Compendium of Abstracts

Presented at the

2nd Annual New York City Watershed Science and Technical Conference

September 21 & 22, 2004

Advancing the Science of Watershed Protection

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Governor

Randy A. Daniels
Secretary of State

2nd Annual New York City Watershed Science and Technical Conference

Advancing the Science of Watershed Protection

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INTRODUCTION AND ACKNOWLEDGMENTS

Dear Conference Participants,

In 1997, the signatories to the historic New York City Watershed Agreement formed a vast partnership to protect and enhance the New York City Watershed and the scores of communities living within it. Integral to this complex and ambitious undertaking has been an unprecedented array of Watershed protection and water quality monitoring measures, coupled with unparalleled efforts and resources devoted to understanding the science of watershed protection.

The New York City Watershed Science and Technical Conference was created as an annual opportunity to bring scientists together with watershed stakeholders and the public, to technically inform, exchange ideas, and present information collected regarding the protection of the nation's largest unfiltered surface water supply. While presenting new research findings and data, we believe that the conference will also serve to enhance technology transfer and increase coordination among the array of entities working to advance watershed science.

Earlier this year, a Call for Abstracts was made to agencies and stakeholders in and beyond the NYC Watershed. The resulting overwhelming response, coupled with a conference constrained by space and time, necessitated a process of review and selection by the Watershed Protection and Partnership Council's Technical Advisory Committee. The abstracts chosen by the Committee for presentation are included in this compendium.

In addition to all who submitted their scientific endeavors, we wish to thank the many agencies, professional organizations, and individuals who contributed to the success of this conference. It is our hope that all who attend will be edified by the scientific data presented, and inspired by the dedication and hard work of those who, each day, advance our insight into the science of protecting the drinking water for 9 million New Yorkers.

Respectfully,

<u>The Conference Sponsors:</u>

The New York State Department of Environmental Conservation
The New York State Department of Health
The New York State Department of State
The New York City Department of Environmental Protection
The Watershed Protection and Partnership Council
The Catskill Watershed Corporation
The New York Water Environment Association
The New York Section of the American Water Works Association

Water Quality Effects of Septic Systems and Domestic Water Softeners on Stream Runoff in Three Small Watersheds in the Croton System, New York

Myriam Adam, Myron Mitchell, Douglas Burns, James Hassett

Three small (50-70 ha) watersheds within the Croton system were monitored for a one year period, August 2001 to August 2002. The watersheds included a forested watershed in a county park, and two watersheds with different degrees of suburban development. Sample collection modes included throughfall, soil water via tension lysimeters, and groundwater via monitoring wells and piezometers, as well as stream samples during both base flow and storm flow conditions. Instruments were installed in 5 to 7 clusters located at different landscape positions (quantified by the Topographic Index) in each watershed. In addition, each watershed was equipped with a V-notch weir for discharge monitoring, and a meteorological station. Domestic water for each household was supplied from groundwater pumped from the fractured bedrock beneath the developed watersheds; each household had a septic tank and leach field.

The efflux of sodium and chloride from B28, the most developed watershed, was disproportionately higher than other water quality constituents. On a per area basis, B28 exported nearly 50 times the quantity of sodium and chloride than WPR, the forested reference watershed, and nearly two and a half times as much as was generated from PWS, the watershed with the intermediate degree of development. Nitrate efflux, often used as a chemical index for suburban development, differed by a factor of slightly less than two between B28 and PWS, a factor consistent with the number of households and hence septic systems densities in these watersheds.

Stream discharge and concentration data had seasonal patterns for some solutes (e.g., sodium, Na^+, and chloride, Cl^-) in runoff from the developed watersheds. During winter snowmelt-runoff events, concentrations of sodium and chloride increased with stream discharge. During summer runoff events, concentrations of these same solutes decreased with increasing discharge, suggesting the importance of a surface runoff transport mechanism during snowmelt, and a dilution of a distributed groundwater source during summer storm events.

The spatial patterns of Na^+, Cl^-, calcium (Ca^{2+}) and magnesium (Mg^{2+}), as determined from analyses of samples obtained from the instrument clusters, were consistent with a distributed source of the ions. The spatial patterns of nitrate were similar to those of Na^+, Cl^-, Ca^{2+} and Mg^{2+}, although the nitrate concentrations were likely affected by seasonal patterns in biological activity.

Samples of domestic drinking water obtained from individual wells in the developed watersheds (n = 42) showed relatively hard water (median hardness 325 mg L^{-1} as $CaCO_3$), and thus the prevalence of water softeners in many households, and thus the distributed source of the Na^+, Cl_-, Ca^{2+} and Mg^{2+} ions. In addition, a positive correlation between nitrate and Cl- in samples of deep groundwater indicates the aquifer might become contaminated with septic effluent, and thus place this source of domestic water in jeopardy.

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Genotypes of *Cryptosporidium* Oocysts in New York City Storm Water

Kerri Ann Alderisio, Lihua Xiaoo, Jianlin Jiang

To compare the sources and public health significance of *Cryptosporidium* oocysts found in different storm waters in the New York City watershed, samples were collected from two distinctly different streams and analyzed using a small-subunit rRNA-based PCR RFLP technique. Forty samples were collected from Malcolm Brook in Westchester county N.Y., and compared with 29 samples collected and analyzed previously from Ashokan Brook in Ashokan, N.Y. Most samples were positive for the recovery of *Cryptosporidium* oocysts, and nearly all of those recovered were determined to have originated from wildlife sources rather than types recovered from humans or domestic animals. An exception was the recovery of *C. hominus* from Malcolm Brook during a two week period in March 2002; however, the brook was sampled repeatedly since that time and *C. hominus* was not recovered again. The predominant sources of oocysts in both watersheds were determined to be deer and muskrats, as well as an unknown genotype (W1). Some *Cryptosporidium* types were found at Malcolm Brook and not Ashokan Brook, including two additional unknown types as well as a likely fox genotype. Conversely, there were a few types recovered from the Ashokan brook that were not recovered at Malcolm brook, such as *C. baileyi*, and two 2 opossum genotypes. In all, 12 genotypes were recovered from these storm waters that can be attributed to known species/ groups of animals, while 6 genotypes are unique and the sources are yet unknown. Results from this study indicate that molecular techniques can be used to compliment current enumeration techniques used in water sample analysis to identify sources of contamination in the watershed. These results are significant since oocyst source identification can help determine the human infective potential and health risks associated with *Cryptosporidium* oocysts found in storm water.

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Stream Macroinvertebrate Communities and their Relationships to Dominant Land Covers/Uses and Water Chemistry in the NYC Source Water Areas

D.B. Arscott, C. Dow, J.K. Jackson, J.D. Newd, A.K. Aufdenkampe, L.A. Kaplan, B.W. Sweeney

Sixty stream monitoring sites in the New York City source water area were visited annually for three years (2000-2002) to collect quantitative (Hess Sampler) benthic macroinvertebrate samples, benthic chlorophyll and ash-free dry mass, and water chemistry. Water chemistry analytes included nutrients, particulates, dissolved organic carbon, major ions, and a suite of molecular tracers (caffeine, fragrance materials, fecal sterols, and polycyclic aromatic hydrocarbons). Dominant land cover/uses, population densities, and known permitted discharges were quantified for watershed area upstream from each study site. Macroinvertebrate assemblages were characterized using macroinvertebrate indices (e.g., total richness) and by multivariate statistical procedures.

Macroinvertebrate indices for sites located in East of Hudson (EOH) drainages indicated a range of biological impairment at sites with higher impervious surfaces, higher population densities, and greatest flow contributions from known point source discharges. Chemical variables helped characterize these gradients. For example, molecular tracers (caffeine, fragrance materials, and fecal sterols, which identify human waste contributions), inorganic nutrients (phosphorus and nitrogen) and dissolved organic carbon correlated (all $r > 0.65$) with area-weighted permitted discharge in EOH drainages. Major ions (Ca, Mg, K, Na, Cl, and SO_4), conductivity, and alkalinity correlated with population density and percent impervious surface in the catchment. In West of Hudson (WOH) drainages macroinvertebrate indices were not related to any land cover/use or water chemistry variable. Given the high integrity of streams in this region, this result was expected. However, there were measurable and predictable changes in water chemistry due to changes in land cover/use across this region. For example, total phosphorus, nitrate-nitrogen, dissolved organic carbon, and benthic chlorophyll *a* standing stock correlated strongly with increases in percent agricultural land cover/use and population density.

A multivariate direct gradient technique, Co-Inertia Analysis (CoIA), was used to assess whether environmental variables potentially explained distribution patterns of species among the sites. Co-Inertia Analysis matched macroinvertebrate patterns to measured environmental and land cover/use variables for EOH and WOH sites separately. The EOH ordination supported patterns observed by relating macroinvertebrate indices to known impact gradients. The WOH ordination indicated that macroinvertebrate community structure changed along two environmental gradients that were related to increasing nutrient concentrations and a pH gradient (~6.5 – 8.5 pH). Macroinvertebrate communities appeared to also be influenced by biogeography.

