An analysis of the New York City water supply system

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Abstract: On January 21, 1997, the signing of the New York City Watershed Memorandum of Agreement (MOA) committed New York City to a long-term watershed management program in support of enhanced watershed protection. Under this agreement, New York City satisfies current provisions of the Environmental Protection Agency's (EPA) Surface Water Treatment Rule (SWTR) and consequently, has had the requirement for filtration of its Catskill-Delaware water supply waived. The MOA marked the culmination of years of negotiation between New York City and watershed communities and was created as a program which combines land acquisition, new watershed rules and regulations, and financial assistance to watershed communities to promote environmental quality and their local economies. The problem remains, however, that watershed boundaries rarely coincide with regional and/or political boundaries. Furthermore, the nonpoint impacts of agricultural practices on watershed areas are highly diverse. Therefore, isolating quantifiable problematic variables requires case by case analysis. This paper first provides an assessment of the current watershed management program and second, weighs alternative environmental strategies to assist in providing cost effective water management while also promoting the sustainable economic growth of watershed communities.

Since the 1840s, New York City has received its drinking water from upstate New York (Brown 2000). To celebrate Independence Day 1842, the city opened its first long distance aqueduct. The Croton River, the sole source of this aqueduct was chosen because of its elevation (Platt et al. 2000). When the river was dammed, the water could be transported to New York City by gravity (Platt et al. 2000). It took a tremendous amount of construction to complete the project. New York was the first city to implement such a system. In the 20th Century the city expanded its supply system by adding the Catskill and Delaware watersheds. These watersheds provide support New York City with 1.3 billion gallons per day (Brown 2000). Currently, the Delaware, Catskills, and Croton watersheds make up 1969 mi^2 northwest of the city, and are composed of 19 reservoirs (Benson 2002). The Croton watershed, the smallest of the three, provides 10% of the city's water. The Catskill watershed extends over 940 mi^2 west of the Hudson River and generates 40% of the water supply. The Delaware watershed, comprising 1625.5 mi^2, provides 50% (Brown 2000). The two west of Hudson watersheds, the Catskills and Delaware, empty into the Kensico Reservoir, which lies 15 miles north of the city. The water is then distributed to the city through two, soon to be three, water tunnels.

The geology and geography of these watersheds play a huge role in why they were chosen and why currently there are water quality concerns. The Catskill watershed is covered with boulders, rocks, and sand (Platt et al. 2000). This allows rainfall and runoff to infiltrate the groundwater quickly. The high soil permeability and steep changes in elevation improve lateral subsurface water flow. The area receives an average of 47 inches of precipitation annually (Platt et al. 2000)

From the 1960s-1980s, water *quantity* was the largest problem the city faced. In 1986, Mayor David Dinkins proposed a Universal Water Metering Program. The city installed 600,000 meters throughout Manhattan in a hope to use pricing to limit water waste (Platt et al. 2000). It also began a water conservation program. Some of the key elements of this program are free leak detection and installation of watersaving devices. From 1990 to 1995, the New York City demand decreased from 1546.8 mgd to 1449.3 mgd (Platt et al. 2000).

Recently, the focus has changed from the quantity of water available to the city to the quality of water provided by the upstate watersheds. Since 1990, disinfection byproducts (DBPs) and microbial pathogens have become more of a concern. The Safe Drinking Water Act (SDWA) mandates drinking water to be filtered unless the supplier demonstrates it will “maintain a watershed control program, which minimizes the potential for contamination by Giardia cysts and viruses in the source water” (Committee 2000). New York City has never filtered any of its water. The water from the Catskill and Delaware watersheds flows into the Kensico Reservoir, where it is stored for 15-25 days (Platt et al. 2000). The water is chlorinated there and then transported to the Hillview Reservoir in Manhattan. The water is treated with chlorine again and then passed through one of the two tunnels for distribution. The city has developed an alternative route for the water to bypass the Kensico Reservoir if the stored water is contaminated (Platt et al. 2000). The Health Department of New York City is most concerned about three pollutants entering drinking water: phosphorous, giardia, and cryptosporidium.

