Thirsty Metropolis: A Case Study of New York City's Drinking Water

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Case Study Subject and Goals

This case study is divided into two parts to explore many aspects of the development of the drinking water supply for New York City. In Part I, a brief history on the evolution of the water supply system is presented within the social and political context of the system's history. The case study lesson divides students into groups to examine various perspectives on a pivotal moment in the development of the water supply. This exercise allows students to consider the practical challenges in such a scenario and work through a real life case study in search of a solution. In Part II, an epilogue section allows students to compare their proposed solutions to the actual actions that occurred. Up-to-date information on the status of the water supply system is provided to provoke discussion among students on recent pressing issues for *stakeholders*.

Through a decision based format, this case study aims to provide undergraduate level students with a solid understanding of the biophysical, social, and economic dimensions of *watershed* management while fostering critical thinking and problem-solving skills. The goals of the case are to promote development of analytical and decision-making proficiency in a group setting, as well as encourage evaluation, reflection, and deeper research into conservation and development challenges.

Part I

It is 1995, New York State: Following the passage of a Congressional Act targeting the safety of the nation's water supply systems, attention is now focused on the current state of New York City's water supply. Tension is building between numerous stakeholders in the future of New York City's water supply. Pressures from all sides, along with the prospect of extensive litigation and political maneuvering, are threatening to destabilize years of progress on the safety of the water from *upstate* watersheds. How to balance the drinking water needs of millions of people with the needs of watershed communities? The controversy over the New York City water supply is about to enter a new phase…

New York City's Water Supply

The first settlers on the island of Manhattan in the early 17th century drew their drinking water from private wells. For the next three centuries, the City's water supply system grew from a series of simple local reservoirs to complex aqueducts systems that carried water to the City from several kilometers away. At the turn of the 20th century, faced with growing demands for reliable water, the city's Board of Water Supply decided to look to watersheds in upstate New York to supplement existing water supplies. Construction on an increasing number of reservoirs and aqueducts continued until the 1960's. Gradually, the upstate system of reservoirs and aqueducts became the primary source of drinking water for one of the largest cities in the world (New York City Department of Environmental Protection [NYCDEP], 2006).

Today, the New York City water supply system is derived from *surface water* north of the metropolitan area (some parts of Queens rely on a *groundwater* supply). The surface water network consists of three watersheds: the Catskill and Delaware watersheds about 160 kilometers north of the city in the Catskill Mountains and the Croton watershed about 80 kilometers north of the city and east of the Hudson River. The system encompasses over 5000 square kilometers across eight counties: Westchester, Putnam and Dutchess on the east side of the Hudson River and Delaware, Greene, Schoharie, Sulli-

van and Ulster in the Catskill Mountains, west of the Hudson (Figure 1). The system stretches *downstate* to NYC via a complex of aqueducts and tunnels to supply 5.3 billion liters of safe drinking water per day to millions of customers including residents, businesses, commuters, and tourists (Foran et al., 2000; Solecki and Rosenzweig, 2001). In fact, the system supplies water to nearly half of the population of New York State. In addition, excess water from upstate reservoirs not used for drinking water is released to the Delaware River to sustain adequate flow in the lower Delaware for New Jersey and other downstream users. The reliable function and safety of this water supply was and is absolutely essential to the existence of NYC (Foran et al., 2000; Solecki and Rosenzweig, 2001, 2004; NYCDEP, 2005b, 2005c).

As New York City and upstate communities have grown, pressures from two different sides have impacted the water supply. Increasing human population and development in watershed communities exerts pressure on natural water flows that supply the water supply system. In addition, expanding populations in New York City exert pressure on the system in order to supply a growing downstate need. The human presence at both ends of the water supply system creates tensions that affect the decisions that must be made to satisfy needs of all stakeholders.

