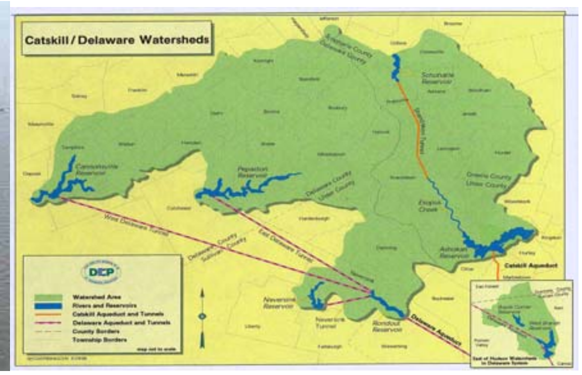
# Large-Scale Watershed Restoration Partnerships

## Annual Report


# New York City Watersheds Study

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# I. Partnership Overview

The New York City (NYC) water supply system provides more than 1.4 billion gallons of high quality drinking water daily to approximately 8 million city residents and 1 million residents of southeastern New York. The NYC Department of Environmental Protection (DEP) and New York State Department of Environmental Conservation (DEC) operate and maintain the entire NYC water supply system, which draws water from 19 reservoirs and three controlled lakes from the 1,969 square-mile total watershed.. Agricultural and forested lands, most of which is privately owned, collectively constitute more than 90% of the Catskill/Delaware watersheds.

The DEP is working with farmers and forest landowners to maintain a traditional open-space landscape that creates rural economic opportunities while protecting the water supply. The DEP works with local partnership programs administered by two nonprofit organizations, the Watershed Agricultural Council (WAC) and the Catskill Watershed Corporation (CWC). The WAC implements voluntary pollution prevention programs based on open-space protection; the largest program, the Watershed Agricultural Program, protects both water quality and the economic viability of farming as a preferred watershed land use. The aim of WAC is to improve the short- and long-term economic viability of forest landownerships and the forest products industry in ways compatible with protecting water quality and sustaining the forests.

Although the quality of NYC drinking water is high, 10 of the 19 reservoirs are classified as eutrophic by Carlson's (1977) trophic state assessment methodology.[1] In 9 reservoirs, all in the Croton District, phosphorus load reductions are due to wastewater treatment plant (WWTP) upgrades and upstream compliance.[2]

It was reported nationally that 40% of rivers in the NYC watershed are unhealthy as a result of nutrient enrichment; 50% of surveyed lakes and reservoirs and 57% of surveyed estuaries are similarly affected. Methods historically used to remove phosphorus from water include adding chemicals, phosphate-accumulating organisms (PAOs), or light-expanded clay aggregates. The NYC Watersheds Study focuses on removing phosphorus from water.

The Forest Products Laboratory (FPL) has an ongoing research program in the use of lignocellulosic fibers to remove dissolved ions from water; removing these pollutants is typically the most difficult and expensive part of water filtration. The natural sorption capacity of lignocellulosic fibers varies, depending on the type of material. FPL researchers have determined that modifying the surface of the lignocellulosic fiber can substantially increase its sorption capacity. Physical, chemical, and biological techniques for modifying lignocellulosic fibers are being studied. FPL has been engaged in the development of filters, the wooden/plastic filtration system, and monitoring technology.

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[1] A trophic state index (TSI) of greater than 50 indicates eutrophic conditions. The TSI is based on measurements of chlorophyll II a (CHLA), total phosphorus (TP), and Secchi depth (ZSD).

[2] *Nonpoint Source Implementation of the Phase II Total Maximum Daily Loads* (TMDLs). 2001. Prepared by NYC Department of Environmental Protection and New York State Department of Environmental Conservation.

The latest area of research is the development of filters from non-lignocellulosic fibers that can be used in combination with lignocellulosic fibers, which cannot be used in certain situations. Non-lignocellulosic media can increase the capacity of filters made from lignocellulosic fibers. Mesophorous media, acid mine discharge precipitant, and slags constitute the main area of study. Efforts toward improving utilization of the wood resource and developing new products and the environmental industry would strengthen local industry, enhance the profitability of forests as a beneficial low-density use of land, and help maintain the overall health and long-term sustainability of the forests.