Of the many pollutants entering the New York City watershed, phosphorous initiates the widest range of complications in achieving water quality. Currently, the Cannonsville Reservoir, located in the Delaware watershed, is at the highest allowable level of phosphorous contamination and is the only phosphorous restricted basin in the entire watershed system. However, phosphorous loading is not an isolated problem. Throughout the system, phosphorous acts as the limiting macronutrient for algal and other plant growth (Committee 2001). Consequently, elevated levels of phosphorous in watershed reservoirs can lead to enhanced growth of algae, photosynthetic and heterotrophic bacteria, and aquatic plants. Under these conditions of enhanced growth, increased production of organic matter can alter conditions within the reservoir and cause eutrophication. Although eutrophication is essentially a natural process, excessive inputs of phosphorous into reservoirs within the Catskill/Delaware watershed can create a number of water quality problems:

1) An increase in water turbidity (a standard measure of inorganic and organic suspended particulate matter) caused by algal material and algal byproducts.
2) An increase in total organic carbon derived from algal biomass that can lead to formation of disinfection byproducts (DBPs).

3) Algal production of potentially toxic compounds, some of which may create taste and odor problems.
4) A decrease in dissolved oxygen levels within the reservoirs and the associated negative impacts on fish habitat. (Committee 2001)

The second problem identified in this list poses the most serious health risk to those dependent on the Catskill/Delaware watershed for their drinking water.

The problem of DBPs in the New York City water supply is one that is actually created by water treatment. The New York City system uses chlorine disinfection to control pathogens (Platt et. al. 2000). Although chlorine does kill microorganisms, it also produces DBPs such as trihalomethane (a carcinogen) when it comes in contact with organic carbons. As stated before, phosphorous is the limiting macronutrient in the New York City watershed. Therefore, phosphorous loading enhances algal productivity in watershed reservoirs, increasing the concentration of DBP precursors. This problem is further exacerbated by high levels of turbidity, which reduces the effectiveness of chlorine disinfection by shielding pathogens absorbed to the surface of sediment particles (Platt et al. 2000). If more chlorine is added to kill these pathogens, then more DBPs will be produced. Because phosphorous loading presents so many potential problems, it is important to identify the primary sources of phosphorous pollution.

Total phosphorous is divided into two categories: soluble and particulate (Committee 2001). The difference between these two forms has to do with their bioavailability. While soluble phosphorous is readily used by algae, particulate phosphorous is not readily available in the environment, and must be mineralized or hydrolyzed prior to uptake (Committee 2001). There are many varied sources of these two forms of phosphorous within the Catskill, Delaware, and Croton watersheds, which include both point and nonpoint sources. Sewage treatment plants are the primary point source of phosphorous pollution within the watersheds. Among nonpoint sources, agricultural runoff from lands treated with manure and from barnyard areas possesses very high levels of phosphorous runoff.

Of the many waterborne pathogens that could potentially contaminate the reservoirs of the Catskill, Delaware, and Croton watersheds, *Cryptosporidium* is considered to be the greatest threat to human health due to its resistance to typical water treatments (Walker Jr. et al. 1999). While cryptosporidiosis, the illness associated with *Cryptosporidium*, is not life threatening to most healthy individuals, it can be fatal for those with weak or weakened immune systems. This may include young children, the elderly, people with AIDS, or those undergoing chemotherapy (Walker Jr. et al. 1999). Just as with phosphorous pollution, sewage and agricultural runoff are the primary sources of this pathogen (Barwick 1998).