Decision time: Controversy Regarding New York City's Water Supply

Prior to the 1980s, drinking water from the Catskill/Delaware watersheds and the Croton water supply system was unfiltered. Due to appropriate management of watershed lands, water quality had been consistently good and there was no perceived need for a *filtration* facility. However, in the late 1980s, public health concerns regarding outbreaks of waterborne illnesses across the country raised awareness of water quality and health issues (Crotty, 2002). In response, Congress passed the Safe Drinking Water Act Amendments of 1986. In 1989, pursuant this Act, the **United States Environmental Protection Agency (EPA)** promulgated the **Surface Water Treatment Rule (SWTR)** to protect drinking water sources against *microbial* contamination. The SWTR required that any public water supply system using unfiltered surface water either filter the *source water* or demonstrate that it met

Box 1. Landscape Changes to NYC Waterways

The familiar land-forms on today's atlases are drastically different from the coastline that greeted Henry Hudson as he sailed into the river that now bears his name. The Mannahatta project, sponsored by the Wildlife Conservation Society, provides an interesting perspective on the native habitat and ecology found on Manhattan Island, then home of the Lenni Lenape people, in the 17th century (Wildlife Conservation Society, 2006). Since that time, vast portions of shoreline have been modified, channels dredged and wooded coasts and *wetlands* disrupted as European settlers poured into the New World. These changes were considered necessary to accommodate increases in trade and growing human population by creating more usable land and disposing of waste (Montalto and Steenhuis, 2004).

According to the recent Health of the Harbor Report sponsored by the NY/NJ Harbor Estuary Program, 80% of the area's original tidal wetlands and underwater lands have been lost due to human activities such as dredging or filling (Steinburg et al., 2004). Well-known locations such as LaGuardia, Newark, and Kennedy Airports, Shea Stadium, and the now closed Fresh Kills Landfill were all built on top of former marshlands (Montalto and Steenhuis, 2004). In this respect, the evolution and development of New York City followed patterns typical of large urban cities. Some hallmarks of this development include the progressive concentration of population and infrastructure, along with changes in the biological and physical components of the original existing environment (Paul and Meyer, 2001; Alfsen-Norodom et al., 2004; Kleppel et al., 2004).

