BMP	BMP Description	Dissolved Phosphorus Removal Rate			Particulate Phosphorus Removal Rate		
		mean	min	max	mean	min	max
Riparian Forest Buffers	An area of trees, shrubs and grasses located adjacent to ponds, lakes, and streams that filter out pollutants from runoff	62%	28%	99%	84%	84%	84%

Table 7.4. Dissolved phosphorus reduction factors for agricultural BMPs in Cannonsville and Pepacton Watersheds

Agricultural BMPs	DP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Cropland	Hayland	Pasture	Barnyard	Cropland	Hayland	Pasture	Barnyard
Cannonsville									
Barnyard Runoff Management	30%	--	--	--	88.8%	--	--	--	26.6%
Conservation Tillage	-167%	0.1%	--	--	--	-0.2%	--	--	--
Contour Strip Crop	45%	5.0%	--	--	--	2.3%	--	--	--
Crop Rotation	50%	47.2%	--	--	--	23.6%	--	--	--
Grass Filter Strip	26%	0.1%	--	--	--	0.0%	--	--	--
Nutrient Management Plan	26%	84.9%	73.0%	60.7%	--	22.1%	19.0%	15.8%	--
Riparian Forest Buffers	62%	6.7%	6.7%	6.7%	--	4.1%	4.1%	4.1%	--
Total	-	--	--	--	--	44.1%	22.3%	19.3%	26.6%
Pepacton:									
Barnyard Runoff Management	30%	--	--	--	90.5%	--	--	--	27.1%
Conservation Tillage	-167%	--	--	--	--	--	--	--	--
Contour Strip Crop	45%	5.0%	--	--	--	2.2%	--	--	--
Crop Rotation	50%	79.3%	--	--	--	39.6%	--	--	--
Grass Filter Strip	26%	--	--	--	--	--	--	--	--
Nutrient Management Plan	26%	91.6%	85.3%	74.7%	--	23.8%	22.2%	19.4%	--

Table 7.4. Dissolved phosphorus reduction factors for agricultural BMPs in Cannonsville and Pepacton Watersheds

Agricultural BMPs	DP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Cropland	Hayland	Pasture	Barnyard	Cropland	Hayland	Pasture	Barnyard
Riparian Forest Buffers	62%	2.9%	2.9%	2.9%	--	1.8%	1.8%	1.8%	--
Total	-	--	--	--	--	55.9%	23.6%	20.9%	27.1%

Table 7.5. Particulate phosphorus reduction factors for agricultural BMPs in Cannonsville and Pepacton Watersheds

Agricultural BMPs	PP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Cropland	Hayland	Pasture	Barnyard	Cropland	Hayland	Pasture	Barnyard
Cannonsville:									
Barnyard Runoff Management	33%	--	--	--	88.8%	--	--	--	29.3%
Conservation Tillage	63%	0.1%	--	--	--	0.1%	--	--	--
Contour Strip Crop	60%	5.0%	--	--	--	3.0%	--	--	--
Crop Rotation	65%	47.2%	--	--	--	30.7%	--	--	--
Grass Filter Strip	41%	0.1%	--	--	--	0.0%	--	--	--
Nutrient Management Plan	46%	84.9%	73.0%	60.7%	--	39.0%	33.6%	27.9%	--
Riparian Forest Buffers	84%	6.7%	6.7%	6.7%	--	5.6%	5.6%	5.6%	--
Total	-	--	--	--	--	61.4%	37.3%	32.0%	29.3%
Pepacton:									
Barnyard Runoff Management	33%	--	--	--	90.5%	--	--	--	29.9%
Conservation Tillage	63%	--	--	--	--	--	--	--	--
Contour Strip Crop	60%	5.0%	--	--	--	3.0%	--	--	--
Crop Rotation	65%	79.3%	--	--	--	51.5%	--	--	--
Grass Filter Strip	41%	--	--	--	--	--	--	--	--
Nutrient Management Plan	46%	91.6%	85.3%	74.7%	--	42.1%	39.2%	34.4%	--
Riparian Forest Buffers	84%	2.9%	2.9%	2.9%	--	2.4%	2.4%	2.4%	--
Total	-	--	--	--	--	73.5%	40.7%	36.0%	29.9%

Urban Stormwater BMPs

Five urban BMPs which are applied by the Stormwater Retrofit Program were considered: Ponding System, Infiltration System, Water Quality Inlet/Catch Basin, Manufactured Devices and Grass Swales. Dissolved and particulate phosphorus removal rates for the urban stormwater BMPs considered (Table 7.6) were estimated based on literature data (EPA, 2002; Schuler, 1987).

Phosphorus reduction factors for urban land uses due to BMPs implemented by the Stormwater Retrofit Program were calculated, similarly as for agricultural land uses, as the product of removal rate and implementation rate (Tables 7.7 and 7.8). Implementation rates (percentages of urban land uses to which BMPs are applied) were determined by analysis of data on existing or planned Stormwater Retrofit projects. Assuming that only one of the five urban BMPs is applied to any one urban development project, the combined effect of all urban BMPs applied to each land use type was calculated as a weighted average of the load reductions for the individual BMPs. The use of additive reductions here is in contrast to the compounding effect used with the agricultural BMPs, for which it is assumed that multiple BMPs can be applied on the same farm fields.

Table 7.6. Dissolved and particulate phosphorus removal rates for urban stormwater BMPs.

BMP	BMP Description	Dissolved Phosphorus Removal Rate	Particulate Phosphorus Removal Rate
Ponding System	Retention pond. Treatment mechanism: particle sedimentation. Peak flow reduction	66%	50%
Infiltration System	Infiltration trench/basin. Treatment mechanism: percolation/ infiltration.	85%	70%
Water Quality Inlet/ Catch Basin	Treatment mechanism: particle settling	5%	5%
Manufactured Devices	Vortechnics, CDS or other proprietary device Treatment mechanism: Mechanical separation	40%	40%
Grass Swale	Treatment mechanism: Filtering action of grass, deposition in low velocity areas and infiltration into soil.	38%	34%

Table 7.7. Dissolved phosphorus reduction factors for urban BMPs in Cannonsville and Pepacton Watersheds

Urban Stormwater BMPs	DP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious	Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious
Cannonsville:									
Ponding System	66%	0.4%	1.8%	0.3%	--	0.3%	1.2%	0.2%	--
Infiltration System	85%	4.9%	3.1%	0.7%	0.7%	4.2%	2.6%	0.6%	0.6%
Water Quality Inlet/Catch Basin	5%	2.3%	0.5%	1.3%	--	0.1%	0.0%	0.1%	--
Manufactured Devices	40%	2.7%	2.4%	3.1%	2.9%	1.1%	0.9%	1.2%	1.2%
Grass Swale	38%	--	--	--	--	--	--	--	--
Total	-	--	--	--	--	5.7%	4.8%	2.1%	1.8%
Pepacton:									
Ponding System	66%	--	--	--	--	--	--	--	--
Infiltration System	85%	--	--	--	--	--	--	--	--
Water Quality Inlet/Catch Basin	5%	0.3%	1.1%	0.5%	0.4%	0.0%	0.1%	0.0%	0.0%
Manufactured Devices	40%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Grass Swale	38%	0.2%	0.1%	--	--	0.1%	0.0%	0.0%	0.0%
Total	-	--	--	--	--	0.1%	0.1%	0.0%	0.0%

Table 7.8. Particulate phosphorus reduction factors for urban BMPs in Cannonsville and Pepacton Watersheds

Urban Stormwater BMPs	PP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious	Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious
Cannonsville:									
Ponding System	50%	0.4%	1.8%	0.3%	--	0.2%	0.9%	0.1%	--
Infiltration System	70%	4.9%	3.1%	0.7%	0.7%	3.5%	2.2%	0.5%	0.5%
Water Quality Inlet/Catch Basin	5%	2.3%	0.5%	1.3%	--	0.1%	0.0%	0.1%	--
Manufactured Devices	40%	2.7%	2.4%	3.1%	2.9%	1.1%	0.9%	1.2%	1.2%
Grass Swale	34%	--	--	--	--	--	--	--	--
Total	-	--	--	--	--	4.9%	4.0%	1.9%	1.7%
Pepacton:									
Ponding System	50%	--	--	--	--	--	--	--	--

Table 7.8. Particulate phosphorus reduction factors for urban BMPs in Cannonsville and Pepacton Watersheds

Urban Stormwater BMPs	PP Removal Rate	Fraction of Land Use Affected by BMP				Total Reduction Factor for Land Use			
		Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious	Res. Imperv	Res. Pervious	Com/Ind Imperv	Com/Ind Pervious
Infiltration System	70%	--	--	--	--	--	--	--	--
Water Quality Inlet/Catch Basin	5%	0.3%	1.1%	0.5%	0.4%	0.0%	0.1%	0.0%	0.0%
Manufactured Devices	40%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Grass Swale	34%	0.2%	0.1%	--	--	0.1%	0.0%	0.0%	0.0%
Total	-	--	--	--	--	0.1%	0.1%	0.0%	0.0%

Septic Systems

The GWLF model simulates nutrient loads from septic systems as a function of the percentage of the unsewered population served by normally functioning vs. three types of failing systems: ponded, short-circuited, and direct discharge (Haith *et al*. 1992). Septic System Rehabilitation and Remediation Program effects are modeled by adjusting the fractions of failing systems. Under *BASELINE* conditions, the Delaware County Soil and Water Conservation District (Day, 2001) estimates that approximately 50% of previously installed septic systems could be expected to fail, based on soil suitability and design criteria analysis. A GIS analysis of dwelling locations relative to waterbodies suggests that 42% of septic systems in Cannonsville and 40% of septic systems in Pepacton are located within 300 ft. of a waterbody. Assuming that failing systems beyond 300 ft. of a waterbody are too far away to significantly add to the stream nutrient load, the effective *BASELINE* septic failure rates for Cannonsville and Pepacton watersheds are 20.8% and 20.0%, respectively. To estimate the percentages of the three types of failing systems, we assume that 80% of the failing systems are ponded failures, 10% are short-circuited, and 10% are direct discharge (professional judgment, DEP Engineering staff). The resultant percentages of the current unsewered population served by normal versus failing systems are given in Table 7.9. These percentages hold for the wet seasons (April through mid-June, mid-September through mid-November). During other times of the year ponded systems are assumed to effectively function normally, and the percentages of failures are reduced accordingly.

The effects of the Septic System Rehabilitation and Replacement Program on nutrient loads under *BMP* scenarios assume that 75% of systems within 300' of a watercourse will be remediated, based on previous DEP estimates (DEP, 2001). This estimate is based on data for systems already remediated or planned for remediation, and program plans to prioritize remediation of systems in close proximity to water courses. Table 7.9 shows the final septic failure percentages for the BMP scenarios.

Table 7.9. Projected reductions in septic system failures rates due to Septic Remediation Program in Cannonsville and Pepacton Watersheds.

	Cannonsville			Pepacton		
Septic Type	BASELINE	BMP	% Reduction	BASELINE	BMP	% Reduction
Normal	79.2%	95.8%		80.0%	95.0%	
Ponded	16.6%	5.3%	75%	16.0%	4.0%	75%
Short-circuited	2.1%	0.65%	75%	0.5%	0.5%	75%
Direct discharge	2.1%	0.65%	75%	0.5%	0.5%	75%

PS Scenarios (PS Management)

Wastewater Treatment Plants

WWTP phosphorus loads for the *BASELINE* Scenario were estimated from WWTP effluent monitoring data. The average daily loads for calendar years 1993-1995 for all WWTPs in each watershed were calculated and summed to give the cumulative average daily WWTP load under *BASELINE* conditions. For Cannonsville, total phosphorus loads from WWTPs were partitioned into 60% dissolved vs. 40% particulate phosphorus for Walton WWTP, and 92% dissolved vs. 8% particulate for the other WWTPs, based on WWTP monitoring data (P. Bishop, NYS DEC, pers. comm.). For Pepacton, total phosphorus loads from WWTPs were partitioned into 85% dissolved vs. 15% particulate (C.Cutietta-Olson, NYCDEP, pers. comm.). *BASELINE* daily WWTP loads as input into the GWLF model are given in Table 7.10.

Nutrient loads from upgraded WWTPs were estimated from average monthly loads for WWTP's for calendar year 2004. Partitioning of total phosphorus loads to dissolved versus particulate phosphorus was assumed the same as for *BASELINE* conditions. The final load reductions due to WWTP upgrades are given in Table 7.10.

Table 7.10. Reductions in Point Source loads due to WWTP Upgrades in Cannonsville and Pepacton Watersheds

	Cannonsville			Pepacton		
	Daily WWTP Load		($kg \cdot day^{-1}$)	Daily WWTP Load		($kg \cdot day^{-1}$)
	BASELINE	PS	%Reduction	BASELINE	PS	%Reduction
Dissolved Phosphorus	9.500	0.300	96.8%	1.056	0.109	89.7%
Particulate Phosphorus	2.700	0.040	98.5%	0.190	0.019	89.7%

7.3 Watershed Modeling Results

7.3.1 GWLF Estimates of Loading Reductions Due to Land Use Change and Watershed Management

Figures 7.2 and 7.3 depict the 39-year annual time series of simulated dissolved and particulate phosphorus loads from the Cannonsville and Pepacton watersheds for *BASELINE* versus *LU-BMP-PS* scenarios. The reduction in loads depicted in these graphs represents the combined effects of non-point BMPs, WWTP upgrades, and the land use changes that occurred between 1990 and 2004.

Figure 7.4 shows the relative *BASELINE* contribution of each land use type to dissolved phosphorus loads for the two watersheds. For Cannonsville, average annual dissolved phosphorus loads for *BASELINE* conditions are mostly attributable to agricultural runoff (36.7%), WWTPs (15.7%) and to non-point source nutrients transported collectively in baseflow (24.5%), with other watershed sources contributing significantly less (urban runoff (5.3%), non-agricultural turf (6.6%), forest/brushland (8.1%), septic systems (3.0%)). In Pepacton the dominant dissolved phosphorus loading sources are agricultural runoff (21.6 %), forest/brushland runoff (21.8%) and baseflow (28.7%). WWTPs are not as dominant in Pepacton, contributing only 4.7% of the annual load. The other sources in Pepacton include septic systems (3.6%), urban runoff (10.5%), and non-agricultural turf (9.1%).

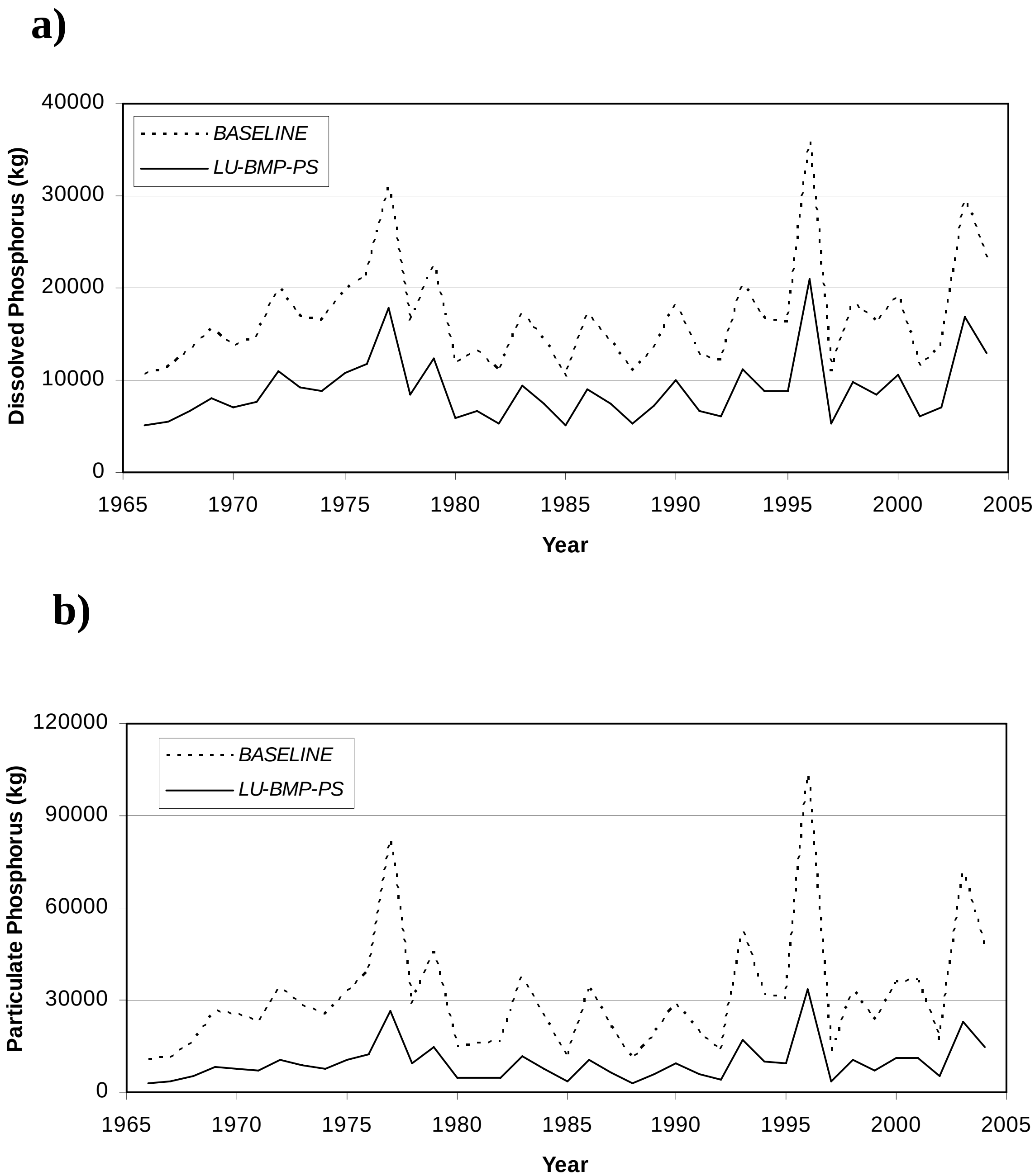


Figure 7.2 A 39-year annual time series of simulated phosphorus loads ($kg \cdot yr^{-1}$) from the Cannonsville Reservoir watershed: (a) dissolved phosphorus, (b) particulate phosphorus.

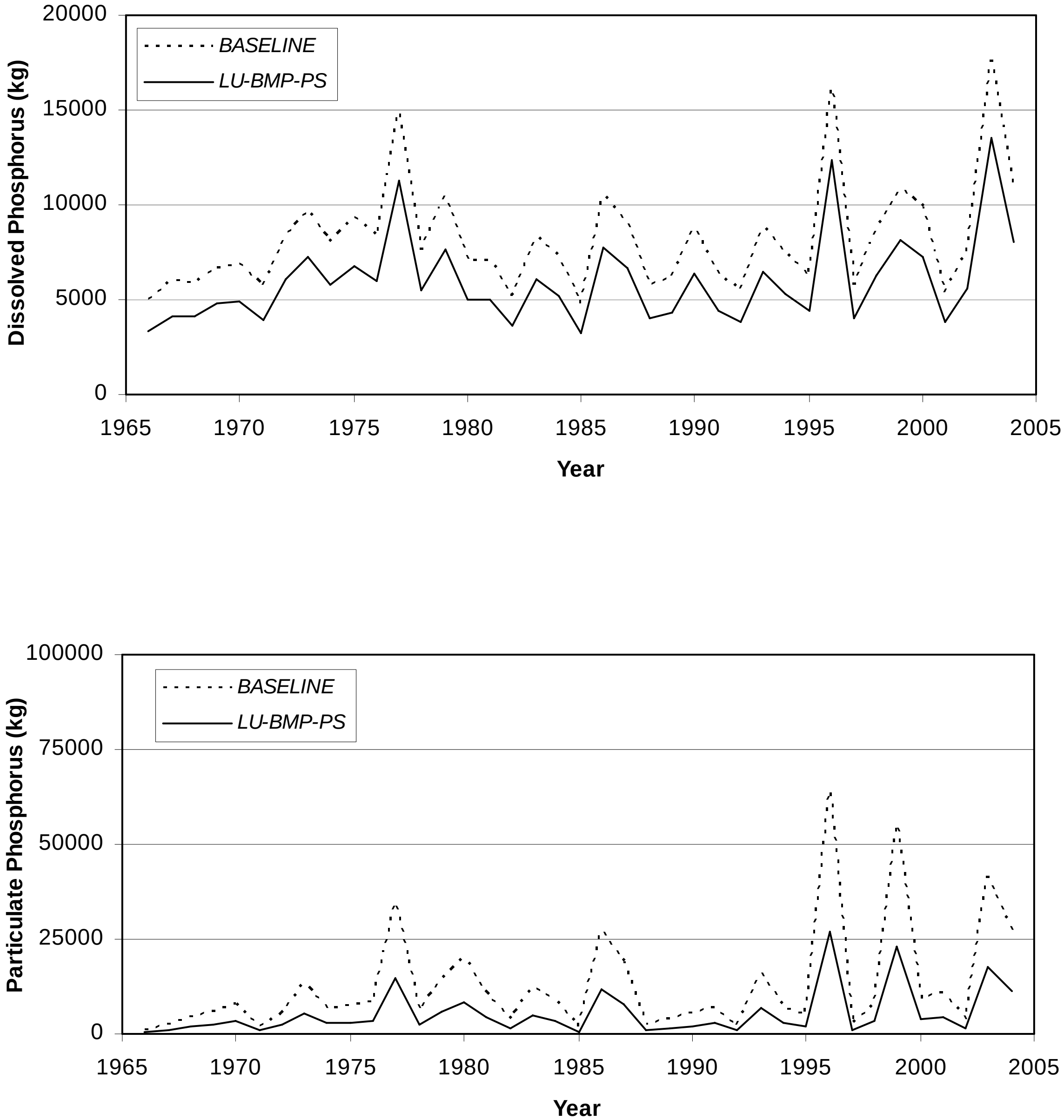
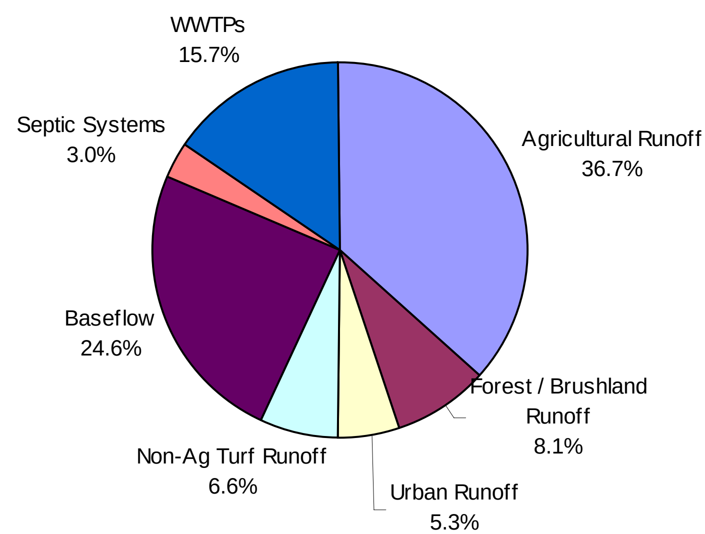


Figure 7.3 A 39-year annual time series of simulated phosphorus loads ($kg \cdot yr^{-1}$) from the Pepacton Reservoir watershed: (a) dissolved phosphorus, (b) particulate phosphorus.

a) Cannonsville



b) Pepacton

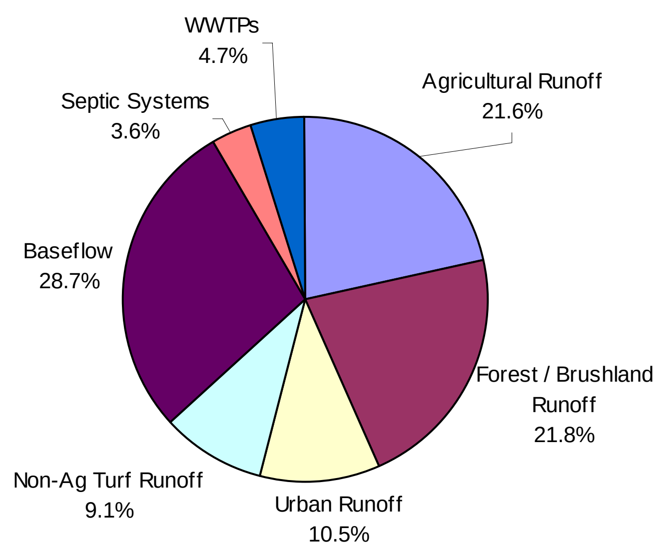


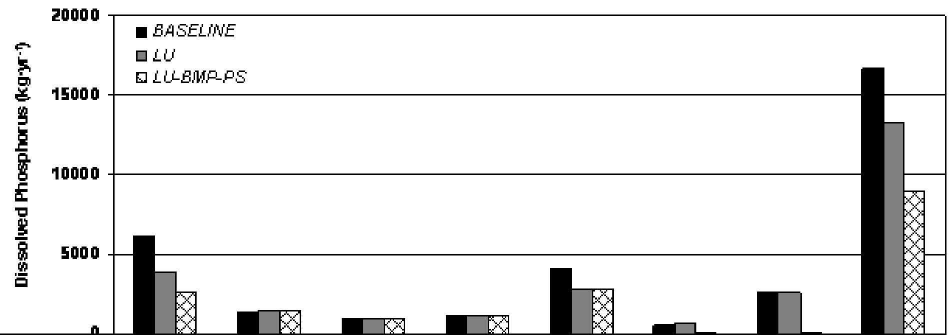
Figure 7.4 Relative *BASELINE* contributions of each land use category to total dissolved phosphorus loads for (a) Cannonsville Reservoir watershed and (b) Pepacton Reservoir watershed.

Dissolved phosphorus load reductions due to land use change and watershed management programs are depicted in Figures 7.5 (Cannonsville) and 7.6 (Pepacton). Three scenarios are depicted –*BASELINE*, *LU*, and *LU-BMP-PS* – with average annual loads from major watershed sources shown. Load reductions for specific land uses are considered separately as well as in context of the total load from the entire watershed area. For example, loads in runoff from agricultural land uses are reduced by 58.1% for Cannonsville due to the combination of land use changes and management programs (*LU-BMP-PS* Scenario). This agricultural source load reduction represents a 21.3% reduction of the total annual dissolved phosphorus load from the entire watershed. Similarly, the load from septic systems alone declines from 508 kg to 139 kg due to the combination of land use change and management programs. This represents a 72.6% load reduction for septic systems. However, because of the relatively small contribution of septics to the total load, the total load reduction due to the septic load reduction is 2.2%.

Comparison of *BASELINE* and *LU* scenarios in Figures 7.5 and 7.6 shows the effects of land use change only. Comparison of these scenarios with the *LU-BMP-PS* scenario shows the additional reductions due to non-point BMPs and point source upgrades. The effect of land use change only (independent of watershed management) was quite significant. For Cannonsville, annual dissolved phosphorus in agricultural runoff was reduced by 35.7% simply due to less farming, including fewer farmed hectares and lower density of animal units in the watershed. An additional 34.8% reduction was achieved by adding the effects of agricultural BMPs. Compounding these two reductions produces the final 58.1% total reduction in annual loads from agricultural runoff. Therefore, for agricultural runoff, roughly half of the expected dissolved phosphorus reductions are due to changes in the level of agricultural activity, independent of watershed management activities. Baseflow dissolved phosphorus load reductions due to land use change were also considerable (>30%). For Pepacton, reductions in agricultural runoff loads due to land use changes and management programs were similar (56.4%) to Cannonsville. However, the influence of the agricultural reduction on the total annual phosphorus load (12.2%) was not as great because agricultural runoff is not as large a source in Pepacton,

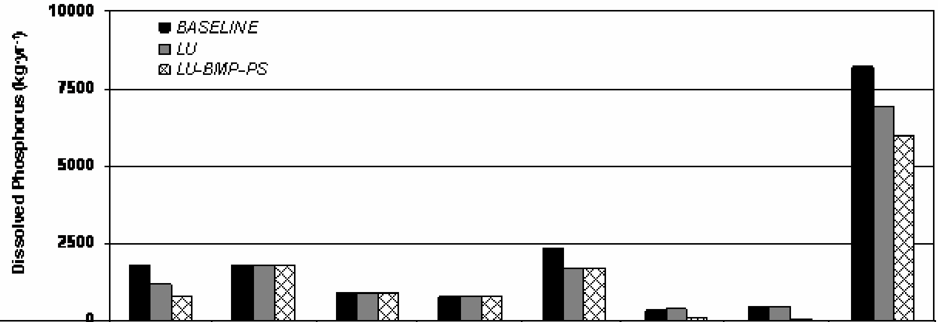
For septic systems the effects of land use change (population increase) and management programs (septic rehabilitation and replacement) work in opposite directions. In Cannonsville, increases in population from the 1990 Census to the 2000 Census, without implementation of septic programs, would have produced an increase of 9.2% in annual dissolved phosphorus load from septic systems. The implementation of the septic program is predicted to reduce septic system loads by 74.9%. When the effects of increased population and watershed management programs are combined the total reduction for septic systems is 72.6%. Results for Pepacton were quite similar with population increase causing a 16.1% increase, management programs producing a 74.9% decrease, and netting a combined 70.9% decrease in septic loads.

Overall dissolved phosphorus reductions from both land use change and watershed management programs are considerable. Of the total 46.4% reduction due to land use change and management programs for Cannonsville, 21.3% comes from agricultural runoff, 15.2% from WWTP improvements, 7.7% from reductions in loads during baseflow periods, and 2.2% from septic systems. For Pepacton, the total load reduction of 27.4% consists of a 12.2% reduction from agricultural runoff, a 2.5% reduction from septics, 8.5% from reductions in load during baseflow periods and a 4.2% reduction from WWTPs.



	Agricultural Runoff	Forest / Brushland Runoff	Urban Runoff	Non-Ag Turf Runoff	Baseflow	Septic Systems	WWTPs	Total
Loads ($kg \cdot yr^{-1}$):								
BASELINE	6,140	1,349	882	1,109	4,123	508	2,619	16,729
LU	3,948	1,364	882	1,109	2,850	555	2,619	13,329
LU-BMP-PS	2,572	1,370	854	1,110	2,833	139	83	8,960
% Reduction for Land Use:								
due to Land Use/Farm Change	35.7%	-1.1%	-0.1%	-0.1%	30.9%	-9.2%	0.0%	20.3%
due to Management Programs	34.8%	-0.4%	3.2%	0.0%	0.6%	74.9%	96.8%	32.8%
Combined	58.1%	-1.5%	3.2%	-0.1%	31.3%	72.6%	96.8%	46.4%
% Reduction for Total Load:								
due to Land Use/Farm Change	13.1%	-0.1%	0.0%	0.0%	7.6%	-0.3%	0.0%	20.3%
due to Management Programs	10.3%	0.0%	0.2%	0.0%	0.1%	3.1%	19.0%	32.8%
Combined	21.3%	-0.1%	0.2%	0.0%	7.7%	2.2%	15.2%	46.4%

Figure 7.5 Dissolved phosphorus loadings ($kg \cdot yr^{-1}$) for *BASELINE* (black), *LU* (gray) and *LU-BMP-PS* (cross-hatch) scenario with corresponding % reductions broken down by land use for the Cannonsville Reservoir watershed.



	Agricultural Runoff	Forest / Brushland Runoff	Urban Runoff	Non-Ag Turf Runoff	Baseflow	Septic Systems	WWTPs	Total
Loads (kg·yr⁻¹):								
BASELINE	1773	1786	866	748	2355	293	386	8207
LU	1167	1789	866	748	1661	340	386	6956
LU-BMP-PS	773	1790	865	748	1661	85	40	5962
% Reduction for Land Use:								
due to Land Use/Farm Change	34.2%	-0.2%	0.0%	0.0%	29.5%	-16.1%	0.0%	15.2%
due to Management Programs	33.8%	-0.1%	0.1%	0.0%	0.0%	74.9%	89.7%	14.3%
Combined	56.4%	-0.2%	0.1%	0.0%	29.5%	70.9%	89.7%	27.4%
% Reduction for Total Load:								
due to Land Use/Farm Change	7.4%	0.0%	0.0%	0.0%	8.5%	-0.6%	0.0%	15.2%
due to Management Programs	5.7%	0.0%	0.0%	0.0%	0.0%	3.7%	5.0%	14.3%
Combined	12.2%	-0.1%	0.0%	0.0%	8.5%	2.5%	4.2%	27.4%

Figure 7.6 Dissolved phosphorus loadings ($kg \cdot yr^{-1}$) for *BASELINE* (black), *LU* (gray) and *LU-BMP-PS* (cross-hatch) scenarios with corresponding % reductions broken down by land use for the Pepacton Reservoir watershed.

Figures 7.7 and 7.8 show the seasonal variability in average dissolved phosphorus loading for each land use type for both the *BASELINE* and *LU-BMP-PS* scenarios for Cannonsville (Figure 7.7) and Pepacton (Figure 7.8). Dissolved phosphorus loads associated with agricultural runoff, urban runoff, forest/brushland runoff, managed turf, and baseflow all follow the seasonal pattern of streamflow, peaking in spring and reaching a low in summer. Dissolved phosphorus loads in agricultural runoff display the most pronounced seasonality, with elevated spring loading. Because agricultural load reductions are applied as a constant percentage of the load, the greatest reductions occur when loads are highest. This means that the majority of agricultural load reduction occurs in the spring. Septic system failures peak during the spring and again in autumn, and are elevated somewhat in summer due to seasonal population increases. The greatest septic load reductions are generated due to the reduction in ponded systems, which fail only during these high load months. WWTP loads and reductions are more or less constant throughout the year. Given that loading reductions from other sources are less during the summer low flow months, the constant WWTP reductions have greater impact on the total dissolved phosphorus reduction during these months.