The DEP has a number of regulatory and non-regulatory nonpoint-source pollution control programs. The Filtration Avoidance Determination (FAD) program involves the development and implementation of many nonpoint source pollution control programs. FAD also imposes strict reporting requirements to monitor the DEP's progress in implementing its programs and to evaluate whether NYC continues to meet the conditions for avoidance. However, as the water quality of NYC watersheds degrades, filtration avoidance might not be feasible. One solution, massive filtration, poses a danger to the watersheds and would cost from $6 to $8 billion.

A small-scale filtration system such as our design will cost only a fraction of the cost of a larger system. The small units will be installed to prevent known point sources of pollution, rather than to attempt to filter the watersheds as a whole. Moreover, most money will stay within the watershed areas.

## II. Partnership Goals

Phase II TMDLs are based on attaining a phosphorus value of 15 μg/L for the seven source water reservoirs (Kensico, West Branch, Rondout, Ashoka, New Croton, Cross River, and Croton Falls) and attaining the NY State phosphorus guidance value of 20 μg/L for the remaining upstream reservoirs. Nine of the 19 reservoirs currently exceed the Phase II TMDL and require phosphorus reductions. In general, Croton watershed, which is east of the Hudson River and close to NYC, needs more phosphorus reduction than do reservoirs west of the Hudson. The nonpoint source reductions for the 9 reservoirs in question are Amawalk (122 kg/yr), Croton Falls (885 kg/yr), Cross River (57 kg/yr), Diverting (983 kg/yr), East Branch (993 kg/yr), Middle Branch (204 kg/yr), Muscoot (2,058 kg/yr), New Croton (1,356 kg/yr), and Titicus (140 kg/yr). Total nonpoint source reduction for these reservoirs is 6,798 kg/yr.

Our long-range goal is to develop a technology based on using modified wood fibers to absorb pollutants from surface water runoff. Specific objectives are as follows:

1. To evaluate a range of wood fibers, including locally available fibers, through physical, chemical, and biological processes to increase their capacity to absorb phosphates/nutrients, specific heavy metals, and residual pesticides; to search for other media that can be combined with lignocellulosic fibers.

2. To design a filtration system so that the effectiveness of lignocellulosic filtration can be proven and adopted by DEP/DEC to reduce non-point source reduction and ultimately prevent eutrophication.

3. To install and monitor demonstration filtration systems.

4. To conduct life-cycle assessment of economic feasibility of using wood fiber filters for storm water filtration.
5. To prepare a technology implementation plan for all NYC watersheds.

The immediate goal is to establish phosphorus load and reduction based on dairy operations. About 350 dairy farms are in the Catskill/Delaware watershed. Our team is studying how much phosphorus reduction can be achieved by application of our system. Demonstration/simulation research has indicated that total phosphorus load and reduction can be calculated, and it is our goal to establish a model for the best management practice (BMP) for a dairy operation.

## III. Accomplishments

### A. Actions

Most of 2000 was spent in developing the filtration media and system. The team decided that the selection of a target pollutant and the source of pollution were important. According to the opinion of several agencies, most pollution in the watersheds is farm related and caused by *Cryptosporidium* bacteria (a seasonal problem) and phosphates. Thus, our main focus was the removal of phosphates. Generally accepted sources of phosphate pollution are fertilizers, agricultural wastes, municipal and industrial byproducts, and plant residues. We planned to work on one source of phosphate pollution per year, beginning with agricultural wastes. The two basic sources of pollution in agricultural wastes are animal manure and milkhouse waste. The process of collecting and spreading animal manure is not easy to monitor or apply to our technology, but it is not impossible. The most effective way of addressing filtration was to study milkhouse waste.

#### 1. Lignocellulosic filters

Juniper (*J. monosperma* ) trees were shredded to small chips, refined (fiberized or pulped), and chemically modified. Resultant fibers or pulp was made into a Rando mat using 5% HC–105 binder. Mat density was 100–120 g/ft$^2$ and thickness was about 13 mm. Mats were cut into 610- by 610-mm pieces. Phosphates were removed by saturating the mats in ferric/ferrous ion rich solution; acid mine drainage (AMD) was the most efficient treatment practice.