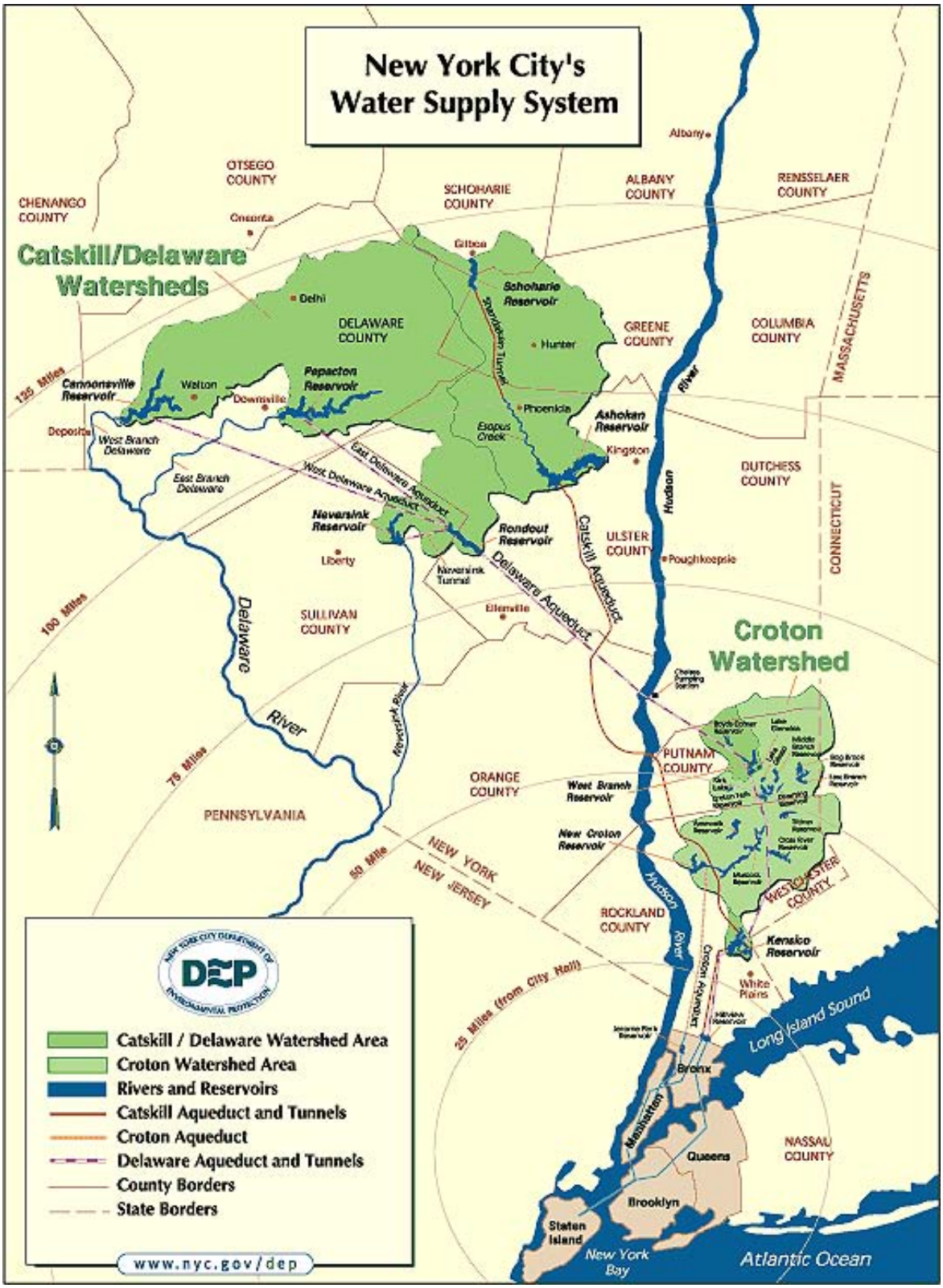

Figure 1. NYC Water Supply System (Source: New York City Department of Environmental Protection)

a series of objective water quality, operational, and watershed control criteria. NYC was faced with a choice between two options: filter the water or satisfy the provisions of the SWTR for unfiltered water.

After a series of initiatives by the City in the early 1990's to comply with the SWTR, the EPA issued a conditional ***Filtration Avoidance Determination (FAD)*** in 1993. The main conditions in the FAD centered on an improved watershed protection plan and a land acquisition program which would regulate activities on water sensitive lands through restrictions and *buffer zones*. EPA also required that the City proceed with preliminary design of a filtration facility for the Catskill/Delaware supply, to minimize any delays if the EPA decided that filtration was necessary in the future. These programs directly affected upstate residents and businesses and created potential for conflict between parties concerning property rights and land use regulations. The history of conflict between NYC and upstate communities dates back to the 1950's, when the City claimed *eminent domain* to build its reservoirs and flooded whole villages and displaced numerous residents in the process (Catskill Watershed Corporation, 2005; Ellison, 2006).

Uncertainty regarding the City's follow-up actions to the FAD and possible use of eminent domain for land acquisition caused relations between the City and upstate communities to deteriorate. Upstate stakeholders, lead by the Coalition of Watershed Towns, filed lawsuits against NYC (Specter, 1992; Pfeffer et al., 2002). These lawsuits caused an impasse in efforts by all stakeholders to reach a compromise about a watershed protection program (Rosenburg, 1995; Ashendorff et al., 1997; National Resource Council Commission on Geosciences, Environment and Resources, 1999; Burnett, 2004).

Since the conditional FAD impacted many disparate stakeholders in New York, EPA and other interested parties recommended that the Governor of New York State, George E. Pataki, convene a meeting of stakeholders to mediate the controversy (National Resource Council Commission on Geosciences, Environment and Resources, 1999). Subsequent negotiations involved the following four primary stakeholder groups: government entities (City of New York, New York State, EPA, NYS Department of Health-DOH, NYS Department of Environmental Conservation-DEC, NYCDEP), upstate stakeholders (Coalition of Watershed Towns, representatives of eight upstate counties), downstate stakeholders (representatives from NYC, Putnam County, Westchester County), and environmental groups (Hudson Riverkeeper, Catskill Center for Conservation and Development, Trust for Public Land, Open Space Institute, and New York Public Interest Group) (New York State Environmental Facilities Corporation, 1997; Wolosoff and Endreny, 2003).

As of 1995, the alternative to meeting the stringent criteria mandated by the EPA is the construction of a filtration facility for all of the water coming from the Catskill and Delaware watersheds. It has been estimated that the cost of such an endeavor would be upwards of $6-8 billion dollars, with annual operating costs of $500 million (Chichilnisky and Heal, 1998; Ellison, 2006).

The Scenario

The FAD is scheduled for re-evaluation within one year of this roundtable meeting. In order to facilitate a compromise between many varied stakeholders that is compatible with legal obligations and economic and environmental concerns, New York State Governor Pataki has assembled representatives from each perspective to present their viewpoint. Each group is charged with producing a position statement that also contains recommendations for compromise with other stakeholders. One additional group will be given the task of facilitating the discussion as each stakeholder presents their position and works towards a compromise. Possible compromises may consist of a land acquisition agreement, watershed rules and regulations, partnerships, or a determination to explore filtration options.