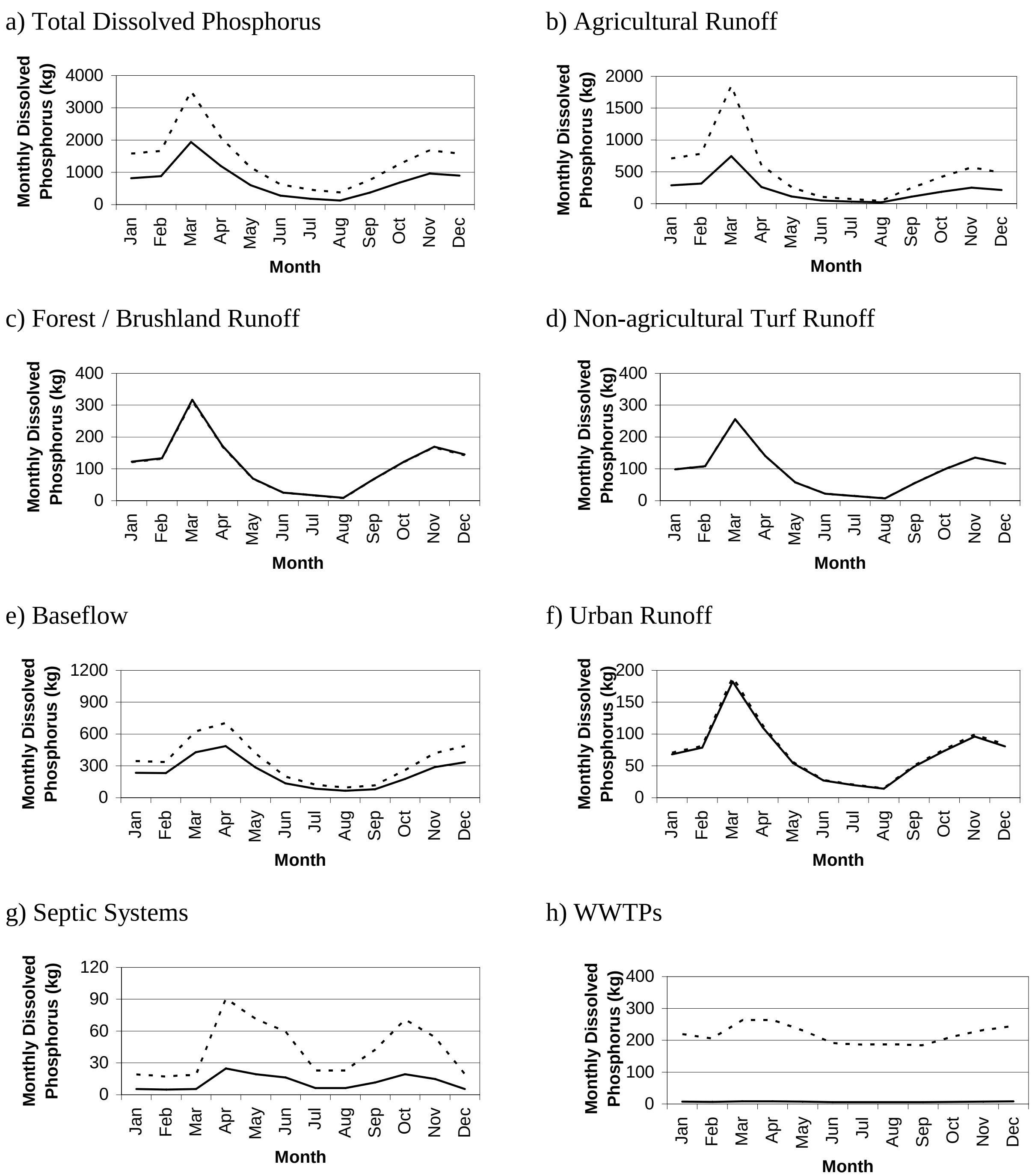


Figure 7.7 Average monthly dissolved phosphorus loads ($kg \cdot month^{-1}$) for Cannonsville *BASELINE* (dashed line) and *LU-BMP-PS* (solid line) scenarios attributable to: (a) all categories together, (b) agricultural runoff, (c) forest/brushland run-off, (d) non-agricultural turf runoff, (e) baseflow, (f) urban runoff, (g) septic systems and (h) WWTPs.

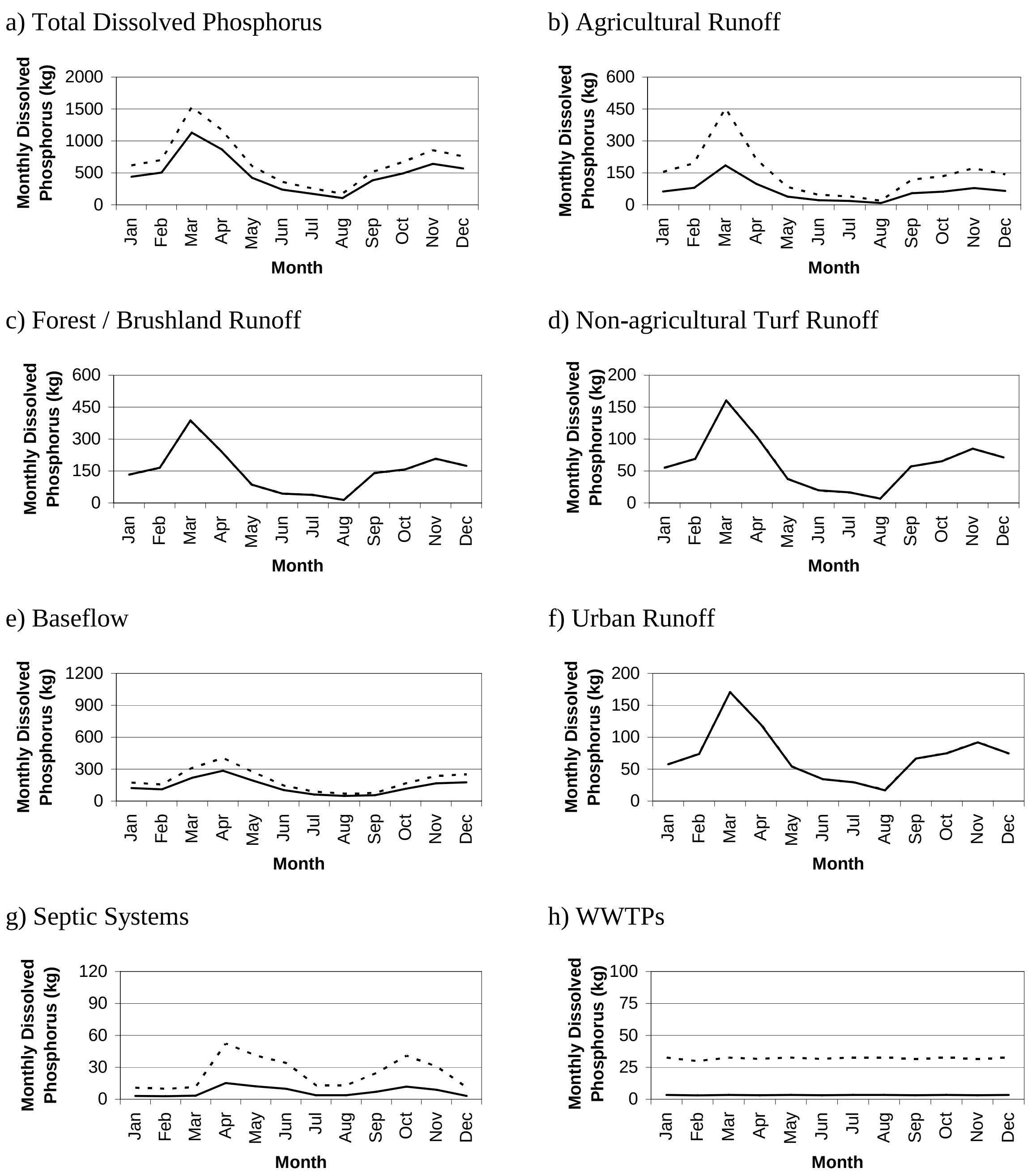
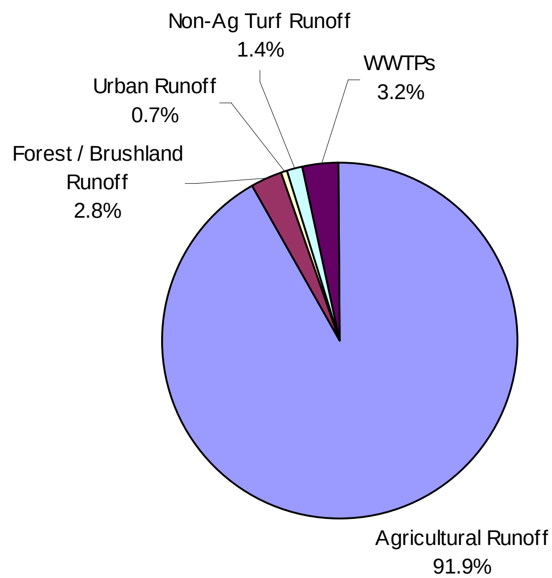


Figure 7.8 Average monthly dissolved phosphorus loads (kg·month^{-1}) for Pepacton *BASELINE* (dashed line) and *LU-BMP-PS* (solid line) scenarios attributable to: (a) all categories together, (b) agricultural runoff, (c) forest/ brushland runoff, (d) non-agricultural turf runoff, (e) baseflow, (f) urban runoff, (g) septic systems and (h) WWTPs.

Figure 7.9 shows the relative contribution of each land use type to particulate phosphorus loads for the *BASELINE* scenario. For Cannonsville, average annual particulate phosphorus loads for *BASELINE* conditions come mainly from agricultural runoff (91.9%). The remaining loading proportions are in Forest/Brushland (2.8%), Non-agricultural Turf (1.4%), Urban (0.7%) and WWTPs (3.2%). Therefore, any reductions in particulate phosphorus from agricultural sources will have a significant impact on total watershed reductions. In Pepacton, agricultural runoff (78.2%) and forest/grass-shrub (16.4%) are also the dominant contributors to the particulate phosphorus load. The remaining contributions to particulate phosphorus in Pepacton are urban runoff (1.3%), Non-agricultural Turf (3.5%) and WWTP (0.5%).



b) <u>Pepacton:</u>

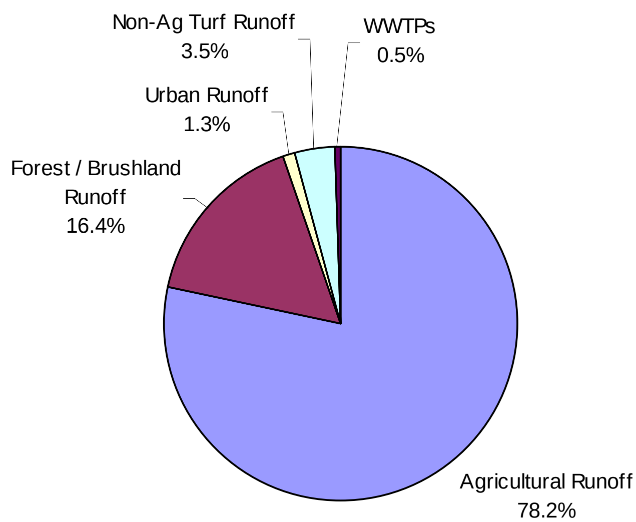
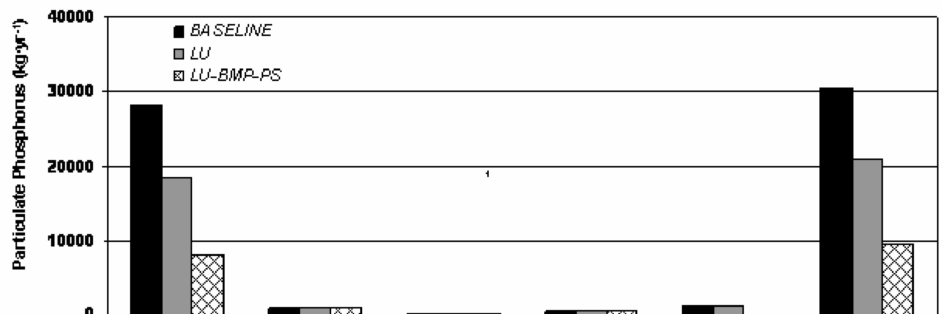


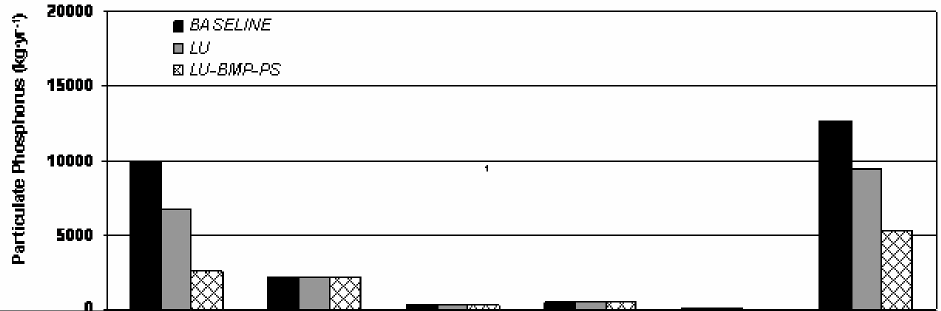
Figure 7.9 Relative *BASELINE* contributions of each land use category to total particulate phosphorus loads for (a) Cannonsville watershed and (b) Pepacton watershed.

Particulate phosphorus loading reductions due to land use change and watershed management are depicted in Figure 7.10 (Cannonsville) and 7.11 (Pepacton). Most of the particulate phosphorus load to both Cannonsville and Pepacton comes from agriculture. The relative importance of changes in farm activity versus watershed management programs on load reduction in Cannonsville is investigated by comparing the *BASELINE* with the *LU-BMP-PS* and *LU* scenarios. For agricultural runoff, annual particulate phosphorus was reduced by 34.2% in Cannonsville and 33.0% in Pepacton due to the reductions in farming, including fewer farmed hectares and lower farm animal density in the watershed. Effects of agricultural BMPs produced an additional 56.2% reduction in Cannonsville and 61.4% reduction in Pepacton. Compounding the reductions due to both land use changes and watershed management produces the final 65.4% total reduction in annual loads from agricultural runoff in Cannonsville and 74.1% total reduction from agricultural sources in Pepacton. Therefore, for agricultural runoff, roughly two-thirds of the expected particulate phosphorus reductions are due to watershed management programs, while the remainder is due to changes in the level of agricultural activity, independent of watershed management activities.



	Agricultural Runoff	Forest / Brushland Runoff	Urban Runoff	Non-Ag Turf Runoff	WWTPs	Total
Loads (kg·yr⁻¹):						
BASELINE	28,076	854	213	420	986	30,549
LU	18,477	865	213	420	986	20,962
LU-BMP-PS	8,103	866	206	421	15	9,610
% Reduction for Land Use:						
due to Land Use/Farm Change	34.2%	-1.3%	0.0%	0.0%	0.0%	31.4%
due to Management Programs	56.1%	0.0%	3.3%	0.0%	98.5%	54.2%
Combined	71.1%	-1.4%	3.3%	0.0%	98.8%	68.5%
% Reduction for Total Load:						
due to Land Use/Farm Change	31.4%	0.0%	0.0%	0.0%	0.0%	31.4%
due to Management Programs	49.5%	0.0%	0.0%	0.0%	4.6%	54.2%
Combined	65.4%	0.0%	0.0%	0.0%	3.2%	68.5%

Figure 7.10 Particulate phosphorus loadings (kg·yr^{-1}) for *BASELINE* (black), *LU* (gray) and *LU-BMP-PS* (cross-hatch) scenarios with corresponding % reductions broken down by land use for the Cannonsville watershed.



	Agricultural Runoff	Forest / Brushland Runoff	Urban Runoff	Non-Ag Turf Runoff	WWTPs	Total
Loads (kg·yr^{-1}):						
BASELINE	9,945	2,085	167	443	69	12,709
LU	6,668	2,105	169	446	69	9,458
LU-BMP-PS	2,571	2,114	169	448	7	5,309
% Reduction for Land Use:						
due to Land Use/Farm Change	33.0%	-1.0%	-0.8%	-0.8%	0.0%	25.6%
due to Management Programs	61.4%	-0.4%	-0.3%	-0.4%	90.0%	43.9%
Combined	74.1%	-1.4%	-1.1%	-1.2%	90.0%	58.2%
% Reduction for Total Load:						
due to Land Use/Farm Change	25.8%	-0.2%	0.0%	0.0%	0.0%	25.6%
due to Management Programs	43.3%	-0.1%	0.0%	0.0%	0.7%	43.9%
Combined	58.0%	-0.2%	0.0%	0.0%	0.5%	58.2%

Figure 7.11 Particulate phosphorus loadings (kg·yr^{-1}) for *BASELINE* (black), *LU* (gray) and *LU-BMP-PS* (cross-hatch) scenarios with corresponding % reductions broken down by land use for the Pepacton watershed.

Figures 7.12 and 7.13 show the seasonal variability in average particulate phosphorus loading for each land use type for both the *BASELINE* and *LU-BMP-PS* scenarios for Cannonsville and Pepacton. Particulate phosphorus loads are sensitive to high streamflow events, so loadings follow the seasonal pattern of streamflow, peaking in spring and reaching a low in summer. The largest magnitude reductions occur during these periods of higher flow.

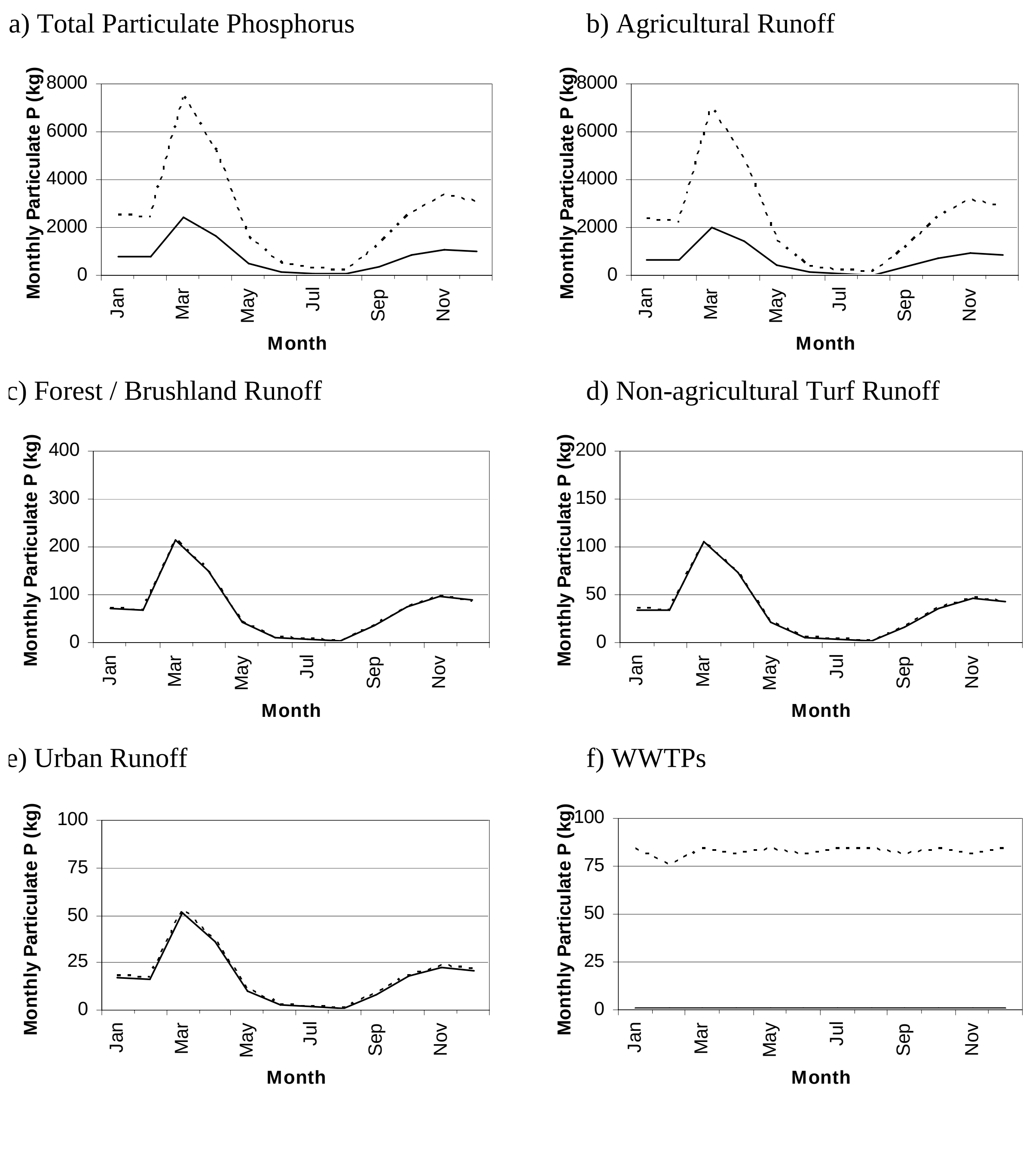


Figure 7.12 Average monthly particulate phosphorus loads (kg·month^{-1}) for Cannonsville *BASELINE* (dashed line) and *LU-BMP-PS* (solid line) scenarios attributable to: (a) all categories together, (b) agricultural runoff, (c) forest/brushland runoff, (d) non-agricultural turf runoff, (e) urban runoff and (f) WWTPs.

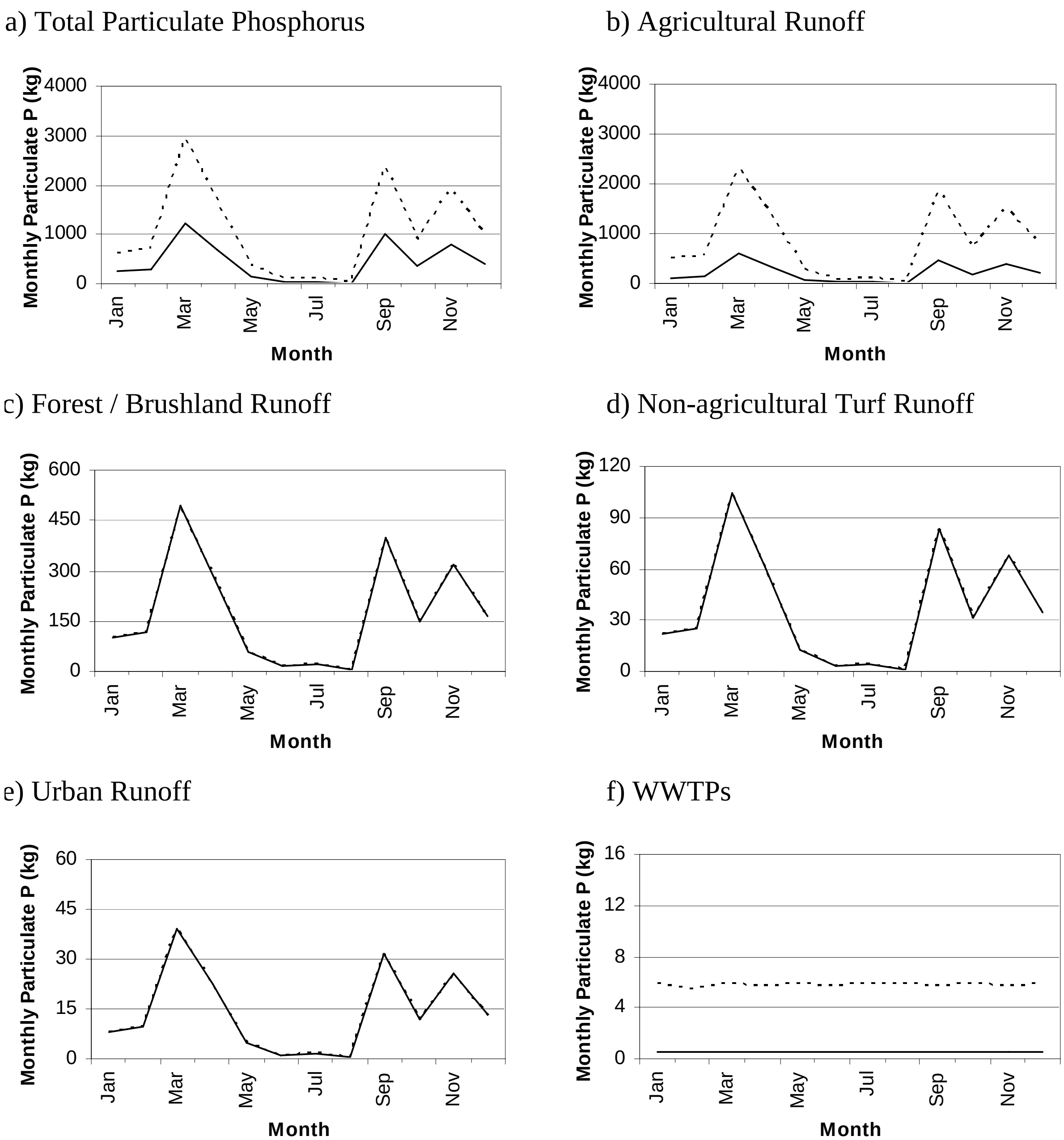


Figure 7.13 Average monthly particulate phosphorus loads (kg·month^{-1}) for Pepacton *BASELINE* (dashed line) and *LU-BMP-PS* (solid line) scenarios attributable to: (a) all categories together, (b) agricultural runoff, (c) forest/ brushland runoff, (d) non-agricultural turf runoff, (e) urban runoff and (f) WWTPs.

7.3.2 GWLF Model Scenario Predictions vs. Observed Trends in Cannonsville Phosphorus Loads

Analysis of water quality data collected by NYSDEC along the West Branch of the Delaware River (WBDR) at Beerston between 1992 and 2004 reveals a considerable reduction in phosphorus loads to Cannonsville Reservoir (P. Bishop, NYSDEC, pers. comm.). The average annual dissolved phosphorus concentration in streamflow at Beerston has dropped from 0.029 mg L^{-1} for the period 1992-1999 (not including the January 1996 extreme event) to 0.016 mg L^{-1} for 2000-2004 – a 45% reduction. In contrast, annual particulate phosphorus concentrations, and annual streamflow, have not declined (Figure 7.14).

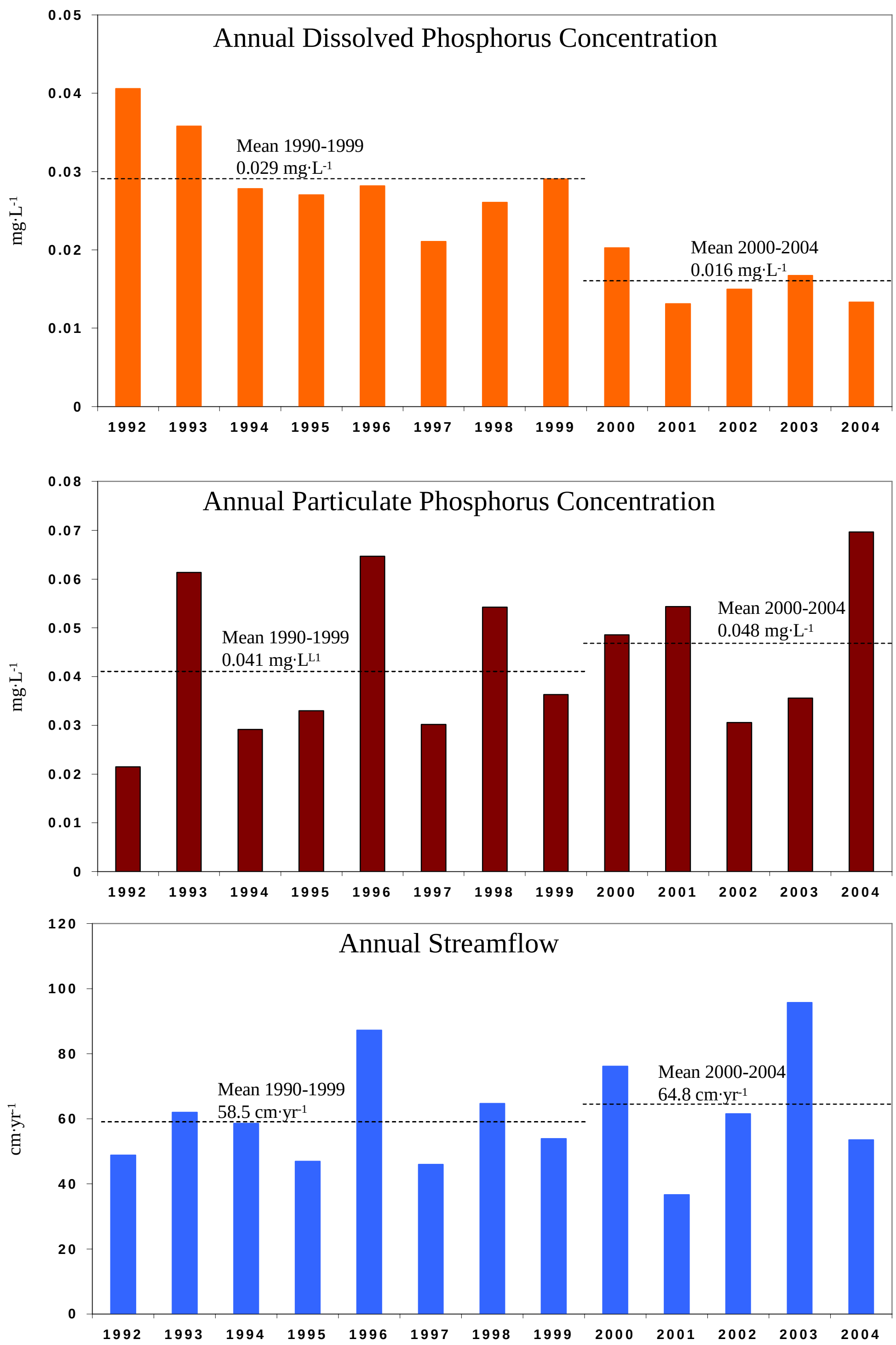


Figure 7.14 Observed annual dissolved and particulate phosphorus concentrations (mg·L^{-1} at Beerston and observed annual streamflow (cm·yr^{-1}) at Walton, 1992-200

The combination of water quality monitoring data collected through the last 13 years along with data on watershed management program implementation and land use change provides a unique opportunity to test the watershed model scenario simulations and to increase confidence in the model predictions. In typical model applications a model is calibrated and validated using data collected for a set period and subsequently used to predict future scenarios under varying watershed conditions; but additional data is rarely available for testing the prediction scenarios. We calibrated and validated the GWLF model for the period 1992-1999 (Appendix 4), which approximate *BASELINE* conditions. With the additional data for the 2000-2004 at hand, we can compare this observed data with model scenario predictions, representing recent land use changes and watershed management program implementation.

Three scenarios were applied to predict loads at Beerston for comparison with observed data for 2000-2004. The *BASELINE* scenario assumes that no land use change and no watershed management implementation have occurred since the calibration period. The *BMP* scenario assumes that all BMPs have been implemented by the three non-point source watershed management programs under consideration, but that no land use change (except for changes that were consciously implemented by a watershed management program) has occurred. The *LU-BMP* scenario adds to the *BMP* scenario the land use changes along with the reduction in farming activity that occurred between *BASELINE* and post-2000 conditions. (See section 7.2 for details on land use changes). For these scenarios, actual WWTP loads for Beerston were input to the model. Differences between predictions and observed data in this analysis can thus only be attributable to non-point sources and/or land use changes.

Land use change alone accounts for a considerable fraction of the observed reductions in dissolved phosphorus loads from *BASELINE* to post-2000 at Beerston, and that combined reductions due to land use change and BMPs are in the range of observed dissolved phosphorus reductions. The *BASELINE* scenario markedly overestimates (>50%) dissolved phosphorus loads during 2000-2004 (Figure 7.15), as expected given the observed reduction in dissolved phosphorus concentrations from *BASELINE* to post-2000. The *BMP* scenario also overestimates (>40%) dissolved phosphorus loads for post-2000. All BMPs implemented by the three non-point source watershed management programs fail to reduce predicted loads to the level indicated by the measured dissolved phosphorus data for post-2000. Only when the land use changes are also considered (*BMP-LU* scenario) do the predicted dissolved phosphorus loads approach (~11% overestimate) the observed loads for post-2000.

For particulate phosphorus (in contrast with dissolved phosphorus) the *BASELINE* scenario predicts post-2000 better than either the *BMP* or the *BMP-LU* scenarios, both of which markedly under-predict particulate phosphorus at Beerston (Figure 7.16). The *BASELINE* scenario predictions of particulate phosphorus are reasonable with an overestimation of 6%, while the LU and LU-BMP scenarios underestimate by 50% and 65% respectively. Watershed changes in land use and BMP implementation have not yet produced observable reductions in particulate phosphorus.

This difference in results for dissolved versus particulate phosphorus indicates that the watershed response time is different for each component. Reductions in phosphorus export may be observed first with dissolved phosphorus because this component is based more on immediate factors such as the amount of manure spread and the time since the last application. Particulate phosphorus export is more dependent on soil concentrations of phosphorus, erosion and transport of these particles through the stream network, which is a considerably slower process.