AMD was developed at FPL in a research program on the utilization of small-diameter trees, which is supported by Large-Scale Watershed Restoration Partnerships and National Fire Prevention funds. The mats are initially used at Wayne National Forest to reduce toxic heavy metal contents from AMD. The composition and concentration of heavy metal contents varies among AMD sites; our BMP is to select an AMD site with a low concentration of toxic heavy metals. The mats are reused at the NYC watersheds to remove anions (phosphates).

#### 2. Non-lignocellulosic filtration media

Mesoporous medium is an ideal material because of its high surface area (about 1,000 m$^2$/g), very regular pore arrangement, and narrow pore size distribution. Since this material is expensive, using it on a large scale is unjustifiable. However, the study of mesoporous materials gave us basic knowledge of chemical modification. We learned that zinc, iron, or aluminum impurities are needed in lignocellulosic and other potential media to enhance phosphate reduction, but the amount needed and their synergistic relationships have not been determined. Other non-lignocellulosic materials are classified as slags, clays, and AMD precipitants. The highest rate of phosphorus absorption developed in the laboratory is 24.64 mg/g; any medium capable of > 1 mg/g phosphorus absorption is potentially useful.

## B. Environmental Outcomes

### 1. Biological/physical outcomes

Our main goal is (2001) remediation of phosphate from milkhouse waste. Phosphate detergents are used to clean milking apparatus, and milkhouse wastewater is discharged to watersheds. A common phosphate detergent contains 0.33% or 0.36% phosphorus. But the measured phosphate content could be as high as 9%. Some farms are equipped with a milkhouse wastewater treatment system(s). This system can be efficient in removing phosphorus; as high as 98% efficiency has been claimed. In addition, the sludge can be used as a soil amendment. However, the system is time-consuming and requires operating funds.

Maximum of about 20 g phosphate from detergent could be discharged in milkhouse waste from an average dairy farm. The next source of phosphate is milk; 8 oz milk contains 247 mg phosphate. In tests of milkhouse wastes, phosphate levels varied from 70 to 100 ppm per 60 gallons discharge [1 gallon = 3.8 L]. In the 350 farms in Catskill/Delaware County, about 4,000 kg/year phosphorus can be traced to milkhouse waste.

Our filtration system can reduce about 70% to 80% of milkhouse-generated phosphorus. The annual rate of phosphorus reduction is expected to be about 3,000 kg/yr, which is half the non-point source pollution from the entire Croton area (6,798 kg/yr). Wastewater treatment plants reduce phosphorus from point sources of pollution. Our filtration system technically reduces phosphorus from non-point sources.

### 2. Socioeconomic outcomes

The NYC Watersheds Study will affect two communities: NYC residents and people living within the watershed areas that supply water to NYC. Support from those within the outlying watershed areas depends on developing a plan mutually beneficial to them and NYC residents. The use of locally grown wood fibers for filtration could provide a new market for forest products. Our study is targeted to utilize low-grade forest products and forest wastes. At present, five New York manufacturing facilities process wood chips and roundwood directly into paper and paperboard. Another facility produces a type of hardboard while processing wood into chips. Although some out-of-state companies utilize sawmill residues and low-grade materials, the closure of a major wood pulping operation in Pennsylvania has meant the loss of a very important market for up to 70,000 tons of wood chips generated annually from lumber production in the Catskill region. There is a growing need to create a more diverse market for new products that can be manufactured economically and efficiently from sawmill residues and other low-grade material.

The entire process of producing a filtration system derived from forest products—fiber selection, fiber processing, chemical modification, mat formation, filtration system design, field tests, and generation of data—will be oriented toward involving the forest products industry in watershed management research.

Our technology will be more cost-effective than treating the raw water supply. Application of this innovative technology may be used as a BMP in watershed management. If our filtration technique proves is accepted by the DEP and DEC, 100% of raw water supply can be filtered using some 30,000 filtration units in the region at a cost of about $60 million, assuming $1,000 per system and another $1,000 for installation and operating expenses for 5 years. This figure is considerably lower than the $6 to 8 billion needed to install a membrane filtration system, and most monies will be returned to the region. Installation and 5-year operation of a filtration system that could serve about 350 dairy farms in the study region is estimated to cost under $1 million. This system would remove approximately 80% of phosphate discharge from milkhouse waste.