Cryptosporidium is spread by the ingestion of an infective oocyst which is shed in the fecal matter of an infected host (Barwick 1998). Animals, both wild and domestic, and humans can act as carriers of the pathogen. Consequently, both human waste and animal manure serve as sources of *Cryptosporidium*. Within the Catskill-Delaware watershed there are 39 sewage treatment plants and 400 dairy farms, which house over 40,000 cattle (Walker Jr. et al. 1999). Because the feces of dairy calves contains very high concentrations of *Cryptosporidium* oocysts, the heavy intensity of dairy farming within the watershed area presents a very serious risk of contamination. This contamination occurs when runoff from lands that have undergone manure spreading enters watershed reservoirs. No less significant, however, is contamination from human sewage. Raw sewage has been shown to possess concentrations of oocysts in the range of

10-170 oocyst/L, while treated sewage possessed a concentration range of 10-60 oocysts/L (Walker Jr. et al. 1999). According to these figures, human sewage is a greater source of *Cryptosporidium* within the Catskill-Delaware watershed. However, this does not take into consideration certain farming management practices that help to reduce *Cryptosporidium* contamination within watershed reservoirs. For example, if farmers were to let all infected calves defecate directly into streams, dairy-derived oocyst loads within the watershed would be at least three orders of magnitude larger than highly contaminated human sewage (Walker Jr. et al. 1999).

Like *Cryptosporidium*, *Giardia*, another waterborne pathogen, is spread through the fecal-oral route in which infective cysts are shed in the fecal matter of an infected host (Barwick 1998). Also similar to *Cryptosporidium*, *Giardia* cysts are found in high concentrations in the fecal matter of dairy calves. Even symptoms of cryptosporidiosis and giardiasis, the two gastrointestinal disorders caused by their respective pathogens, are similar. Both disorders are characterized by diarrhea, abdominal pain, fever, nausea, and vomiting (Barwick 1998). The primary difference between the two pathogens is their susceptibility to treatment. *Giardia* contamination can be reduced by the antibiotics albendazole and fenbendazole, which reduce the numbers of *Giardia* cysts calves shed (Barwick 1998). *Cryptosporidium*, however, has no approved treatment. Despite the antibiotic treatments available for dairy calves infected with *Giardia*, most animals are asymptomatic while shedding cysts and consequently, remain untreated (Barwick 1998). These pollutants cause serious health concerns and management is essential in ensuring water quality.

In 1986 the Environmental Protection Agency (EPA) promulgated the Surface Water Treatment Rule (SWTR) as an amendment to the SDWA. Under the SWTR, the EPA can waive the need for the city to filter its water if it can show that the supplier is undertaking an adequate water quality management program. A filtration avoidance determination (FAD) is based on five criteria: implementation of a watershed management program, turbidity standards, fecal and total coliform, adequate disinfection, and waterborne disease outbreak (Committee 2001).

The city had been trying to get a waiver from the EPA because building a filtering facility is estimated to cost between $3 billion and $8 billion (Platt et al. 2000). A conservation plan would be much less expensive to implement; the current plan has only cost the city $1.5 billion. The counties where the watersheds are located, especially Delaware County opposed the waiver because of the tax it would take on the local economy. Twenty percent of Delaware County is agricultural land. In 1997 the stakeholders - the Department of Environmental Protection (DEP), the Coalition of Watershed Towns, the EPA, 40 watershed communities, 5 conservation organizations, the Trust for Public Lands, and a few other interest organizations - signed a Memorandum of Agreement (MOA) (Platt et al. 2000). This was a ten-year plan that would be evaluated five years into the program, in 2002. The EPA waived the need for New York City to build filtering facilities for the Delaware and Catskill watersheds. The Croton watershed did not meet the water quality criteria and therefore had to be filtered (Committee 2001). The city has begun constructing the facility, and it is expected to open in 2007 (Brown 2000). The watershed management program, known as the New York City Watershed Management Strategy, agreed upon in the MOA has three components: a land acquisition program, watershed rules and regulations, and watershed protection and partnership programs (Brown 2000).

1. New York City owns 6% of the land in Delaware County. The New York State Catskill forest preserve owns 20%. The remaining 74% of the land is privately owned (Brown 2000), which poses additional compilations to achieving long-term state and private cooperation. The city agreed to spend $260 million to buy parcels of land, at fair prices, from willing sellers. Over the ten-year period, the city was supposed to contact the owners of 355,000 acres of land for possible sale (Landers 2002). Property owners of 200,000 acres of this land have been contacted, and the city has successfully acquired 40,000 acres through sale and property easements (Landers 2002). New York State agreed to spend $7.5 million to buy private land (Brown 2000). The biggest concern that Delaware County had with the FAD was that it did not want the city to acquire more land for fear that it would stifle economic development, lower property values, and lower the local tax base (Platt et al. 2000). Under the MOA, the city will pay Delaware County the taxes on land under conservation easements (Platt et al. 2000).