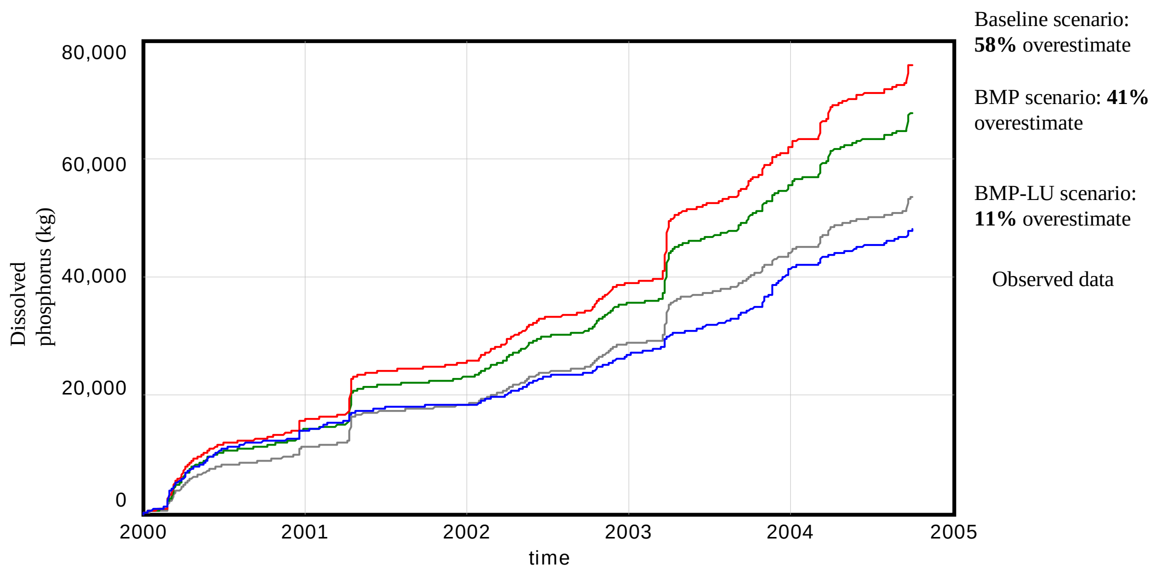


Figure 7.15 Observed vs. model scenario predictions of cumulative dissolved phosphorus at Beerston 2000 – 2004.

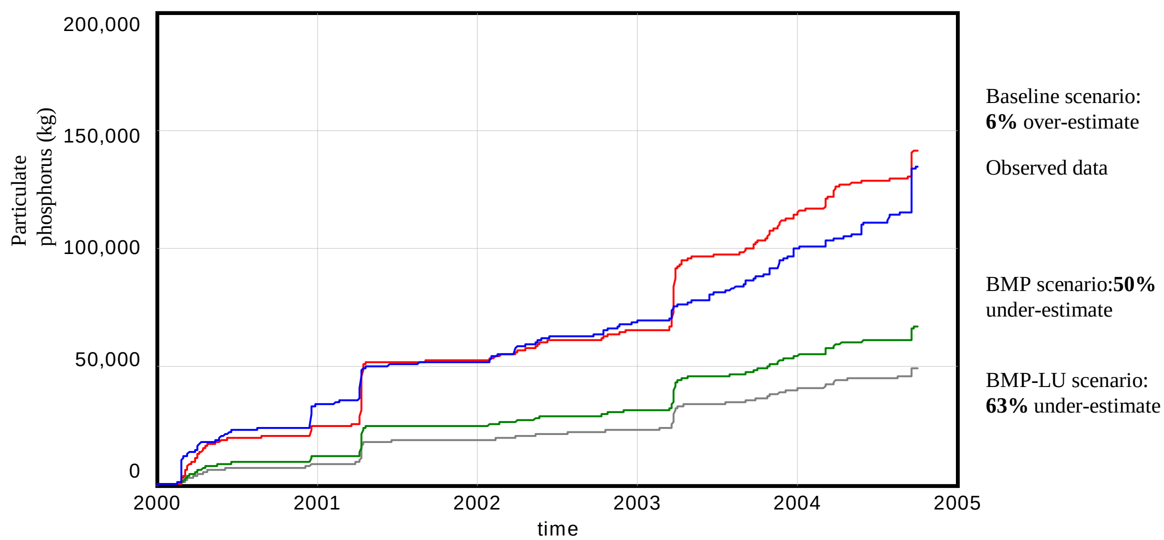


Figure 7.16 Observed vs. model scenario predictions of cumulative particulate phosphorus at Beerston 2000 – 2004.

7.3.3 Summary of GWLF Model Run Results

Land use change and four watershed management programs in the NYC Cannonsville and Pepacton watersheds were evaluated. The management programs included Point Source management (WWTP Upgrades), and three non-point source management programs: Watershed Agricultural Program, Urban Stormwater Retrofit Program, and Septic System Rehabilitation and Replacement Program. Land use change focused on the decline in agriculture and increase in unsewered census population that occurred from the 1990 to 2004.

In the Cannonsville watershed, significant loading reductions are predicted due to the decline in agriculture that has occurred (independent of watershed management) from *BASELINE* to post-2000 (~ 10% reduction in agricultural land area and ~ 30% reduction in farm animal units). These changes result in ~20% reduction in predicted total dissolved loads (~13% reduction in runoff and ~7% reduction in baseflow loads), and ~30% reduction in total particulate loads to Cannonsville Reservoir. When watershed management programs in Cannonsville watershed are considered in addition to the land use change, predicted load reductions are quite substantial, exceeding 46% for dissolved phosphorus and 68.5% for particulate phosphorus. For dissolved phosphorus, Point Source WWTP upgrades and the implementation of agricultural BMPs by the Watershed Agricultural Program provide most of the loading reductions. Particulate phosphorus load reductions stem mostly from the Watershed Agricultural Program. Urban stormwater management provides relatively small reductions in both dissolved and particulate phosphorus, due to the lack of urban acreage in the watershed.

Estimated loading reductions for the Pepacton watershed due to land use change and watershed management were less than for Cannonsville, but still substantial (27.4% for dissolved phosphorus, 58.2% for particulate P). The decline in farming activity over the last decade also produces large reductions in dissolved phosphorus loading. This land use change results in ~15% reduction in predicted total dissolved loads (~7% reduction in runoff and ~8% reduction in baseflow loads), and ~25% reduction in total particulate loads to Pepacton Reservoir. For the watershed management programs, the implementation of agricultural BMPs by the Watershed Agricultural Program provides much of the loading reductions for both dissolved and particulate phosphorus. Reductions in both dissolved and particulate phosphorus from urban stormwater management are quite low, due to the small amount of urban area in the watershed.

Comparison of model scenario results with observed loading data for the W. Br. Delaware River at Beerston corroborates the scenario predictions for dissolved phosphorus loading from Cannonsville watershed. A close match was found between observed annual dissolved phosphorus loads at Beerston for 2000-2004 and predicted loads using the *LU-BMP-PS* model scenario that accounts for reductions due to both land use change and watershed management programs. Neither land use change (observed decline in agriculture) nor watershed management programs considered alone provides reductions that match observed dissolved phosphorus reductions from *BASELINE* to post-2000. In contrast, particulate phosphorus predictions that include reductions due to either (or both) land use change and/or watershed management tend to under-predict when compared to observed particulate phosphorus loads at Beerston during 2000-2004. This suggests that a rapid watershed response to both land use change and watershed management has and is occurring for dissolved phosphorus, while for particulate phosphorus the response, if it is occurring, is much slower. Such differences in watershed response time to changes in the overall phosphorus balance of the watershed might be expected, since dissolved phosphorus is much more mobile than particulate phosphorus in the environment.

Loading reductions exhibit seasonal patterns. Dissolved phosphorus reductions due to agricultural BMPs are greatest in spring and lowest in summer, following the seasonal pattern of streamflow. In contrast, reductions due to WWTPs do not exhibit a seasonal pattern, causing the relative reduction due to WWTP upgrades to be greater during the summer, and least during spring. Particulate phosphorus reductions also exhibit strong seasonality, following the seasonal pattern of streamflow. These seasonal patterns are significant when considering the effects of loading reductions on eutrophication in the reservoirs, as in-lake algal growth is sensitive to the timing of nutrient inputs.

7.4 Reservoir Modeling Results

Trophic status is commonly measured in terms of phytoplankton chlorophyll concentration or total phosphorus concentration, and it is the model output of these two variables that is examined here. Furthermore, water quality issues related to eutrophication almost always occur during the summer period, and in the epilimnion (upper mixed layer) of the reservoir. For this reason, chlorophyll and total phosphorus are examined during the summer period (June-September) using data contained within the epilimnion. Yearly summer averaging was also used since similar averages (based on measured data) are used by DEP to monitor reservoir water quality, and are compared to critical threshold concentrations in the TMDL estimation procedure.

Model output from the different simulation scenarios can be interpreted in terms of the probability of occurrence of a given chlorophyll *a* or total phosphorus concentration (Figure 7.1). Measures of central tendency associated with these derived probability distributions give an overall estimate of the effects of the programs, while the range of variability provides a realistic description of the variations in water quality that will be experienced under any given nutrient loading scenario. In addition to summer averages, the distribution of daily epilimnetic chlorophyll was also examined. Daily data show the influence of the different nutrient loading scenarios on shorter term increases in chlorophyll *a* concentration (i.e., "algal blooms"). These events can lead to significant water quality problems, but will not be well measured by long term averages.

Time series of the 39 summer epilimnetic chlorophyll and total phosphorus concentrations associated with each year of the model simulations for the Cannonsville and Pepacton reservoirs are plotted in Figure 7.17 Differences between the scenarios represent the effects of changes in land use and the cumulative effects of land use change coupled with differing combinations of FAD management programs. These differences are consistent through time and between reservoirs. Variations occurring through time result from changes in model forcing related to climate and reservoir operations. Three important factors influencing the temporal response of the reservoir simulations are also plotted in Figure 7.17. Clearly, these environmental factors which influence the timing, delivery and availability of phosphorus to the phytoplankton vary significantly from year to year. For this reason, yearly variations in chlorophyll can be greater than inter-scenario differences. Changes in land use and watershed management have a more pronounced effect on Cannonsville, since this reservoir was the most eutrophic under *BASELINE* conditions, and since there is a greater proportion of land use in the Cannonsville watershed that was impacted by the watershed management programs (section 7.3.2).

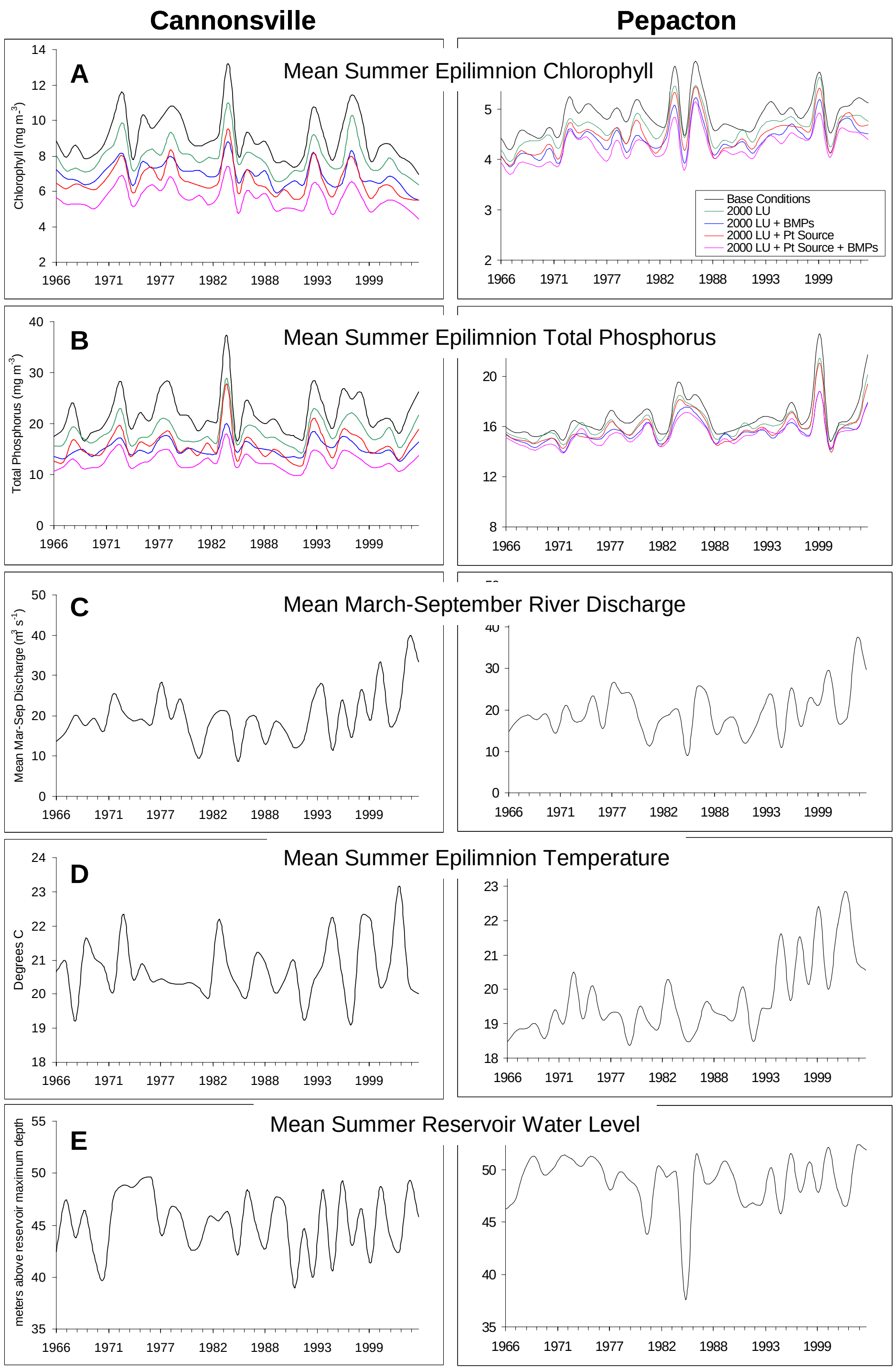


Figure 7.17 Time series of the modeled mean summer epilimnetic chlorophyll (A) and total phosphorus (B) for Cannonsville and Pepaction reservoirs. Variations in three physical factors which affect the temporal variations in A and B are also plotted. C). Mean total river discharge into the reservoir ($m^3 s^{-1}$) D) Mean Summer Epilimnion Temperature (C). E) Mean summer reservoir water level (m).

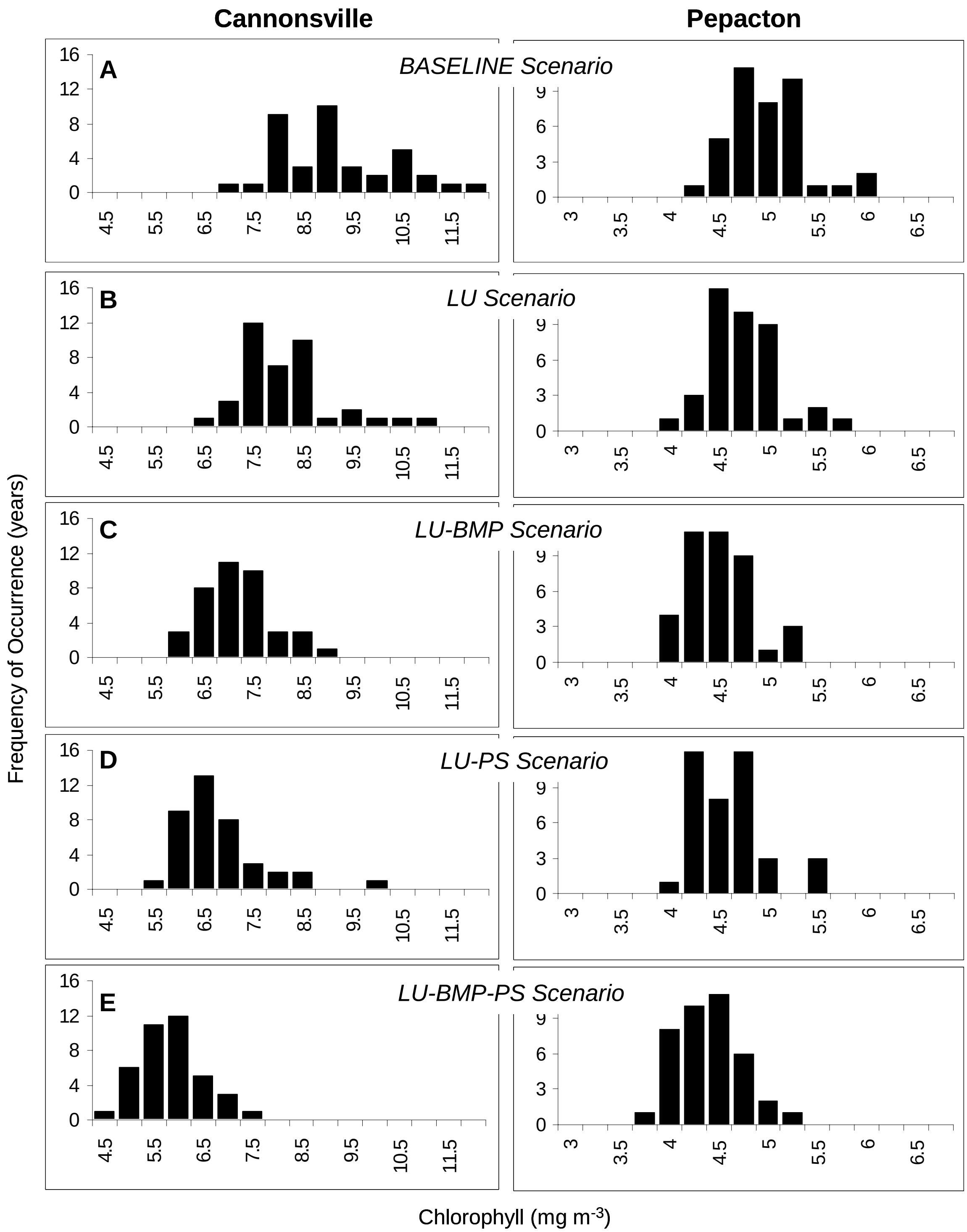


Figure 7.18 Frequency distributions of the mean summer epilimnetic chlorophyll concentrations that are calculated from the output of the reservoir model simulations of Cannonsville and Pepacton reservoirs driven by the differing nutrient loading scenarios.

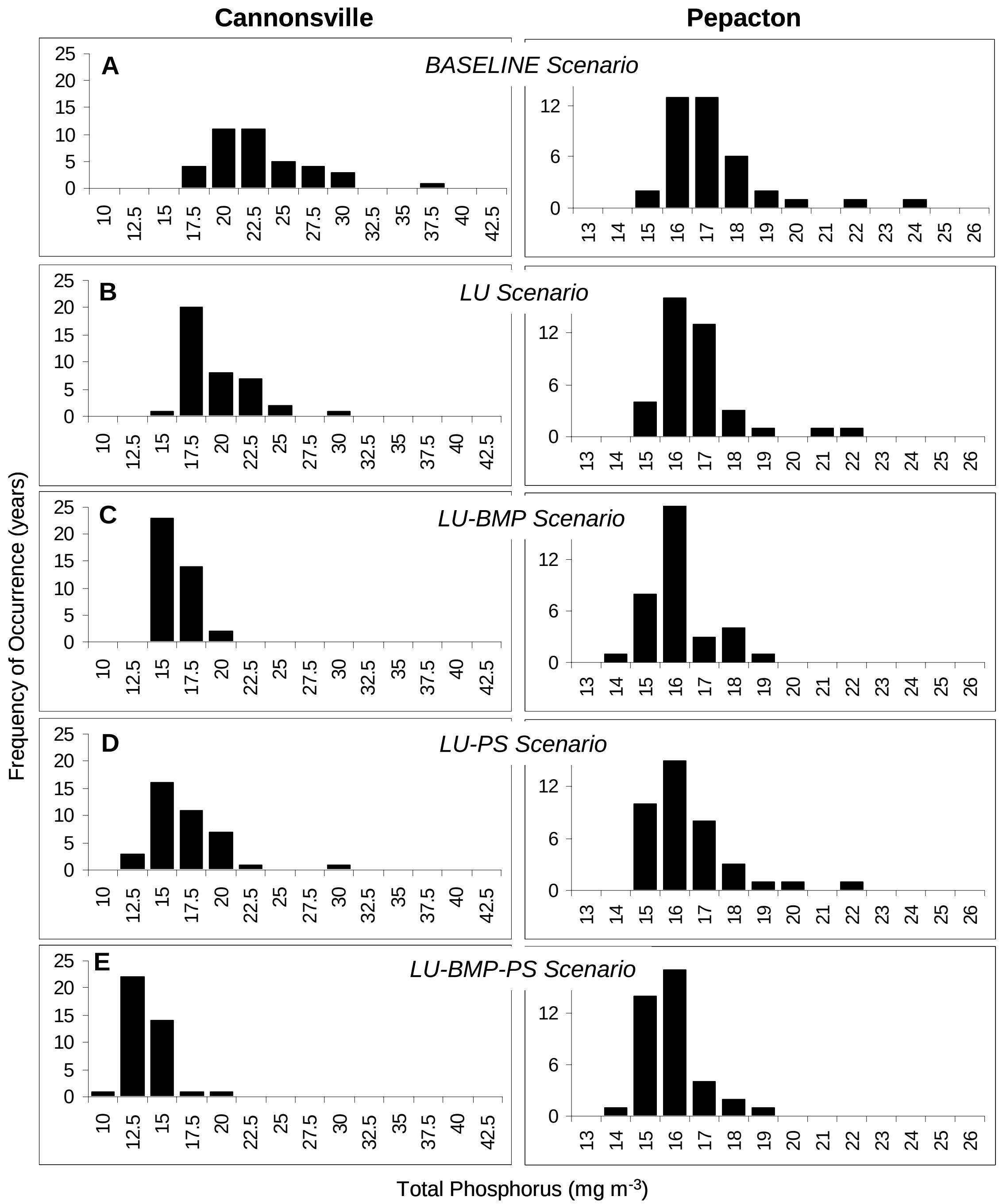


Figure 7.19 Frequency distributions of the mean summer eplimnetic total phosphorus concentrations that are calculated from the output of the reservoir model simulations of Cannonsville and Pepacton reservoirs driven by the differing nutrient loading scenarios.

Table 7.11. Long term epilimnetic mean values of chlorophyll and phosphorus calculated over all summer periods for each of the 5 scenarios. Numbers in parentheses are the percent change of the scenario mean from the baseline mean.

Reservoir	Scenario	Summer Mean Chlorophyll (mg m^{-3})	Summer Mean Total Phosphorus (mg m^{-3})
Cannonsville			
	BASELINE	9.00	21.97
	LU	7.88 (-12.5)	18.36 (-16.4)
	LU-BMP	6.93 (-23.0)	15.13 (-31.1)
	LU-PS	6.56 (-27.1)	15.79 (-28.1)
	LU-BMP-PS	5.60 (-37.8)	12.60 (-42.6)
Pepacton			
	BASELINE	4.88	16.74
	LU	4.63 (-5.2)	16.18 (-3.3)
	LU-BMP	4.39 (-10.0)	15.59 (-6.9)
	LU-PS	4.49 (-8.1)	15.88 (-5.1)

The mean summer chlorophyll and total phosphorus data plotted as a time series in Figure 7.17, are re-plotted as histograms in Figures 7.18 and 7.19. Separate histograms are plotted for each simulation scenario, and a separate series of histograms are plotted for Cannonsville and Pepacton reservoirs. Comparison of the histograms for the *BASELINE* and *LU* scenarios suggests that changes in land use alone will result in a noticeable shift to lower total phosphorus and chlorophyll concentrations, which correspond to a 13% reduction in the long term mean chlorophyll concentration and a 16% reduction in the long term mean total phosphorus concentration in the Cannonsville watershed (Table 7.11). A similar but smaller shift in chlorophyll (-5%) and total phosphorus (-3%) occurred in the Pepacton reservoir as a result of land use change.

Land use changes, as previously discussed, are pronounced due to the changing demographics in the these two reservoir watersheds, particularly the Cannonsville watershed, which has led to a reduction in agricultural activity and in the intensity of agricultural practices on the remaining agricultural land. As the Cannonsville watershed is the most intensively farmed watershed in the WOH system the shifts in epilimnetic chlorophyll and phosphorus are greatest in this reservoir.

The next two sets of histograms (parts C and D of Figures 7.18 and 7.19) show the cumulative effect of land use derived changes and the changes associated with either the implementation of watershed BMPs (*LU-BMP*) or point source upgrades (*LU-PS*). From these data it can be seen that both of these two watershed scenarios are predicted to have a similar beneficial effect on reservoir water quality, reducing the long term mean Cannonsville reservoir chlorophyll concentrations by a further 12-15% and mean total phosphorus concentrations by an additional 11-15% (Table 7.11). Of the two programs, point source nutrient reductions lead to a slightly greater decrease in the long term mean Cannonsville chlorophyll concentration, which is also evident in as shifts shown by the frequency distributions in Figure 7.18 The long term mean total phosphorus concentrations (Table 7.11) are affected similarly by both the *LU-BMP and LU-PS* scenarios; however, the total phosphorus histograms (Figure 7.19) shows a significant difference between these two scenarios. Implementation of the watershed BMP programs not only reduced reservoir concentrations of total phosphorus, but also reduced the variability in the summer epilimnetic total phosphorus values. A number of BMP programs affect storm event runoff, which increases event based phosphorus loading. Implementation of the BMP programs appears to have had a beneficial effect on reservoir water quality by reducing the occurrence of higher epilimnetic total phosphorus concentrations resulting from storm event runoff.

In contrast to the BMP programs, the PS scenario (sewage treatment plant upgrades) leads to relatively constant decreases in phosphorus loading (figs 7.7-7.8 and 7.12-7.13). While these reductions have clearly led to significant water quality improvements, improvements associated with the LU-PS scenario tend to reduce the magnitude more than change the shape of the total phosphorus frequency distributions. Differences in the total phosphorus frequency distributions between the *LU-BMP* and *LU-PS* scenarios are not closely mirrored in the chlorophyll distributions, since particle bound phosphorus is generally not bioavailable, and does not support phytoplankton growth.

The response to changes in nutrient loading associated with the *LU-BMP* and *LU-PS* scenarios, simulated to occur in Pepacton is again similar to that described above for Cannonsville, but is less distinct and of a smaller magnitude. Both non-point BMPs and point source management had a beneficial effect on reservoir water quality, reducing the long term mean concentrations of chlorophyll and total phosphorus to levels 3-5% lower than the reductions attributed solely to changes in land use (Table 7.11). There is also an indication that the *LU-BMP* management scenario led to decreased variability in the summer eplimnetic total phosphorus concentration in Pepacton, as was the case for Cannonsville; however the shift in the frequency distributions is not as distinct (Figure. 7.19)

The bottom panel (E) of the histograms (Figures 7.18-7.19) shows the cumulative effect of land use change and both watershed management programs on reservoir water quality. Both in terms of chlorophyll and TP there are significant shifts in the frequency distributions for both reservoirs, as the cumulative effects of land use change and watershed management progressively reduce nutrient loading to the reservoir. The long term scenario means (Table 7.11) shows that there is roughly a 40% reduction in chlorophyll and phosphorus in the Cannonsville reservoir. This model prediction represents a significant improvement in water quality which can be largely attributed to DEP’s watershed management programs. Furthermore, the variability in the final

LU-BMP-PS scenario frequency distributions (Figures 7.18-7.19) is also reduced relative to the *BASELINE* scenario, so that the year to year variations in chlorophyll and total phosphorus become less. This will lead not only to improved water quality, but also to lower and more predictable variations in water quality, which will in turn lead to a reservoir that is more easily managed.

The data for Pepacton Reservoir shows much the same pattern as that discussed for Cannonsville reservoir above. Here the long term mean reductions are less suggesting an overall reduction between the *BASELINE* and *LU-BMP-PS* scenarios of approximately 13% for chlorophyll and 8% for total phosphorus (Table 7.11). The relative shifts in the chlorophyll and total phosphorus frequency distributions between simulations scenarios (Figures 7.18 and 7.19) or the relative differences in the long term mean concentrations simulated for each scenario are similar to Cannonsville; however, the absolute magnitude of the differences is less. This is due to the fact that Cannonsville was the most eutrophic reservoir in the WOH system, and therefore, that the FAD watershed programs have had a proportionally greater effect there. Secondly, Cannonsville is also the reservoir watershed which had the most agricultural land use of any WOH reservoir. Implementation of agricultural BMP programs and reduction in agricultural activity therefore, has had the greatest effect on this reservoir.

In addition to examining variations in epilimnetic chlorophyll averaged over the summer period of each year, variations in daily epilimnetic chlorophyll concentrations were also examined (Figure 7.20) The medians of the scenario distributions are shown by the blue line and number at the bottom of the graphs. The upper limit of the bar plotted for each scenario is the 95 percentile level associated with the frequency distributions of the daily data from the *BASELINE* simulation for each reservoir. We took this value as a reasonable reservoir specific threshold to define extreme or “bloom” levels of epilimnetic chlorophyll. The same threshold is used for all scenarios associated with each reservoir, and each daily epilimnetic chlorophyll concentration exceeding the threshold is plotted as a point above the bar. The total number of values exceeding the threshold is also shown at the top of the graph. Values exceeding the threshold are an extreme occurrence for the reservoir in question, but do not necessarily represent an actual water quality concern.

These data show that the effects of changes in watershed land use and the implementation of watershed nutrient reduction programs, not only reduces the long term median values of epilimnetic chlorophyll, but that these changes also lead to important improvements in water quality by dramatically reducing the frequency of extreme chlorophyll values. This is an important finding since it is extreme events rather than long term averages which actually influence the usability of the reservoirs as sources of drinking water. Most regulations (i.e., TMDL calculations) implicitly assume a linkage between the occurrence of extreme events and long term mean concentrations. Here this is explicitly demonstrated.

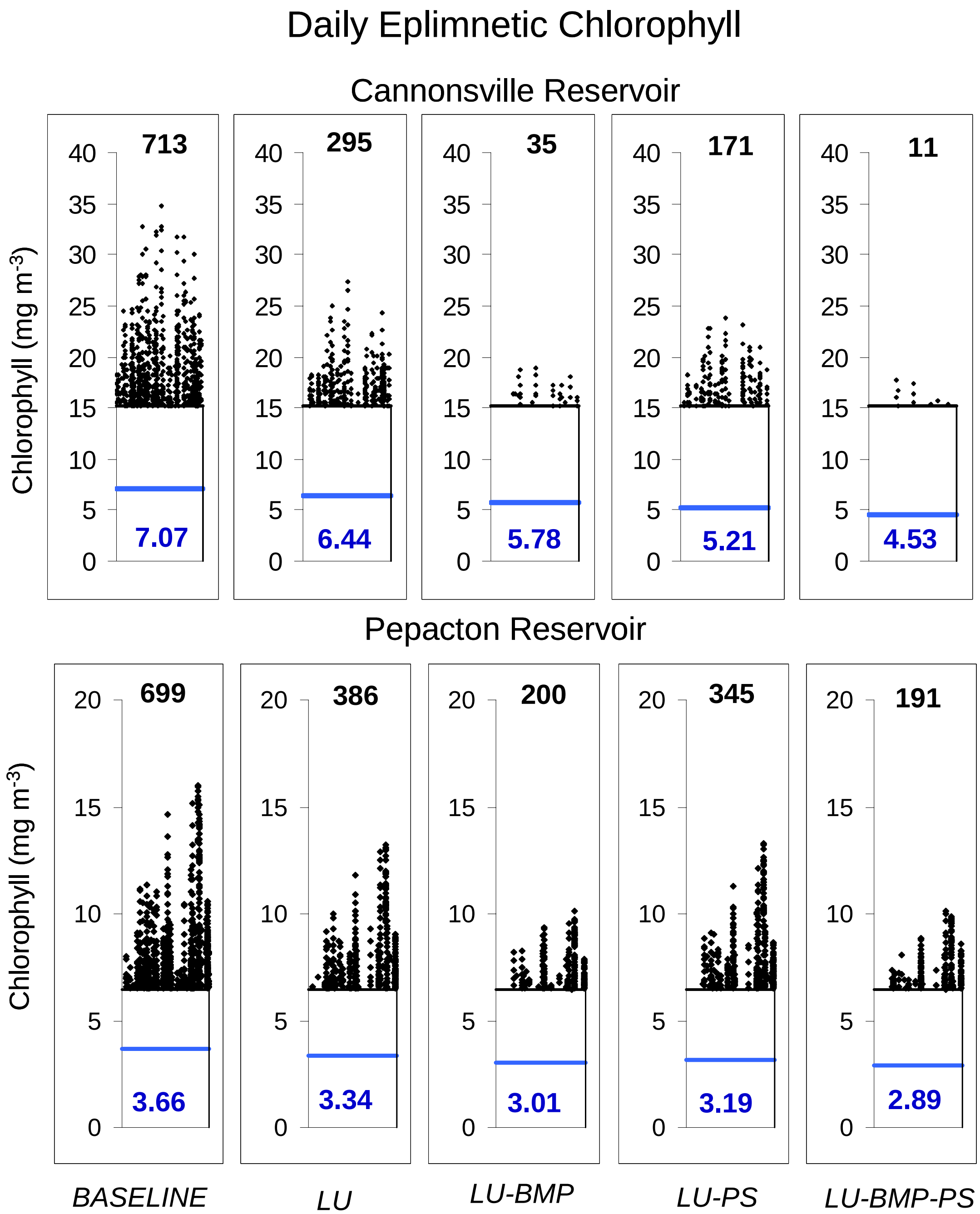


Figure 7.20 Plots based on simulated values of daily epilimnetic chlorophyll concentration. The upper limit of the bars for each reservoir is defined by the 95^{th} percentile of the frequency distribution of the *BASELINE* chlorophyll concentrations. Values exceeding this threshold are plotted as points and number of exceedances is at the top of each bar. The value of the median chlorophyll of the each scenario is show by the horizontal line and the number at the bottom of each bar.