Multivariate techniques confirmed macroinvertebrate community response to site specific water quality changes in moderately and severely impacted biological communities and were complimentary to macroinvertebrate indices. Multivariate techniques based on taxon specific (primarily genus/species resolution) density estimates (ind./m^2) resulted in greater sensitivity to changes in community structure than macroinvertebrate indices. The multivariate technique revealed shifts in dominance and species replacement that could ultimately be used to assess biological health at sites in early stages of change due to altered habitat and/or water quality.

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Response of Fish Communities to Restored Geomorphic Stability in Streams of the Catskill Mountains, New York

Barry P. Baldigo, Anne Gallagher-Ernst, Walter Keller, Dana R. Wareen, Daniel Davis, Sarah J. Miller, Thomas Baudanza, Jake R. Buchanan, Doug DeKoskie

Natural-channel design (NCD) techniques were used to restore geomorphic stability of three small Catskill Mountain streams to reduce erosion and sedimentation and, thereby, maintain or improve water quality. The effects of channel restoration on biological integrity were evaluated through a comparison of fish-community characteristics in stable-reference (control) reaches with those in unstable-treatment reaches for one or two years before and two years after restoration. Before-after-control-impact (BACI) methods were used to standardize the response of fish communities (indices) at treatment sites due to restoration to normal interannual fluctuations that occur in nearby control reaches. One- and two-factor analysis of variance (ANOVA) was used to assess differences in BACI-adjusted indices (differentials) among streams, before and after restoration, and between the types of responses observed in the three streams. Changes in density differentials at restored reaches were not consistent; however, community richness, biomass, and equitability (based on species biomass) differentials were significantly greater after restoration than before, although the response often varied among streams. Blacknose dace, longnose dace, and slimy sculpin populations generally declined, whereas, trout species either were reestablished or increased in density and (or) biomass. The findings indicate that NCD restorations can enhance the biological integrity of aquatic ecosystems in Catskill Mountain streams.

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Water Quality In Cattaraugus Creek, Northwestern New York State

Gloria Patricia Basto-Salgado, Carl G. Johnston, Thomas Diggins

Assessing the ecological health of rivers has become one of the most important environmental policies worldwide. Thus, the need for methods to evaluate river health has generated a vast array of tools to evaluate, maintain and restore streams. Water quality assessments include a wide range of parameters that determine, or at least estimate, the condition of a stream at any given time. Physical and chemical variables and biological data have been intensively used in the last decade. In contrast, to date microbial aspects, such as quantification and diversity, in streams are currently poorly characterized. The present study aims to identify possible relationships between physical and chemical characteristics, benthic community structure and microbial quantification as a holistic understanding of water quality of the Cattaraugus Creek, Zoar Valley Canyon, New York State. Consequently our study provides a first unified baseline that will be used for further monitoring of the river system, and will aid the development of future watershed management practices. Water quality variables including nitrogen, phosphorus, chlorophyll, turbidity, temperature, pH, conductivity, dissolved oxygen and salinity are being measured throughout the calendar year using either an YSI 6600 Multiparameter Probe or standard wet chemistry methods. Additionally, benthic macroinvertebrate community and microbial quantification including fecal coliform, direct total microbial counts, and heterotrophic plate count (HPC) are being cataloged at nine sampling sites at Cattaraugus Creek. Preliminary results from summer and fall 2003 have not indicated any significant association between water quality and bacteria numbers (regression of Coliform Forming Units-CFUs- on water quality factors -principal component analysis of dissolved oxygen, chlorophyll, turbidity, temperature and pH-). Thus far benthic macroinvertebrate data appeared to be influenced more by substratum type (bedrock, riffle-cobble and pool-soft sediment) than by water quality variables. Further data will be collected during the summer fall 2004.

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High Turbidity Events: Chemical Intrusion and Potential Public Health Consequences

Irina Birman, Ph.D., Jelena Tuneva

Elevated turbidity in the source water can compromise the efficacy of the disinfection process, provide nutrients for microbial growth and stimulate disinfection byproducts formation. These outcomes may increase associated public health risks, and therefore create a particular concern to the unfiltered systems water suppliers. When a 'high turbidity event' occurs in the New York City system, it necessitates a series of regulatory, monitoring and operational actions. These actions may include in-reservoir applications of turbidity reducing agents, typically aluminum-based coagulants, and obtaining the approval of its use from the regulatory agencies. In the decision-making process, public health officials should conduct an informative risk-benefit analysis. To assist in this analysis, an attempt was made to study the effect of aluminum on cerebellar granule cells (neurons) and thymocytes in mice via the flow cytometry method. Although no direct correlation between aluminum uptake and neurodegenerative processes in brain was established by the scientific community previously, it has been suggested that various neurodegenerative disorders (e.g. Alzheimer disease) are associated with the excessive exposure to aluminum. In this study, a mechanism of aluminum neurotoxicity has been investigated and some potentially-related morphological and biochemical changes in neurons and thymocytes have been documented. The findings will be presented and the potential public health consequences discussed.

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Extended Detention Basin Storm Monitoring

Dale L. Borchert, James D. Mayfield, David G. Smith

As part of its Filtration Avoidance Determination, the New York City's Department of Environmental Protection has developed a comprehensive storm water management plan for the Kensico Reservoir watershed, a key terminal reservoir in the New York City system. Part of that plan required the construction of extended detention basins on several streams draining into the reservoir, to reduce fecal coliform bacteria and turbidity. Storm monitoring has been carried out at two of the extended detention basins to determine their efficiency at reducing loads and peak values of fecal coliform, turbidity (quasi-load), suspended solids and total phosphorus. For each storm, an average of 15 discrete samples are collected from each monitoring location. A regression of loads analysis technique is used to determine each basin's load reduction efficiency. Results from the first BMP have been previously presented. This presentation will examine the preliminary results from the second BMP. Using this technique, we preliminarily estimate that based on two years of data, one of the extended detention basins reduced stream loads by an average of 59% for fecal coliform, 72% for turbidity (quasi-load), 71% for total suspended solids and 40% for total phosphorus. Monitoring data will be collected at the second BMP throughout 2004, and results to date will be presented.

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Effects of Suburban Land Use on Water Quality in the Croton Watershed

Douglas Burns, James Hassett, Paul Heisig, Tomas Vitvar

About 10% of the New York City water supply originates in the Croton Watershed located east of the Hudson River and about 50 – 80 km north of the city. This water supply region includes extensive suburban/urban land development; about 180,000 people reside within the drainage area of the 11 reservoirs that make up the water supply system. We studied the effects of land use on water quality during 2001-02 at two temporal/spatial scales in the Croton Watershed: (1) 3 intensively-monitored small watersheds (< 0.1 km^2 each) with a range of population density (0, 450, and 1080 houses/km^2), and (2) 22 small watersheds that encompass a broad range of land use and hydrologic settings. Overall, housing density was strongly related to concentrations of inorganic nitrogen (N) and phosphorus (P) species, but was only weakly related to dissolved organic carbon (DOC) and associated disinfection byproduct (DBP) concentrations; DOC and DBP concentrations were strongly related to watershed hydrologic setting, wetland type, and wetland area. Here, we highlight four results from this study that are of significance to researchers interested in land use effects on water quality as well as planners and managers with responsibilities for maintaining water of high quality. First, groundwater discharge from septic systems in unsewered watersheds contributed to enhanced baseflow and poor water quality relative to the undeveloped reference watershed. This result is counter to the prevailing concept that human land use and associated impermeable area decrease groundwater recharge and baseflow. Baseflow during a dry period was about 0.25 mm/day greater in a suburban-density residential watershed than in the nearby undeveloped watershed. Some water-quality constituents such as nitrate (NO_3^-) were highest during low flow and diluted during storms in the suburban watersheds, the opposite of that observed in small watersheds in the Catskill and Delaware watersheds where the highest NO_3^- concentrations are observed during rainstorms and snowmelt when NO_3^- is flushed from the shallow soil into streams. Second, sewered watersheds had higher concentrations of Total P, DOC, and some DBP species than unsewered watersheds in equivalent hydrologic settings; this suggests that sewer mains that often parallel streams are leaking water of poor quality into adjacent streams. Third, salt pollution is widespread in the Croton watershed. Previous work indicated that road salt is the major contributor to high sodium and chloride concentrations in the Croton Watershed, but we have identified flushing of accumulated salt from water softeners as an important source of salt as well in areas where water supply is derived from groundwater. Finally, while DBP concentrations are generally related to DOC concentrations and to wetland type, DBP species that contain bromine are associated with medium- and high-density residential development, where likely sources of bromine include fertilizer and human waste. The results of this study have important implications for the management of future land use and water quality in the Croton Watershed.

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Field Study of Stormwater Treatment Systems and Catch Basin Inserts for the Removal of Pollutants from Urban Runoff

Nazzareno Callipo, Kostantinos Kostarelos, Kyoung S. Ro, Eakalak Khan, Ph.D., P.E., Jennifer Velasquez, Rungrod Jittawattanarat

Non-Point Source Pollution (NPS), unlike pollution from industrial and sewage treatment system plants, comes from many diffuse sources. It is caused by the movement of rainfall or snowmelt that picks up and carries pollutants to receiving waters. NPS pollution represents the main cause of the contamination of many rivers, streams and other water bodies in the United States.