2. The watershed rules and regulations promulgated under the MOA were the first updates in forty years. They include upgrading wastewater treatment plants, repairing septic systems, roads, and impervious surfaces (Brown 2000). Impervious surfaces may no longer be built within 100 feet of above ground water sources, lakes, streams, and rivers (Platt et al. 2000). Since 1997, the compliance of wastewater treatment plants has gone up from 70% to 92% (Brown 2000). New York City succeeded in upgrading the six city-owned wastewater treatment plants, which treat 40% of the wastewater in the region to microfiltration capabilities (Brown 2000). The city still has

not upgraded the remaining 34 non-city-owned wastewater treatment plants (Brown 2000). Critics of the MOA have harped on this fault. The city reasoned in 2000 that it was negotiating contracts with each of these facilities and needed time to settle them (Brown 2000).

3. The watershed protection and partnership programs have successfully increased the environmental concern in the Catskills and Delaware watersheds. The Catskills Watershed Corporation (CWC) has played a large part in implementing these programs. The city entrusted the CWC to oversee and distribute $240 million from the city for infrastructure, economic development, conservation, and education in the watershed communities (Platt et al. 2000). These variables play a key role in the cost efficiency of the management plan and will be discussed later.

In 1999, the National Research Council (NRC) formed a committee to review the New York City Watershed Management Strategy. This committee released a report, listing 93 recommendations for these aspects of the watershed system:

- water quality monitoring
- geographic information systems
- waterborne disease surveillance and public health protection
- microbial risk assessment
- land acquisition
- land use planning
- total maximum daily loads
- phosphorous offset pilot program
- U.S. and N.Y. antidegradation policies
- dual track approach (filtration plant design and watershed management)
- Watershed Agricultural Program
- Watershed Foresty Program
- Stormwater Pollution Prevention Plans
- riparian buffer zones
- wastewater treatment

(Platt et al. 2000)

Midway through the project the EPA reviewed the FAD. The Kensico Reservoir, since it is the depository of all the water from the Catskills and Delaware watersheds, was the main focus of this examination. The New York City DEP implemented a tremendous management plan for the reservoir. The department mapped the sewer system. It also installed a turbidity curtain that redirects fecal coliform and turbidity. In this five year review the EPA congratulated the DEP for “repairing nearly 1000 septic systems; implementing a disease surveillance program; enlisting more than 90% of the watershed’s farms in a program to reduce pollutant runoff; exceeding goals for soliciting land.” (Landers 2002). The EPA extended the FAD through the remaining five years of the program. The city must however, open an ultraviolet disinfection facility to control waterborne pathogens for the Kensico Reservoir by August 2009 (Landers 2002). This is expected to cost $188 million (Landers 2002). It seems that the New York City watershed management project has been successful. Some of the original criticisms still remain though. How can such a project improve the local economies of the two watersheds? The commissioner of the New York City health department believes that Giardia and crypotsporidium pose a larger health risk than phosphorous, and filtration is the most efficient way of controlling these pathogens (Brown 2000).

Overall, there have been many successes in the management process to achieve ecological and social balance. However, every day more environmental strategies are being explored and thus additional opportunities to achieve a higher appreciation for sustainable resource management are being uncovered. As long as current practices still include ecological and social inefficiencies, we still face unsettling reality that our industrial/agricultural priorities are taking their toll on our limited resources. To address this problem, one must examine how to implement those environmental strategies that are not being fully taken advantage of.