Comparison of the *LU-BMP* and *LU-PS* scenarios further supports the contentions made above concerning the effects of these two management programs on water quality variability. Even though reductions in nutrient point sources led to similar or even slightly greater reductions in the median epilimnetic chlorophyll concentrations, implementation of the BMP programs led to a much greater reduction in the frequency of extreme chlorophyll values. The BMP programs lead to reductions in storm event runoff, and the high levels of nutrient loading that can be associated with storm event runoff. Consequently, the BMP programs also have an affect on reducing the frequency of algal blooms by reducing the nutrient loading associated with runoff events. Comparison of the final three scenarios in Figure 7.20 shows that the point source nutrient and BMP programs both have complimentary effects on reservoir chlorophyll concentration. Reduction in point source nutrients clearly leads to improved water quality by decreasing both long term average chlorophyll levels and the frequency of algal blooms. The BMP programs however, have an even greater effect on reducing algal blooms. The best outcome is achieved by implementing both programs, which leads to the greatest reductions in both long term chlorophyll concentration and in the frequency of extreme events.

7.5 Summary of Program Effects Estimated by Models

The effects of non-point source management, point source upgrades, and land use change on eutrophication in the Cannonsville and Pepacton Reservoirs were evaluated using DEP's Eutrophication Modeling System. Output from the GWLF watershed model served to provide loading estimates to evaluate various watershed programs implemented as part of the MOA. Four watershed management programs were evaluated: Point Source WWTP Upgrades; Watershed Agricultural Program; Urban Stormwater Program and Regulations; and Septic System Rehabilitation Program. In addition, a significant decline in agricultural activity that occurred from *BASELINE* to post-2000 (independent of the effects of agricultural management program) was evaluated as a land use change scenario.

Calibrated and validated GWLF models for Cannonsville and Pepacton were used to estimate nutrient load reductions from different watershed sources due to non-point source management programs, WWTP upgrades, and under *BASELINE* vs. post-2000 land use conditions. Nutrient reduction factors due to each watershed management program were estimated from BMP nutrient removal and implementation data. These reductions were applied in management scenarios to estimate the effects of the land use change and the four watershed management programs on nutrient loading and eutrophication.

Land use change (decline in agriculture) and watershed management both produced substantial reductions in predicted phosphorus loading. Loading reductions due to land use change alone were ~20% for dissolved phosphorus and 30% for particulate phosphorus in Cannonsville, and ~15% for dissolved phosphorus and ~25% for particulate phosphorus in Pepacton. The combination of land use change and watershed management produced reductions of ~46% for dissolved phosphorus and 68% for particulate phosphorus in Cannonsville, and ~27% for dissolved phosphorus and ~58% for particulate phosphorus in Pepacton. Point Source WWTP upgrades and the implementation of agricultural BMPs by the Watershed Agricultural Program provided most of the loading reductions, followed by septic system remediation. Urban stormwater management provided insignificant reductions in both dissolved and particulate phosphorus, due to the small urban land use areas that result in low contributions of urban sources to phosphorus loading under baseline conditions.

The effects of land use change, non-point BMPs, and point source management on the trophic status of the Cannonsville and Pepacton reservoirs were evaluated by driving reservoir water quality models with the different nutrient loading scenarios simulated using GWLF. For Cannonsville Reservoir, lower watershed loads due to the decline in farming that occurred between 1992 and 2004 resulted in considerable reductions of 13% for in-lake growing season chlorophyll *a* and 16% for total phosphorus. Greater reductions were predicted when non-point and point source watershed management in addition to land use change were considered (38% for chlorophyll *a* and 43% for total phosphorus). The response of Pepacton Reservoir (which exhibited less eutrophication under baseline conditions) was similar, but the magnitude of the reductions were less, suggesting that reservoirs with higher eutrophic condition tend to benefit proportionately more from watershed load reductions.

Examination of daily, as well as long term mean reservoir chlorophyll levels, suggests that the occurrence of extreme “bloom-like” epilimnetic chlorophyll concentrations are also affected by the differing nutrient loading scenarios, and that the implementation of the watershed management programs greatly reduced the occurrence of these extremes. Implementation of non-point BMPs was most effective at reducing the frequency of “bloom-like” concentrations of chlorophyll. This is apparently related to the effects of non-point BMPs on the magnitude and timing of storm event runoff, and the phosphorus loads associated with it.

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Appendices

Appendix 1. Catskill & Delaware System UV Facility and Filtration Contingency Planning

Background

In 1993 USEPA issued two Filtration Avoidance Determinations for the Catskill and Delaware Supplies that required the City to proceed with conceptual and preliminary design of a water filtration facility that could be built in the event that filtration was someday deemed necessary. The 1997 Filtration Avoidance Determination added deliverables for Final Design and the completion of a Final Environmental Impact Statement (FEIS), but included a provision for the City to seek relief from these deliverables if the remaining conditions of the FAD were being adequately addressed and the Catskill and Delaware water supplies appeared likely to meet federal water quality standards for the foreseeable future.

In anticipation of the Long Term-2 Enhanced Surface Water Treatment Rule (LT2-ESWTR), the City implemented an enhanced disinfection study which evaluated chlorine, ozone, and chlorine dioxide for use as a means of disinfecting *cryptosporidium* oocysts .Ultraviolet Light disinfection was considered but not piloted at that time.

As contemplated by the 1997 FAD, the City applied for and later received relief from the final design deliverable and related Environmental Impact Statement activities including the release of a Draft Environmental Impact Statement (DEIS) and the completion of a FEIS. As conditions for relief, the City agreed to perform biennial updates of the preliminary designs for a water filtration facility, conduct feasibility studies for ultraviolet light disinfection and if the technology was found suitable, design and construct an Ultraviolet (UV) Light Disinfection Facility.

Filtration Design Updates

The September 2001 Preliminary Design for the Catskill/Delaware Water Filtration Facility called for an 1840 mgd Ozone/Direct Filtration Facility to be built at the City-owned site known as Eastview. The project site is a divided into two sections by Route 100-C. The northern 88 acre site is located in the Town of Mount Pleasant and the southern 67 acre site is within the Town of Greenburgh. Shaft 19 of the Delaware Aqueduct features uptake and downtake shafts on the northern parcel. The Catskill Aqueduct runs adjacent to the eastern boundary of the southern parcel. A filter connection chamber for the Catskill Aqueduct is located on this site. These existing aqueduct installations were installed during the construction of the aqueduct to facilitate conveyance of Cat/Del water to and from the site. Due to hydraulic considerations the main process area was sited on the northern tract, while the residuals management facilities were to be located on the southern parcel. Neighbors of the site include Westchester Medical Center, Westchester County Correctional facilities, the Bee-Line Bus garage, emergency training facilities, a corporate park and a small residential community.

In September 2003 DEP submitted the first biennial update of the preliminary designs for the Catskill/Delaware filtration facility. Since the designs were first completed, DEP had conducted a master planning workshop which considered siting several additional facilities at Eastview. In addition to being the proposed site for a new DEP police precinct as well as uptake and downtake shafts for the future Kensico-City Tunnel, the Eastview site was one of three locations being evaluated for the Croton Filtration Facility. Coordination with these additional projects, primarily for site layout, was addressed in the design update.

The latest filtration Design Update was completed in September 2005. This update focused on the effect on the filtration plant layout and elevations based on hydraulic analyses which accounted for the UV facility being downstream of a future water filtration facility. The modifications to the layout for the Filtration facility also account for changes to the site layout for facilities planned for the Eastview site, namely the final plans for the police precinct and the potential for connections to the Kensico-City Tunnel. The update also accounted for the removal of the Croton Filtration Facility from the Site Plan following the decision to construct the Croton facility in the Bronx.

Changes to the hydraulic profile were made in response to an increase in head losses due to the relocation of flow control from Kensico to Eastview, the substitution of venturi meters for the ultrasonic meters that were previously specified for downstream flow measurement, and changes to the path for plant effluent including a new flow control weir and changes to the treated water piping at the connection chamber on the Catskill Aqueduct. The next filtration Design Update will be submitted in September 2007 as required by the Filtration Avoidance Determination.

Feasibility Studies for Ultraviolet Light Disinfection

Following an initial assessment of the feasibility of using Ultraviolet Disinfection as a second means of disinfection for the Catskill and Delaware supplies, the City conducted a UV Feasibility and Planning/Peer Review Workshop on November 1, 2001. Based on UV Feasibility Assessment completed in December 31, 2001, the City proposed the use of UV disinfection as an additional barrier which would significantly enhance the City's water supply protection program. When the City applied for relief from the deliverables related to the further advancement of designs for the filtration facility a series of new deliverables related to UV were developed including an in-service date of August 31, 2009. These changes were established in correspondence dated November 29, 2001 and later incorporated into the 2002 FAD.

Conceptual Designs for UV Disinfection

As originally conceived, two separate UV disinfection facilities were to be built at Kensico Reservoir (one for Catskill Supply and the second for the Delaware Supply). At the time, this configuration seemed the most expedient means of implementing UV disinfection. Following a master planning workshop held by NYC DEP in September 2002, the project team reevaluated three potential project sites, including city owned land at Kensico and Hillview Reservoirs, and the Eastview site. It was determined that the City's long-term needs would be better served by siting a 2020 mgd UV disinfection facility to treat the combined flows of the Catskill and Delaware Supplies at Eastview. Due to the high capacity of the facility it was determined through a cost/benefit analysis that 56 – 40 mgd units should be incorporated into the design.

UV Disinfection at Eastview

The UV Facility will be constructed along the Eastern side the northern Eastview Parcel. At start-up, water from the Delaware Aqueduct will enter the facility through the North Forebay and will be delivered to downstream consumers through the Catskill and Delaware Aqueducts. Provisions have been made for future connections to the North Forebay to be made from the Catskill Aqueduct, the Kensico-City Tunnel and the proposed Catskill/Delaware water filtration facility. The current design also provides for the return finished water to the Kensico City Tunnel and provides design elements to facilitate connections for local consumers. During earlier stages of the UV design process, the Eastview site was also under consideration for the Croton Water Filtration Facility. The City has since initiated Site Preparation activities for the Croton facility at the Van Cortlandt Park project site in the Bronx and no longer needs to reserve space in the Eastview site for this facility.

Value Engineering

During the week of August 4, 2003 the first of two value-engineering (VE) workshops was conducted by the City's Office of Management and Budget. A second VE workshop was conducted during the week of September 20, 2004. For the VE workshops teams of academic and industry professionals were gathered to review and assess the conceptual and preliminary facility designs respectively. Value-engineering workshops are structured forums that begins with a presentation by the design team and a review of the projects goals. The next phases of the workshops includes an analysis of the specific functions of the proposed facility and a brainstorming session to identify modifications to the design that address specific facility needs. These suggestions are then ranked and reviewed with DEP to ensure that suggested alterations to the project would not be prohibited. Top ranked suggestions are then developed and their implementation costs or related costs savings are calculated. A closing session is conducted to share the recommendations of the VE team with the design team. Following a period of review and evaluation, an implementation meeting is held to discuss which proposals would be implemented, studied further or rejected.

As a result of the first VE workshop the design team was advised to consider eliminating the superstructure above the forebays at Shaft 19 of the Delaware Aqueduct, optimizing the UV design dose based on guidelines presented in the UV guidance manual, reducing the length of the UV reactors, associated influent and effluent piping to lower related infrastructure and maintenance costs, collecting UVT data using an integrating sphere and recalculating the UV system requirements accordingly, consider using 80 mgd medium pressure UV reactors, and modify the emergency power generation configuration. While some of these recommendations received further study and were partially incorporated into the facility design, DEP found that many of these recommendations could not be implemented.

Following the second VE workshop the following design changes were implemented: Six motorized sluice gates were eliminated and replaced by stop shutters at the emergency bypass structure, Roller gates were substituted for 10 sluice gates in the raw and filtered water conduits at the North and South Forebays facilitating the elimination of the superstructure at Shaft 19, where practical, controlled low strength material has been substituted for reinforced concrete for pipe encasement in low load areas and outside the UV facility, the green roof zones above the were reevaluated, knife gates were substituted for full-bore gate valves at the UV reactor inlets.

Lamp Technology & Equipment Selection

Two types of UV lamps are widely used in the drinking water industry -- low pressure/ high output, and medium-pressure lamps. These designations refer to the operating pressure of the mercury within each lamp. While there are differences in their properties, each delivers light within the germicidal wavelength of 230-300 nanometers (nm). Low-pressure/high output (LPHO) lamps deliver nearly monochromatic light with peak wavelengths at 185 nm and 253.75 nm. Due to the natural absorbance of water (up to 220nm), only the peak at 253.7 nm will be applicable for the disinfection of microorganisms in drinking water. Medium-pressure (MP) lamps deliver polychromatic light with wavelengths within and beyond the germicidal range.

DEP determined that it would be prudent to avoid using parallel design tracks to support bidding opportunities for two different lamp technologies. In addition to streamlining the eventual procurement of UV disinfection equipment, the selection of a single lamp technology allowed the design team to focus their attention on a single design and eliminate the need for performing numerous validation scenarios and additional environmental assessments. To assist in the decision between the two lamp technologies, conceptual plans were developed for both LPHO and Medium pressure UV facilities and estimates for the costs of construction and operation of the two facilities were prepared. These costs, as well as several non-economic factors including ease of operation, likelihood of technological improvement and availability of manufacturers, provided the basis for comparing the two technologies.

On June 24th and 25th representatives from DEP and the JV visited several UV disinfection installations to observe both medium pressure and low-pressure/high-output UV equipment in operation. In Westview, Pennsylvania the project team was able to inspect a single Calgon Corporation Medium Pressure UV reactor. In Clayton County Georgia the team visited two facilities featuring Wedeco Low Pressure/High Output UV equipment. In addition to observing the UV facilities, the tour participants had the opportunity meet and interview facility operators about their experiences with the selection, installation, testing, operation and maintenance of the UV equipment. Though all of these facilities were installed downstream of pre-existing water filtration plants, each had unique design characteristics (lamp type, design flow, dose, etc.). Observations gathered during these facility visits enabled the design team to identify possible improvements to the Catskill/Delaware designs and to better understand the differences between medium pressure and low-pressure/high-output installations that were not readily apparent from technical literature. As a result of these visits and economic and non-economic evaluations, DEP selected the low-pressure/high-output UV technology.

A Request for Expression of Interest was published in the Engineering News Record (ENR) on November 10, 17 & 24, inviting Low-Pressure/High Output UV vendors to identify their interest in this project. Three vendors responded; Wedeco, Trojan Technologies and Ultratech/Emcor. The three UV System Suppliers were invited to enter into Memoranda of Understanding that outlined their intentions to supply a custom fabricated test-unit for validation and provided sealed pricing information for the disinfection equipment and various replacement parts. Guarantees concerning life expectancy of the various components were also incorporated into the sealed bids. Each vendor was expected to provide detailed shop drawings and equipment modeling information prior to delivering their equipment for validation. By mutual consent, Ultratech/ Emcor was dropped from further consideration, while Trojan and Wedeco proceeded with validation of their equipment.

Full-Scale Validation of UV Disinfection Equipment

Due to lack of an adequately sized validation facility and the need for custom-fabrication of 40 mgd units, the City and their design consultants, the Joint Venture of Hazen and Sawyer/ CDM, proposed the use of computer modeling as a means of validating the disinfection equipment for the facility. With the cooperation of Fluent, Inc. and Bolton PhotoSciences, Inc. the project team developed models which combined computational fluid dynamics (CFD) with light intensity distribution (LID) techniques for UV disinfection equipment representing different "off-the-shelf" sizes/lamp types and different manufacturers that could be used to predict *cryptosporidium* inactivation. By comparing these predictions to actual results from bio-assay testing for the same units, the team concluded that validation through modeling was possible. For added assurance NYSDOH conducted "blind" testing using data from UV disinfection equipment that had not been previously modeled. Though the results of the computer-based modeling effort were found to be within appropriate limits of confidence, there remained concern for the ability to adequately "scale-up" the models for validating 40 mgd units. NYCDEP was asked to provide full-scale bio-assay testing of the actual units that would be installed in the facility. Once full-scale testing showed that UV disinfection could be achieved by the 40 mgd units, and adequately modeled, a CFD/LID model of the equipment could be considered for future applications on the project.

With the absence of a validation facility capable of handling flows equal to or greater than 40 mgd, the City evaluated scenarios and sought a location for conducting full-scale validation. City owned properties within the watershed, wastewater treatment facilities within City limits and several opportunities presented by outside parties for development and use of validation facilities in other US locales including Portland Oregon and Chattanooga, Tennessee were considered. To conduct bio-assay validation the following requirements needed to be met:

- A suitable supply of source water (+/- 1.5 MG per run of water with appropriate water quality characteristics)
- The infrastructure to deliver, spike, treat, test and dispose of the water used in testing at a flow rate no less than 40 MGD
- Challenge microbes (or suitable surrogate) in volumes to support multiple runs
- Ability to achieve or simulate a range of UV transmittance conditions
- Superstructure to house testing equipment and support facilities (i.e.: electrical equipment and storage space)

Concurrent with this effort, the New York State Energy Research & Development Authority (NYSERDA) convened a Technical Advisory Committee (TAC) to assist in the development of a regional validation facility in the Northeast. Representatives from NYCDEP, NYSDOH and USEPA and the engineering design and academic communities were invited to participate on the TAC and were made aware of an opportunity to conduct validation testing at the Johnstown/Gloversville wastewater treatment facility in New York State. Though testing facilities for units as large as 40 mgd were not originally contemplated by NYSERDA, the City was able to develop an additional test-stand at the UV Validation and Research Center of New York.

The Johnstown/Gloversville wastewater treatment facility offered access to sufficient volumes of high quality drinking water through a connection to a fire hydrant on the local distribution system which allowed for a wide range of operating conditions The infrastructure to deliver, spike, disinfect, test, treat and dispose flows up to a rate of 60 mgd was installed by Hydroqual, Inc.. Testing protocols which were developed in conjunction with a Peer Review panel with input from US EPA and NYSDOH were executed by representatives from Hydroqual, Inc. in the presence of an observer from the Joint Venture. Lignin sulfonate was used to alter the transmissivity of the water and MS-2 was used as a surrogate organism for *cryptosporidium*. Full-Scale testing of equipment by Trojan Technologies and Wedeco was performed between mid-March and late-September 2005 and both units met or exceeded the validation criteria. Using the price commitments which were provided in Memoranda of Understanding (MOUs) prior to validation, a recommendation for a UV system supplier for the project was established. On October 13, 2005, DEP notified the two UV system suppliers that Trojan Technologies was selected to provide all fifty-six full-scale UV disinfection units for the project. In correspondence summarizing the validation results, DEP notified NYS DOH that the disinfection equipment from Trojan Technologies met the design criteria and would be incorporated into the final designs for the Cat/Del UV facility.

Though 40 mgd was the design point established for the UV equipment, the Trojan Technologies reactor was successfully tested for flows up to 60mgd. While the average UV Transmittance for the Cat/Del supplies is 91%, the 5^{th} percentile value of 87% UVT was specified for design purposes. According to UV dose recommendations cited in LT2-ESWTR 3 log *cryptosporidium* inactivation is likely to be achieved using design doses equal to or less than 36 mJ/cm^2, however the design dosage for this facility was set at 40 mJ/cm^2 to ensure compliance with NYS DOH standards. The facility will be capable of achieving 3-log *cryptosporidium* inactivation, but will follow an operational goal of 2-log inactivation. Combined with chlorination, the City will be able to achieve 4-log inactivation of viruses and 3-log inactivation of *giardia*.

Catskill Aqueduct Investigations/ Catskill Aqueduct Pressurization

As currently configured, the Catskill Aqueduct delivers water from Kensico Reservoir to the Eastview site at an operating head which is too low to meet the hydraulic gradeline of the proposed UV disinfection facilities. To meet the design flow of the proposed UV facilities and address DEP's concerns for redundancy and reliability DEP is planning to pressurize the Catskill Aqueduct between Kensico Reservoir and Eastview in order to raise the hydraulic gradeline approximately 44 feet. This will allow DEP to continue delivering water to it's consumers through a gravity fed system.

With the assistance of Jenny Engineering Corporation (JEC), a JV sub-contractor, DEP and the JV conducted a series of seven short term aqueduct shut-downs in late-Winter and early-Spring 2004 that allowed personnel to enter the 12,500 foot long segment of aqueduct between the Upper Effluent Chamber at Kensico Reservoir and the connection chamber at Eastview. In addition to conducting visual inspections, sonic and ultrasonic testing was conducted and ground penetrating radar was used to assess the thickness of the tunnel lining and locate voids in the vicinity of the aqueduct. Windsor probes were used in the vicinity of core sample collection points. Information from these tests provided insight into the aqueduct's ability to withstand pressurization. Where groundwater intrusion was encountered, water samples were collected. These samples were tested to assess the likelihood of corrosion of any materials to be used in the aqueduct.

Following the inspections, staff from JEC, the JV and DEP continued evaluations with regard to pressurizing the Catskill Aqueduct. The results of the inspections have been compiled in a draft inspection report dated March 2005 which includes an evaluation of the repairs needed in the Aqueduct and the recommended method for connecting to the Eastview site (tunnel or pipelines/conduits). Since this section of the aqueduct includes siphons and grade tunnels each with different types of construction and tunnel shapes, various alternatives for pressurizing the aqueduct and connecting the proposed bypass chamber with the influent forebay for the UV facility (drift tunnel) have been developed. Three alternatives differentiated by the amount of leakage that will be considered acceptable for the rehabilitate conduit have been developed. They range from a watertight option to an option featuring limited and site specific grouting. Three alternatives have also been developed for the path of the drift tunnel; one based on developing the bypass chamber near the existing Catskill Connection Chamber, the second is geographically closest to the forebay and the third avoids the brick-lined portion of the Eastview tunnel. In anticipation of the series of seasonal shutdowns that will need to be implemented to affect pressurization, DEP has been communicating with consumers along the Catskill Aqueduct between Kensico and Hillview Reservoirs, to ensure that each community has a reliable alternate water source.

The City intends to negotiate for a design services contract with the Joint Venture to advance designs for pressurizing the Catskill Aqueduct using the alternatives that provide a drift tunnel which avoids the brick-lined section of the existing aqueduct and provides an adequate seal on the aqueduct without seeking watertight conditions. The schedule for the series of seasonal shutdowns to perform the work necessary to seal and reconfigure the aqueduct will be developed under this contract

EIS/Site Plan Approval

In accordance with the FAD, the City compiled a Draft Environmental Impact Statement (EIS) which presented the project, identified potential impacts and project alternatives and proposed on- and off-site mitigation measures. Following a period for public review and comment the City issued a Final Environmental Impact Statement. The Notice of Completion issued on November 30, 2004 Significant Impacts related to operation of the facility were cited in the areas of traffic, historic resources and natural resources. In addition, temporary impacts due to construction were identified for noise, traffic and neighborhood character. A detailed description of these impacts and recommended mitigation measures is provided in the two-volume Final Environmental Impact Statement.

In addition to the Towns of Mount Pleasant and Greenburgh, the host communities for the UV Disinfection Facility, several Federal, State, local and City entities were identified as having discretionary actions or approval related to the advancement of the project. A detailed listing of the involved and interested agencies is provided in the FEIS. Copies of the FEIS and the Notice of Completion have been placed in repositories in New York City, and Westchester County. A copy is also available via the NYC DEP website.

Following a series of public meetings with officials from the Town of Mount Pleasant, the City was granted Site Plan Approval was granted on May 16,2005 for the work proposed at the Kensico and Eastview Sites as well as along the length of the Catskill Aqueduct within Mount Pleasant which is to be pressurized.

2005 Modifications to the Project Schedule

Due to the change in the project site to the Eastview and the decision to proceed with full-scale bio-assay validation the City submitted correspondence to US EPA in August 2005 requesting modifications to the project schedule. The request, which was consistent with ongoing discussions between representatives from the City, USEPA and NYSDOH proposed a modified project schedule that incorporated interim milestones and phased construction and in-service dates. The proposed schedule was based upon the presumption that the City would receive three outstanding permits (including a building permit from the Town of Mount Pleasant; a Section 401 permit from the New York State Department of Environmental Conservation and a Section 404 permit from the United States Environmental Protection Agency) on or before September 15, 2005 and provided for financial penalties if the permits were in place by this date and future milestones were missed. The need for further schedule modification in the event that the remaining permits were not secured by this date, was equally noted.

Site Preparation Contract

Bids for CAT-200 SP, the site preparation contract were received on March 15, 2005 and a contract was subsequently awarded to the low bidder, Granite Halmar in May 2005. Although the contract with Granite-Halmar was registered in August 2005, commencement of construction was prevented by a delay in securing a Section 404 "Protection of Waters" permit from the United States Army Corps of Engineers. Citing concerns for their ability to maintain their bid prices and retain use of their proposed off-site work zones due to this delay, Granite Halmar withdrew their bid on December 19, 2005. Although the US Army Corps permit was issued on December 23, 2005, the City no longer had a contractor available to commence work. The City immediately evaluated three options for securing a new contractor for the Site Preparation work; including establishing a contractual relationship with the second bidder; re-bidding the contract; and repackaging the contract along with the facility construction work and releasing the combined contract for bid and determined that it would be most expeditious to establish a contractual relationship with the original second bidder, ECCO III. NYCDEP met with ECCO III on January 13, 2006 to discuss their interest in proceeding with contract registration using their original bid price. Subsequent to this meeting ECCO II submitted the necessary procurement documents and an award package has been submitted for approval by the City.

Permits

Consistent with discretionary actions and approvals cited in the EIS, the project team has been working with various federal, State and local agencies to secure permits necessary to execute the project designs. To date, the following permits have been obtained;

- Dredge and Fill Permit/Freshwater Wetlands (ACOE) - Clean Water Act Section 404 Permit,
- 401 Water Quality Certification from NYSDEC,
- Town of Mount Pleasant Building Permit including permit to Excavate and Remove Soil,
- SPDES General Permit (GP-02-01) for Stormwater Discharge from Construction Activity from NYS DEC (including SWPP for Kensico, NOI and 5-Acre Disturbance Waivers for Eastview and Kensico),
- Memorandum of Understanding with SHPO concerning resource recovery work at Eastview and Letter of Resolution from same for filling and landscaping aerators at Kensico,

- Highway Work Permit and Traffic Enhancement Permits from NYSDOT for hauling fill material between Eastview and Kensico,
- Permit to perform work on a County Road and County Road Access permits from Westchester County , and
- Special Use Permit, Site Plan Approval and Wetlands permit from Mount Pleasant.

Several actions related to the facility construction contracts remain under discussion or review with the Towns of Greenburgh and North Castle, Westchester County and NYS DOT and all are expected to be resolved in the near future.

Final Design

Final Design was completed in November 2005. To facilitate review of the design deliverable submitted on November 30, 2005, a design review meeting for representatives from NYSDOH and USEPA was conducted on December 1, 2005. In addition to the incorporation of drawings and specifications consistent with the selection of the Trojan Technologies as the UV system Supplier, the facility designs were modified to include the use of energy dissipation valves for flow control and related modifications to Shaft 19 of the Delaware Aqueduct as well as the proposed North and South Forebays. Details for many other aspects of the facility have been fully developed since preliminary design. They include but are not limited to:

- Completing a detailed layout of the UV building process area, including HVAC, electrical, and plumbing facilities, based on information provided by the UV system suppliers,
- Further developing and detailing the layout of administrative areas in the UV building including offices, laboratory and control room, following a series of focused meetings on laboratory and electrical requirements,
- Providing a detailed layout of the Generator Building in its relocated position at the northeast corner of to the UV Building,
- Refining the requirements for emergency power and UPS, including the development and submittal of an emergency power plan,
- Evaluating the fire protection and plumbing design together for building code compliance,
- Advancing the site layout and road system around the UV facility and related structures, including the stormwater management system with its detention basins,
- Incorporating provisions for raw and treated water sampling,
- Developing details for modifications to the Catskill Connection Chamber, including provisions for drains and sampling,
- Assessing flow control provisions including the requirements for possible future connections to the KCT at Eastview,
- Providing additional details or the security system to be provided for the UV facility, including its integration with the DEP Police facility and site entrance, and
- Confirming the basis for developing detailed cost estimates based on the final design documents.

Following a series of telephone calls and a work session following the monthly progress meeting in December 2005, NYS DOH issued a letter endorsing the facility design.

Inspection of the Filter Connection Chamber at Shaft 19 of the Delaware Aqueduct

Detailed inspections of Delaware Aqueduct Shaft 19 were conducted to assess the condition of the substructure and to verify facility dimensions. A remote operating vehicle (ROV) was used to inspect the drain valve at the bottom of the uptake shaft and waterways. This work was conducted in combination with cleaning of the stop shutter grooves. Following a brief interruption of the manned inspections for remediation of asbestos containing materials found atop the substructure, the inspection program was completed on the morning of December 2, 2005. A report on the findings of the inspections is being developed. Overall, the structure was found to be in good condition. The report will make recommendations for any necessary rehabilitation and will provide documentation of as-built dimensions and current conditions

Facility Construction

To avoid a substantial delay between the opening of bids for the facility construction contract and the period when work could commence and risk repeating a loss of contractors for the facility construction contracts as a resulted of outdated bids, the City intends to delay release of the bid documents until after the Site Preparation Contractor has begun work. Once the Site Preparation work is underway, the City will be able to establish an appropriate start date for the facility construction contracts. At that time, a revised project schedule will be developed and provided to USEPA for consideration.

Pilot Studies (UV Lamp Fouling Study)

Modifications were made to the original SPDES permit application for the pilot study at Kensico Reservoir/Shaft 18 to allow. NYSDEC approved the SPDES modification request on November 7, 2005 to allow for a change in the discharge location due to problems with the originally proposed catch basin. The SPDES expiration date is October 31, 2010. This modification was required to include an additional outfall location at Shaft 18 to temporarily accommodate the total amount of finished water for the pilot study. Pilot facility set-up continued and the and the final power connections were completed on December 20, 2005.

Start-up activities for the pilot-scale UV equipment fouling study began on January 15, 2006. Following a series of visits by the UV equipment representatives for equipment testing, programming and minor troubleshooting including periodic problems with the electrical system and remote alarm systems, the project team has began collecting usable data points in mid-February

AWWARF Research

The American Water Works Association Research Foundation (AwwaRF) serves as a centralized non-profit research organization fro the drinking water community as is dedicated to advancing the science of water to improve the quality of life. As an AwwaRF subscriber, the City has been afforded opportunities to support, contribute to or sponsor research projects compatible with current or future water supply projects. As the Cat/Del UV disinfection facility will be the largest such facility in the world we are actively involved in several research projects related to the application of UV disinfection for drinking water supplies.

DEP currently serves as the project sponsor for AwwaRF Tailored Collaboration Project No. 2983 – Optimization of UV Reactor Validation. The cities of Phoenix, Arizona and Tacoma, Washington have agreed to co-sponsor this work. The research will be working toward four research goals:

1. Identification of a new microbial surrogate for *Giardia* and *Cryptosporidium*;
2. Identification of an absorbing chemical that mimics low UVT waters better than the surrogates currently available;
3. Analyze the impact of lamp and sleeve aging on dose delivery and monitoring; and
4. Experimental verification of potential UV reactor validation tools.

To date, the study has evaluated several bacteriophage and found that some available surrogate organisms, such as T7 and SP8, while providing closer matches to the UV dose response curves than MS2 do not titer in significant concentrations. Q-Beta has a dose response characteristic that could reduce RED bias by approximately 25% and has been identified as the best alternative to MS2. Work will continue on other phages.

Findings indicate that lignin sulfonate and coffee are still most the feasible agents for establishing an array of UV absorbance conditions during validation. Although a number of UV absorbing compounds were evaluated to more closely simulate operating conditions during validation, limited availability of the products tested hinder their widespread application. This work is more applicable to the polychromatic light applied in Medium Pressure UV systems.

A third component of the research focuses on the effects of lamp aging on dose delivery. As expected, output from aged lamps appears to be less uniform at the ends of the lamps than at the middle of the lamps. As a result the placement of sensors at different points along the lamps will be critical as results from various segments of the lamp will predict in a wide array of germicidal effects -- some over-estimated and others underestimated.

This research project is progressing under the guidance of a research team at Carollo Engineers and is expected to reach completion in mid-2006.

DEP also participated in the following Cat-Del related AWWARF Projects:

AWWARF Project No. 2568 - Tailored Collaboration Study for Membrane Treatment of Filter Backwash Water for Direct Reuse. DEP met with representatives from the New York Power Authority, New York State Energy Research and Development Authority and CDM (as Lead Researcher) on November 18, 2005. A site visit was also conducted at the UV pilot plant located at Kensico Reservoir. Following successful start-up of the UV pilot study, equipment procurement, installation and start-up will be initiated for this AwwaRF study.

AWWARF Research Study No. 2861 – Integrating UV Disinfection Into Existing Surface Water Treatment Plants. The goal of this project was to develop tools that can help utilities decide whether UV disinfection should be used (even when not required by regulation) and if so, how the technology should be implemented. Participation in this project afforded DEP the opportunity to address some issues related to integrating UV into our existing infrastructure and treatment regime (chlorination and fluoridation). The final report for the project was issued by AwwaRF in 2005.

Appendix 2. Cross Connection Control Program

Cross Connections in a drinking water distribution system are a potential source of contamination. Cross connections can be caused by improper or direct connections, excessive back pressure on the system, back siphonage and other reasons. It is important to eliminate areas where such conditions exist to eliminate the possibility for cross connection contamination. DEP's Cross Connection Control Program has as its primary objective the avoidance of any potential for backflow from within premises to the public water supply system. To accomplish this objective, property owners are required to install backflow prevention containment devices in water service lines for premises that pose a potential hazard. After installation, backflow prevention containment devices are required to be tested by a certified tester at least once a year.