1. Your task is to adopt the concerns of the stakeholder group you have been assigned to represent. The four perspectives are: upstate stakeholders, federal and state level government agencies, downstate stakeholders, and environmental groups. Strive to understand and accept the

Box 2. American Museum of Natural History's Survey

In 2005, the American Museum of Natural History completed a nationwide survey to gauge American's knowledge of and attitude towards water and water-related issues. Remarkably, most respondents did not recognize that some of the main sources of water quality degradation are flushing toilets (through the effluent of wastewater treatment plants), *runoff* from treated lawns, and stormwater *runoff* from roads. As further development occurs in upstate watersheds, each of these threats to water quality may lead to lower drinking water quality for New York City. Both upstate and downstate residents are tightly linked.

The survey also found that of the 78% of respondents on a municipal water system such as New York City's system, only one-third gets their drinking water from an unfiltered tap. The rest of the respondents either filter their tap water or drink only bottled water. All respondents were asked to rate the quality of their tap water. Over 65% responded with positive reviews, while 1/3 of the sample gave fair or poor responses.

validity of your assigned position. You should familiarize yourself with the details of your position so that you can present your particular viewpoints clearly and comprehensively in a discussion.

2. During the roundtable discussion, be open to creative solutions and collaborative approaches. In Part II of the case, you will be able to compare your recommended course of action with the realities of the case. You will further consider how the real outcomes have affected various stakeholders in the years since the decision and the current status of the NYC water supply system.

Information statements on each of the stakeholder groups are provided below. Your assignment is to review the background of your assigned stakeholder group and create a 5 minute position statement on your view of the situation. Discuss your goals for the stakeholder meeting, and prepare suggestions for solutions that can incorporate these goals into plans for the future of the New York City water supply.

Upstate Stakeholders

Upstate stakeholders who live and work in the rural watersheds of the Catskill and Delaware systems are intimately involved with decisions regarding New York City's water supply. NYC owns less than 10 percent of the watershed, which covers roughly 5,000 square kilometers (Figure 1). The watershed has a year-round population of around 78,000, as well as a significant number of summer residents (Ashendorff et al., 1997). The main economic sectors of the upstate communities focus on tourism, recreation (such as skiing) and the arts, agriculture (mainly dairy farms), small businesses and manufacturing, and natural resource based industries such as agriculture, forestry and mining products. Citizens and businesses in these watersheds have varying degrees of concern regarding the impact that a land acquisition program might have on the character and economic viability of their communities (Hamilton et al., 1998). A majority of residents of Westchester County support the prospect of land acquisition in their county, for example. Notably, these residents depend on the NYC water supply system for their drinking water. However, residents of many towns west of the Hudson River have opposed any land acquisition plans that might devalue private property and have expressed concerns regarding property rights. For example, in 1993, the **NYC Department of Environmental Protection (NYCDEP)** released a draft impact statement for revised watershed rules and regulations according to the FAD. New regulations called for buffer zones around waterbodies and restrictions on the construction of sewerage and service connections. Residents are concerned that these regulations could reduce property values by

making land unavailable for development.

Uncertainty over NYC's intent to use eminent domain to gain control of the watershed lands and the perception that NYC is shifting the costs of watershed protection to upstate communities has resulted in the deterioration of relations between NYC and upstate communities. Watershed residents claim that efforts to protect surface water quality will impose unreasonable costs on property owners directly and indirectly on all watershed residents by reducing economic growth and associated economic opportunities. In responding to the NYCDEP's statement, the **Coalition of Watershed Towns (CWT)** (a group that has emerged to represent the interests of upstate stakeholders) has concluded:

"*The City has hidden from discussion … land acquisition programs which it is already beginning to implement. The total program would involve the acquisition of approximately half of the developable land. The net result is that the watershed will suffer unmitigated impacts of both the regulatory program and a land acquisition program.*"

The tensions peaked when the CWT, representing about thirty watershed communities, filed suit to prevent NYC from implementing its filtration avoidance plans. The CWT cited economic burdens on watershed residents resulting from restrictions placed on the use of privately owned land. The group claimed that NYC would benefit almost exclusively from environmental measures in the countryside to protect drinking water supplies at their source (Pfeffer et al., 2002).