As explained above, contamination of the watershed conflicted with EPA standards and management needed to be implemented. Watershed management was necessary for many reasons, including meeting requirements of the Clean Water Act (CWA) “to maintain the physical, chemical, and biological integrity of the nation's waters,” the Safe Drinking Water Act (SDWA) “to protect drinking water supplies,” (Committee 2001) and state programs, or meeting local community needs. One method required NYC to invest in full filtration of the Delaware and Catskill watersheds in addition to the already required filtration of the Croton system. The Croton filtration project is estimated to cost $600 million for construction, and $45 million per year for operation. (Porter 1994) The net present value of the Delaware/Catskill filtration ranged from $5 billion to $8 billion. To avoid this unnecessary cost (FAD), NYC management adopted a cooperative management program, NYC Watershed Strategy. Its third division, watershed protection and partnership programs, held a powerful opportunity to examine the use of environmental strategies.

One aspect of this plan dealt with varying degrees of stakeholder investment. As experience has shown, the task of accommodating all the conflicting interests of the watershed, in addition to the ecology of the system, is extremely taxing. It requires the ”recognition of a full range of key interests and tradeoffs, the building of trust, and identification of effective and equitable solutions.” (Committee 2001) However, its benefits are well worth it. It was observed that when farmers were given the opportunity to play an “integral part of the decision-making process” (Cameron and Muller 2001) as with the Whole Farm Program, there was higher participation. By increasing various “channels for involvement” and “creating and maintaining an openness to a wide range of methods for integrating stakeholder inputs" (Committee 2001) the system can work toward long term sustainability and avoid spending excess costs. Division of costs also can play an important role in stakeholder investment. Farmers will participate in voluntary and educational programs if "adequate cost sharing is provided: over 75% of respondents indicated that they would participate in such a program if it was 100% cost shared." (Poe 2001) Understanding the mix of public preferences for the watershed resources, and understanding which benefits are considered to be of critical importance by stakeholder groups, is a significant step in a viable resource allocation process.

Once cooperation is initiated, proper incentives must be set in place for management to be successful. Conservation tax cuts are one example of motivating individuals and business toward sustainable management. Conservation tax cuts, which provide additional funding for ecologically minded investments, help small businesses like farmers choose to upgrade their operations with ecological efficiency in mind. The purpose of these specific tax cuts is often just a means to bridge the financial gap that exists between the net present value of cheaper, environmentally degrading practices, and long term 'green' practices. Further, taxes provide revenue for environmentally friendly programs. According to Cameron and Muller, Iowa State University's Leopold Center for Sustainable Agriculture is one example (Cameron and Muller 2001).

Another strategy that has potential to play a large role in the NYS watershed system is nutrient trading. As long as competition for profit is the regulatory mechanism of our economy, competition will drive business toward cost efficiency (Chapman 2000). If by placing a cap on phosphorus input, corporate enterprises must either adapt or perish at the whim of their own economic foundation. By initiating transaction between businesses, it becomes economically cost effective to reduce phosphorous practices and then sell ones rights to less conservative farms. Similar to the NYC watershed, phosphorous plays major role in water quality of the Kalamazoo River (Cameron and Muller 2001). The Kalamazoo River Water Quality Trading Demonstration Project was set up to address this problem (Cameron and Muller 2001). Using this same logic, one can apply a similar model over the NYC watershed to encourage farms to externalize production costs as much as possible away from the degradation of the watershed

One final strategy, which, I believe holds the largest importance, is direct physiological and psychological conservation. Instead of developing new tools in response to a lifestyle, individuals could evolve a new ecological lifestyle in response to old tools (Leckie 1981). Despite the increasing rate of efficiency of surfacing economic theory, one cannot deny that symbiotic, ecological consciousness is a productive solution to environmental degradation.

Over the past 30 years, New York City has undertaken numerous projects to sustain both the water quantity and quality of its watersheds. The success of the New York City Watershed Management Strategy, negotiated under the 1997 Memorandum of Agreement is in large part attributed to its market-based approach. The plan focused not only on improving the water quality, but on increasing public awareness as well. The plan has room to grow from here. The mandates for this project came from the EPA, but this economic, community-based conservation program is on its way toward successfully achieved its goals.

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