Best Management Practices (BMPs) are intended to reduce pollutant from highway runoff, which include oil and grit separators, grassed swales, vegetated filter strips, retention pond, catch basin inserts (CBIs), etc.

In this project, six commercially available CBIs and two existing water quality inlet treatment systems are being tested in the field. NYS DOT (New York State Department of Transportation) has funded this project to test these two technologies.

A Catch Basin Insert (CBI) is a device that reduces stormwater pollution from the runoff, without requiring any land use. Inserts are devices that attach to the entrance of a catch basin or mount inside the catch basin. A part of this study will focus on the installation characteristics, durability and maintenance of the catch basin inserts, as well as whether the inserts can be conveniently, safely, and economically installed and maintained. Six commercially–available devices are installed in highways in Westchester (NY) and are being tested for this project.

The other part of this study evaluates the pollutant removal efficiencies of two existing water quality inlet treatment systems: V2B1TM and VortechsTM. These systems are installed at Hauppauge and Bay Shore in Long Island (NY), respectively. In both locations, two autosamplers are installed to collect the influent and effluent samples during rainfall events for twelve months. The samples collected are analyzed to evaluate the pollutant removal performance of these systems. The measured parameters that will be used to determine the system efficiency are: conductivity, pH, TKN, TP, TPH, BOD5, TSS and FCB.

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The Watershed Approach - A Comprehensive Management of Watershed Stressors

Ramesh Dwivedy, Ph.D., P.E.

The presentation will discuss various elements of the watershed approach that strives to achieve a balanced and cost-effective management of natural resources and stressors. The watershed management drivers such as regulatory requirements and the public desire to provide a sensible approach to managing resources will be reviewed. Several watershed management components such as federal and states watershed initiatives, TMDL development process and schedule, Source Water Protection requirements, and multi-pollutant trading potentials will be discussed. The emphasis will be provided on the importance of adopting the watershed approach as a new way of doing business in the area of water and wastewater management.

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Modeling of Turbidity and a Pathogen Surrogate in Kensico Reservoir

Todd Echelman

Kensico reservoir, located in southern Westchester County of New York state, is an important component of the New York City water supply, where an average of about 90% of the City's potable water flows through it. With a storage capacity of about 30 billion gallons and average outflows of more than a billion gallons a day, the reservoir has an average retention time of about a month. Turbidity and pathogen water quality levels have been monitored in this important reservoir for at least 20 years. Ten years ago New York City began a water quality modeling program for this reservoir, with the development of a three-dimensional model (RMA based). Subsequently, in 2001, New York City began a two-dimensional modeling program (CE-QUAL-W2 based). Although both two- and three-dimensional models have been adapted to address management strategies for reservoir operations, in recent times the two-dimensional CE-QUAL-W2 model has been more widely used. Here, two-dimensional modeling studies have evaluated the transport and dilution of turbidity loads entering the reservoir. Systematic analyses examine the effects of varying the turbidity and inflow discharges from the two aqueducts entering the reservoir during stratified and non-stratified conditions. This will provide water managers with guidelines to minimize turbidity entering the distribution system and insight into particle (as a surrogate for pathogen) transport through the reservoir.

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Limnological and Kinetic Process Studies for EOH Reservoirs: Integration into Water Quality Models

Steven W. Effler, Rakesh K. Gelda, Susan M. O'Donnell

Interdisciplinary limnological and kinetic/process studies were conducted for the East of Hudson (EOH) reservoirs over the 1999 - 2002 interval, with the primary objective to support development and testing of water quality management models for nutrients/eutrophication and color. The scope of these studies is described within the context of the following five categories: (1) development and specification of model forcing conditions, (2) limnological characterization and analysis, (3) process and specialty studies, (4) optics, and (5) water, material and heat budget calculations. The role such information plays in an **integrated** modeling approach is reviewed. The results of the EOH studies will serve to: (1) specify limnological conditions (e.g., model state variables) and thereby form a basis to test model performance, (2) guide identification of model needs with respect to physical and biochemical structure and capabilities, and (3) specify necessary model forcing conditions, such as hydrologic and material loadings, reservoir operations, and meteorological conditions, that drive the observed water quality. A phased water quality modeling program, that is now underway and utilizes the data from the EOH limnological and kinetic/process studies, is preliminarily described. An example of the integration of results from the studies into the modeling process is presented.

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The Village of Brewster as a Model Community in the Watershed

John A. Degnan, Anne Lee Degnan, Ph.D., John E. Folchetti, P.E.

Multiple categories highlighted in the Call for Abstracts apply to the Village because of the holistic project approach we have taken in becoming a model watershed community. The Village presentation can cover the categories listed below by providing a case study approach. Alternately, individual categories can be addressed.

Over the past six years, the Village has focused on significant infrastructure upgrades. Scheduled improvements for this year include constructing a new WWTP, wastewater collection system, water distribution system, and water supply well. In addition, we are rehabilitating our water supply booster pumps and replacing the undersized culvert across Route 6. These projects follow other significant infrastructure improvements including a new million gallon water tank and the construction of a state of the art stormwater detention and wetland treatment facility to improve water quality. What follows are brief descriptions of Village work.

Best Management Practices: Critical Path Decisionmaking and Leveraging Assets

The Village's early environmental management efforts can be characterized as "learning by doing." However, within the last six years, many of our initiatives can be more accurately characterized as *critical path decisionmaking*. Many of our overall development milestones, and the critical management decisions that brought us there are offered as examples of best practice. In particular, we can share our knowledge on asset development and use, how and when to leverage funds, and identifying appropriate sources of funding for key projects.

Research: Communities as Living Laboratories

The Village offers a unique research perspective, one that explores what it takes for municipalities to engage with institutions of learning and research as *living laboratories*. During the spring of 2003, the Village of Brewster teamed with faculty and graduate students from Columbia University's Urban Planning Program on the role of environmental stewardship in economic development. This engagement involved defining a research focus, establishing a relationship with key stakeholders, and agreeing on research methods and products. This negotiated process is itself a useful case study, with implications for future studies on fostering relationships between local governments and public/nonprofit colleges on watershed protection.

Water Quality Monitoring and Improvement: How to Green Your Streams

In order to improve water quality, the Village has found that multiple infrastructure improvement initiatives are best addressed simultaneously, including stormwater BMP's GIS mapping, impervious surface consolidation, and construction of a new WWTP and collection system.

Management, Planning and Outreach: Stewardship Drives Socio-Economic Planning and Development

The Village recently completed a Comprehensive Plan highlighting our location within the watershed and our commitment to supporting environmental stewardship as a means of driving sound socio-economic planning and development. Our perspective, while not new to literature, is very new to practice, particularly after 25 years of urban sprawl throughout the watershed. This presentation will highlight our Master Plan process, including review of techniques of outreach, team review, consensus building and the important role of information in the planning process. The Village welcomes the chance to share how we are creating a synergistic relationship between our natural environment, particularly water, and the quality of life in our watershed.

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Why New York City Needs A Filtered Croton Supply

Salome Freud, Richard Friedman, Kimberlee Kane, Ph.D., Michael A. Principe, Ph.D., Dave Warne

Filtration of public drinking water supplies, such as New York City's Croton Reservoir System, is the standard and predominant method of treating drinking water across the country. There are compelling reasons why New York City is now moving to filter the Croton System, and why the City has not requested a waiver from the federal Safe Drinking Water Act's filtration requirement.

Filtration of the Croton supply will significantly enhance the reliability of the Croton system in meeting downstate water needs in the 21st century. Filtration will effectively address the Croton System's chronic problems such as color and odor, remove midge larva and enhance public comfort with the adequacy of the Croton water supply. Furthermore, by removing algae and other organic materials, filtration will reduce the formation of disinfection by-products in the Croton water supply and significantly reduce the potential threats posed by microbial contaminants, and help assure high water quality from the Croton System for decades to come.

Construction of the Croton filtration plant, in addition to the above-described benefits to New York City water consumers, is necessary for New York City to remain in compliance with the federal Safe Drinking Water Act and a federally enforceable Consent Decree. Advancing a filtration plant for the Croton System reservoirs will not mean an end to watershed protection in this system. Several investigations have indicated that the combination of filtration and a strong watershed protection program is needed for the Croton system. In sum, a Croton water treatment facility, in conjunction with a strong watershed protection program, is the most effective way of achieving public health protection, regulatory compliance and water supply reliability.