Government Agencies

A diverse array of government agencies has a stake in the outcome of decisions regarding the New York City water supply. The USEPA, New York City Department of Environmental Protection (NYCDEP), NYS Department of Health, and NYS Department of Environmental Conservation are all concerned with compliance with the SWTR and the safety and regulation of an enduring water supply for NYC. In particular, the DEP holds primary responsibility for the water supply system, with a mandate to ensure the public's continued access to safe drinking water. In New York State, EPA Region II has primary enforcement responsibility for the SWTR regarding the unfiltered Catskill/Delaware systems, and therefore it has ultimate enforcement authority over the state and local agencies.

According to the STWR, filtration avoidance criteria are comprised of three main areas that must be enforced for the water supply system to remain unfiltered.

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

Representatives of government agencies are committed to the safety of the New York City water supply system. Notably, all the surface water and groundwater entering the City's water system is treated with chlorine for disinfection, fluoride to prevent tooth decay, orthophosphate to reduce the release of metals from household plumbing, and in some cases sodium hydroxide to adjust pH.

The objectives of the government agencies vary. If the system does not meet the criteria for the FAD, the EPA may decline to renew the FAD and trigger the utilization of a filtration plant. Therefore, the EPA is solely concerned with maintenance of water quality either by ensuring quality of unfiltered water, or filtering the water if quality drops. In contrast, the local agencies such as the NYCDEP are in favor of the most cost-effective solution for the continued safety of the water supply system. For this reason, the NYCDEP is most likely to favor the creation of a compromise that allows water to flow unfiltered from upstate communities to avoid costly fil-

tration.

Downstate Stakeholders

The New York City metropolitan area is one of the most populous and heavily industrialized coastal areas on earth. According to the last decennial census by the US Census Bureau in 1990, almost 17 million people live in the metropolitan area of New York City, Long Island, Northern New Jersey, and Northeastern Pennsylvania, including the over 7.3 million people living in the five boroughs of NYC. The pressures of a large population, with associated requirements such as clean water and waste disposal, impact the need for a consistent water supply. The City of New York, Putnam County, and Westchester County currently receive the unfiltered water from upstate watersheds. Residents, businesses, commuter and tourists in these areas are concerned with a safe, consistent supply of water.

New York City's drinking water has long been renowned for its safety and quality, and has even been described historically as the "champagne of drinking waters." Some proponents have argued that the drinking water is the secret ingredient in the famous New York City bagel and pizza. As the recipients of this drinking water supply, downstate residents have a considerable stake in maintaining the quality of their supply.

Notably, residents and business would be faced with shouldering the potential costs of a filtration plant if mandated. NYC faces upfront costs of multiple billions of dollars for the construction and maintenance of a filtration plant for its Catskill/Delaware water supply. As the City's annual budget is about $29 billion, this cost could double water rates in the City, adversely affecting residents, especially NYC's large low income population (Perlee et al. 1994; Appleton 2002) Drastic rate increases could also lead to closure of housing units in rent-controlled areas of the City where the landlords cannot pass the additional cost of the water on to their tenants (Mouat, 1993; Burnett, 2004). However, it is also notable that the costs for administering the requirements of any future FADs and associated agreements are also borne by the City.

Environmental Groups

The principal environmental groups involved with the decision regarding NYC's water supply are: Hudson Riverkeeper, Catskill Center for Conservation and Development, Trust for Public Land, Open Space Institute, and New York Public Interest Group. These groups are concerned with advocacy for safe water for all parties. In addition, these stakeholders are concerned with other aspects of the Catskill, Delaware and Croton watersheds, such as preservation of biodiversity and riparian corridors, which may be protected under the umbrella of water purification (Daily et al., 1999). In addition to supplying NYC's drinking water, rural upstate watersheds contain wetlands and waterways that provide numerous *ecosystem services* such as nutrient cycling and mitigation of floods and drought (Baron and Poff, 2004).

The freshwater ecosystems in the Delaware, Catskill, and Croton watersheds also support a large amount of biodiversity (Foran et al., 2000, Edinger et al., 2002, also see the New York State Biodiversity Project at http://cbc.amnh.org/center/cbcnews/state.html). For example, watershed lands serve as a major core area for several regionally rare large mammal species, including black bear (*Ursus americanus*), bobcat (*Lnyx rufus*), and fisher (*Martes pennanti*). The waters that supply the reservoirs support healthy populations of coldwater fish such as brown (*Salmo trutta*), rainbow (*Oncorhynchus mykiss*), and brook trout (*Salvelinus fontinalis*), and the reservoirs themselves are important fisheries for smallmouth bass (*Micropterus dolomieu*), redfin pickerel (*Esox americanus*), yellow perch (*Perca flavescens*) (Dowhan et al., 1997).