Since the promulgation of the 2002 FAD, DEP's Bureau of Water and Sewer Operations (BWSO) has achieved or exceeded most FAD goals for the program. Implementation of DEP's Cross Connection Control Enforcement procedures in September 2002, has accelerated the rate of achievement of compliance for "High Hazard" premises. The enforcement procedure involves issuance of letters, Commissioner's Orders, Notices of Violations, Environmental Control Board hearings, Cease and Desist Orders, and termination of water service. To date, water service has been terminated for three buildings due to failure to install backflow preventers.

One notable change to the program since its inception has been a shift in reliance upon preliminary inspections of "High Hazard" premises. In the initial stages of the program, more than 20,000 facilities were identified as possible "High Hazard" locations based on several parameters (facility type, commercial/residential, facility size, etc.). After these 20,000 facilities were identified, DEP inspectors proceeded to determine which facilities warranted more detailed inspections based on "drive by" preliminary inspections. As the program became further developed, DEP recognized that these preliminary inspections served little value as it was increasingly difficult to assess whether a facility required a more in-depth full inspection based on a curbside assessment. Therefore, DEP has chosen to phase out the preliminary inspection step and opt for routine performance of a complete full inspection of "High Hazard" locations. By concentrating efforts on "High Hazard" inspections and enforcement, DEP believes that the most hazardous premises will achieve compliance in a more effective and timely manner.

Based on building data provided by the NYC Department of Buildings, DEP has established a list of about 24,251 potentially "High Hazard" premises. Due to discrepancies in addresses, blocks, and lots, 2,721 of these locations warrant further investigation before an inspection can be performed. Of the remaining 21,530 "High Hazard" premises, 3,038 (14.1%) enforcement actions have been initiated. This includes enforcement where inspection was done prior to January 1, 2001.

DEP also pursues enforcement of annual test requirements for cross connection control containment devices. Property owners who fail to submit test reports annually are issued a Notice of Violation. This new protocol has resulted in a significant increase in the number of test reports received. In 2005, DEP began a program of calendar year compliance for annual testing. This program ensures issuance of Notices of Violations to property owners who failed to submit annual test reports during the previous calendar year.

Appendix 3. Water Quality Data Analysis

Status and Trends

Sites

Site selected for water quality status and trends are listed in Table A.1 and shown pictorially in Figures A.1 and A.2. The reservoirs evaluated are: all reservoirs in the Catskill and Delaware systems; West Branch Reservoir, which acts as a balancing reservoir for water received from Rondout Reservoir; Kensico Reservoir, which is normally the main source reservoir for the entire system; and Cross River and Croton Falls reservoirs because water from these reservoirs may, on occasion, be pumped into the Delaware Aqueduct prior to its entering Kensico Reservoir.

Table A.1. Inputs (streams and aqueduct keypoints), reservoirs, and outputs (aqueduct keypoints and releases) included in the water quality status and trends analysis.

System/District	Inputs[1]	Reservoirs[3]	Outputs[1]
Catskill	S5I[s]	Schoharie (SS)	SRR2
	E16I[s]	Ashokan (West—EAW)[2]	—
	—	Ashokan (East—EAE)[2]	EAR
Delaware	NCG[s]	Neversink (NN)	NRR2
	PMSB[s]	Pepacton (EDP)	PRR2
	WDBN[s]	Cannonsville (WDC)	WDTO
	NRR2[k], PRR2[k], WDTO[k], RDOA[s]	Rondout (RR)[2]	RDRR
east of Hudson	DEL9[k], BOYDR[s], HORSEPD12[s]	West Branch (CWB)[2]	DEL10
	CATALUM[k], DEL17[k], WHIP[s]	Kensico (BRK)[2]	CATLEFF, DEL18
	—	Cross River (CCR)[2]	CROSSRVR
	—	Croton Falls (CCF)[2]	CROFALLSR

[1] Keypoints have been abbreviated as above, omitting, as appropriate, the last two letters of the code, CM (Continuous Monitoring), for ease of use. These letters were added to the code for WOH keypoints within the last two years of this study period. The superscripts [s] and [k] refer to streams and keypoints, respectively; all outputs are keypoints except for CROSSRVR and CROFALLSR which are releases.

[2] Indicates a source or potential source water.

[3] The reservoirs listed are represented by an amalgam of multiple locations and depths (see text).

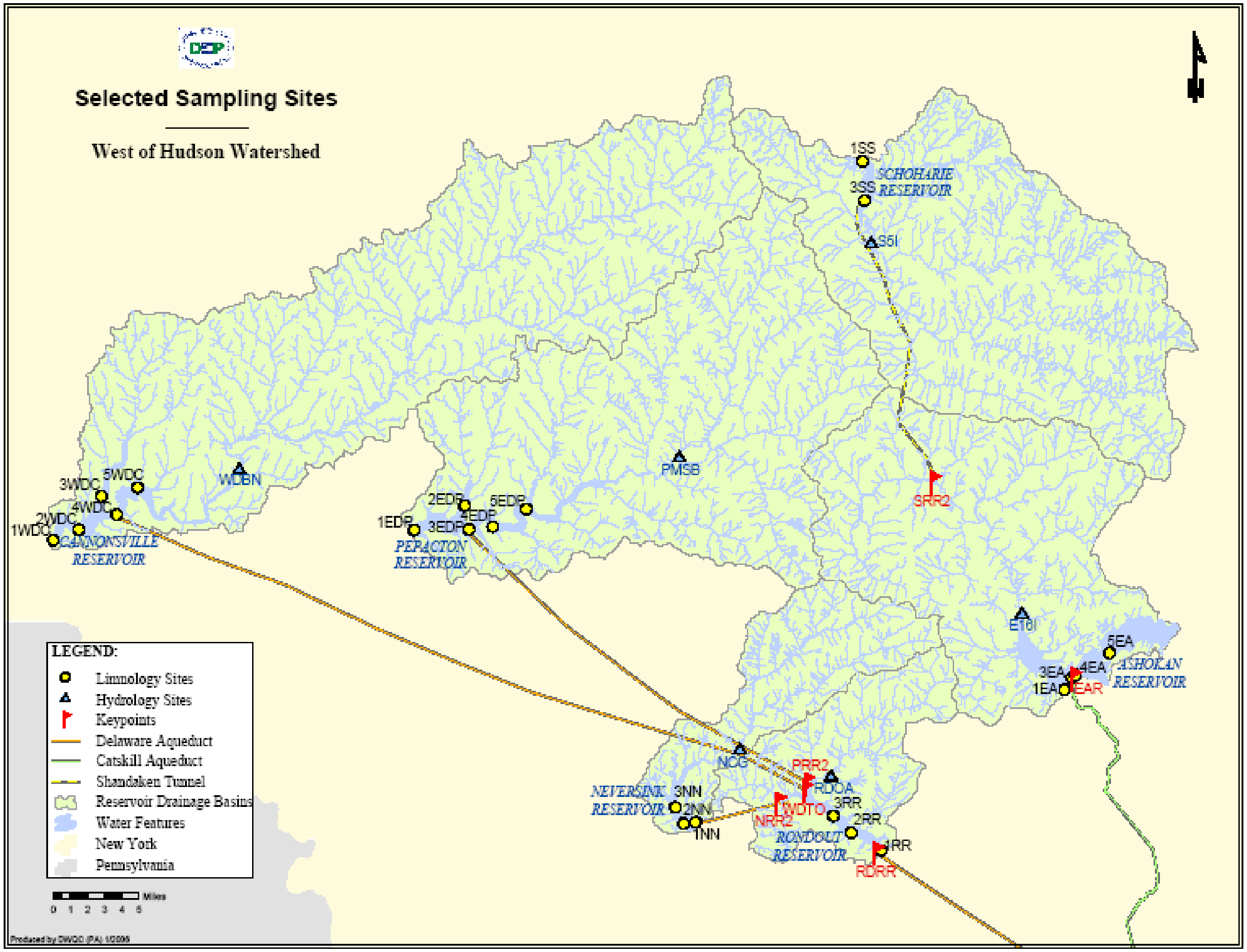

Figure A.1 Map showing the sites included in the status and trends analysis for the west of Hudson reservoirs, aqueduct keypoints, and streams.

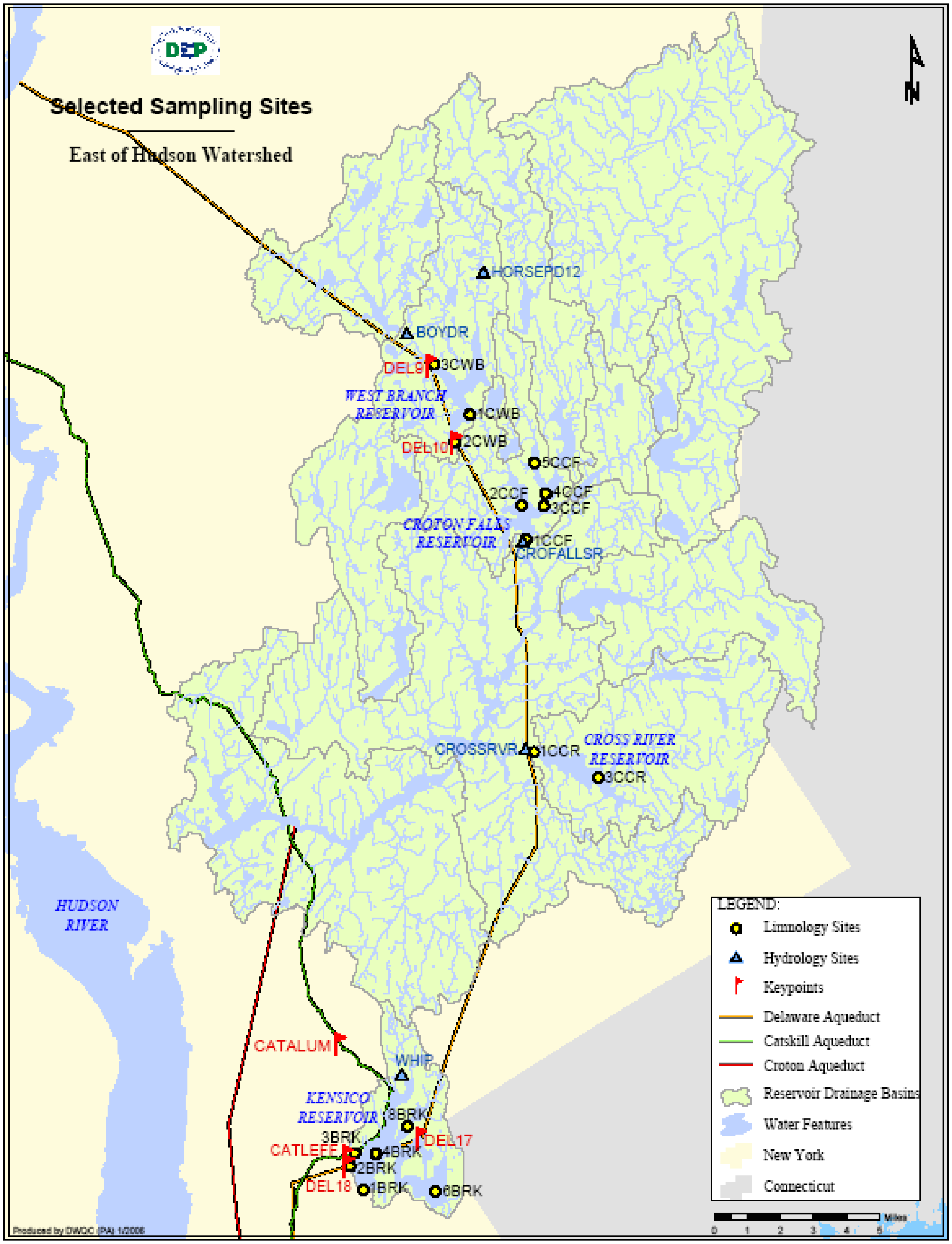

Figure A.2 Map showing the sites included in the status and trends analysis for the east of Hudson reservoirs, aqueduct keypoints, and streams.

The reservoir inputs comprise the main streams and, where appropriate, aqueducts. For all west of Hudson reservoirs and West Branch Reservoir, the stream sites selected are the furthest sites downstream on each of the main channels leading into the reservoirs, that is, they are the main stream sites immediately upstream of the reservoirs and therefore represent the bulk of water entering the reservoirs from their respective watersheds. For Rondout, West Branch, and Kensico reservoirs, the keypoint inputs are also the keypoint outputs (effluents) from upstream reservoirs. Reservoir outputs are normally keypoints except for Cross River and Croton Falls where the outputs are the releases. Cross River and Croton Falls Reservoirs were added to the FAD in 2002. Many of the protection programs for these basins are still in the early stages of implementation and are unlikely to have achieved any impact on water quality thus far. Therefore no stream inputs sites for these basins have been included in this analysis.

Data collection

The stream data used were collected by DEP's Division of Drinking Water Quality Control (DWQC) Hydrology Program. Streams that are major inputs to reservoirs are generally collected twice per month. Sub-basin sites that are not direct inflows to reservoirs are collected monthly. The reservoir water quality data were obtained from the routine monitoring operations by the DWQC Limnology Program. Samples are collected from March-December at Kensico Reservoir and from April-November at Croton Falls, Cross River and Cannonsville Reservoirs. Remaining reservoirs are sampled from April-December. Each reservoir is sampled from multiple depths at the dam, mid-reservoir, near major stream influent areas, and at other important sites, for instance near aqueducts. Only riverine sites were eliminated for this analysis because they are not representative of the bulk of the water in the reservoir. The full sampling programs are given in DEP (2003). The keypoints samples are collected by the DWQC Laboratory Operations staff who also analyze all samples.

Analytes

The analytes considered for status and trends analysis are turbidity, fecal coliform, total phosphorus, and conductivity, plus trophic state index (derived from chlorophyll *a* measurements). These are considered the most important for the City supply. All are used in reservoir assessment. For rivers, keypoints, and releases all but trophic state index are used because this analyte is only appropriate for the reservoirs.

TSI was calculated from the chlorophyll concentration using the following equation (Carlson, 1977):

$$TSI = 9.81 \times \ln(\text{chlor } a) + 30.6$$

where chlor *a* = chlorophyll *a* concentration ($\mu g\ L^{-1}$).

Only samples collected from the Photic Zone (either integrated samples taken from the surface to the 1% light level, or discrete samples taken at 3m depth) were used to calculate TSI. For trends in Kensico, West Branch, Croton Falls and Cross River reservoirs, 1995-1997 data were not used because of chlorophyll-*a* extraction problems.

Methodology

Data manipulation: prior to trend analysis, data was plotted over time and examined for outliers. Suspect data was flagged and the original records reviewed to determine if a transcription error had occurred. All discovered transcription errors were corrected. Remaining outliers were removed only if they were far outside the normal range of historic data. Results reported at instrument detection limits are problematic because these values could range down to zero. All detection limit results were converted to half their value, and this value was used in all subsequent data analyses.

Changes in sampling frequency and location during the period of record may produce a bias in the data, thereby obscuring or enhancing a trend. To create a balanced dataset we eliminated all special surveys and restricted data to that which was collected routinely each month. For reservoirs, we also needed to eliminate some shallower riverine sites, which could not be sampled consistently in dry years. Extra water column sampling, begun in 2002, was also eliminated to maintain a consistent sampling regime throughout the period of record. Additional data review indicated that in some reservoirs more samples were collected per site in certain years. Review also indicated that 2 to 3 more surveys were conducted per month in some years. To ensure that the data was consistently representative of the reservoir through the period of record we balanced the data by taking a series of medians. The first median combined multiple samples collected within thermal zones at each site. The second median combined samples by year, month, site and zone. The last median resulted in one value per month for each year and reservoir. Similarly, keypoint and stream data was pooled by taking the median of all results within each month resulting in one value per month for each year and site.

At the time of data analysis, data for east of Hudson sites for 2003 and 2004 were considered provisional, as were USGS flow data for the period October 1 through December 31, 2004, and as such are subject to (probably very minor, if any) change.

There have been some analytical methodology changes over the period 1993–2004 and, where they are suspected of possibly affecting trend analysis, comments have been made in the text.

<u>Status</u> - For water quality 'status', the time period used has to be sufficiently short so that any trends are minimal, but sufficiently long so that short-term fluctuations are minimized. A three year time period was considered appropriate and monthly medians from the years 2002–2004 were used. During this time period the mean daily flows for the stream inputs were somewhat higher than the historical mean daily flows. For example, the annual mean daily flow for

Schoharie Creek at Prattsville for the period of record (1907-2004) was 13.2 m^3 sec^{-1}, while the mean daily flow for the 2002-04 period was 16.8 m^3 sec^{-1}. In general, the mean daily flows for the 2002-2004 were 20-27% higher than the historical mean daily flows.

Where applicable, the results are compared to: Surface Water Treatment Rule standards, i.e., 5 NTU for turbidity and 20 coliform forming units (CFU) 100 mL^{-1} for fecal coliform; TMDL "Target Values" for total phosphorus (TP) in reservoirs (20 µg L^{-1} and 15 µg L^{-1}, for non-source and source reservoirs, respectively); and Carlson's Trophic State Index (TSI) where reservoirs with values <40 are considered oligotrophic, values between 40 and 50 are mesotrophic, and values >50 are considered eutrophic.

The turbidity and fecal coliform standards apply only to waters destined for distribution and are used here as benchmarks. To assist in the evaluation of stream status for fecal coliform, data have been compared to the water quality standard developed by New York State Department of Environmental Conservation. The water quality standard [6 NYCRR Part 703.4(b)] for fecal coliform for all streams examined here states that the monthly geometric mean, from a minimum of five examinations, shall not exceed 200 CFU 100 mL^{-1}. This value (200) has been used here as a guidance value. Box plots have been used as a visual aid to graphically display status using the Kaleidagraph™ software version 4 (Synergy Software, Reading, PA)—see Figure A.3 which provides a key for interpreting the box plots.

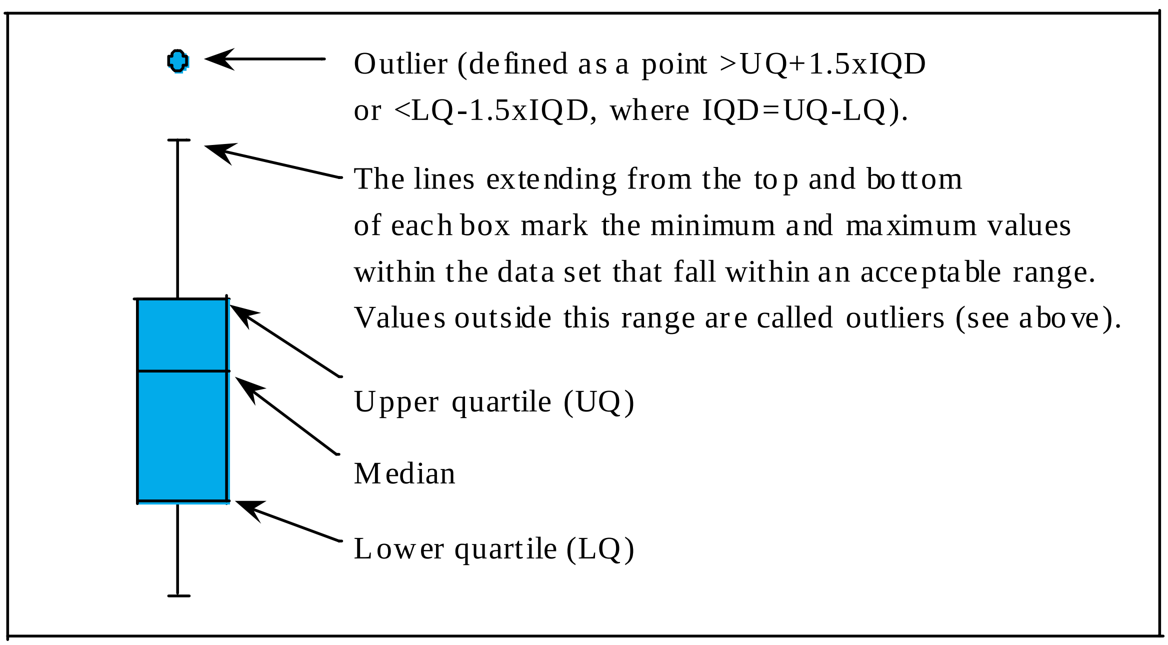

Figure A.3 Description of box plot statistics (Kaleidagraph ™) used in the status evaluations.

Trends - Temporal trends have been determined over the 12 year period 1993-2004, the starting point coinciding with the start of the EPA Filtration Avoidance Determination. To increase confidence in our results, two independent techniques were used to detect trends in our data. The first was a visual approach using a smoothing function LO(W)ESS (LOcally WEighted Scatterplot Smoothing) curve drawn though the points (Cleveland 1979). The second approach uses the non-parametric Seasonal Kendall Test (Hirsch *et al*. 1982). The magnitude of detected trends was determined using the Seasonal Kendall Slope Estimator (Hirsch *et al*. 1982).

LOWESS curves were fitted to the data to describe the long-term data pattern. The non-parametric LOWESS technique was chosen because, unlike parametric methods such as linear regression, it provides a robust description of the data without pre-supposing any relationship between the analytes and time, and because the distribution of the data does not need to be of a particular type (e.g. normal). The LOWESS technique is also preferable to parametric methods because it performs iterative re-weighting which lessens the influence of outliers and highly skewed data.

LOWESS curves were constructed using the PROC LOESS procedure in SAS 8.0 (SAS 1999). In PROC LOESS, weighted least squares are used to fit linear or quadratic functions to the center of a group of data points. The closer a data point is to the center, the more influence or weight it has on the fit. The size of the data group is determined by the smooth factor chosen by the user. In our analysis we chose a smooth factor of 0.3, which means that 30 percent of the data is used to perform the weighted least squares calculation for each data point. Through experimentation we found that a smooth factor of 0.3 provided a good description of the overall long-term trend and important intermediate trends as well.

Increasing the number of iterations or re-weightings that PROC LOESS performs on the data can further reduce the influence of outliers. With each iteration, data points are weighted less the further they are removed from the data group. Selecting one iteration corresponds to no re-weighting. Given the prevalence of extreme values commonly observed in coliform data, we found that selecting one iteration produced a fit that was excessively driven by outliers. Three iterations, corresponding to two re-weightings, has been recommended in other studies (Cleveland 1979) and yielded a good fit with our coliform data. For the other analytes presented (e.g. turbidity, total phosphorus) the number of iterations chosen had little discernible effect on the LOWESS fit. For ease of presentation, in this report, LOWESS curves for all analytes were determined using three-iterations.

In addition to LOWESS curves, the Seasonal Kendall Test (which produces the Seasonal Kendall Test Tau Statistic with sign indicating direction of slope and value the statistical significance) was used to determine the statistical significance of trends in our data. The test was performed using a compiled Fortran program provided in Reckhow *et al*. (1993). The Seasonal

Kendall test poses the null hypothesis that there is no trend; the alternative hypothesis being that there is in fact an upward or downward trend (a two-sided test). Results are tabulated in the text. The *p* values for each trend test are symbolized as follows:

p value	Symbol
$p \leq 0.20$	NS (Not Significant)
$p < 0.20$	*
$p < 0.10$	**
$p < 0.05$	***

The lower the *p* value, the more likely the observed trend is not attributable to chance.

Note that the term "NS" does not mean that there is no trend. It means that the null hypothesis of "no trend" cannot be rejected (at the $p = 0.2$ level of significance—80% confidence level), and any observed trend could be attributed to chance.

A strong advantage of the non-parametric test is that there are no assumptions made, apart from monotonicity, about the functional form of any trend that may be present; the test merely addresses whether the within-season/between-year differences tend to be monotonic. Outliers also have a lesser effect on the non-parametric tests because non-parametric tests consider the ranks of the data rather than actual values. The effects of serial correlation are always ignored; this is justified because the scale of interest is confined to the period of record (Loftis et al. 1991; McBride 2005).

For rivers and streams, the values of many water quality analytes are dependent on flow. Therefore data variability caused by flow has been removed where appropriate. This process is well described in Smith *et al*. (1996). The required concentration/flow relationships were derived using a LOWESS procedure using SAS software and allowing it to produce the best smoothing function. Trend analysis was performed on the flow-adjusted data as well as the raw data for rivers and streams. There is a major caveat here: Helsel & Hirsch (1992) pointed out that there are potential pitfalls when using flow-adjusted values, stating that they should not be used where human activity has altered the probability distribution of river flow through changes in regulation, diversion or consumption during the period of trend analysis. For example, the flow of the Esopus Creek at Boiceville is often greatly influenced by the contributions of the Shandaken Portal to the Esopus Creek. Hence, flow adjustment at this site would not be appropriate. Where flow adjustment was appropriate, the statistics have been presented and discussed in the text.

The Seasonal Kendall Slope Estimator technique is used to estimate trend magnitude (*i.e.* amount of change per year). In this technique, slope estimates are first computed for all possible data pairs for each month. The median of all the slopes is then determined. This median is the seasonal Kendall slope estimator. It should also be pointed out that it is possible to obtain a 'statistically significant' trend with the Seasonal Kendall Test, yet obtain a zero Seasonal Kendall Slope Estimator. This is an odd feature of the procedures and occurs when there are many tied values in the dataset, e.g., many "non-detects". There is a dislocation between the trend test and the slope estimate, that is, the two procedures are carried out independently of each other. The trend slope is computed from the median of all slopes between data pairs within the same month and, in this instance, is zero.

Note that in practice one can rarely, if ever, say that there is 'no trend'. All one can say is that you have failed to 'detect' a trend at a certain level of confidence. In fact, there is nearly ALWAYS a trend and the null hypothesis of "no trend" is nearly always false to begin with! Note also that *p* values produced with data having different *n* values are not comparable (McBride 2005).

Case Studies

Case Studies are described for a variety of stream and aqueduct effluent sites to examine the effects of one or several programmatic initiatives on water quality. For the stream sites the initiatives discussed include: a selection of WWTPs (for TP and fecal coliform); the Whole Farm Planning program (for P species); the Kensico Reservoir Extended Detention Basin BMPs; and a combination of Septic Remediations and Whole Farm Planning. The effects on reservoir effluent water quality include: the Kensico Reservoir Turbidity Curtain and Malcolm Brook Cove Extended Detention Basin BMPs at the Kensico Reservoir effluent keypoint site CATLEFF (for turbidity and fecal coliform); and the Kensico Reservoir Waterfowl Management Program at both of Kensico's effluent chambers (for fecal coliform).

In addition, the effects of the Stream Management Program's stream restoration efforts on the Batavia Kill (Schoharie basin) and Broadstreet Hollow (Ashokan West Basin) are reported (in Section 2.4) from the viewpoint of potential benefits to fish communities.

All water quality case studies on streams and effluent chambers, their locations, reason(s) for study, and the analytes studied are listed in Table A.2 and shown pictorially in Figure A.4 and A.5.

Table A.2. Sites used for stream and aqueduct keypoint water quality case study analysis.

Reservoir basin	Location (Sites)	Reason for selection[1]	Analytes
Schoharie	Gooseberry Creek (S1, S2)	Tannersville WWTP	TP, F coliform
	Bearkill (S8, S9)	Grand Gorge WWTP	TP, F coliform
Ashokan	Birch Creek (E3, E15)	Pine Hill WWTP	TP, F coliform
Cannonsville	R Farm	WFP	P species

Table A.2. Sites used for stream and aqueduct keypoint water quality case study analysis.

Reservoir basin	Location (Sites)	Reason for selection[1]	Analytes
	Trout Creek (C-7)	Septics/WFP	TP, F coliform
	Loomis Creek (C-8)	Septics/WFP	TP, F coliform
	W B Delaware R (WDSTA,WDSTM,WDSTB)	Stamford WWTP	TP, F coliform
	W B Delaware R (WDHOA,WDHOM,WDHOB)	Hobart WWTP	TP, F coliform
	W B Delaware R (DTPA, DTPB)	Delhi WWTP	TP, F coliform
	W B Delaware R (WSPA, WSPB)	Walton WWTP	TP, F coliform
Pepacton	E B Delaware R (PMSA, PMSB)	Margaretville WWTP	TP, F coliform
	Tremper Kill (P-13)	Septics/WFP	TP, F coliform
Neversink	—		
Rondout	Chestnut Creek (RGA)	Septics/WFP	TP, F coliform
	Chestnut Creek (RGA, RGB)	Grahamsville WWTP	TP, F coliform
West Branch	—		

[1] The reason for selection is to assess the effects of a single or combination of management practices. For Wastewater Treatment Plants (WWTPs) there are upstream and downstream sites.
WFP = Whole Farm Planning
Septics = Septic System Remediations

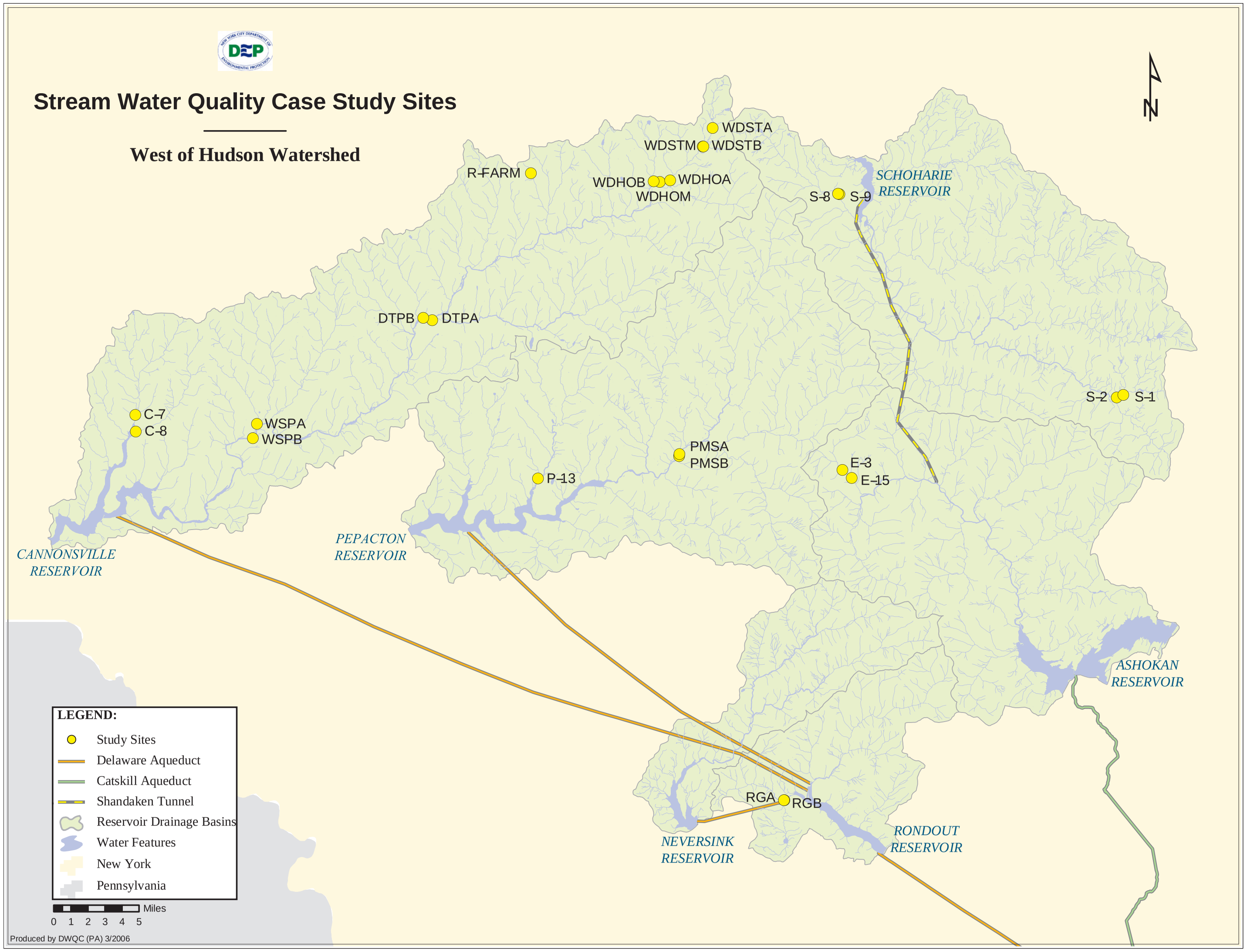

Figure A.4 Map depicting the locations of the sites used for stream and aqueduct keypoint water quality case study analysis, west of Hudson.