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Stream Base-Flow Chemistry Responses to Hydrogeology and Nonpoint Sources, Pepacton Reservoir Watershed, New York

Paul M. Heisig, Patrick J. Phillips

Base-flow samples were collected seasonally from 20 small streams in the 372-square-mile Pepacton Reservoir watershed to evaluate nonpoint-source effects on water chemistry. The watershed is part of New York City's water supply. The subbasins represented one of three general types of land use, each with at least 45 percent forested area (mostly on the hillsides)¾ farmed (dairy) land, formerly farmed land with low-density residential development, or forested land with little or no development. The subbasin areas ranged from 0.38 to 10.23 square miles. All streams were sampled in December 2000 and in May, July, and October 2001. Three of the sites were designated as land-use-index sites and were sampled more frequently during the study. No samples exceeded State or Federal drinking-water standards for chloride, sodium, nitrate, orthophosphate, herbicides, or herbicide degradates.

The chemical composition of base-flow samples were classified into major-ion water types and broadly defined as naturally occurring and road-salt-affected water types. About one-third of the base-flow samples were road-salt-affected types. Natural water types were differentiated as dilute or evolved. Dilute waters have bicarbonate and sulfate as dominant anions and evolved waters have only bicarbonate as a dominant anion. Dilute water types indicate relatively short ground-water residence times or contact with unreactive aquifer material. Evolved waters have either longer ground-water residence time or contact with more reactive aquifer material than dilute ground waters. The larger subbasins with wider valley-bottom areas were more likely to have evolved water types than small subbasins with little floodplain development.

Positive correlations between selected constituents and the intensity of nonpoint sources emphasize the connection between land use, shallow ground-water quality, and stream base-flow water quality. Chloride and sodium - relatively conservative constituents - showed strong linear relations with annual estimates of road-salt application during all four sampling periods. Non-conservative constituents, such as the nutrients nitrate and orthophosphate, show linear relations with manure production rate among farmed basins, but only at specific times of year. Nitrate showed the best relation in winter, when losses to biological activity were at a minimum. Orthophosphate showed the best relation in early summer, when hydrologic and chemical conditions appear to favor release from sediments. Atmospheric nitrogen deposition is an additional source of nitrogen that can be released from mature or stressed forests.

Detections of herbicides (atrazine, metolachlor, simazine) and herbicide degradates (Metolachlor ESA, alachlor ESA, deethylatrazine) in baseflow were closely correlated with subbasins in which corn was grown during the study. Atrazine was detected at the farmed index site only in early summer, after application and two rain storms. This detection corresponded to the peak orthophosphate concentration. In contrast, metolachlor ESA was detected in nearly all farmed-index-subbasin samples and peaked in late summer, when percentage of base-flow contributions from farmed valley bottom areas was likely highest.

This study indicates that seasonal base-flow surveys of water chemistry from small streams can refine the understanding of local hydrogeologic systems and that a strong connection exists between nonpoint-source contamination and baseflow water quality.

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Quantifying the Effect of Best Management Practices on Turbidity and Total Suspended Solids in the Batavia Kill

Francis Huber, James H. Porter, Ph.D.

Observations and preliminary sampling have documented that the Batavia Kill delivers a significant amount of suspended sediment and turbid water to Schoharie Creek, the main inflow to Schoharie Reservoir. Major sediment source areas are known above and below Red Falls. Through a contract with the Stream Management Program of DEP's Division of Watershed Lands and Community Planning (WLCP), Greene County Soil and Water Conservation District will design and implement best management practices (BMPs) to reduce the sediment and turbidity originating in the Red Falls area. The geomorphic approach will be used, in which the stream channel will be modified to create a "stable" reach that will minimize the erosion of its bed and banks. DWQC's Hydrology Program has been monitoring several sites on the Batavia Kill prior to BMP implementation, and will continue to do so for several years after implementation (currently scheduled for 2005). The objective of the project is to quantify the effectiveness of the various BMPs at reducing suspended sediment and turbidity. This presentation will discuss the monitoring design and show some of the pre-BMP data from extensive storm event monitoring done in the Batavia Kill Basin.

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Water Supply Issues Related to Climate Change

Lorraine L. Janus, Ph.D., Kerri A. Alderisio, Dale L. Borchert, Christopher A. Nadareski, Donald C. Pierson

Changes in climate are expected to have a major effect on the dynamics of precipitation, streams, lakes, and reservoirs. In order to plan for water resources management (including new policy and infrastructure), models must be developed to predict future water quality and quantity conditions. Potential impacts must be estimated through modeling work since many trade-offs exist in the future conditions that will affect water quality. NYCDEP is in the process of developing a suite of linked models that can predict responses of streams, lakes, and reservoirs to future changes in climate. Key water quality and quantity issues for the upstate watershed include drought, flood, turbidity, stormwater (nutrients and bacteria), eutrophication (algal blooms, taste and odor, and THM precursors), temperature effects (such as coliform bacteria related to waterfowl migration, Giardia seasonality inversely correlated with temperature), BMP efficacy, and dam safety. Next steps include the development of future climate scenarios for the watershed at a regional or watershed scale to estimate the severity of more extreme weather conditions. These in turn will be used to predict future hydraulic and nutrient loadings to reservoirs, to determine the impacts of eutrophication (such as THM levels or taste and odor problems), and to allow a re-evaluation of current watershed protection programs, Watershed Rules and Regulations, and recent dam safety upgrades in the context of new future conditions.

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Croton System Watershed Management

Kimberlee Kane, Ph.D., Michael A. Principe, Ph.D.

In advancing filtration of the Croton System, New York City has no intention of cutting back on watershed protection efforts in the Croton. Watershed protection is a critical component of the multiple barrier approach for protection of the water supply. A multiple barrier approach uses several lines of defense to ensure a high quality water supply. By optimizing raw water quality, watershed protection can minimize the risks of pathogens and other contaminants entering the distribution system. Indeed, DEP has had an extensive watershed management program in the Croton System, consisting of regulatory and non-regulatory components DEP believes that a strong watershed protection program will continue to be an essential part of safeguarding the Croton supply for future generations. The following ongoing Croton Watershed protection efforts will be discussed:

- Wastewater Treatment Plant Upgrades and Diversion
- Land Acquisition
- East-of-Hudson Nonpoint Source Program
- East-of-Hudson Watershed Agricultural Program
- East-of-Hudson Reservoir and Terrestrial Models
- Croton Watershed Strategy
- Wetland Programs
- DEP Source Water Monitoring Program
- Phosphorus Total Maximum Daily Loads
- Croton Planning and Water Quality Investment
- Regulatory Enforcement

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Development of a Stormwater BMP Monitoring Program

Tracy Lawrence

The Water Quality Impact Assessment Group (WQIA) of the New York City Department of Environmental Protection (DEP) in partnership with the Catskill Watershed Corporation (CWC) has developed and implemented a water quality monitoring project to measure the efficiency of stormwater best management practice (BMP) retrofits to remove pollutants. Three different types of structural BMP devices were selected to be monitored for this project; an infiltration bed, a Stormceptor™ filter chamber and a Vortechnic™ water swirling chamber. Each of these BMPs was newly installed in West-of-Hudson towns as part of the NYC Watershed Agreement's Stormwater Retrofit Program. The objectives of this monitoring program are to quantify the removal of pollutants from stormwater runoff, mainly total suspended solids and nutrients, and to compare pollutant removal rates among different BMP types. This 2-year project began in the spring of 2004 and will end in the fall of 2005. Plans are to sample up to 35 storms at each BMP. WQIA is providing the study design and field sample collection expertise while the CWC is funding the cost of sample analyses by a NELAP certified laboratory.

Implementing a scientifically sound stormwater BMP monitoring program that can be used to compare the ability of a variety of different BMP types to remove pollutants requires skill, patience, and a bit of luck. Representative sampling of rain event-based runoff relies in part on accurate weather prediction to provide foreknowledge of the timing, amount, intensity and duration of expected rainfall. In addition to collecting representative water samples for each event, the volume of stormwater flowing into and out of each BMP must also be measured. This requires the installation and calibration of flow measuring devices and data logging equipment. Finally, collected field data and reported laboratory results must be analyzed using appropriate statistical methods and reported in a comprehensive manner.

The presentation of this monitoring program will begin with a description of the development of the project's objectives and carry through with a discussion on how the project is being implemented in the field using automated monitoring equipment. Project design issues discussed will include determining data quality objectives, sample size estimation, composite sample procedures and the estimation of event mean concentrations (EMCs) along with the calculating of BMP efficiency ratios and their statistical confidence. Project implementation issues will include the programming of automated sampling equipment to obtain flow weighted composite samples, techniques for estimating and recording flow measurements within BMP structures, and responses to unforeseen field conditions.

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Nutrient Imbalances in Catskill Forest Soils

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Nitrogen has long been considered the growth-limiting nutrient of northern temperate forests. Decades of atmospheric deposition have increased inputs of nitrogen to these forests, particularly in areas of high deposition such as the Catskill Mountain region. By 1990, elevated concentrations of nitrate in Catskill streams, and elsewhere, led to concerns that nitrogen availability in forest soils had increased beyond that which the forest ecosystem could retain and utilize. During this time the Catskills have also been receiving high levels of acid deposition that have led to acidification of surface waters where calcium availability in soil and subsoil is insufficient for neutralization. Because neutralization of acidity in soil water involves the release of calcium, concern developed that calcium availability in soils was decreasing as a result of acid deposition. Like nitrogen, calcium is an essential nutrient. All trees utilize calcium for wood formation and other physiologic functions, although the demand for calcium varies among species. Sugar maple is among the species with the highest demand for calcium in the Catskill forest. Sites with high densities of sugar maple also tend to release high amounts of nitrate to soil water.