The watershed lands support numerous endangered and threatened species. Federally listed threatened species include the northern wild monkshood (*Aconitum noveboracense*) and the bald eagle (*Haliaeetus leucocephalus*). Bald eagle pairs have successfully nested at reservoirs such as Ashokan, Rondout, Schoharie, and Neversink, all of which are part of the NYC water supply system. State-listed endangered species include the shoreline sedge (*Carex hyalinolepis*) and roseroot stonecrop (*Sedum rosea*), and threatened species include the timber rattlesnake (*Crotalus horridus*), red-shouldered hawk

Lake ecosystem created by beaver dam - Catskill watershed (Source: F. Laso)

(*Buteo lineatus*), fragrant cliff fern (*Dryopteris fragrans*), moschatel (*Adoxa moschatellina*), and Appalachian Jacob's ladder (*Polemonium van-bruntiae*). Other species are state-listed as special concern, including the spotted salamander (*Ambystoma maculatum*), eastern hognose snake (*Heterodon platirhinos*), spotted turtle (*Clemmys guttata*) and eastern bluebird (*Sialia sialis*) (Dowhan et al., 1997). Many environmental groups support environmental protection measures that protect both New York City's water supply and the resilience and diversity of upstate ecosystems.

Part I: Issues for Further Analysis and Discussion

1) What are some of the benefits and weaknesses of using the approach of conserving watershed integrity rather than relying on a water filtration plant?

2) Consider that the upstate watersheds are experiencing increases in population. Downstate residents have also been acquiring second homes in watershed communities, which has resulted in a new wave of development pressure (Commission on Geosciences, Environment and Resources, 2000 and The Nature Conservancy, 2005). What additional threats might this settlement and development pose to the water supply of New York City?

3) How does this model compare to other urban water supply systems throughout the world (see Fitzhugh and Ritcher, 2004)? For example, consider Mexico City's water supply. The city's water is delivered from a groundwater system that is experiencing a reduced water table and pollution problems (see Excurra and Mazari-hiriart, 1996; Tortajada and Castelan, 2003). Comprehensive information in order to make a comparison can be found in Joint Academies Committee on the Mexico City Water Supply et al. 1995. Further comparison can be made to other American cities that depend on surface water systems, such as Los Angeles (Archibold, 2007).

Part II

Epilogue

Following years of negotiations between downstate and upstate stakeholders (including 270 meetings over a period of 2 years), a New York City Watershed Memorandum of Agreement (MOA) was signed on January 21, 1997. This landmark agreement successfully resolved long-standing controversies and set forth responsibilities and benefits for all major parties.

Generally, the MOA represented a consensus of a stakeholder coalition and provided a legal framework for protecting the drinking water supply of New York City while safeguarding the environmental quality and economic prospects of upstate watershed communities. In order to address the deadlock

imposed by litigation, all parties agreed to drop outstanding lawsuits and abstain from filing legal challenges to the MOA. Most importantly for government stakeholders, the agreement satisfied provisions of the SWTR that allowed the City to avoid filtering its upstate Catskill/Delaware water supply until at least 2002, thereby avoiding the multi-billion dollar construction costs of a water filtration plant. Notably, the FAD provisions required that the City begin construction of a water filtration plant for the more populated and developed Croton watershed. Currently, a $1.2 billion filtration plant is under construction in the Mosolu Golf course site in the Bronx for the Croton water supply. The MOA also delegated responsibility to various agencies and institutions for the goals of economic growth and environmental protection in upstate watersheds (Ellison, 2006, U.S. EPA Region II, 2006a). Noted environmentalist Robert Kennedy Jr. expressed the difficulty in reaching this landmark agreement by stating "there was blood shed over every word (Ellison, 2006)."

More specifically, the MOA consisted of three major components: a watershed land acquisition program, revised watershed rules and regulations, and watershed protection and partnership programs. Each component was created to address the challenges posed by the SWTR requirements and the political and social contexts of the resource issue.