### C. Project Growth

Since 1999, several changes have been made to increase the effectiveness of our operation. Two engineering colleges had been involved, but only one university has been retained, because of its proximity to the work. Bray Engineering was added as a partner for work in the Catskill/Delaware area. Activity in the Delaware County Soil and Water Conservation District has increased. We expect to involve new communities as our research becomes more visible.

### D. Products

Two manuscripts were published[3] and one manuscript was submitted for publication.[4] The fiber selection process, refining process, formation of mats, test procedures for filter capacity, and design of filtration box were accomplished. The system was tested in the Wayne National Forest, the Monroe Street detention pond (Madison, WI) and Lake Stewart (Mount Horeb, WI).

The team is in a process of simulating the flow vs. the system design. The aim is to simulate the flow numerically and provide information on flow inside the system. The numerical model is based on solving the Reynolds–Averaged Navier–Stokes Equation (RANSE), taking into account the free surface via volume of fluid (VOF) method. We are using a commercial program, STAR–CD, that implements such methods. We will be able to obtain vital information about the flow and size of the filtration system without actually building the system. To date, the predicted flow agrees with the current flow of about 30 gallon/min using an 8- by 4- by 2-ft (2.4- by 1.2- by 0.6-m) filtration box with 12 parallel filters. Plywood, plastic, and fiberglass were assessed as building materials for filtration boxes. Physical strength, degradability, and cost were the main evaluation criteria.

### E. Features

The NYC Watershed team at FPL designed a method for using pinyon juniper for filter material. This underutilized species has been effective in removing heavy metals from AMD and subsequently removing phosphates. Our dual goals are to remove water pollution and conserve natural resources.

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[3] Han, J. S. 1999. Stormwater filtration of toxic heavy metal ions using lignocellulosic materials: selection process, fiberization, chemical modification and mat formation. Proceedings of 2nd Interregional Conference on Environ-Water 99, Lausanne, Switzerland. Han, J. S., Park, J. K., and Min, S. H. 2000. Removal of toxic heavy metal ions in runoffs by modified alfalfa and juniper. In Proceedings of 1st World Congress of International Water Association, p. 3¥7.

[4] Min, S.H., Park, J.K., and Han, J. S. Removal of heavy metals in stormwater using low cost base treated juniper fiber. Prepared for publication in proceedings of 2002 International Water Congress, Melbourne, Australia.

## IV. Challenges and Changes

The socioeconomic dynamics in the Catskill area and NYC is delicate. As is true of most city people in the United States, most NYC residents do not know where their water comes from.

There are pros and cons to the three materials (plywood, plastic, and fiberglass) tested as building materials for filtration boxes. The challenge is the design criteria for the box. We are trying to keep the price per box under $1,000, and we may be able to reduce this cost by half.

The next challenge is selecting experimental sites. Installation of a filtration box requires an approximately 10- by 5-ft (3- by 1.5-m) piece of land as well as accessibility to the area. Installation of the filtration system requires logistics. A good partnership is essential.

We learned that establishing experimental sites east of the Hudson River–Croton watershed is difficult and we eventually abandoned this possibility. In searching for sites west of the Hudson River, we found that the DEP is very cautious about issuing permits to researchers. In the interest of time, we decided to limit our search to one good experimental site.

Our original plan was remediation of all four categories of water pollution: (1) oil/grease, (2) toxic heavy metals, (3) pesticides/herbicides, and (4) phosphates/nutrients. Our partners suggested that we limit our scope to two pollutants: phosphates and the pathogen *Cryptosporidium*. Because we are not equipped to handle pathogens and the problem with *Cryptosporidium* is seasonal, we decided to focus on phosphates, for which our designated site is suitable for study.

Preliminary investigations indicate that modified wood fibers are potentially effective as sorbents for removing ions and soluble materials from waste streams. Nonetheless, successful demonstration of this technology within the project area will depend to a great extent on the following:

***Knowledge of wood chemistry:*** The design of high capacity and efficient wood fiber filters requires a thorough understanding of the chemistry of cellulose, lignin, and extractives.