Water-quality monitoring, ongoing in the Neversink River valley since the early 1980's does not provide a record of sufficient length to determine if nitrate concentrations in stream water increased as a result of atmospheric deposition, which was likely to have been underway by 1950. Longer records elsewhere in the Catskills do support this possibility, however, and analysis of nitrification potential in soils indicates that nitrate release rates in the Neversink River valley are among the highest in the northeast. Historical information on calcium availability in Catskill soils before the onset of acid rain does not exist, but records of stream water chemistry and soil-leaching experiments suggest that calcium availability has decreased, although the magnitude and timing of the decrease is not clear. Concentrations of total and exchangeable calcium concentrations have been found to be similar to data measured at sites on ridgetops in western Pennsylvania, where unusually high levels of sugar maple mortality have been found. Fertilization with calcium and magnesium were shown to reverse dieback and significantly improve growth of sugar maple on these sites. Preliminary analysis indicates that similarly poor growth rates and canopy condition of sugar maple can be found on ridgetops in the Neversink River Valley.

To evaluate the possible relationship between an imbalance in the availability of nitrogen and calcium (and possibly magnesium), and tree growth and health, a long-term study was initiated in the fall of 2003, in which forest plots in the Neversink River valley were fertilized with dolomite and/or nitrogen. This experiment is a component of the USGS Nutrient Controls Study that is evaluating the effects of forest harvest intensity on water quality. Effects on soil and soil water chemistry are being monitored in conjunction with the response of canopy trees and understory to the fertilization. The goal of this experiment is to determine the degree to which soil conditions are controlling tree growth and health. This information on nutrient status will enable forest managers to develop management strategies that will promote healthy regrowth and avoid impairment of water quality.

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Forest Regeneration Issues in the NYC Water Supply Watershed

Deborah Layton

DEP's Natural Resources Section of the Division of Drinking Water Quality Control provides the scientific basis for management of wetlands, fisheries and forests on New York City water supply lands. Since the 1990's there have been some efforts to inventory and study terrestrial ecosystems to provide better management and, where necessary, protection of critical areas in order to maximize the potential for high water quality.

The forestry studies can be categorized in four major areas: 1) Forest Ecosystem Health Assessment, 2) Effects of Silvicultural Treatment on Forest Ecosystem Health, 3) Forest Regeneration Assessment Following Salvage Cutting, and 4) Effects of Deer Herbivory on Forest Regeneration. After 2 to 5 years of gathering data on various studies, several pieces of information are coming to light.

In the East of Hudson region, there is a gradient from the north to the south for deer impacts on forest regeneration. Impacts become more severe moving from north to south. Across the watershed, most forests, particularly planted conifers, are of a relatively even age (around 70 years on average) and approaching maturity. Invasive exotic plant species, combined with deer herbivory and possibly other factors, have created a situation in the southern end of the EOH watershed where native tree regeneration is unlikely to occur without intervention. Silvicultural treatments meant to control invasive species and encourage growth of native seedlings have some success but more frequent treatment of invasives along with deer management may be required. Deer exclosure fences are only beginning to show some positive results three or more years into the study and more time is required to determine whether ecosystems can recover after excluding deer. Baseline information has been gathered for a couple of areas that have been opened to deer hunting West of Hudson to determine whether hunting alone will help forest regeneration. West of Hudson there are significant differences among the forests in the three basins inventoried to date. Differences in tree size, growth and vigor are likely related to variation in underlying rock, soils, elevation, aspect, climate, past history, and other factors. Hemlock woolly adelgid and beech bark disease are likely to impact the basins to different degrees, based on species occurrence and existing advanced regeneration.

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Comparability of Laboratories Conducting Phosphorus Analyses for Natural Waters in the Nyc Reservoir Watershed

Michael R. McHale, Dennis McChesney

The NY District of the U.S. Geological Survey in cooperation with EPA Region 2 conducted a study of laboratory comparability between ten laboratories that analyze phosphorus (P) in natural waters within the New York City Reservoir system. The NYC Reservoir System supplies drinking water to over 9 million people and as such is an area of active environmental research funded by many local, city, state, and federal programs. Because research is conducted by many different groups, water samples from the reservoir system are analyzed by several different laboratories. Water resource management decisions must be made using the data collected from these various research projects and therefore managers must know the accuracy and precision of the laboratories analyzing water samples from the area and the degree of inter-comparability between labs.

Ten labs received twelve samples for comparative analyses of total phosphorus (TP), total dissolved phosphorus (TDP), and soluble reactive phosphorus (SRP) which is sometimes referred to as orthophosphate. Three samples were Standard Reference Samples prepared by the U.S. Geological Survey Branch of Quality Services, 9 samples were environmental samples collected from streams throughout the NYC West of Hudson Reservoir watershed. All samples were analyzed in triplicate to quantify the precision of the labs. Eight of the 10 labs were graded as acceptable to excellent for each P fraction however the two labs that did not meet the criteria for acceptable performance were not the same two labs for all P fractions. Half of the labs failed to meet acceptability criteria for at least one of the P fractions in at least one of the twelve samples analyzed. Differences in laboratory methods accounted for most of the variation in results and some of the sample concentrations were close to or below the limit of quantification for the labs (sample concentrations for TP ranged from 0.01 to 0.78 mg/L). All of the labs had a high level of precision based on sample triplicate results.

This study identified several issues that must be considered when using data from different laboratories: (1) Differences in laboratory methods must be taken into account when evaluating data. (2) Differences in laboratory reporting procedures can affect lab results (i.e., some labs use digested P standards while others use undigested P standards). (3) All labs whose data will be used to make management decisions in a region should be required to participate in a regular sample exchange program to verify whether data from the various labs is comparable over time.

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Seasonal Variations in *Cryptosporidium* and *Giardia* Concentrations in New York City Watersheds

Yves B. Mikol, Gerry Pratt, Kerri Alderisio, Lisa Blancero

NYCDEP began weekly monitoring of *Cryptosporidium* and *Giardia* at its source water in 1992 and extended monitoring to the entire watershed in 1993. In 2003 911 samples collected at 152 sites were analyzed. Additionally, DEP conducts research and participates in validation studies sponsored by USEPA for the development of improved analytical methods. Over the past 12 years DEP has used three different methods for routine analyses of *Cryptosporidium* oocysts and *Giardia* cysts. The current method, Method 1623 HV used since October 2001, has improved recoveries of these organisms. While water quality has not changed, the number of oocysts and cysts recovered is higher than with previous methods. In the past, the number of "no detect" prevented simple statistical analyses. The number of *Giardia* cysts detected can now be used in statistical analyses. Data from source waters and other keypoints show seasonal variations. Increases are observed during high flow periods ("winter months"). Many sites throughout the watersheds show similar trends. *Cryptosporidium* appear to present a similar seasonality but the effect is not as visible because detections are less frequent and concentrations are lower than these of *Giardia*. Of interest, is the comparison of the seasonality of *Cryptosporidium* and *Giardia* observed in the watershed ("winter months") with the seasonality of cases of cryptosporidiosis and giardiasis cases observed in New York City ("summer months") suggesting that these seasonal increases, occurring at different time of the year, are unlikely to be related.

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Early Warning Surveillance Systems for Watersheds, From Streams to Source Water

Yves B. Mikol, William Richardson

Early warning surveillance (EWS) has been used in Europe for over 20 years following accidental contamination and non-point source pollution of surface water used for water supplies. The terrorists' attacks of September 11th increased the need for information on systems that can be easily deployed at source waters and upstream from water intakes. Early warning surveillance programs should also be designed to identify common and potential accidental contaminations. DEP initiated an EWS pilot program in 1999 and has increased resources allocated to this program. The objectives of this presentation are to outline (a) the need for watershed assessment to identify potential accidental sources, (b) the components of an EWS system; (c) on-line real-time instrumentation commercially available; (c) strategies for developing a program based on watershed activities and other possible threats; (d) strategies to confirm events and rule out false alarms; and (e) other planning required.