1) For the watershed land acquisition program, New York State issued a land acquisition permit that allowed the City to purchase or provide conservation easements to vacant water quality-sensitive watershed lands on a 'willing buyer/willing seller' basis (New York State Environmental Facilities Corporation, 1997). At the time of the MOA signing, NYC owned less than 10% of the land in the Catskill/Delaware watersheds (U.S. EPA, 2006).

2) For the revised watershed regulations, the City was tasked with the revision of watershed regulations that addressed both *point* and *non-point source pollution* from sources such as waste-water treatment plants, disposal systems, and stormwater runoff. The goal of these revisions was to protect the public health by averting future contamination to, and degradation of, the water supply and by remediating existing sources of pollution or degradation (NYCDEP, 1997; DOH and DEC, 2002).

3) The innovative watershed protection and partnership programs were designed to foster collaborative understanding between upstate and downstate stakeholders regarding the water supply. The MOA included provisions for substantial funding for economic and environmental partnership programs targeted at upstate communities. The MOA explicitly mandated the creation of two partnership programs: the **Watershed Protection and Partnership Council (WPPC)** and the **Catskill Watershed Corporation (CWC)** (New York State Environmental Facilities Corporation, 1997; U.S. EPA Region II, 2006a). The WPPC was delegated the responsibility of evaluating the many watershed protection and partnership programs specified by the MOA, while the CWC was more specifically tasked with developing and implementing several city-funded programs, including education initiatives, residential septic rehabilitation, stormwater controls and economic development through the city-funded $59.7 million **Catskill Fund for the Future (CFF)** (WPPC, 2004; CWC, 2005).

Each of these three complex components presented considerable challenges for implementation. Furthermore, as an innovative agreement, the MOA had no comparable pre-existing model. Each component of the agreement therefore demanded creative approaches in implementation, maintenance, and assessment.

In the years since the signing of the MOA, the City has finalized its regulations for watershed land uses, acquired sensitive lands to protect key reservoirs and waterways, conducted more extensive water quality testing in the watershed, and supported upstate/downstate partnership programs. These projects have required an estimated investment of $1-$1.5 billion by New York City. New York State adopted the City's watershed regulations and land acquisition permits, and established a new Watershed Inspector General's Office to ensure that the City's regulations are implemented to protect public health. Watershed residents have been able to develop

property to the extent the regulations allow, or sell it to the City if they chose. In addition, upstate community representatives have participated in the regional watershed partnership council, which included representatives of the State, City, and downstate consumers (Platt et al., 2000).

Progress on the MOA objectives has been continually evaluated. In 2002, the FAD was reviewed and renewed by the EPA, with the provision that NYC begin construction of an ultraviolet (UV) light disinfection treatment facility in Westchester County for the Catskill/Delaware system. Just four years later, progress on the many requirements of the 2002 FAD (infrastructure, protection and remediation programs, watershed monitoring, etc) was positively reviewed by the EPA. Notably, NYC's water supply system became the largest surface water supply system in the United States for which a FAD has been authorized (in 1997) and re-authorized (in 2002 and 2006) due to continued compliance (Mugdan, 2004; U.S EPA Region II, 2006a).

The NYCDEP has also evaluated progress since the MOA. The 2005 Drinking Water Supply and Quality Report, published by the DEP, noted that progress has been made on several fronts (NYCDEP, 2005d). For example, land acquisition

Box 3. New York City: Unexpected Source of Aquatic Biodiversity

For all its famous terrestrial landmarks, the NYC metropolitan area is actually dominated by water, with approximately 2400 kilometers of coastline (see Figure 1) (Solecki and Rosenzweig, 2001). The city itself has a 930 kilometer coastline and four of its five boroughs are located on islands (Goldstein and Izeman, 1990; Solecki and Rosenzweig, 2001). A complex network of waterways connects the metropolitan area to its heavily urbanized neighbors New Jersey and Connecticut via the New York/New Jersey (NY/NJ) Harbor Estuary and the Long Island Sound. Just outside the NY/NJ Harbor Estuary is the New York Bight, a 39,000 square kilometer sector of the Atlantic Ocean (Friedman et al., 2000). There is a remarkable diversity of ecosystems throughout these waterways. The ocean waters support marine deepwater and subtidal and intertidal ecosystems (Edinger et al., 2002). At the interface between marine and terrestrial environments are the coastal estuarine wetlands. These wetlands provide many important ecological functions such as the dissipation of wave energy and buffering of storm surges, which would otherwise result in accelerated erosion of the coasts. The frequency of tidal inundation and rates of runoff from tidal marshes are important in determining the magnitude of exchange of nutrients, organic matter, toxins, and pollutants between marshes and their surrounding estuaries (Montalto and Steenhuis, 2004).