***Logistics:*** The research team is represented by people in the Midwest and Northeast regions of the United States.

***Identification of demonstration sites:*** Sites must be located where pollutants are present and the water flow rate can be controlled. An ideal site would be immediately downstream from a wet detention pond.

***Regulatory structure:*** An understanding of the many layers of governmental structure within the project area is necessary to ensure cooperation and assistance for installing and monitoring demonstration sites.

***Weather:*** Storm water flows vary widely, depending on weather conditions and storms. The adverse impact of intensive runoff needs to be considered in filtration system design and location of demonstration sites.

Problems could occur if the demonstration filtration systems are not properly designed and installed; for example, excessive flow rate of water through the filtration box, erosion around the exterior of the box, and leaking of the box. We anticipate that all of these problems can be remedied. Risks can be minimized through careful attention to design parameters for constructing the filtration boxes. Applying a sealant to all joints after installation can prevent leaking.

Successful demonstration of the wood fiber filtration technology does not necessarily imply that this technology can be applied throughout the NYC watersheds. Application will depend on many factors, which are difficult to access accurately at this time. Important factors are legislation to mandate high water quality and funding for installation and maintenance.

The nature of the problem may be difficult to handle politically. Water pollution is caused by small amounts of polluted runoff from many acres of land, owned by different entities and people. We assume that if the public is aware of a low-cost technology for improving water quality, there may be political support to install filtration systems where appropriate. We also assume that improved water quality will benefit the environment as a whole and particularly the biological communities that depend on lakes and rivers. It is essential that local organizations participate in decisions on the siting, operation, and maintenance of the demonstration projects. Local officials will be asked to help monitor the condition of the demonstration project periodically and to inform the project team if there are any signs of problems.

Despite these challenges, the NYC Watershed Study promises to be very beneficial. The concept of storm water filtration is in the embryonic stage, and the application of wood fibers for storm water remediation is versatile. The wood fiber resource is locally available, inexpensive, recyclable, and sustainable.

## V. Future Actions and Opportunities

The NYC Watershed team is planning to estimate phosphate loads from farm animals in both dairy and beef farms in 2002. In 2003, we expect to study fertilizers since a better assessment of phosphate pollution will be available. By 2004, we hope to have a good understanding of heavy metal treatment. To date, our method of treating fiber mats at the AMD and reusing them at farms has been well received.

Another possibility of applying lignocellulosic filtration is two-stage filtration. This concept has arisen from the application of ill designed but highly effective media or the application of highly effective media that produce deleterious side effects. We found a medium that can remove phosphates very effectively but discharges a trace of iron metals. Since lignocellulosic filters can remove iron, we can use this medium and at the same time remove the discharge. Many ion-exchange resins will discharge sulfur after removing phosphates.

Life-cycle assessment of the filtration boxes will be conducted in the final year (2004) of this study. In addition to providing information on the efficacy of the filtration technology, life-cycle assessment will allow us to estimate how much the technology will cost.

## VI. Partnership Budget and Costs

The NYC Watersheds Study is a unique research program. Our involvement with our partners is rather limited compared with that of other large-scale watershed restoration groups. In our case, the partner's contribution to the project usually takes the form of technical assistance. We received $10,000 from Northeastern Area State and Private Forestry (Marcus Phelps). Additional funds may be obtained from the Watershed Agricultural Council in 2002 (Brian Fisher) if funds from Large-Scale Watershed Restoration Partnerships are not available.