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Multi-Scale Evaluation of the Effects of Soil Calcium Depletion on Forest Health and Stream Water Quality in the Northern Delaware River Basin of Southeastern New York

Peter S. Murdoch, M. McHale, G. Lawrence, D. Burns

The depletion of forest soil nutrients as a result of acidic deposition could be affecting (1) water quality in the New York City drinking water supply reservoirs and (2) rates of forest regrowth following harvesting in some watersheds of the Catskill Mountains. The effects of soil calcium on tree condition and nearby stream calcium concentrations were assessed using plot-scale, watershed-scale, and regional-scale sampling approaches as part of a collaborative monitoring strategy between New York City Department of Environmental Protection, the US Geological Survey, and the US Forest Service in the northern Delaware River Basin. An experimental clearcut of a forest in a calcium-poor soil in the Catskill Mountains resulted in a significant stream export of soil calcium in the two years following harvest. Biogeochemical analysis of foliage near this watershed indicates that trees are under stress due to low concentrations of soil calcium. A water quality survey of the nearest, forested first-order stream to the USFS Forest Inventory and Analysis (FIA) plots (n= 250 streams) in the Delaware basin shows a band of low-calcium streams that extends from the eastern Catskills south to the Delaware Gap region, then west to the western Pocono Mountains. Calcium concentrations in soils collected at FIA plots in the Delaware Basin indicate a similar regional pattern. The combination of intensive and extensive data collection, and the integration of forest-, soil-, and water-sampling programs of the NYCDEP, USGS, and USFS provides a strong regional picture of the extent of soil calcium depletion in the upper Delaware River Basin in New York. Ongoing research on the effects of harvesting on nutrient export to rivers and the role of calcium and nitrogen in forest growth is being combined with regional surveys of soil and stream chemistry to provide a detailed look at the importance of soil chemistry to forest health, water quality, and resource management in the Catskill region.

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Pesticides in Surface Water Runoff in Southeastern New York State: Seasonal and Stormflow Effects on Concentrations

Patrick J. Phillips, Robert W. Bode

Samples from two streams (Kisco River and the Middle Branch of the Croton River) in the Croton Reservoir system in southeastern New York State, USA were sampled from May 2000 through to February 2001 in order to document the effect of land use, streamflow, and seasonal patterns of application on pesticide concentrations in runoff from developed watersheds. Many of the pesticides detected most commonly in this study are generally used in developed areas, and particularly on turfgrass.

Pesticide concentrations were generally higher, and the numbers of compounds were generally larger in samples from the Kisco River than in samples from the Middle Branch, probably because the Kisco River drainage has a greater population density and is more extensively developed. Four pesticides (2,4-D, 2,4-D methyl ester, dicamba, and metalaxyl) were detected in at least one sample from the Kisco River at a concentration above 1 g litre-1, and no pesticides were detected at concentrations > 0.4 g litre-1 in Middle Branch samples. No human health-based water-quality standards were exceeded by samples from either site in this study, but samples from the Kisco River contained four insecticides (carbaryl, chlorpyrifos, diazinon, and malathion) and one herbicide (2,4-D) in concentrations that exceeded water quality criteria for the protection of aquatic life.

The highest concentrations of most compounds occurred during stormflows in both streams in June, September, and December, 2001. The lowest concentrations of most compounds at both sites occurred during baseflows from October 2000 through February 2001, even though the concentrations of many compounds increased substantially at the Kisco River site during stormflows in November and December.

Detailed data on the variability of pesticide concentrations during stormflows indicate that there may be two sources of pesticides in the Kisco River watershed: (1) elevated concentrations of pesticides during peak flows that occur early in stormflows likely reflects runoff from paved areas, and (2) elevated concentrations during peak flows that occur later in stormflows from areas with lesser amounts of pavement. Overall, data from the Kisco River indicate that the relation between storm discharge and pesticide concentrations varies among compounds, in part because of variation in seasonal application patterns. These variations in the timing of application result in not all stormflows producing increased concentrations of pesticides.

Overall, these results indicate the importance of stormflow sampling throughout the year in assessing pesticide fate and transport in urbanized, developed areas.

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Overview of the Croton Reservoir System

Michael A. Principe, Ph.D

The Croton Reservoir System, with twelve reservoirs and three controlled lakes located in Westchester, Putnam and Dutchess Counties, provides essential flexibility and vital redundancy for the New York City water supply. The smallest of the City's three reservoir systems, the Croton ordinarily provides about 10% of New York City's total daily water needs. But in times of drought or during maintenance shutdowns or other system outages, the Croton supply can be relied upon for up to 30% of the City's total water supply.

But over the past ten or fifteen years, the Croton system has been less reliable, with eutrophic conditions in many of its reservoirs and other problems necessitating that the system be shut down for months at a time, often during the peak periods of water demand — the summer and fall. Under present conditions, Croton water consumers may sometimes receive lower quality water then consumers receiving Catskill/Delaware water.

A discussion of the history of the Croton system and an overview of the water quality concerns facing the City will be presented.

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Pesticides in Streams of the Croton River Basin (Southeastern New York): Use of a Pesticide Toxicity Index to Evaluate Relative Toxicity of Stream Water to Aquatic Organisms

Karen Riva-Murray, Patrick J. Phillips, Robert W. Bode

Pesticides in the water column are potential stressors to stream biota. A multidisciplinary study of 47 Croton River Basin streams (southeastern New York) by the US Geological Survey (USGS) and the New York State Department of Environmental Conservation (NYSDEC), in 2000, showed an association between catchment urbanization and the variety, type, and concentration of pesticides, particularly insecticides, in streamwater. Bioassessment scores based on benthic invertebrate communities also were shown to decline with increasing urbanization. A causal link between pesticide concentrations and biological integrity is less clear, however, because (1) biota are exposed to complex mixtures of pesticides having different toxicities, (2) biota can be affected by other urban-related stressors such as habitat disturbance, hydrologic alteration, and nutrients), and (3) pesticide concentrations vary with streamflow, particularly during storms. A Pesticide Toxicity Index (PTI), developed by the USGS, was applied to the Croton pesticide data to address some of these issues. The PTI sums individual pesticide concentrations, weighted by laboratory-based toxicity values, to obtain indices of potential toxicity to invertebrates and fish. PTI does not determine a sample's actual toxicity, nor does it consider all pesticides that may be present; rather, it provides a general indication of potential toxicity. The PTI is used herein to describe the relation between potential pesticide toxicity of stream water and stream-catchment urbanization, and to evaluate stressor-response relations between potential pesticide toxicity and biological communities.

The PTI of Croton-watershed streams (based on samples collected during summer base flow) increased with degree of urbanization. Spearman rank correlations between human population density and PTI for invertebrates and fish were 0.60 and 0.66, respectively ($p < 0.0001$, $n = 40$). NYSDEC's Invertebrate BioAssessment Profile (IBAP) score was significantly correlated with invertebrate PTI (rho -0.36, p 0.03, $n = 36$). A stronger correlation resulted (Kendall tau -0.50, $p = 0.009$, $n = 16$) after elimination of (1) sites with notable habitat impairment or impoundment effects, and (2) sites classified by NYSDEC's Impact Source Determination method as affected by sewage or organic enrichment. The observed decline in IBAP with increasing PTI was primarily a function of species loss (declining taxa richness, tau -0.51, $p = 0.009$). Neither the Fish BioAssessment Profile (FBAP) nor any of its component metrics were significantly correlated with the fish PTI, even in the smaller subset of sites.

The increase in potential toxicity of streamwater with increasing urbanization is consistent with results of recent USGS studies of urbanization in other metropolitan areas across the Nation, and corresponds with the frequent application of insecticides throughout the growing season in urban settings. The loss of sensitive invertebrate species with increasing PTI suggests that pesticides may be one of the more important stressors to invertebrate fauna in urban settings.

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Regulatory Upgrade of the Clearpool WWTP with Membrane Bioreactor Technology

Andric Rodriguez, P.E., Lowell Kachalsky, P.E.

In January 1997, New York City, New York State, the USEPA Regional Administrator, and several local agencies within the New York City watersheds signed the New York City Watershed Memorandum of Agreement (MOA). The MOA established the New York City Watershed Rules and Regulations, which set new mandatory requirements for existing wastewater treatments plants (WWTPs) within the Catskill/Delaware and Croton Watersheds.

The Watershed Rules and Regulations affect more than one hundred existing public and private surface discharging WWTPs located within the New York City Watershed. These plants are required to incorporate sand filtration, disinfection, phosphorus removal, and membrane filtration. In addition, all these WWTPs must also provide standby power units sufficient to run the entire plant, back-up disinfection systems, flow meters with recording devices, and alarm systems capable of telemetering to a manned central location or an operator's home.

The Clearpool Educational Facility is located within the Croton Watershed. O'Brien & Gere's scope of work, for the Regulatory Upgrade of the Clearpool WWTP, consists of preparing a facility plan, contract specifications and drawings, assistance during bidding, and contract administration and part time inspections during construction.

The pre-upgrade Clearpool WWTP consisted of a dosing tank, buried intermittent sand beds, and disinfection with sodium hypochlorite and a metering pump. The pre-upgrade facilities would not have been able to meet the effluent requirements imposed by the Watershed Rules and Regulations, or the revised SPDES permit requirements for ammonia. O'Brien & Gere investigated several technologies for a new WWTP, including extended aeration, rotating biological contactors, and membrane bioreactors.

O'Brien & Gere recognized that a membrane bioreactor WWTP was the best option for the Clearpool facility for the following reasons:

- The need for final clarifiers would be eliminated. Intermittent flows at the Clearpool facility could be problematic for clarifiers, but not for membrane bioreactors.
- There would be no outside tankage (i.e., clarifiers), which has advantages from an odor control point of view and from a safety point of view considering the site is an educational facility for children. Only a buried equalization tank would be located outside the proposed building.
- The need for a sludge holding tank would be eliminated, since sludge could be wasted directly from the membrane bioreactor tank to a sludge hauling truck.
- The construction period could be shortened, since all the ancillary equipment would be delivered to the site pre-piped and pre-wired within a shipping container that would be placed on an equipment pad within the proposed building.