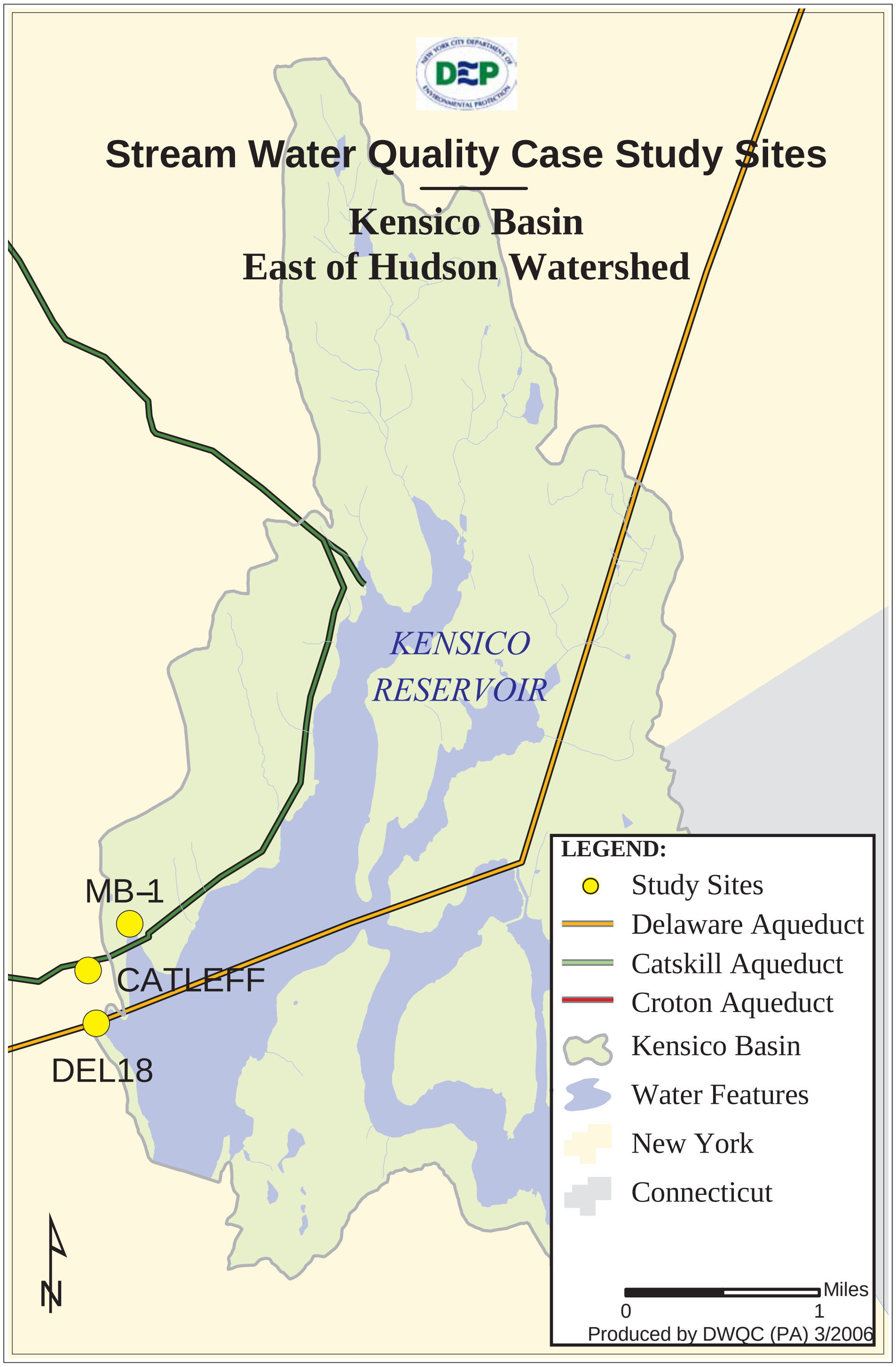

Figure A.5 Map depicting the locations of the sites used for stream and aqueduct keypoint water quality case study analysis, east of Hudson.

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Appendix 4. Cannonsville GWLF Model Calibration and Validation

Introduction

The GWLF model (NYCDEP, 2005; Schneiderman et al, 2002; Schneiderman et al, 1998; Haith et al, 1992) has been used by NYC DEP to simulate streamflow, nutrient and sediment loads to the Catskill/Delaware watersheds. The hydrology and water quality modules of GWLF have been previously calibrated and validated for the Cannonsville watershed (Schneiderman et al. 2002). The purpose of this report is to present the updated version of the calibration and validation for hydrology and water quality for Cannonsville watershed. The model calibration and validation presented herein are based on the most recent water quality monitoring data and model updates of GWLF.

Calibration and validation of model parameters is necessary to ensure that the model best represents the processes and relationships that control flows, nutrient and sediment export from the watershed. The calibration step involves optimizing model parameters against known flows and constituent loading data. The validation step is used to test the model's ability to predict flows and loads for time periods or events that are independent of the calibration data.

GWLF Model

The GWLF watershed loading model is a lumped-parameter model that simulates daily water, nutrients, and sediment loads from non-point and point sources. GWLF was originally developed at Cornell University by Dr. Douglas Haith and associates (Haith and Shoemaker 1987, Haith et al. 1992) as "an engineering compromise between the empiricism of export coefficients and the complexity of chemical simulation models". The GWLF approach conceptualizes the watershed as a system of different land areas (Hydrologic Response units or HRUs) that produce runoff, and a single groundwater reservoir that supplies baseflow. Dissolved and suspended substances (e.g. nutrients and sediment) in streamflow are estimated at the watershed outlet by loading functions that empirically relate substance concentrations in runoff and baseflow to watershed and HRU-specific characteristics. The strength of this approach lies in its fairly robust hydrologic formulation of a daily water balance, and in the ability to adjust loading functions to an ever increasing body of knowledge and data on the factors that influence the export of substances in streamflow from a watershed.

The current version of GWLF that DEP uses, termed GWLF-VSA, has been developed by DEP, with modifications as described in Schneiderman et al. (2002), DEP (2005), and DEP (2006). GWLF-VSA has a modified runoff algorithm to account for saturation-excess runoff; optional snowmelt, evapotranspiration, and groundwater algorithms for tuning hydrologic simulation to varied physiographic settings; a modified sediment algorithm that utilizes sediment rating curves; BMP reduction factors; utilizes Vensim visual modeling software (www.vensim.com) for transparent viewing of model structure and for viewing tables, graphs, and statistics for all model variables at daily, weekly, monthly, annual, and event time steps; and has built-in model calibration and testing tools.

GWLF generates the following daily time series which subsequently can be input to the reservoir receiving water model: streamflow, dissolved phosphorus (P) and nitrogen (N) from non-point and point sources, particulate P, and dissolved organic carbon (C). Loads in surface runoff from different land uses, in sub-surface flows, from septic systems and from point sources are explicitly tracked in GWLF and summed to provide total loads delivered to the reservoir.

Calibration and Validation for Cannonsville Watershed

Study Watershed

GWLF Model calibration and validation is performed for the watershed outlet located at the NYS DEC water quality sampling location located on the West Branch of the Delaware River at Beerston. This sampling site is approximately 7 km downstream from USGS streamflow gage 01423000 at Walton, NY. Data from the USGS flow gage is used for hydrology model testing, while data collected at the DEC sampling site is used for water quality calibration and validation Figure A.6 illustrates the stream network, the USGS flow gage and DEC sampling site locations, wastewater treatment plants and the location of the Beerston watershed within the Cannonsville watershed.

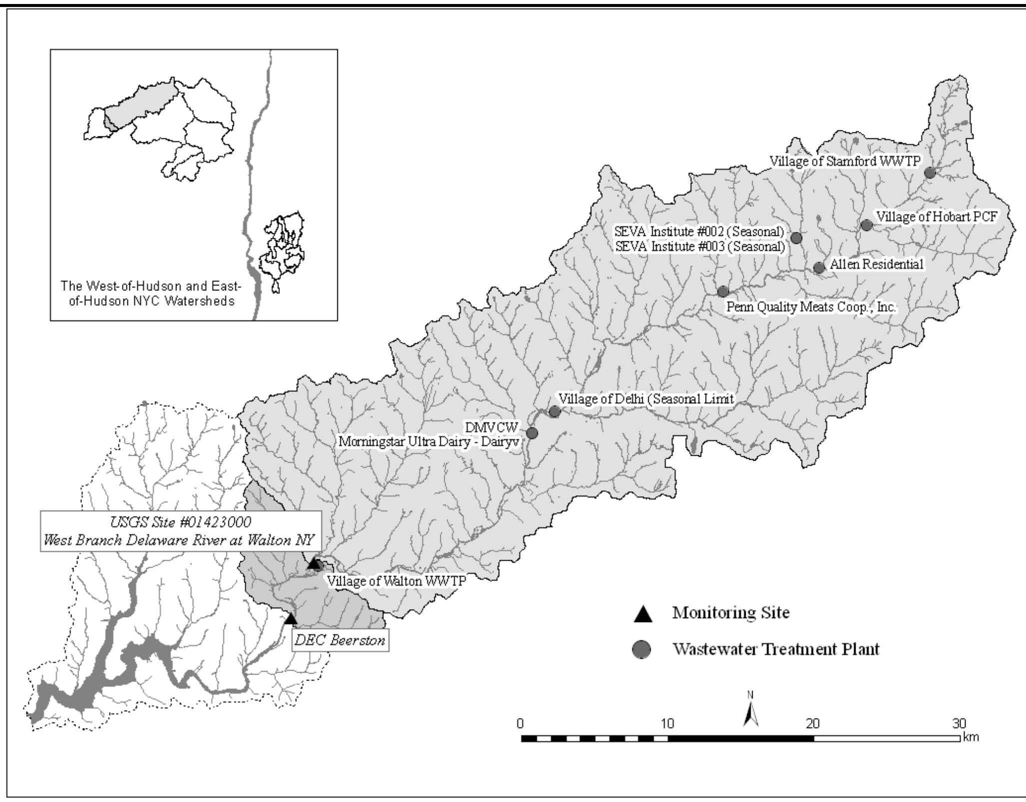

Figure A.6 Location map of watershed draining to DEC Beerston sampling site showing the stream network, the location of USGS streamflow gage 01423000 and wastewater treatment plants in the Cannonsville Watershed.

Data Used for Model Calibration

Streamflow Data

USGS streamflow gage 01423000 located at Walton has a continuous flow record from 1950 through the present. This streamflow data is used to calibrate and validate the hydrology portion of the GWLF model. The hydrology results are the basis for model calculation of nutrient and sediment loads.

As part of hydrology model calibration, the streamflow was separated into baseflow and storm runoff components using a digital filter technique (Nathan and McMahon, 1990; Lyne and Hollick, 1979; Arnold et al., 1995). The digital filter was originally developed for signal processing by Lyne and Hollick (1979) and later adapted by Nathan and McMahon (1990) for baseflow separation in hydrology. The streamflow component filter program has a filter parameter (0.925) that was determined by Nathan and McMahon (1990), and Arnold et al. (1995). The filter outputs three filtered passes. The first pass provided the best results in the North Eastern States (Arnold and Allen, 1999). To maintain consistency with these findings, the same filtered parameter and first pass was applied. Figure A.7 depicts an example of the baseflow-separated daily streamflow data for gage 01423000 (West Branch Delaware River at Walton) for calendar year 1995.

Event periods were defined based on the baseflow separation. The start of each event occurs when the slope of the baseflow-separation line begins to deviate from the slope of the streamflow line. Following Hewlett and Hibbert (1967), the flow records were divided into contiguous event periods, each period beginning at the start of each event. Events smaller than a threshold size of 0.01 cm are ignored and included in the previous event period, as in Hewlett and Hibbert (1967). Total streamflow, direct runoff, and baseflow were summed up for each event period to provide data for calibration validation the hydrology portion of the GWLF model.

Water Quality Monitoring and Loads

Water quality model calibration data consists of event loading estimates calculated by NYS DEC from storm sampling and routine monitoring data for the Beerston water quality monitoring station along with flow data from the 01423000 USGS gage. The DEC monitoring station has been active since Oct. 1991. Event loads are estimated for total suspended solids (TSS), total dissolved P (TDP), total dissolved N (TDN), dissolved organic C (DOC) and particulate P (PP). For each event period nutrient and sediment loads are derived by summing daily constituent loading estimates.

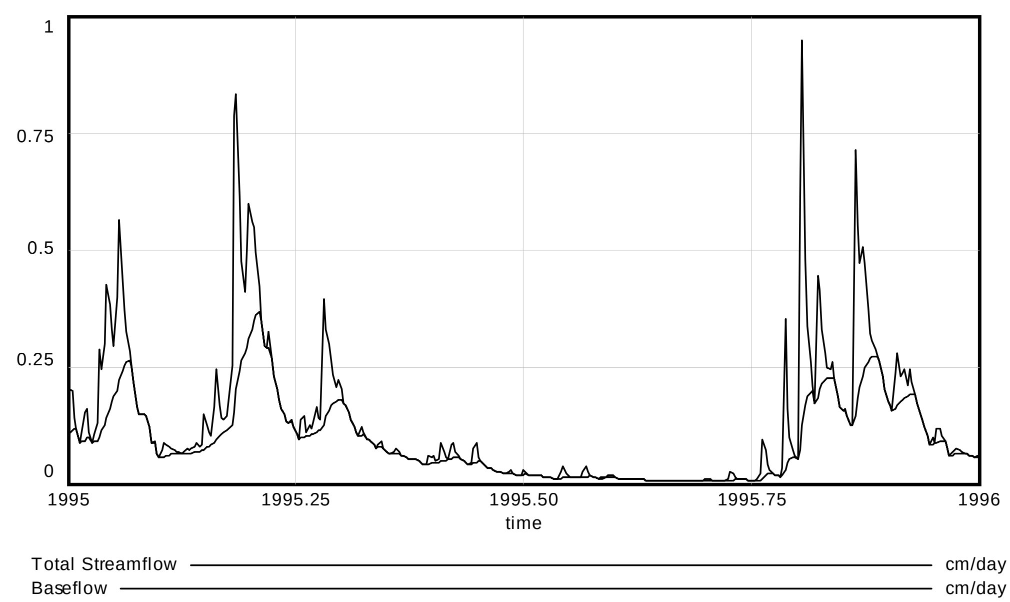

Figure A.7 Example of baseflow separation for West Branch Delaware River at Walton (USGS gage 01423000) for calendar year 1995. Area between baseflow line (dashed) and total flow (solid) represents direct runoff; area below baseflow line represents baseflow.

Model Input

Land use and Physiography Data

Land use, soils, physiography and geology characteristics are essential to developing the hydrology, nutrient and sediment transport parameters required as input for the GWLF model. Parameters developed from this data include land use, topographic wetness index, soil water capacity, Runoff Curve Numbers and Universal Soil Loss Equation (USLE) factors.

Land cover and land use (LC/LU) data for model input was derived from the DEP 2001 LC/LU classification. Modifications to the 2001 data set were made in order to more effectively incorporate information regarding impervious surface of rural roads and road shoulders, the breakdown of farm data, the areas of built-up land covers and selected water and wetland features. The LC/LU data were reclassed into categories appropriate for the GWLF-VSA version of GWLF. Detailed descriptions of the LU/LC modifications are described in NYCDEP, 2006.

Sixteen land use classes are distinguished in the model classification – deciduous forest, coniferous forest, mixed forest, brushland, non-agricultural grass, cropland, permanent hayland, pasture, barnyard, rural roads, residential pervious and impervious, commercial/industrial pervious and impervious, wetland and water. Forests and brushland are taken directly from the LC/LU coverage. Farm data collected by the New York City Watershed Agricultural Program was used to estimate cropland, permanent hayland, pasture, and non-agricultural grass land use areas. Barnyard areas are estimated based on the number of farms, as obtained New York City Watershed Agricultural Program. DEP GIS impervious surface coverage was used to divide Residential and Commercial/Industrial pervious and impervious areas. Rural road surface area outside built-up areas is estimated from New York State Department of Transportation GIS road data. Soils data is derived from the USDA digital soils database (SSURGO).

Topographic and wetness index information was derived in the GIS from a 30-meter Digital Elevation Model (DEM). (NYCDEP, 2005; 2006). Wetness indices are split into ten classes, 1 through 10, with 1 being the wettest class and 10 being the driest. In the GWLF-VSA version of the model, runoff is produced from the wettest class (1) first and the driest class (10) last. Tables A.3 and A.4 list the land cover/land use and wetness index class breakdown for the USGS flow gage and NYS DEC water quality monitoring station catchments.

Table A.3. Land cover/land use and wetness index class areas for West Branch Delaware River watershed 01423000 at Walton.

		Wetness Index Class									
Land Use Class	Area (ha)	1	2	3	4	5	6	7	8	9	10
Forest – Deciduous	44544	2636	3856	4563	4347	5224	4354	5327	4697	4918	4624
Forest – Coniferous	7800	1045	773	743	656	742	638	710	708	790	994

Table A.3. Land cover/land use and wetness index class areas for West Branch Delaware River watershed 01423000 at Walton.

		Wetness Index Class									
Land Use Class	Area (ha)	1	2	3	4	5	6	7	8	9	10
Forest – Mixed	2968	287	287	291	274	315	260	298	285	314	358
Brushland	5157	624	611	559	446	501	422	450	472	532	541
Non-Agricultural Grass	7508	1071	838	753	627	695	637	643	682	758	804
Cropland	4206	600	470	422	351	389	357	360	382	425	450
Permanent Hayland	4647	663	519	466	388	430	394	398	422	469	498
Pasture	4990	712	557	501	416	462	423	427	453	504	534
Barnyard	35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Impervious	453	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Pervious	1474	235	177	147	113	118	103	115	120	152	194
Commercial/ Industrial Impervious	154	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial/ Industrial Pervious	197	55	21	14	10	9	9	10	10	19	39
Rural Roads	492	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wetland	696	696	0	0	0	0	0	0	0	0	0
Water	604	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	85925										

Table A.4. Land cover/land use and wetness index class areas for West Branch Delaware River watershed at Beerston.

		Wetness Index Class									
Land Use Class	Area (ha)	1	2	3	4	5	6	7	8	9	10
Forest – Deciduous	47949	2824	4090	4861	4667	5643	4708	5753	5068	5310	5025
Forest – Coniferous	8269	1092	805	782	696	789	682	757	753	843	1072
Forest – Mixed	3162	303	300	306	292	337	278	319	304	337	387
Brushland	5338	651	625	574	460	516	437	465	491	552	566
Non-Agricultural Grass	7784	1119	862	777	648	720	660	665	705	789	839

Table A.4. Land cover/land use and wetness index class areas for West Branch Delaware River watershed at Beerston.

Land Use Class	Area (ha)	Wetness Index Class 1	2	3	4	5	6	7	8	9	10
Cropland	4361	627	483	435	363	403	370	373	395	442	470
Permanent Hayland	4818	693	533	481	401	445	408	412	436	489	519
Pasture	5174	744	573	517	430	478	439	442	469	525	558
Barnyard	37	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Impervious	478	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Residential Pervious	1557	252	185	153	119	124	108	120	126	161	208
Commercial/ Industrial Impervious	163	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial/ Industrial Pervious	210	59	22	15	10	10	10	11	11	20	41
Rural Roads	518	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wetland	714	714	0	0	0	0	0	0	0	0	0
Water	672	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	91204										

Point Source Data

The watershed of the West Branch Delaware River at Beerston includes Stamford, Delhi, Walton, and Hobart municipal wastewater treatment plants and an industrial wastewater plant at Penn Quality Meats. Locations of these plants are shown in Figure A.6. P loads for water years 1992-1999 were estimated based on data from DEP's sampling program combined with flow and total P concentration information listed in the Discharge Monitoring Report (DMR) from each facility (Cutietta-Olson and Curry, 1994). Sampling for N at the wastewater treatment plants ended in 1995. For the purposes of these runs, monthly N loads are assumed to equal the values for 1995.

Septic System Data

Septic system loads are derived from estimates of the unsewered population of a drainage area, both seasonal and year-round as described in DEP (2006). Unsewered populations for period 1992-1999 are estimated based on 1990 Census population counts. Seasonal homes and persons per home were used to derive a seasonal population multiplier for each county of the watershed. (NYC DEP, 2006). The GWLF model simulates nutrient loads from septic systems as a function of the percentage of the unsewered population served by normally functioning versus three types of failing systems: ponded, short-circuited, and direct discharge (Haith et al., 1992).

The failing percentages are further adjusted to account for the number of systems within 300 feet of a waterbody. Additionally, ponded systems are only assumed to fail during the periods April – mid June and mid September – mid November.

Precipitation

The model requires daily precipitation data. This data is obtained from cooperator stations recognized by the National Climate Data Center and obtained from the Northeast Regional Climate Center. The precipitation station data is averaged using a Thiessen polygon method (Burrough, 1987; NYCDEP, 2004). The watershed is broken into areas represented by the nearest precipitation station. The proportion of the area of each polygon representing a precipitation station to the total watershed area is the weight given for averaging the value from that station. Using this method the daily watershed average precipitation is calculated by:

$$P_w = \frac{\sum_{i=1}^{nsta} A_i P_i}{A_w} \qquad (2.1)$$

where A_i is the area of the Thiessen polygon for station *I*, A_w is the watershed area, and P_i is the daily precipitation observation for station *i*, and *nsta* is the number of measurement stations. Figure A.8 shows a map of the Thiessen polygons used for the WOH watersheds. Table A.5 shows the Thiessen weightings for each of the precipitation stations for the West Branch Delaware River calibration and verification watersheds.

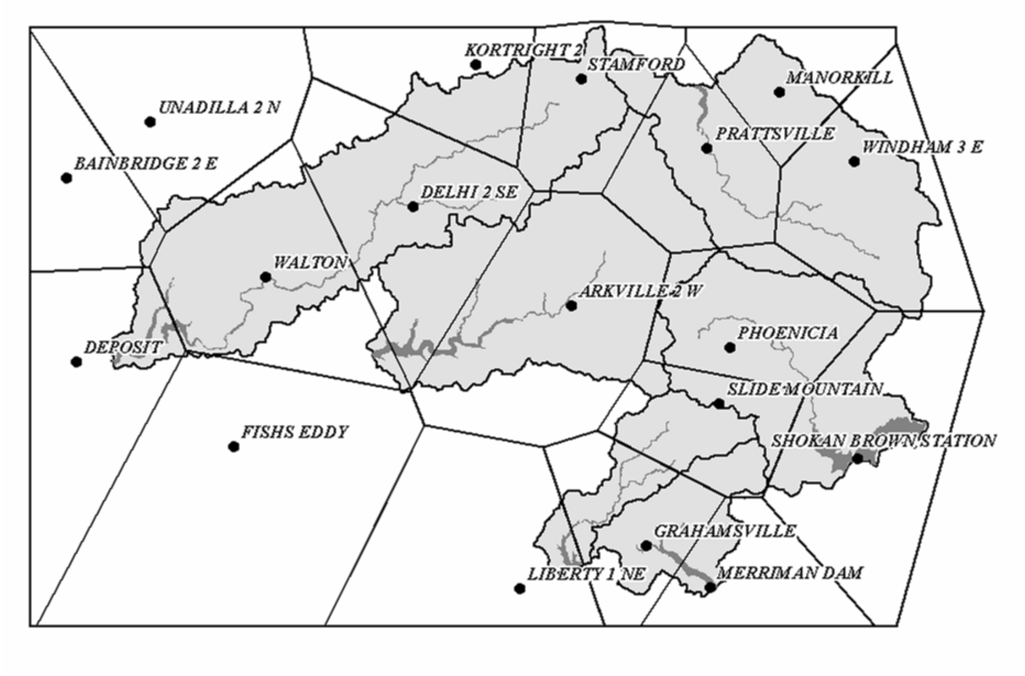

Figure A.8 Map of the Thiessen polygons and associated NRCC precipitation stations used for watershed average precipitation for WOH watersheds.

Table A.5. Thiessen polygon weightings used to calculate watershed wide average precipitation for Cannonsville Watershed calibration and verification basins.

Precipitation Station	Thiessen Weighting for Watershed Averaging
Walton	0.2656
Delhi	0.3805
Stamford	0.1977
Kortright	0.1475
Arkville	0.0088

Temperature

Minimum and maximum daily air temperatures are used for model input are derived from four stations in the NRCC data set: Cooperstown, Liberty, Slide Mountain, and Walton (Figure A.9). Each of these stations has been active since 1965 or earlier. The averaging method includes the application of an environmental lapse rate to correct for elevation differences between the station and the watershed elevation and use of inverse distance squared weighting for spatial averaging of the four stations. (DEP, 2004)

An environmental lapse rate is applied to each of the stations to account for the elevation difference between the temperature station and the watershed. The lapse rate is applied to each station measurement using:

$$T_{Ews} = L(E_{sta} - E_{ws}) + T_{sta} \tag{2.2}$$

where T_{Ews} is the station temperature adjusted to the mean elevation of the watershed, L is the environmental lapse rate, E_{sta} is the elevation of the measurement station, E_{ws} is the mean elevation of the watershed, T_{sta} is the temperature measurement at the station. The applied lapse rate used for this study is equal to 6.0 ^{o}C/km (Gersmehl et al., 1980).

To find the watershed wide temperature value for input to the model, the four temperature stations are averaged using an inverse distance squared weighting procedure:

$$T_w = \frac{\sum_{i=1}^{nsta} \frac{T_{Ews-i}}{D_{i-cent}^{2}}}{\sum_{i=1}^{nsta} \frac{1}{D_{i-cent}^{2}}} \tag{2.3}$$

where T_w is the watershed average daily minimum or maximum temperature, $T_{Ews\text{-}i}$ is the temperature measurement for station *i* adjusted to the median elevation of the watershed, $D_{i\text{-}cent}$ is the distance from station *i* to the centroid of the watershed, and *nsta* is the number of temperature measurement stations. Table A.6 shows the inverse distance squared weightings and the environmental lapse rate for each of the temperature stations used for the Cannonsville watershed.

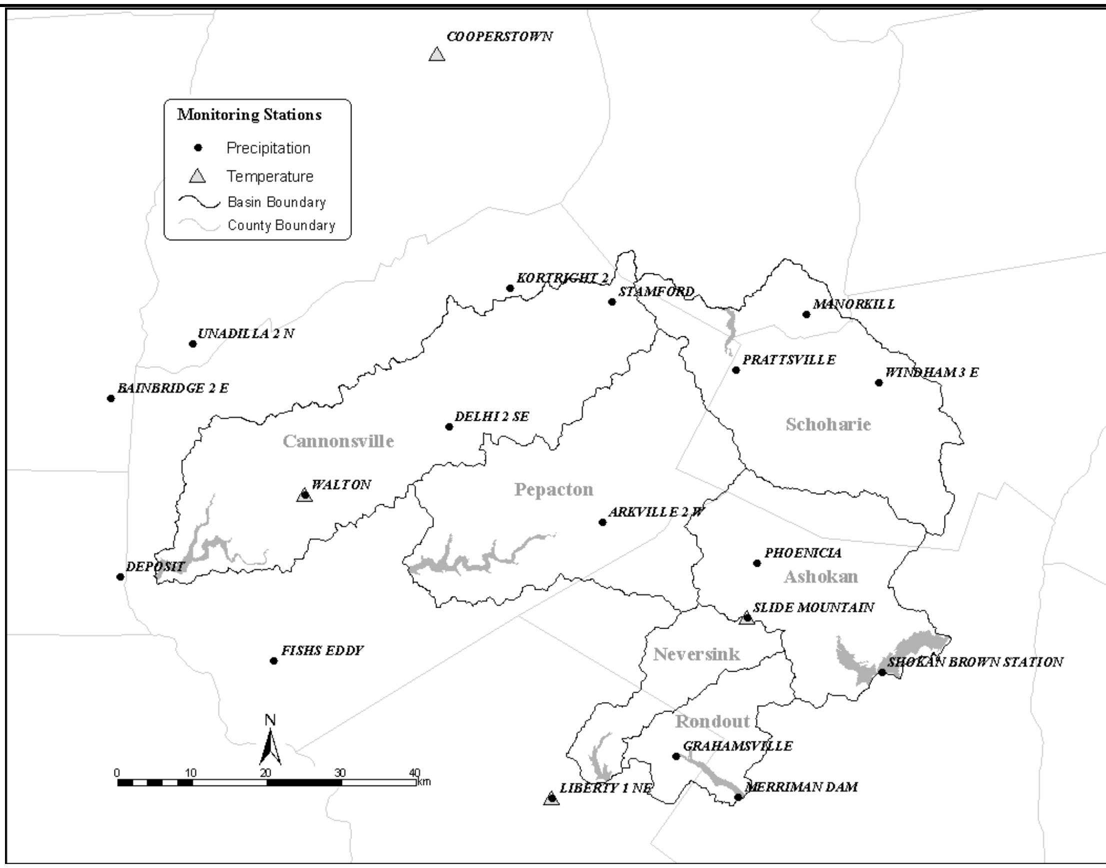

Figure A.9 Location of NRCC daily precipitation (dots) and temperature (triangles) stations.

Table A.6. Weightings used to calculate watershed wide average daily minimum and maximum temperature using the inverse distance squared weighting and environmental lapse rate adjustment for each temperature station for Cannonsville Watershed calibration and verification basins.

Temperature Station	Inverse Distance Squared Weighting	Lapse Rate Adjustment (^oC)
Slide Mountain	0.131	1.31
Liberty	0.104	-0.70
Walton	0.620	-0.83
Cooperstown	0.146	-1.34

Calibration and Validation Methods

The period 1/1/1992 through 12/31/1999 was chosen for calibrating and validating hydrology and water quality for Cannonsville watershed. 1992-1999 was selected because it is the period prior to or at the initial stages of implementation of watershed management programs in Cannonsville watershed. This period therefore represents baseline conditions, against which watershed management and land use change scenarios can be compared. Continuous streamflow and water quality data are available for this period, and the sample size (243 storm events) is adequate for calibration and validation.

The model was calibrated using all 1992-1999 data (with the exception of 1 event), to maximize calibration sample size and accuracy. The model was validated using a jackknifing method (discussed below) that provides estimates of model prediction accuracy that are independent of the model calibration.

The extreme storm event of January 19-20, 1996 was omitted from the water quality model calibration and testing. This event was the maximum stream flow of record with an estimated return period > 70 years, and estimates of observed particulate P and sediment loads for this single event exceeded average annual loads (Longabucco and Rafferty 1998). Simulation of an event of this magnitude is outside the range for which the model is designed.

Model Performance Statistics

Two statistics were used as measures of model performance. The Nash-Sutcliff coefficient of model efficiency (Nash and Sutcliffe 1970), referred to as R_{NS}^2, measures the goodness of fit of model-predicted vs. measured data (equation 2.4). The R_{NS}^2 statistic can range from –infinity to 1, with 1 indicating a perfect fit. If R_{NS}^2 is < 0 the model-predicted values are worse than simply using the observed mean (Loague and Green 1991).

$$R_{NS}^2 = 1 - \frac{\sum (observed - predicted)^2}{\sum (observed - mean\ observed)^2} \quad (2.4)$$

Another goodness of fit measure is the bias, or relative error (Thomann 1982). Bias is a measure of the accumulation of differences in measured vs. model-predicted values:

$$\%\ bias = \frac{mean\ observed - mean\ predicted}{mean\ observed} \cdot 100 \quad (2.5)$$

The two statistics are complementary and measure different aspects of model performance. The R_{NS}^2 statistic is a measure of the proportion of the variance in observed values accounted for by the model, analogous to the coefficient of determination (Nash and Sutcliffe, 1970). It thus measures the degree to which observed and predicted time-series are correlated. In contrast, the % bias statistic measures the cumulative error of model predictions. % bias can be zero in spite of very large deviations between observed and predicted values (low R_{NS}^2). Alternatively, observed and predicted time series may track closely (high R_{NS}^2) in spite of significant non-zero % bias. Ideal model performance will be characterized by R_{NS}^2 near 1 and % bias near zero.

Hydrology Calibration Procedure

Hydrology parameters are calibrated by the following stepwise procedure, where each step builds on the results of the previous step. At each step a parameter is optimized to either minimize the % bias or maximize R_{NS}^2 for measured vs. simulated data. For runoff and groundwater flow, "measured" data is derived by baseflow separation of measured streamflow hydrograph, as described in DEP (2004).

1. Optimize the precipitation correction factor to minimize % bias of measured vs. simulated streamflow. This factor is used to adjust for systematic errors due to spatial variability in precipitation station data.
2. Optimize input runoff curve number adjustment factor for pervious land uses (Input CN Perv Adj) to minimize % bias of measured vs. simulated runoff during dormant season. This step adjusts CNs to more accurately calculate direct runoff during the dormant season.
3. Optimize the SPAW Curve Number Coefficient (SPAW CN Coeff, DEP 2006) to minimize % bias of measured vs. simulated runoff during growing season. This factor controls seasonal variation in runoff.
4. Optimize the runoff recession coefficient (Runoff Recess Coeff) to maximize R_{ns}^2 for measured vs. simulated runoff. This step adjusts the timing of runoff to account for the travel time to the watershed outlet.
5. Optimize Melt Factor to maximize R_{ns}^2 for measured vs. simulated streamflow. The melt factor controls the rate at which the snowpack melts.
6. Repeat step 2
7. Repeat step 3
8. Repeat step 4
9. Optimize groundwater recession coefficient (Recess Coeff) to maximize R_{ns}^2 for measured vs. simulated groundwater flow. This coefficient controls the groundwater flow recession.
10. Optimize the unsaturated leak coefficient (Unsat Leak Coeff to maximize R_{ns}^2 for measured vs. simulated groundwater flow on days when measured streamflow is less than the low-flow threshold (20th percentile value of measured flow). This factor accounts for contributions from groundwater during extended low flow periods.

11-20. Repeat steps 1 – 10

Water Quality Calibration Procedure

A stepwise procedure is used to calibrate water quality parameters. Sediment yield parameters are calibrated first (step 1), followed by particulate P parameter (step 2), followed by dissolved P, N, and C parameters.

1. Optimize transport capacity power (and sediment delivery ratio to both minimize % bias of measured vs. simulated sediment yield and maximize R_{NS}^2 for measured vs. simulated event sediment yield. These two parameters control the rating curve used to estimate sediment yield.
2. Optimize enrichment ratio to minimize % bias of measured vs. simulated particulate P.
3. Optimize groundwater nutrient concentrations to maximize R_{ns}^2 for measured vs. simulated dissolved P on days when measured runoff = 0 and ratio of simulated runoff:simulated streamflow<=0.01.
4. Optimize RUNOFF CONC PARM B (NYCDEP, 2006) to minimize % bias of measured vs. simulated dissolved P
5. Repeat steps 3 and 4.
6. Optimize RUNOFF CONC PARM B and RUNOFF CONC PARM C (NYCDEP, 2006) to both minimize % bias of measured vs. simulated dissolved P and maximize R_{ns}^2 for measured vs. simulated dissolved P

7-10. Repeat steps 3-6 for dissolved N

11-14. Repeat steps 3-6 for dissolved C.