Expenditure New York City Watersheds Study 2001

| | | | |
|---|---|---|---|
| **Chemical Analysis** | | 4042.00 | |
| **Shipping** | | 1201.08 | |
| **Engineering & sampling** | | 14725.05 | |
| **Equipment** | | 26581.18 | |
| **Chemicals** | | 2431.67 | |
| **Data Processing** | | 2629.94 | |
| **Supplies** | | 4219.20 | |
| **Travel** | | 8855.83 | |
| **Salary** | | 62232.55 | |
| | **Total** | **126918.50** | |
| **Deposit (NY)** | | | 115,000 |
| **State and Private Forestry** | | | 10,000 |
| **Carryover** | | | 5,146 |
| | **Balance** | **-3227.5** | |

## Partnership Contacts

### *Public partners*

- **USDA Forest Service Northeastern Area State and Private Forestry—**Albert Todd, Chesapeake Bay Program Liaison, Annapolis, MD; Marcus Phelps, Franklin, NJ. Todd and Phelps will serve as the bridge between the New York area EPA, the U.S. Geologic Survey, and various Federal and local organizations.
- **USDA Forest Service, Wayne National Forest, Ohio**—Mike Baines, Mike Nicklow, Pam Stachler. About 300 AMD sites are in the Wayne National Forest. These sites will be an important factor in removal of phosphates.
- **Delaware County Soil and Water Conservation District—**This organization has the highest level of participation in our project. Brian Danforth, our primary contact and technical collaborator, has been involved in all aspects of work in the Catskill area. This organization works very closely with the Watershed Agricultural Council.
- **EPA—**Links will be established with EPA during the field-testing stage (Phase II), with direct participation in Phase III. Results from Phase II will provide the basis for research proposals.

- **U.S. Geological Survey—**David Owens and Peter Murdock. Owens, a hydraulic engineer, will provide practical advice. Owens previously worked with Han on a detention pond in Madison, WI.
- **NYC Watershed Agricultural Council (WAC), Watershed Forestry Program—**Brian Fisher will coordinate project activities among governmental agencies. He will also participate in assessing economic benefits of using local timber resources as raw material for fiber filters, with emphasis on species with low economic value.
- **NYC Department of Environmental Protection (DEP)—**Regulatory authority for compliance with water quality standards; responsible for implementing 15-year program to protect surface water quality within the project area. John Schwartz (Kinston, NY) is our main contact. Our main contact in Valhalla is Jean Marc Roche.

***Academic partners***

- **University of Wisconsin–Madison—**James Park, professor of civil and environmental engineering, will work on wastewater treatment with an emphasis on removal of phosphorus. Jim works with more than a dozen PhD students who can provide GIS maps and instant information about phosphates. FPL is providing the basic concepts in utilization of fiber and the students are responsible for implementation.
- **Ècole Polytechnique Federale de Lausanne—**Oliver Jolliet, professor, economic costs and environmental impact of remediation technology. Life cycle assessment will be conducted in 2003 with Prof. Jolliet.

***Private partners***

- **Catskill Watershed Corporation (CWC) and WAC—**The CWC facilitates development within the watersheds by issuing permits for remedial measures to reduce pollution in new and existing development. It serves 8 counties and 25 townships in the Catskill Mountains. The CWC and WAC will be instrumental in siting the demonstration projects and coordinating communication with landowners and regulatory agencies. Ken Heavey, a CWC engineer in the Catskill area, will be the primary contact for filtration sites. Justin Perry, a WAC forester, will be the primary forester for utilization of local wood species and processing and fabrication of forest products into the filtration system.
- **Mat, Inc. and Odbek, Inc.—**These companies have been cooperating with FPL for several years in developing nonwoven fiber mats using modified wood fibers. Mat, Inc. is bigger and more experienced in refining and mat formation than is Odbek. Mat has its own refiner and can produce a 152-cm Rando mat. Odbek can produce a 61-cm mat, and Odbek owners are familiar with design, fabrication, and marketing. We anticipate establishing a licensing agreement with Mat or Odbeck for fiber mat production and marketing. We may also explore local production of mats in the greater New York area.
- **Bray Engineering—**Dr. Walter Bray is a professional engineer who works in the Catskill area. His company has been maintaining our filtration system and his engineers have taken samples. The partnership between Bray Engineering and FPL was formalized in 2001. Bray Engineering hires local people and promotes the filtration system. We hope to establish more sites in the Catskills next spring and to save money by letting Bray install the system. One problem Bray is trying to resolve is running the system during the winter. So far, the system

has had to be closed during the winter because the water freezes. The company is a potential candidate for technology transfer.

- **Stoop and Heanning Farms—**These dairy farms are our most important private partners. The water filtration systems are located on their lands.