As of April 27, 2004, the construction of the Clearpool WWTP is still in progress (see pictures below). Functional Completion and performance testing is scheduled for June 2004. This will be the first operational membrane bioreactor constructed under the Regulatory Upgrade Program. By the Watershed Science and Technical Conference scheduled date of September 2004, the new Clearpool WWTP will be up and running. This will allow actual operating data from the plant to be discussed at the presentation. The presentation will consist of a discussion of design considerations and actual operational data.

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A Study of Water Quality Benefits Provided by Stormwater BMPs in the Staten Island Bluebelt

Dan Gumb, Rob Brauman, Sandeep Mehrotra, Eric Rosenberg, Deeya Deb

The Staten Island Bluebelt Program, since its establishment in 1996, is one of the Northeast's most ambitious efforts in the development of Best Management Practices (BMPs) as an efficient alternative for stormwater management. For years, the 12,000-acre region of southern Staten Island has been prone to frequent and severe street flooding, erosion, and degraded water quality due to failing septic systems. To address these conditions, the New York City Department of Environmental Protection (NYCDEP) developed and implemented the Staten Island Bluebelt Program, an innovative endeavor to provide area-wide flood control and water quality benefits. The NYCDEP has successfully planned and sited 90 BMPs, including 25 that are complete and in service, and 16 more that are under construction.

To evaluate the performance of the constructed BMPs, a monitoring program has been implemented that includes dry and wet weather sampling at the inlets and outlets of four completed stormwater wetlands. Measured parameters include temperature, turbidity, pH, total and fecal coliform, nutrients (TKN, nitrates, nitrites, ammonia, total and orthophosphates), suspended solids, biochemical oxygen demand (BOD), total organic carbon (TOC), and dissolved oxygen (DO). The four sampling sites include two constructed wetlands with drainage areas of 107 and 117 acres each, one constructed wetland with a drainage area of 14 acres, and one existing pond retrofit with a drainage area of 89 acres.

Basic physical features are similar for all four facilities. The storm sewer outfalls into a relatively deeper section called the forebay, reducing the flow velocity and causing sediment load deposition. Flow from the forebay passes a heavily vegetated section of the wetland in a meandering path to further improve water quality by enhancing contact time for assimilation and biofiltration. Close to the outlet structure, the micropool allows for additional sedimentation while trapping floatables prior to conveyance downstream. Improvements in water quality are also achieved with the provision of weirs and low-flow orifices that detain peak flows and reduce downstream erosion through gradual release over a 24-hour period.

Plantings are selected to provide stormwater biofiltration and microclimate improvement. Aquatic plants with rhizomatous root masses create both aerobic and anaerobic conditions, attracting nitrogen-consuming bacteria and absorbing trace amounts of phosphorus from the stormwater. Soft rush (Juncus effusus) and soft stem bulrush (Scirpus tabernaemontanii) are chosen because of their high success rates in fluctuating water levels typical of the Bluebelt BMPs. These rushes and other aquatics like pickerel weed (Pontederia cordata) provide shade that reduces water temperature and prevents eutrophic conditions from developing.

Preliminary findings have been encouraging. Lab results of dry weather samples indicate significant drops in nutrient and turbidity levels, with as much as 85% reduction in BOD and 95% reduction in fecal coliform counts. The greater flows and smaller detention times typical of wet weather are yielding substantial but less drastic reductions. We expect the sampling that will continue throughout the spring and summer to further corroborate the early results.

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Improving GWLF Models for NYC Watersheds Using the USDA SWAT Model

Elliot M. Schneiderman, Mark S. Zion, Guillermo Mendoza

DEP has developed and tested GWLF watershed models for simulating stream flow, nutrient, and sediment loads to NYC Reservoirs. The models have been used for preliminary evaluation of the effectiveness of watershed management programs, and are being used to investigate the potential effects of future climate change on NYC water supply. Efforts are ongoing to improve and test GWLF models as more data and research results become available.

To support these improvements and to enhance the robustness of its watershed modeling applications, DEP is currently developing, in collaboration with USDA-ARS, a SWAT model application for the Cannonsville Reservoir watershed. GWLF and SWAT share a basic hydrologic formulation, but also differ in significant ways. We focus on two major differences: the method for applying runoff curve numbers in the calculation of runoff and infiltration; and the determination of dissolved nutrient concentrations in runoff. Comparison of the two models applied to the Cannonsville Watershed yields insights into watershed processes, and provide the basis for improving GWLF hydrologic partitioning, dissolved nutrient loading estimates, and the effects of watershed management practices on loads.

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Practical Issues of Ownership of a Membrane Plant

Simon Dukes, Benjamin Antrim, John McArdle

In the last few years there has been a move to install membrane systems as tertiary polishing operations in New York Watershed waste water plants as part of the Watershed Protection scheme. Membrane systems provide a positive barrier to pathogens such as bacteria and cysts, and will also reduce the level of virus in a treated effluent as well as reductions in turbidity. In general this is dependent only on insuring the integrity of the membrane system, however, as the quality of the effluent is virtually guaranteed, attention needs to be paid to the effluent quantity to insure that the desired output is always maintained.

Membrane systems have several operating characteristics that are different to conventional plants, such as response to changing feed water conditions and the maintenance of throughput performance. An appreciation of these differences is important to smooth startup and operation of the plant. There are also aspects of operation that are unique to membrane plants, such as monitoring and maintenance of integrity, periodic chemical cleaning and methods of flux maintenance.

In this paper we will endeavor to outline the differences that an operator can expect between a conventional plant and a membrane plant, and we will explore the practical issues faced in operating a membrane plant. This will cover important practical aspects such as the technology of membrane separation, the importance of membrane integrity, membrane cleaning and plant maintenance.

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Development of a Multi-Objective, Community-Based Stream Management Plan: A Case Study of the Stony Clove Creek

Mark Vian

Where private landholdings dominate the riparian corridor, managing streams to protect sourcewater supplies requires an approach that addresses the interests of multiple stakeholders. The development of multi-objective, community-based stream management plans can play a key role in this process. Challenges remain, however; multi-objective plans require management for multiple functions simultaneously. The integration of diverse and often conflicting mandates and political jurisdictions of the many public agencies, planning bodies, civic organizations and individuals with a stake in stream resources is a labor intensive process. Each player employs a distinct tradition of management practices, scientific disciplines that inform that tradition, and vocabulary to articulate his or her world view. This paper presents a case study of the strategy and methods being used to bring these world views together in a subbasin-scale stream management plan for the Stony Clove Creek, an 85 km2 rural watershed in the Catskills region of upstate New York with a moderate density of development along the stream corridor, and a major tributary to the Esopus Creek. The study presents the unique integration of landowner participation with system-wide assessments of channel morphology, meso-scale habitat distribution, riparian vegetation and land use. Decision-systems are described for determination and prioritization of the practices and programs recommended in the management plan to protect water quality, enhance aquatic habitat functions and reduce undesired flood impacts in the stream corridor.

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Analysis of the Payment in Lieu of Taxes Program for the Metropolitan Boston Water Supply

Joel A. Zimmerman

The Massachusetts Department of Conservation and Recreation, Division of Water Supply Protection (DCR/DWSP, formerly the Metropolitan District Commission, Division of Watershed Management) controls the drinking water supply watershed system comprised of the Quabbin Reservoir, Ware River, Wachusett Reservoir, and Sudbury Reservoir watersheds. DCR owns over 100,000 acres of land encompassed by these watersheds. A legislatively mandated Payment in Lieu of Taxes (PILOT) program, M.G.L. c. 59, §5G, guarantees regular and stable payments to the 31 communities which contain the land and water bodies that comprise one of the nation's largest unfiltered water supply systems.

The DCR PILOT program is distinct from other state payments in lieu of taxes. It is funded by the Massachusetts Water Resources Authority (MWRA), and the DCR makes the payments directly to the communities. The PILOT amount is determined by multiplying the land valuation, determined every five years by the Department of Revenue (DOR), by the local commercial tax rate. The DCR PILOT amount is paid in full annually and can never decrease from the previous year. Payments in lieu of taxes made by other state agencies are determined by a formula that significantly discounts the land's value, and then these payments are made through the annual state aid to municipalities ("cherry sheets").

18,000 acres of land, at a cost of $130 million, were acquired from 1985 to 2003 to protect this watershed system. The majority of these transactions occurred in the Wachusett Reservoir watershed, with approximately 5,000 acres purchased between 1996 and 1999. The PILOT value from 1996 to 2000 averaged $3 million. However, after the DOR revaluation in 2000 took into consideration all land acquired over the previous five years, the average PILOT amount increased to $5 million.