Model Validation using Jackknifing

Jackknifing (McCuen 2005) was used to validate the hydrology and water quality modules of GWLF for Cannonsville watershed. Jackknifing is a model validation alternative to split sample testing. Split sample testing, where the available data is divided into two independent samples (one for calibration, one for validation), has the distinct disadvantage of unnecessarily decreasing the prediction accuracy of the model because of reduced sampling size.

In jackknifing the data set is not split, but one observation point is successively omitted in a series of steps. The model is calibrated with one data point withheld and the resultant calibration based on n-1 data points is used to predict the withheld point. This process is repeated until each data point has successively been withheld from the calibration and predicted using the corresponding n-1 calibrated model. The predicted data points are then combined into a jackknife time series that can be compared to the data to derived goodness of fit statistics, referred to as jackknife statistics. Since each point in the jackknife time series is predicted by a model that was calibrated with the corresponding data point excluded, it represents a model prediction that is independent of the model calibration. The jackknife statistics will differ from the calibration goodness of fit statistics and reflect prediction accuracy rather than calibration accuracy.

Calibration and Validation Results

Hydrology

Hydrology model calibration and validation pays particular attention to accurately simulating the major streamflow components (streamflow, runoff, baseflow) during both dormant and growing seasons. The final calibrated hydrology model is shown to have low calibration and prediction error for all flow components and during both seasons. Tables A.7 and A.8 show results for calibrated parameters and error statistics. Figures A.10 through A.15 depict scatterplots and time series that compare observed streamflow, runoff, and baseflow with either simulation results of the calibrated model or with the jackknife validation time series. The calibration results reveal the calibration error, while the jackknife validation results measure the prediction error of the model. Error statistics and plots are given for dormant season (November through April) and growing season (May through October) events as well as for all events in the 1992-1999 period.

The results show high R_{NS}^2 (> 0.7) and low %Bias (~ 5% or less) for all flow components and seasons, for both the calibration and the validation. These statistics and visual inspection of the scatterplots and time series confirm that the model is working quite effectively for hydrology.

Table A.7. List of calibrated hydrology parameters for West Branch Delaware River at Walton (USGS Gage 01423000).

Parameter	Calibrated Value
Precipitation Correction Factor	0.953
Input CN Perv Adj	14.16
SPAW CN Coeff	0.821
Runoff Recess Coeff	0.432
Melt Coeff	0.383
Recess Coeff	0.061
Unsat Leak Coeff	0.048

Table A.8. Calibration and Validation Results for West Branch Delaware River at Walton (USGS Gage 01423000).

Hydrology Result	Statistic	Calibration			Validation		
		all events	dormant season	growing season	all events	dormant season	growing season
# Events		244	121	123	244	121	123

Table A.8. Calibration and Validation Results for West Branch Delaware River at Walton (USGS Gage 01423000).

Hydrology Result	Statistic	Calibration			Validation		
		all events	dormant season	growing season	all events	dormant season	growing season
Event Streamflow	R_{NS}^2	0.910	0.901	0.896	0.898	0.885	0.889
	% bias	0.05%	0.14%	-0.48%	0.12%	0.20%	-0.10%
Event Runoff	R_{NS}^2	0.861	0.864	0.749	0.830	0.831	0.705
	% bias	-0.04%	1.50%	-5.37%	-0.04%	1.11%	-3.83%
Event Baseflow	R_{NS}^2	0.891	0.861	0.911	0.886	0.853	0.911
	% bias	0.09%	-0.62%	1.50%	0.20%	-0.30%	1.41%

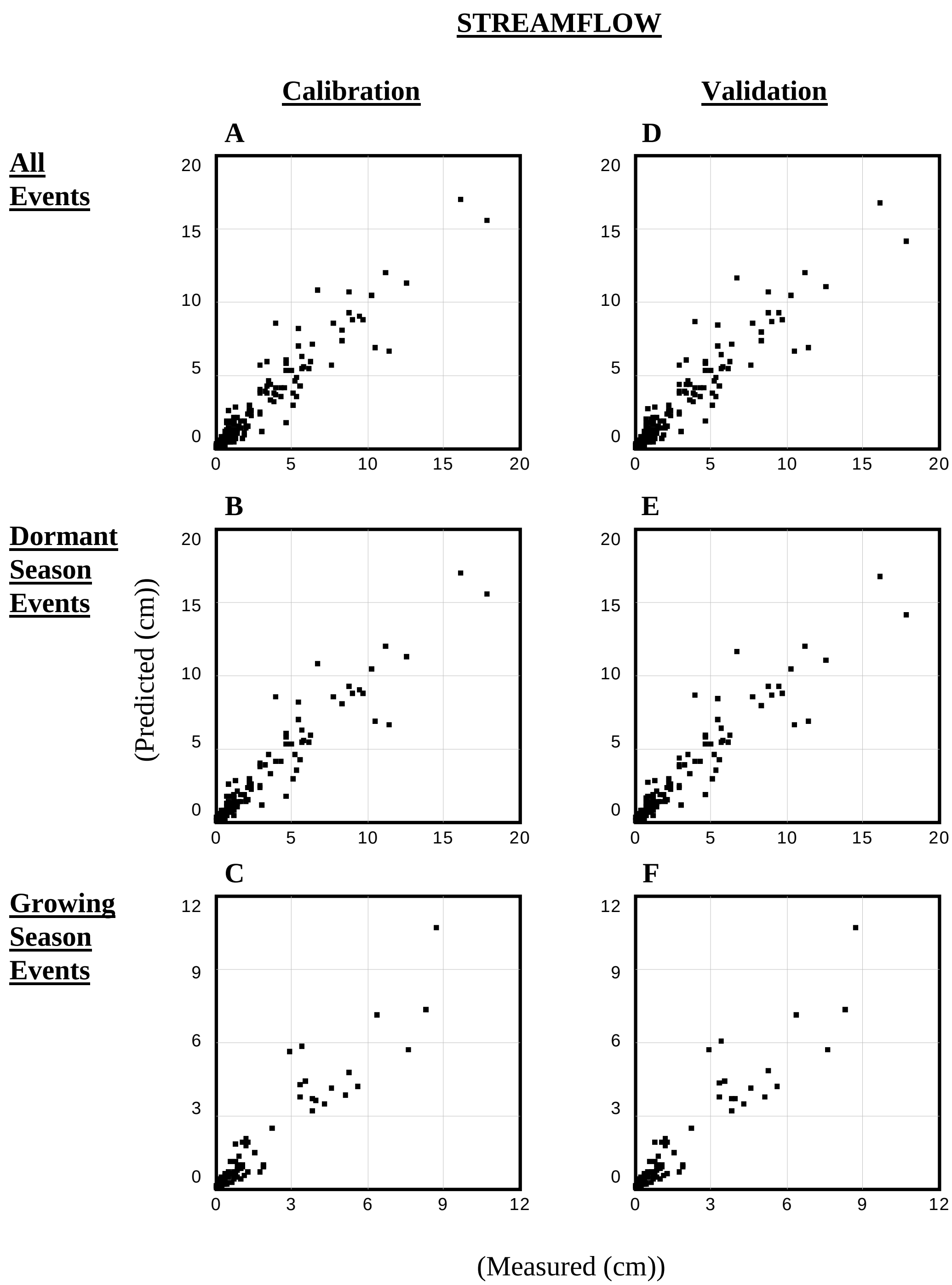

Figure A.10 Scatterplots of observed vs. predicted event streamflow for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

STREAMFLOW

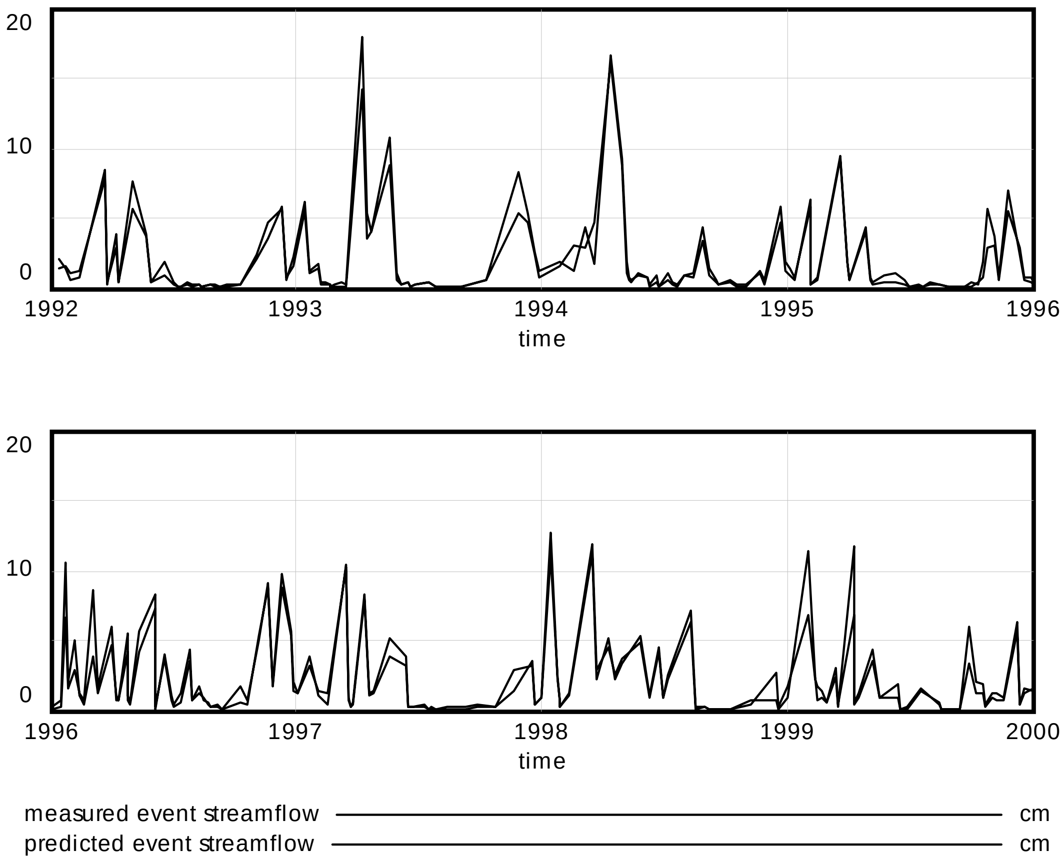

Figure A.11 Observed and predicted (jackknife) event streamflow, 1992-1999.

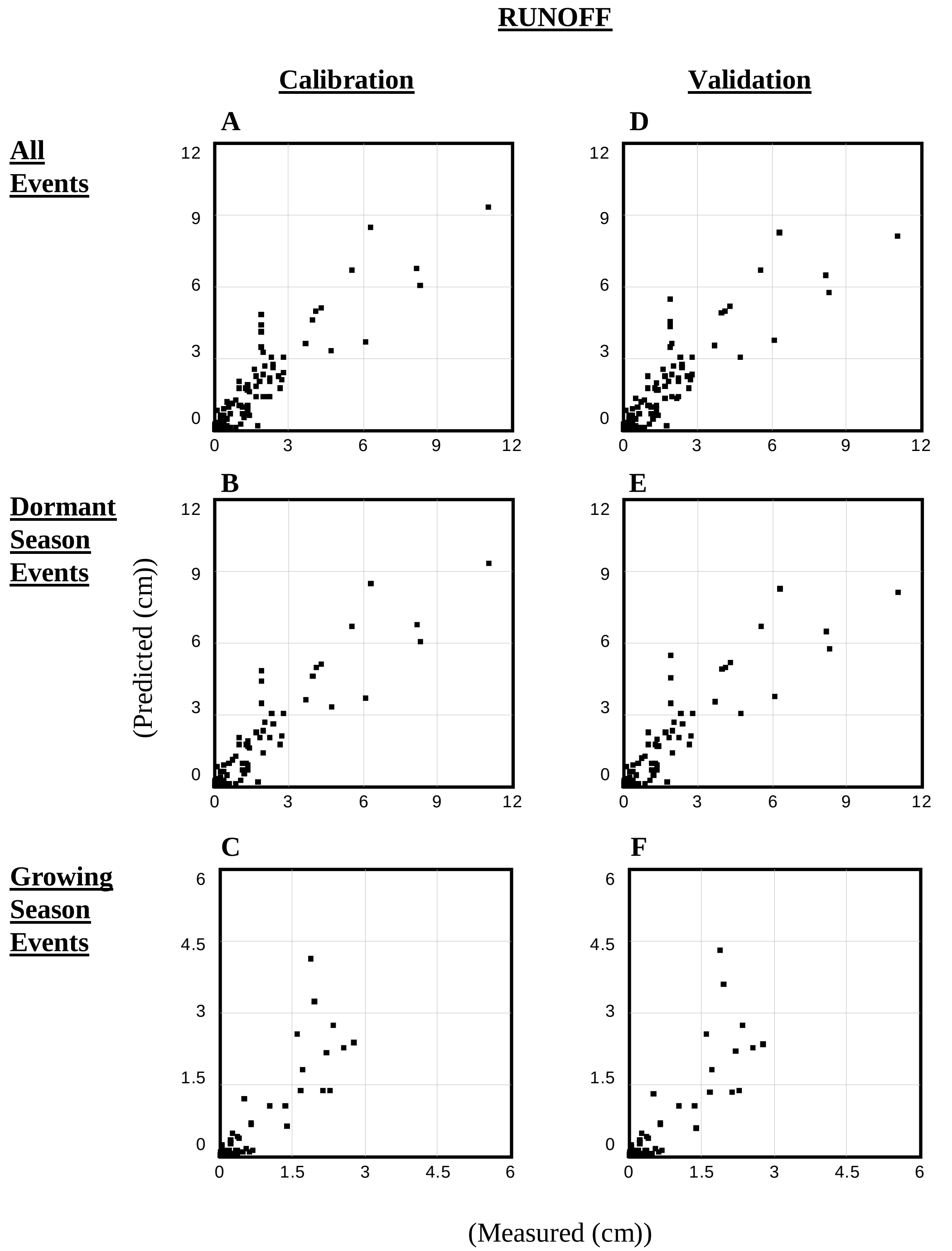

Figure A.12 Scatterplots of observed vs. predicted event runoff for period 1992-1999.
A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

RUNOFF

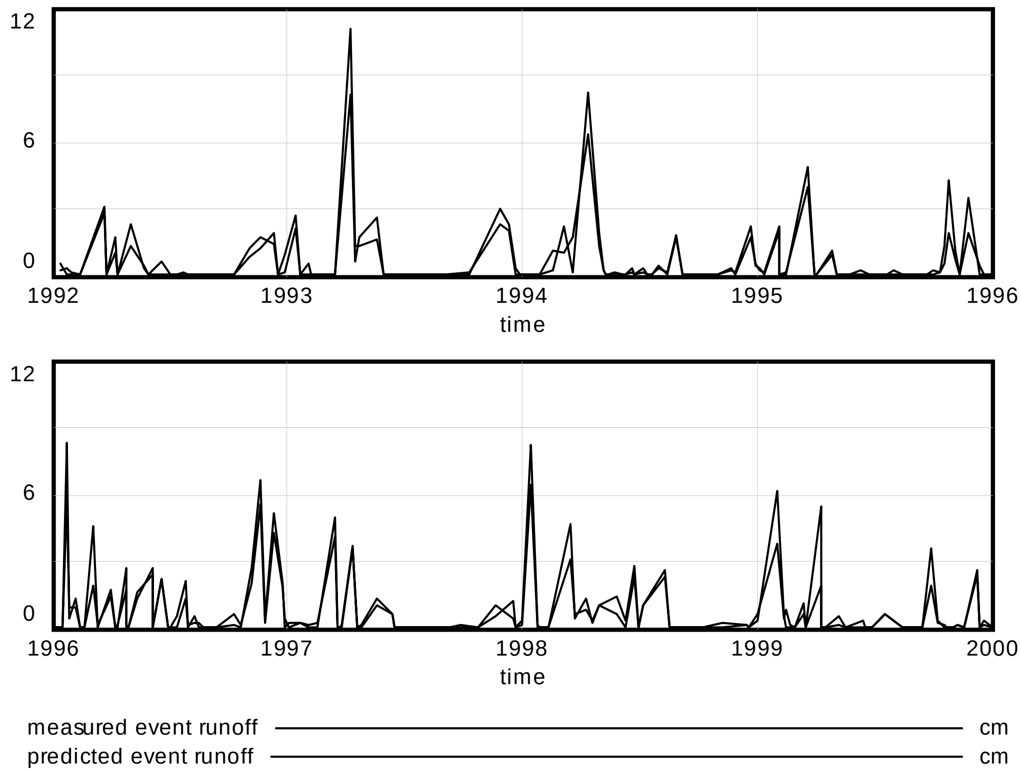

Figure A.13 Observed and predicted (jackknife) event runoff, 1992-1999.

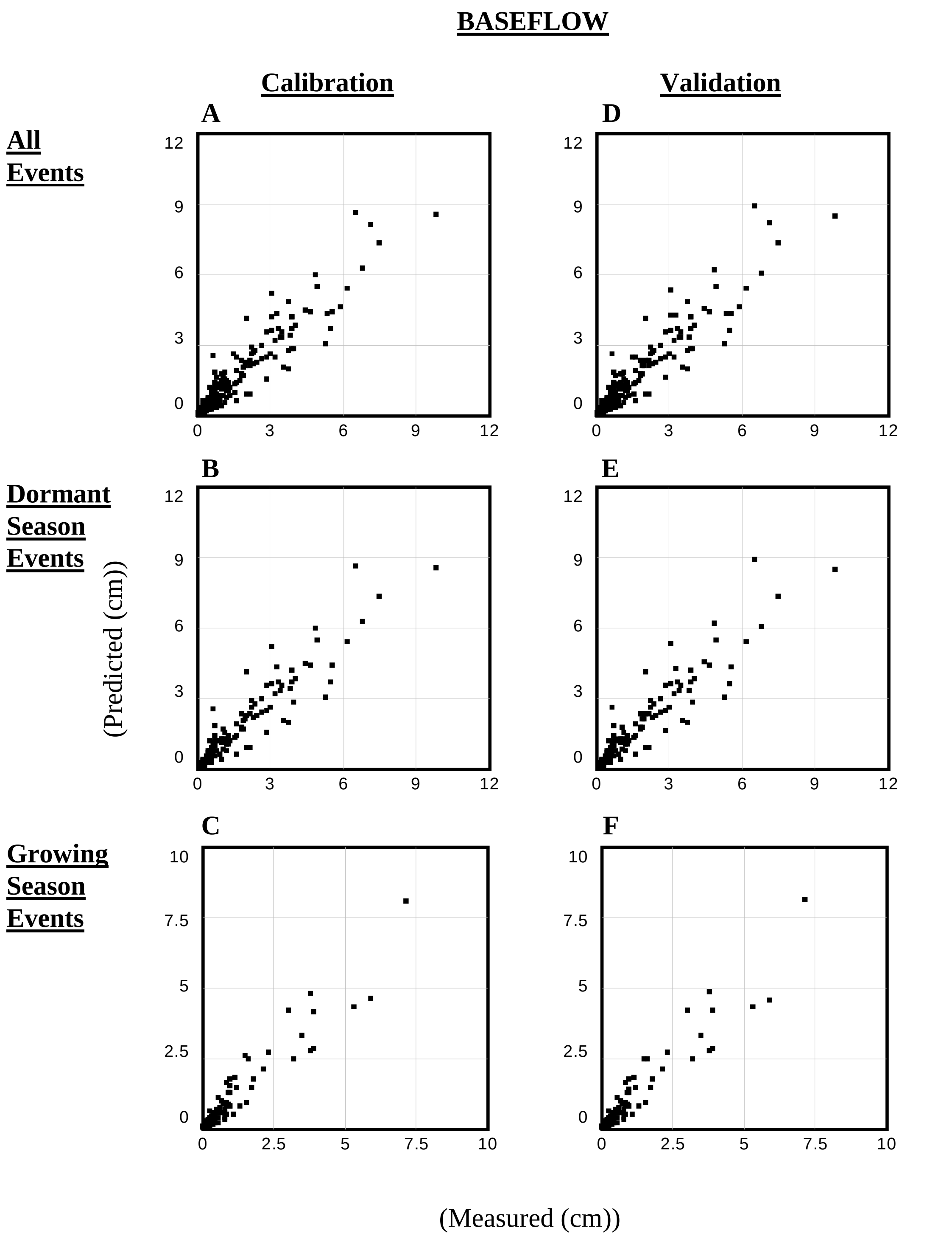

Figure A.14 Scatterplots of observed vs. predicted event baseflow for period 1992-1999. A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

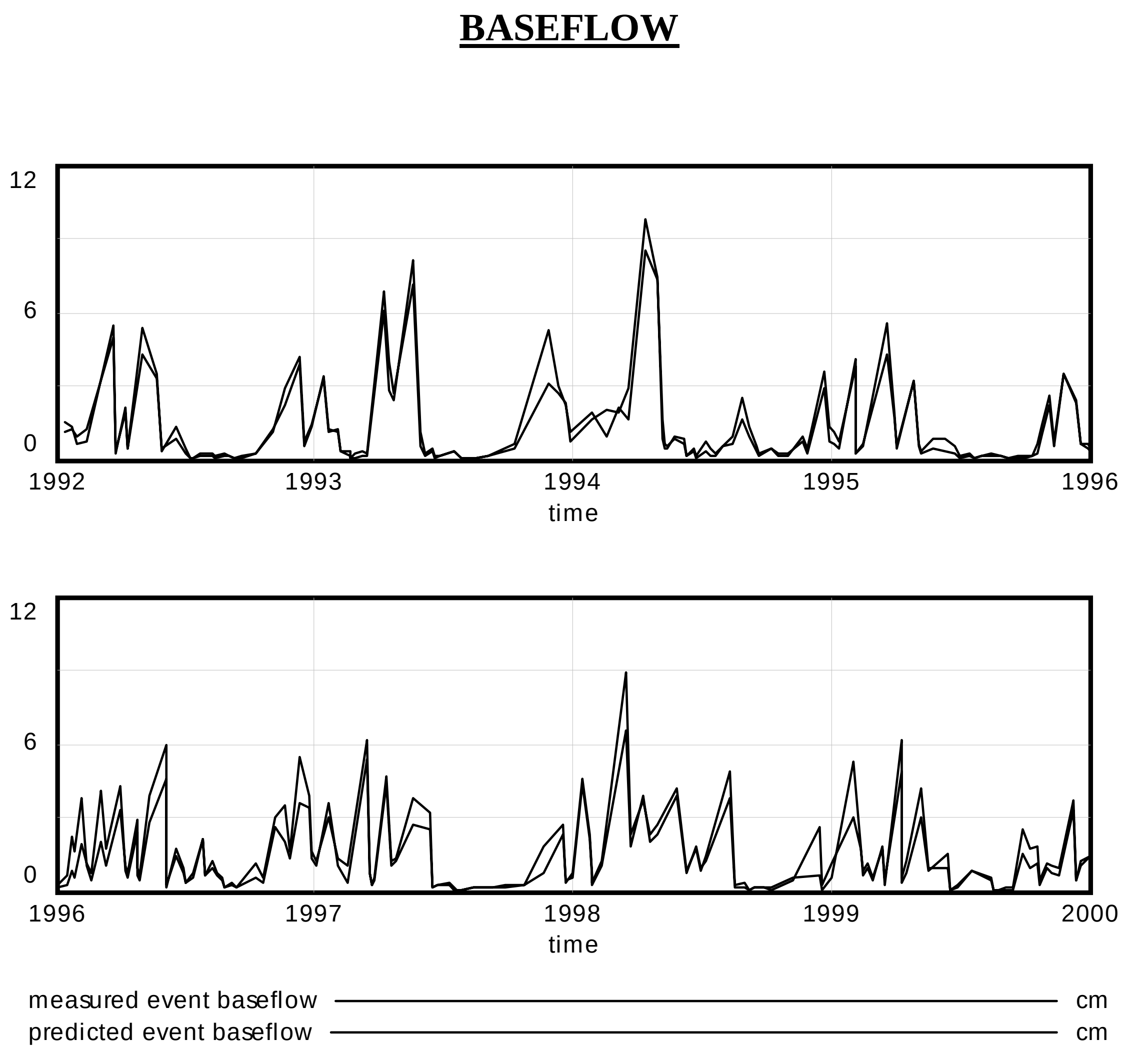

Figure A.15 Observed and predicted (jackknife) event baseflow, 1992-1999.

Dissolved Nutrients

For dissolved nutrients the following parameters are calibrated: groundwater (GW) concentration, Runoff Conc Param B and Runoff Conc Param C (DEP, 2006). The GW concentration is multiplied by the baseflow component of streamflow. The runoff concentration parameters B (multiplicative) and C (exponential) are applied to the runoff component to obtain a runoff factor that is then multiplied by the median runoff dissolved nutrient concentrations for each land use.

Tables A.9 and A.10 show results for calibrated parameters and error statistics. Figures A.16 through A.21 depict scatterplots and time series that compare observed dissolved nutrients (P, N, C) with either simulation results of the calibrated model or with the jackknife validation time series. The calibration results reveal the calibration error, while the jackknife validation results measure the prediction error of the model. Error statistics and plots are given for dormant season (November through April) and growing season (May through October) events as well as for all events in the 1992-1999 period.

The calibrated model predicts dissolved P well for both dormant and growing seasons, with ${R_{NS}}^2$ exceeding 0.7. There is a mild tendency to underestimate growing season dissolved P (~11% bias)., suggesting some additional seasonal variation in P concentrations that is not accounted for in the model. The model tracks variation in event dissolved P quite well in both seasons.

Error statistics and plots for dissolved N show very good tracking of temporal variation in loads during all seasons, with ${R_{NS}}^2$ exceeding 0.8. The calibrated model clearly overestimates dissolved N during the growing season (%bias ~25%). This is not unexpected, since the model does not account for increased denitrification rates (which are temperature dependent) and accompanying loss of N to the atmosphere during the growing season.

Results for dissolved C are good when considering all events, with ${R_{NS}}^2$ exceeding 0.7 and % bias <3%. Seasonal model performance has more prediction error (dormant season ${R_{NS}}^2$ ~0.5, seasonal % bias +/-15%. Underestimation of dissolved C during the growing season may reflect the model not accounting for increased organic decomposition rates (which are temperature dependent) with accompanying increase in available dissolved organic C during the growing season. The elevated errors in dissolved C predictions when compared to dissolved P and N may also be due to the smaller sample size (54 events for C vs. 243 events for N and P).

The calibrated exponents of the flow:dissolved nutrient concentration relationships (Runoff Conc Param C, TableA.9) deserved mention. The positive value of the flow:concentration exponent for P indicates that P concentrations tend to be elevated during high flow events. One explanation for this pattern is that there are sources of P in the watershed that only become available for transport during high flows. Such sources may include variable source areas that only contribute runoff during very large storms, while accumulating P between the large storms. In contrast, the negative values of the flow:concentration exponents for N and C suggest that for these nutrients a watershed-scale dilution effect occurs, with concentrations declining for high flow events.

Table A.9. List of calibrated dissolved nutrient parameters for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Parameter	Calibrated Values P	N	C
GW Concentration ($mg \cdot L^{-1}$)	0.0094	0.5876	0.9532
Runoff Conc Param B	1.039	0.682	2.366
Runoff Conc Param C	0.430	-0.178	-0.307

Table A.10. Calibration and Verification Results for dissolved nutrients for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Dissolved Nutrient Result	Statistic	Calibration			Validation		
		all events	dormant season	growing season	all events	dormant season	growing season
	# Events	243	120	123	243	120	123
P	R_{NS}^2	0.792	0.774	0.829	0.755	0.732	0.817
	% bias	-0.06%	4.71%	-11.07%	-0.96%	3.32%	-10.86%
N	R_{NS}^2	0.857	0.836	0.825	0.844	0.819	0.816
	% bias	-0.11%	-7.61%	24.49%	-0.22%	-7.93%	25.07%
C	# Events	54	25	29	54	25	29
	R_{NS}^2	0.788	0.539	0.912	0.751	0.474	0.888
	% bias	2.61%	17.02%	-13.08%	0.47%	16.52%	-17.02%

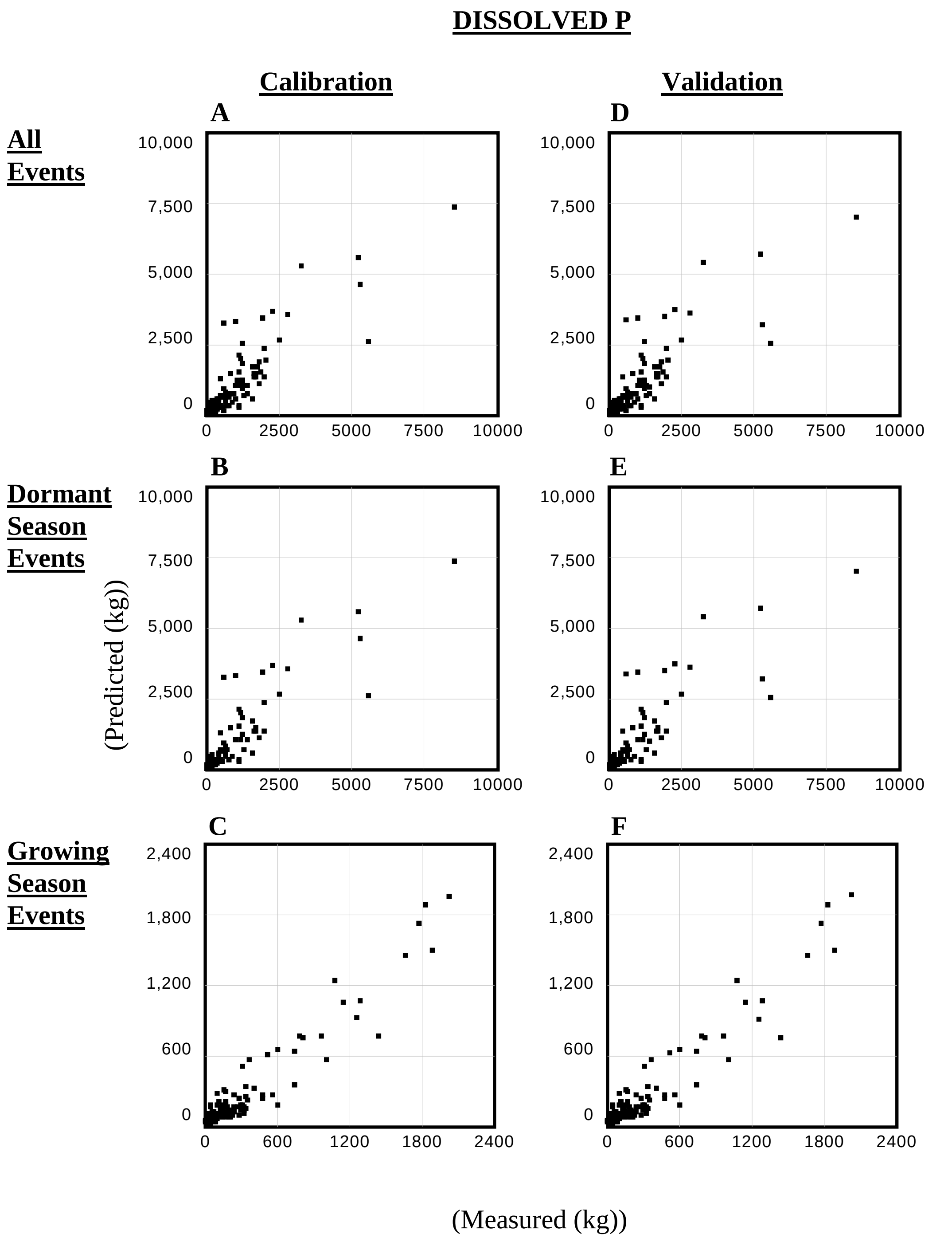

Figure A.16 Scatterplots of observed vs. predicted event dissolved P for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

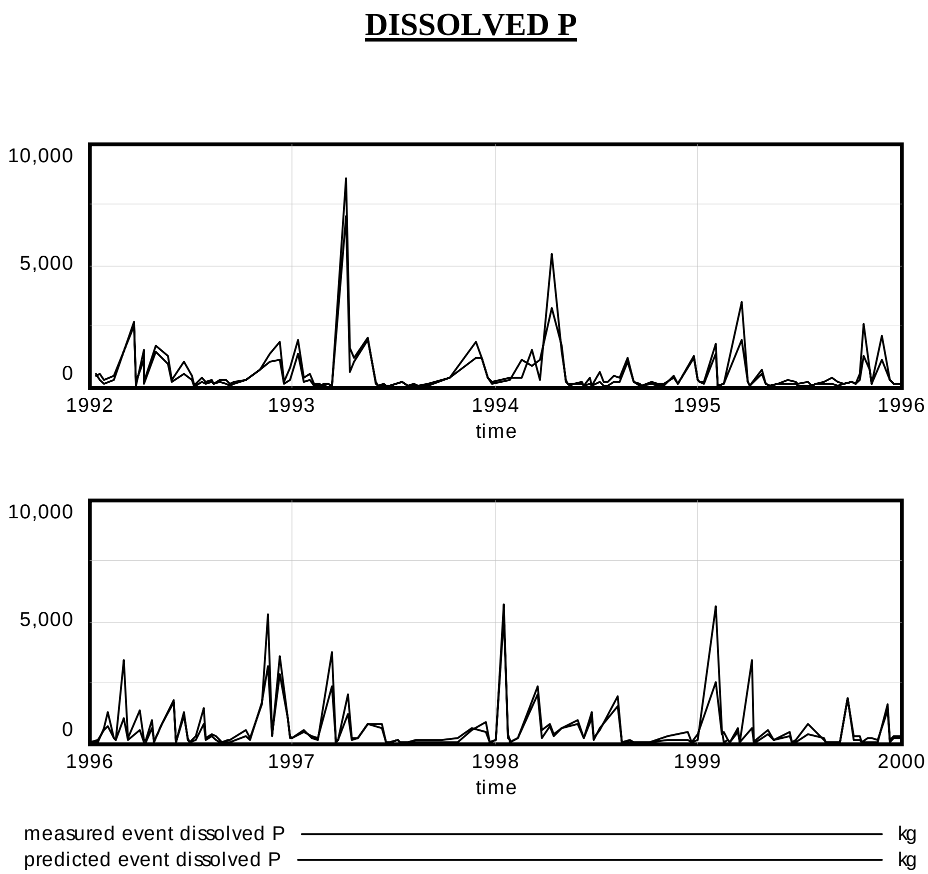

Figure A.17 Observed and predicted (jackknife) event dissolved P, 1992-1999.

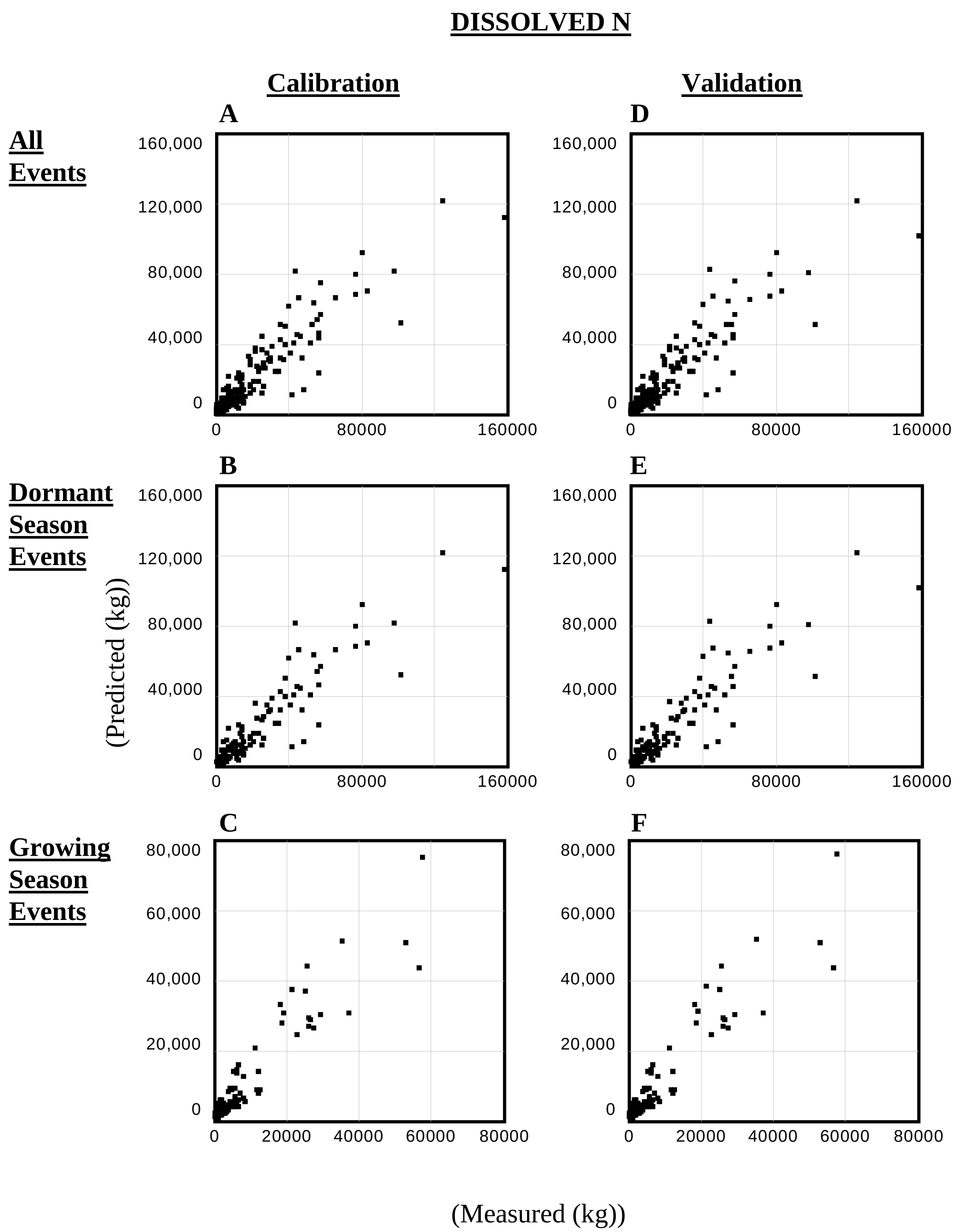

Figure A.18 Scatterplots of observed vs. predicted event dissolved N for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

DISSOLVED N

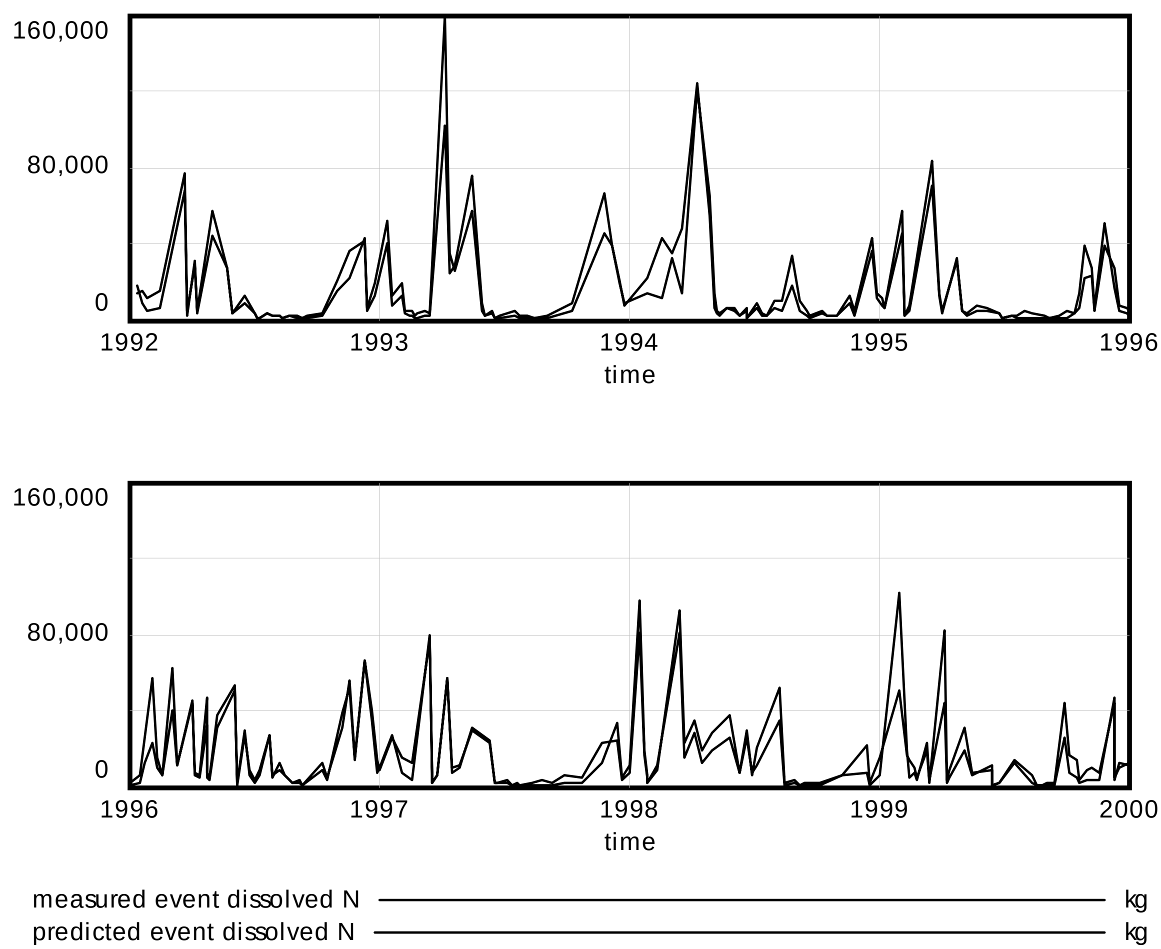

Figure A.19 Observed and predicted (jackknife) event dissolved N, 1992-1999.

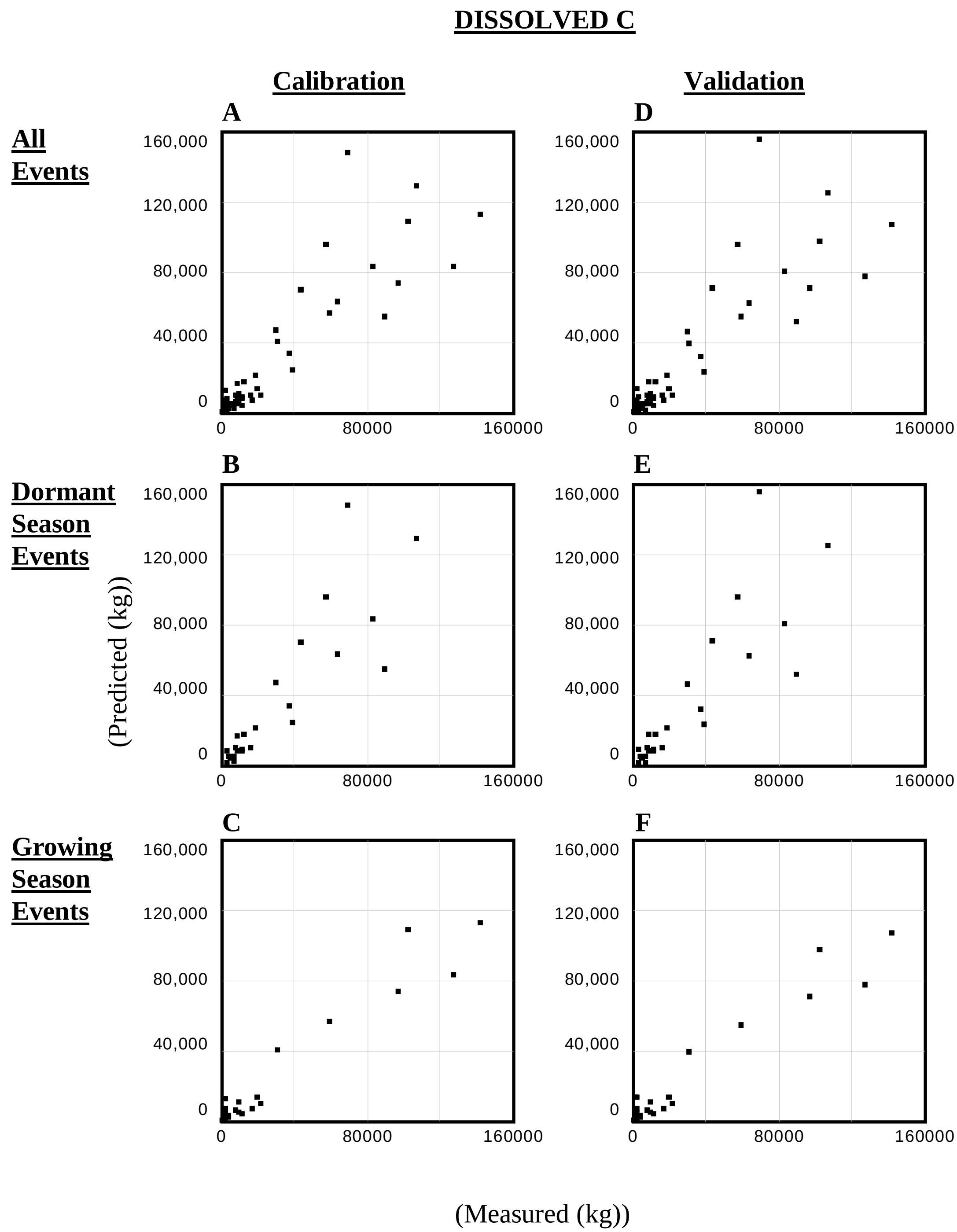

Figure A.20 Scatterplots of observed vs. predicted event dissolved C for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

DISSOLVED C

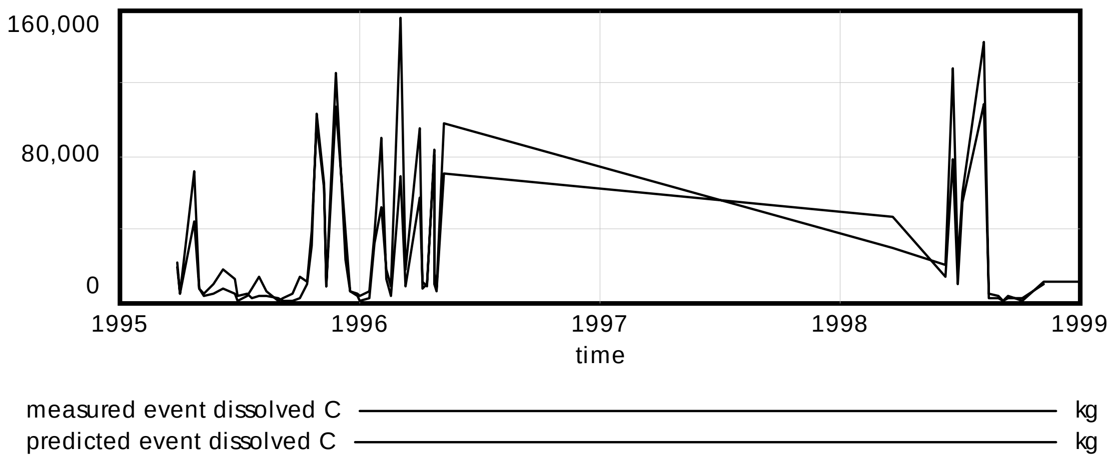

Figure A.21 Observed and predicted (jackknife) event dissolved C, 1992-1999. Observed data was available for 3/22/1995-5/10/1996 and 5/7/1998-11/3/1998.

Sediment Yield

The parameters that determine sediment yield magnitude (sediment delivery ratio) and timing (transport capacity power) are calibrated. These two parameters are optimized to simultaneously maximize R_{NS}^2 and minimize the % bias between simulated and observed event sediment yield.

Tables A.11 and A.12 show results for calibrated parameters and error statistics. Figures A.22 and A.23 depict scatterplots and time series that compare observed sediment yield with either simulation results of the calibrated model or with the jackknife validation time series. The calibration results reveal the calibration error, while the jackknife validation results measure the prediction error of the model. Error statistics and plots are given for dormant season (November through April) and growing season (May through October) events as well as for all events in the 1992-1999 period.

The resulting R_{NS}^2 for all events and for dormant season events exceed 0.7, suggesting low prediction error. Prediction error for growing season events is higher, with R_{NS}^2 ~0.4 and % bias ~ -25%. The sediment rating curve algorithm in the model appears to be less accurate for the growing season when relatively small storms generally occur.

Table A.11. Calibrated sediment yield parameters for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Parameter	Calibrated Values
Transport Capacity Power	2.393
Sediment Delivery Ratio	0.058

Table A.12. Calibration and Verification Results for sediment yield for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Sediment Yield Error Statistic	Calibration			Validation		
	all events	dormant season	growing season	all events	dormant season	growing season
# Events	243	120	123	243	120	123
R_{NS}^2	0.798	0.830	0.440	0.758	0.787	0.413
% bias	-0.21%	8.10%	-26.75%	0.37%	8.81%	-26.59%

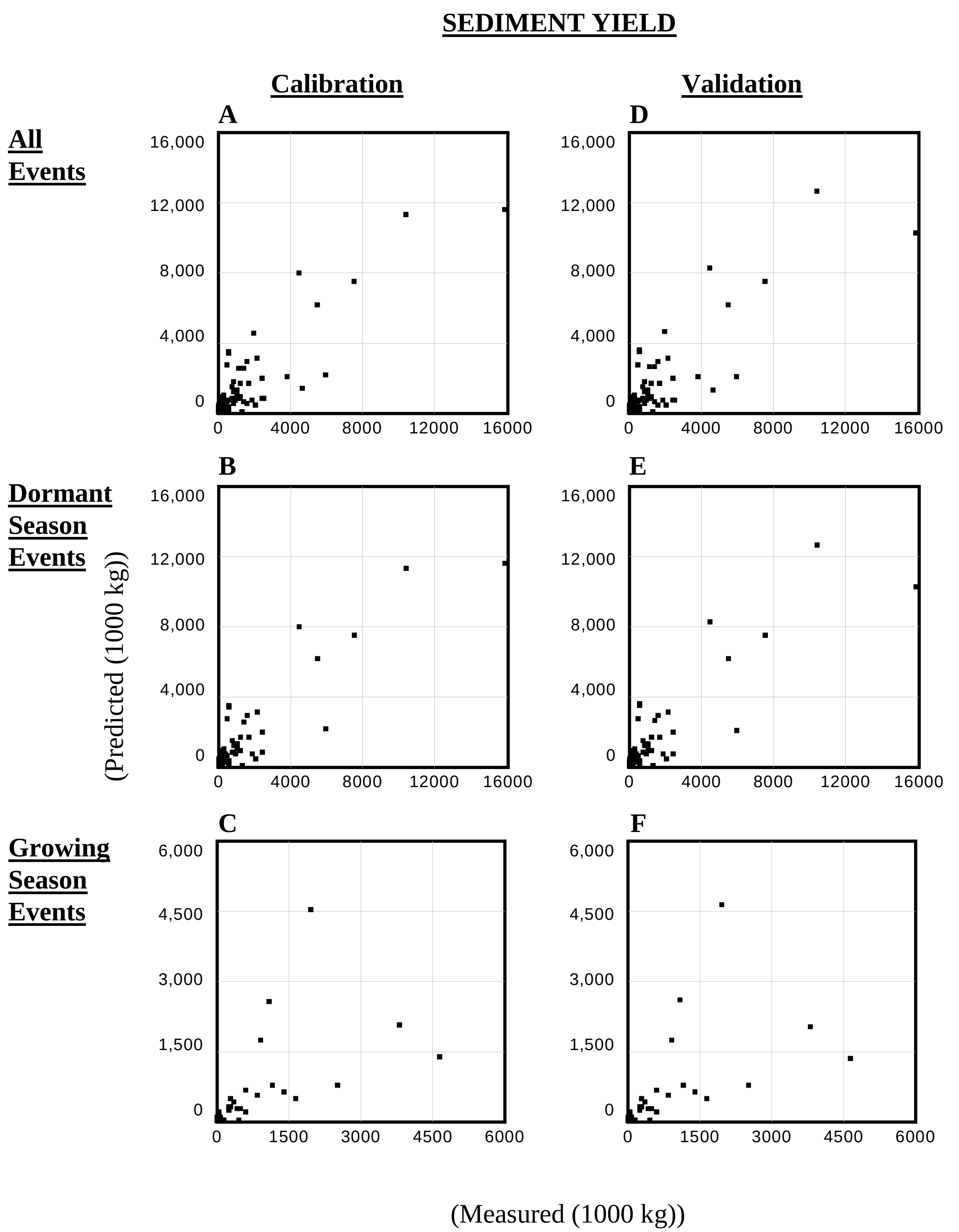

Figure A.22 Scatterplots of observed vs. predicted event sediment yield for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

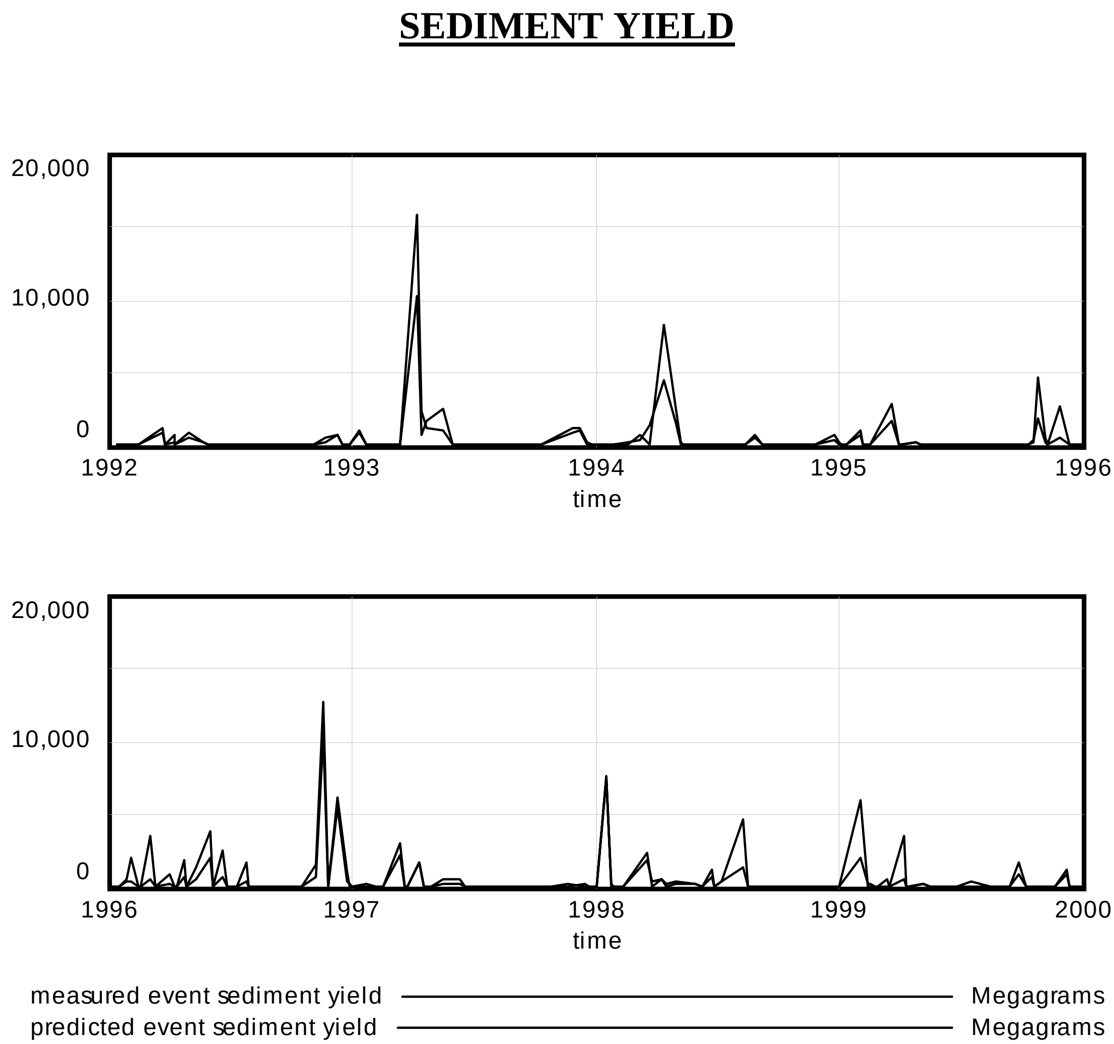

Figure A.23 Observed and predicted (jackknife) event sediment yield, 1992-1999.

Particulate P

The enrichment ratio, which controls the magnitude of particulate P, is calibrated using event particulate P loads. Tables 2.11 and 2.12 show results for calibrated parameters and error statistics. Figure A.24 depict scatterplots and time series that compare observed particulate P with either simulation results of the calibrated model or with the jackknife validation time series. The calibration results reveal the calibration error, while the jackknife validation results measure the prediction error of the model. Error statistics and plots are given for dormant season (November through April) and growing season (May through October) events as well as for all events in the 1992-1999 period.

The results show good Nash-Sutcliffe coefficients of 0.82 and 0.79 for calibration and validation respectively when all events are considered. As was found with sediment yield predictions, prediction error for growing season events is higher, R_{NS}^2 ~0.4 and % bias ~ -22% underestimation.

Table A.13. Calibrated enrichment ratio for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Parameter	Calibrated Values
Enrichment Ratio	2.487

Table A.14. Calibration and Verification Results for particulate P for West Branch Delaware River at Beerston (NYS DEC Beerston Sampling Site).

Particulate P Error Statistic	Calibration			Validation		
	all events	dormant season	growing season	all events	dormant season	growing season
# Events	243	120	123	243	120	123
R_{NS}^2	0.820	0.849	0.463	0.794	0.821	0.438
% bias	0.00%	7.43%	-22.20%	0.56%	8.13%	-22.03%

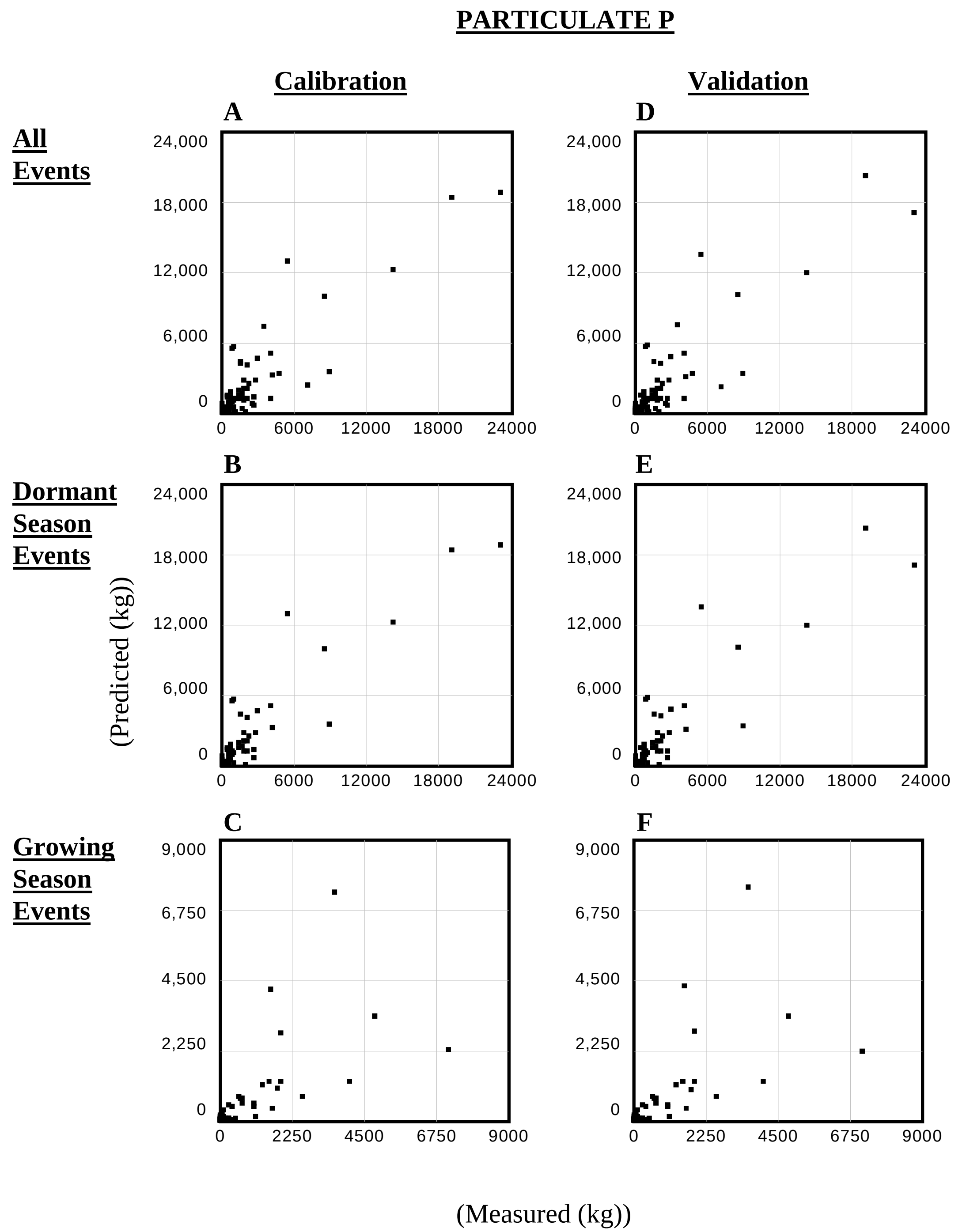

Figure A.24 Scatterplots of observed vs. predicted event particulate P for period 1992-1999.

A) Calibration predictions, all events. B) Calibration predictions, dormant season. C) Calibration predictions, growing season. D) Validation predictions, all events. E) Validation predictions, dormant season. F) Validation predictions, growing season.

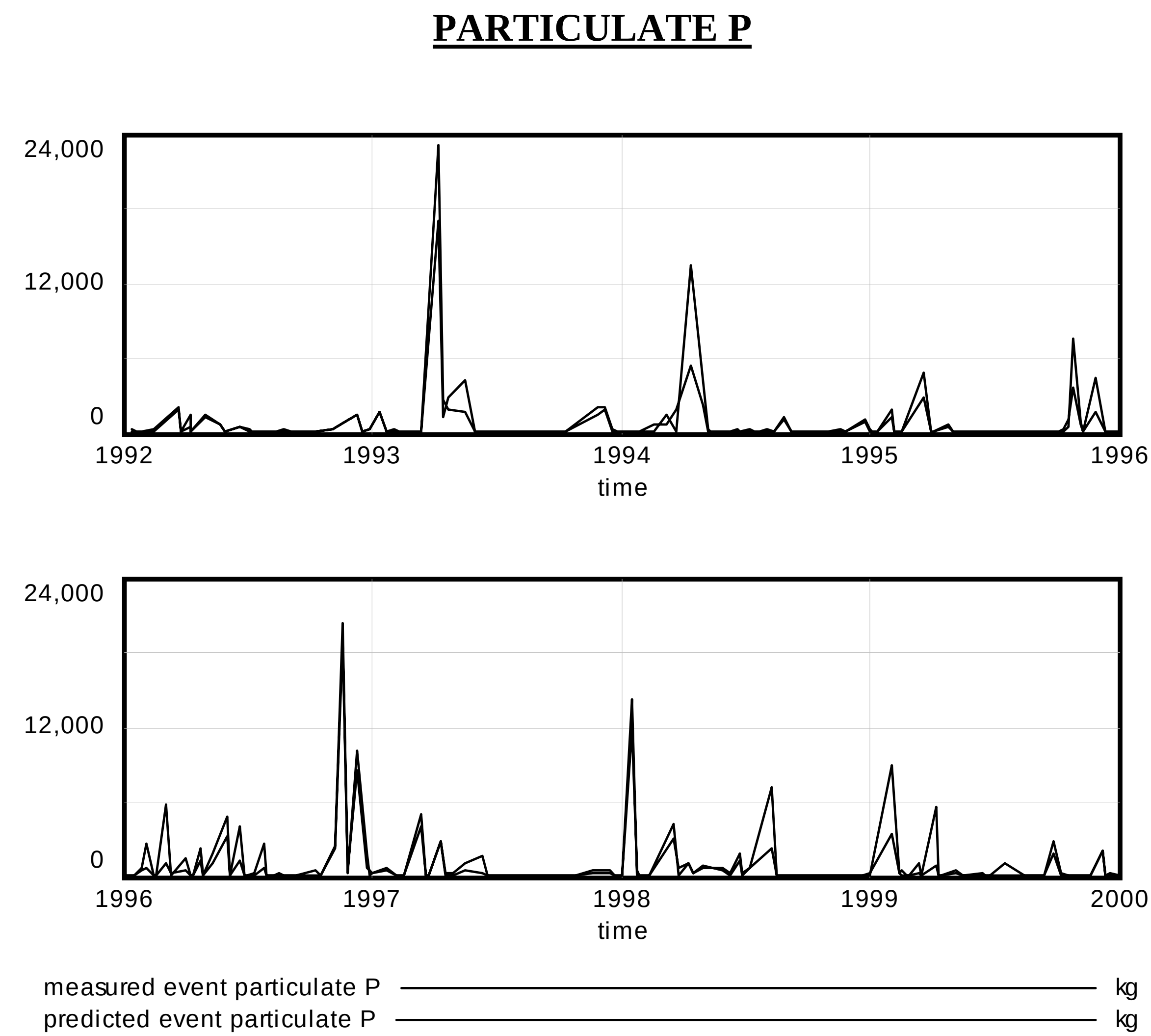

Figure A.25 Observed and predicted (jackknife) event particulate P, 1992-1999.

Summary

The GWLF model was calibrated and validated for the 1992-1999, which corresponds to the baseline period prior to extensive implementation of watershed management programs in the New York City watersheds. This calibration and validation is updated from previous work, using the newer version of the GWLF model, and updated data, calibration and validation methods.

The calibrated hydrology model demonstrates low calibration error and low prediction error for all flow components (streamflow, runoff, and baseflow) in both dormant and growing seasons. By all accounts the hydrology model calibration and validation is very good. Results for the water quality calibration and validation were also good. Dissolved P prediction errors were low in dormant and growing season, with mild (~10%) tendency to underestimate growing season dissolved P. Dissolved N is predicted well when all events are considered and for the dormant season. The model tends to overestimate dissolved N in the growing season, probably due to elevated growing season denitrification rates that are not accounted for in the model. Dissolved C predictions were reasonable, considering the smaller sample size of available data for calibration and validation. The model tends to underestimate growing season dissolved C, possibly due to elevated warm weather decomposition rates that are not accounted for in the model. Sediment and particulate P predictions were good when all events are considered and for the dormant season. The model tends to underestimate sediment and particulate P during the growing season, which typically has smaller events than the dormant season.

DEP will continue to use this updated calibrated and validated model for Cannonsville watershed, and improve the model as necessitated by future model applications.

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