Some watershed towns have ongoing concerns that DCR ownership of land precludes the community from taking care of its current municipal needs and limits opportunities for future growth. There is also a widely held opinion that the PILOT payments are not equitable and have not kept up with inflation. The DCR recognizes the loss to the community of private lands, including active agricultural sites, however, there are also fiscal benefits to DCR land ownership. An analysis of the before and after local tax implications of two acquisition in the town of West Boylston demonstrates the positive financial impacts of watershed protection.

This discussion of the PILOT program highlights some of the fiscal benefits to the town of DCR/DWSP land ownership. It is not comprehensive, nor can it take into account the fact that each acquisition presents a different revenue loss/gain scenario. It is also difficult to quantify all of the benefits, whether economic or environmental, of permanently protected open space. The DCR recognizes that there can be short-term losses to a town's tax revenue due to the time lag between acquisition and DOR revaluation. The figures presented, however, demonstrate a significant, long-term benefit to the community's tax base from the PILOT program.

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Due to space and time limitations,
the following abstracts were not able to be presented at the 2004 conference, but are instead printed on the following pages with the gracious permission of the authors:

Modeling Streamflow Components in NYC Cannonsville Reservoir Watershed with SWAT2000 Model

Guillermo Mendoza, Elliot M. Schneiderman, Mark S. Zion

The Soil Water Assessment Tool (SWAT) is a model that simulates hydrology, nutrient dynamics in the soil, and landscape processes in a watershed. All these processes are integrated to simulate water quality in streams. A first step in developing a SWAT model application is to accurately simulate the streamflow components because these control the timing and quantities of chemical loads from a watershed. Given the complexity of interdependent functions modeled by SWAT it is appropriate to establish a methodology to adequately represent individual hydrologic processes. The approach is to constrain simulated output to adequately represent our best expectations of streamflow components from analysis of data. We developed and applied such a methodology to systematically analyze streamflow components and capture the key hydrological processes.

SWAT2000 model parameters that control quantity and timing of the runoff and baseflow components of streamflow were estimated from streamflow records for NYC Reservoir watershed streams in the Catskill Mountains, NY. Daily streamflow records were separated into direct runoff and baseflow time series. These time series were analyzed to determine respective lag parameters in the model, and were used to calibrate flow partitioning parameters by optimization methods. Model calibration and performance were greatly improved by a model revision allowing vertical movement of water in frozen soils. The revised SWAT model simulates streamflow components well in Catskill Mountain streams, providing a firm hydrologic basis for water quality modeling in the NYC water supply watersheds.

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Next Generation High Rate Dissolved Air Flotation (DAF): Design and Optimization of Full Scale Process at Lake DeForest WTP, NY

Simon Morris

Dissolved air flotation (DAF) has been used as a conventional means of water treatment throughout the world for over thirty years. More recently there has been wider acceptance of this technology in the United States due to numerous process advancements. The next generation of drinking water DAF systems introduces the concept of turbulent flow and application rates of up to 20 gpm/sq.ft, tripling conventional DAF loading rates.

High application rates result in a significant reduction in process footprint when compared to conventional DAF and settling systems. Typical footprints are approximately equal to other high rate processes such as ballasted flocculation yet the high rate DAF process utilizes less energy and chemicals.

There is much operating history for this technology in Europe, however, the Lake DeForest WTP, West Nyack, NY, commissioned in July 2003 is the first full scale operating installation of next generation high rate DAF in the United States. This 20 MGD process was designed and delivered following a successful pilot study and features DAF loading rates of up to 13 gpm/sq.ft.

This paper will discuss the basic principles of turbulent flow DAF systems, cost & operational benefits, and present full-scale and pilot data from European and United States sites. Primary focus for operational information is the Lake DeForest WTP installation with additional data from pilot studies at Haworth, NJ, Seneca, SC, South San Joaquin, CA and Las Vegas, NV.

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Prioritizing Watershed Protection Efforts

Daniel D. O'Brien, P.E.

There are seldom enough resources to accomplish all that is needed or desired. This is true in watershed protection. Limited time, funding and other resources makes you choose what to do and when to do it. How do you decide what to do. What is more important to you? Is there a better way?

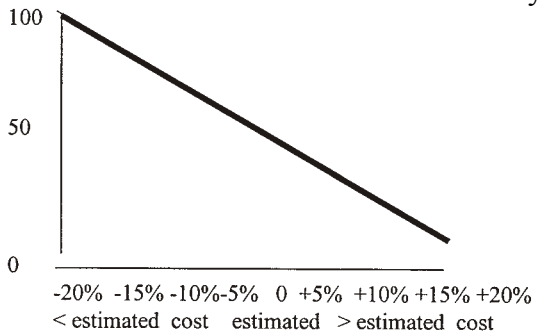
This paper will discuss how to use utility theory to help make prioritization decisions. A workshop will be conducted at the conference.

The use of utility theory has been around for some time now and has been used in other areas of decision making. This practice attempts to put order into a sometimes chaotic process called decision making. It is a tool and is not guaranteed to always give the right answer. Watershed protection is a complex arena and, as in all tools, the job can be made easier.

Step 1 Choose your decision making criteria. Decision criteria for water resources planning and design and water shed protection can be broken down into four main areas: Environmental Considerations, Economic and Financial Feasibility, Engineering Feasibility and Social/Cultural/Political Considerations. Environmental includes regulatory and other guidance criteria. Economic Feasibility is whether the benefits outweigh the costs or if the best value is obtained over the life cycle of a project or program. Financial Feasibility is whether the project or program can be funded. You can have an economical project, but not be able to fund it. Engineering Feasibility is whether the project can be built or there is an adequate factor of safety. The Social/Cultural/Political Considerations are whether society will allow the project; not in my back yard, lack of political support, lack of stakeholders support are important for project or program success. Any of these broad areas can be the reason for success or failure. The paper will discuss how to choose the criteria that is important to you. Trying to compare different alternatives against different criteria is sometimes confusing. Utility theory allows a structure to do this. Utility theory is composed of two parts: part 1 is scaling within the decision criteria and part 2 is weighting the decision criteria. A couple of examples are given and the paper will go into more detail on how this is done.

Step 2: Scaling within the decision criteria. You select a utility function or graph on a scale of 1-100. This can be as complex as you like, but represents how you perceive the value of the criteria. For example if you are scaling costs you might decide that you would give 50 points to a costs that matches your estimate and 100 points to any costs that comes in less than 20%. You might also decide that if the costs are 20% over your estimate that it has 0 points.

A graph is then constructed.



Step 3 Weighting among criteria. All your decision criteria will then be on a scale of 0 to 100. The weighting then looks at importance between criteria. The total weight is 1 and is spread among the criteria. The scale is multiplied by the weight and the values added to give you a total score that you can use to compare options. You might decide that the Political criteria are twice as important as the Economic and that Environmental is twice as important as the Political. Your weights would be .145 for Economic, .285 for Political and .57 for Environmental. As with every decision tool, it is an aid. The results must be reviewed and discussed to determine if they are valid and reflect the values of the stakeholders. This process might take several iterations to get to a tool that is acceptable.

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Management, Planning, and Outreach

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The Wachusett Reservoir, the Quabbin Reservoir, and Ware River are the active water supply sources for 2.2 million residents of Massachusetts. The Department of Conservation and Recreation, Division of Water Supply Protection (DCR/DWSP, formerly the Metropolitan District Commission, Division of Watershed Management) is legislatively mandated to manage and protect these drinking water supply watersheds, providing pure drinking water for distribution to 43 communities by the Massachusetts Water Resources Authority (MWRA).

The first formally written Watershed Protection Plans to address the comprehensive protection of the metropolitan Boston water supply watershed system were developed in 1991. Since the preparation of these original Plans, DWSP has greatly expanded its watershed protection programs. The first update to these Plans, the 1998 *Watershed Protection Plan Update for the Metropolitan Boston Water System Wachusett Reservoir,* established a new set of objectives for DWSP to attain.

There were several reasons why another update was necessary in 2003. An update will integrate the achievements of the past five years that have augmented DWSP's understanding of potential watershed contamination sources, their influence on intake water quality, and the most feasible and effective control approaches. Another reason for the Plan update is the DCR and MWRA focus on public health and the continued high priority concern of the U.S. Environmental Protection Agency (EPA) and Massachusetts Department of Environmental Protection (DEP) focusing on the threat of *Giardia* and *Cryptosporidium* pathogens. Finally, as a component of the application for a waiver from the Safe Drinking Water Act (SDWA) filtration requirement, DWSP and MWRA were committed to update the Watershed Protection Plan on a five-year cycle.

The *2003 Watershed Protection Plan Update for the Wachusett Reservoir Watershed* continues the trend established by earlier plans of identifying key issues and setting priorities for the DCR Division of Water Supply Protection. This Plan Update:

- Documents the recommendations of the 1998 Wachusett Reservoir Watershed Protection Plan Update that have been completed.
- Incorporates increased knowledge of the watershed and water quality.
- Assesses the current "state of the watershed."
- Formally states goals and five-year objectives for each program area.
- Establishes a schedule of activities for the next five years.

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