Biodiversity, or biological diversity, is defined as the variety of life on Earth at all its levels, from genes to ecosystems, and the ecological and evolutionary processes that sustain it. Even in the highly urbanized environment of New York City, there are pockets of high aquatic biodiversity in the many marine, coastal, and freshwater ecosystems. For example, the biodiversity of the coastal wetland communities in the New York City metropolitan area is notable for its wide variety. Located at a critical point along the Atlantic flyway, the wetlands of the NY/NJ Harbor Estuary provide habitat for resident and migratory birds (Edinger et al., 2002; Montalto and Steenhuis, 2004; Steinburg et al., 2004). The marshes of Jamaica Bay (see Figure 2) support over one-fifth of all North American bird species and even the endangered Kemp's Ridley turtle can be found there (Goldstein and Izeman, 1990; Brown et al., 2001; NY/NJ Clean Ocean and Shore Trust, 2004). Many fish species occupy the estuaries of New York City's waters for at least some portion of the year, including migratory species such as sturgeon and resident species such as white perch (Dowhan et al., 1997). These estuaries also contain habitats that support shellfish such as oysters, fauna such as crustaceans and nematodes, and microbiota such as blue-green algae (Dowhan et al., 1997; Edinger et al. 2002). All types of wetlands serve as important links in food webs (Steinburg et al., 2004).

continues and the City has worked to manage these newly owned lands appropriately, while providing opportunities for recreation including fishing and hiking. There has been a 60% increase since 1997 in the number of City owned watershed lands open for recreation. Partnership programs have also been continually progressing. In particular, the CWC continues to work to improve failing septic systems and stormwater control measures.

Most recently, the success of the MOA approach has been reinforced by the USEPA's April 2007 release of a draft FAD for the Catskill/Delaware water systems that will last until 2017. This draft FAD hinges on the City's 2006 Long-Term Watershed Protection Program and plans to continue the land acquisition progress started by the MOA (NYCDEP 2006b, NYCDEP 2007).

The Scenario

Currently, NYC is part of an exclusive group of major American cities including Boston, San Francisco, Seattle, and Portland, Oregon that have unfiltered water supply systems. Numerous considerations are affecting current plans for and perceptions of the water supply system. Listed below are issues that may be used to begin a discussion in the class about the future of the NYC water supply system. Students should apply the knowledge they have acquired about the history of the system to address one or more of these issues.

1) *Epilogue:*
Part II of this case provides an overview of the sequence of events that occurred after "decision-time" on the NYC water supply system. How does the MOA agreement and epilogue compare with the stakeholder forum suggestions from the class exercise in Part I? To what extent does reality match the recommendations? Do the class groups have an idea of how each of the stakeholders might have responded to the decision?

2) *Stakeholders:*
Part I of this case study listed four stakeholders in the NYC water supply system (upstate and downstate stakeholders, government agencies, and environmental groups). In the 10 years since the signing of the MOA, are there any additional stakeholders that must now be considered regarding the water supply system? Review the February 2006 article in the *New York Times* "Floodwaters Reveal a Divide Between Upstate and Down (Applebome, 2006)", the March 2006 article in *New York Times* "City Takes Steps to Balance Its Water Needs With Flood Protection Upstate (DePalma, 2006b)" and publications by the Croton Watershed Clean Water Coalition (http://www.newyorkwater.org/) to enhance this discussion.

3) *Current water quality issues:*
   a. Turbidity – A New York Times article from July 2006 describes the increased concentrations of clay particles in the drinking water supply, washed into reservoirs by storms and increased runoff from land development. This increased turbidity can interfere with chlorination to remove contaminants. Currently, turbidity is treated chemically, with aluminum sulfate, to clear out the clay particles by lumping them together so they settle out. What potential implications could this water quality issue hold for the city and the FAD (DePalma, 2006a)?
   b. The DEP's 2005 Drinking Water report notes the delicate balance between treating water with chlorine to disinfect microbial contaminants and the resultant disinfection by-products such as haloacetic acids (chlorine reacts with naturally occurring metals in drinking water) (NYCDEP, 2005d). What potential implications could this water quality issue hold for the city and the FAD?

4) *Implications of climate change:*
Studies have shown that air temperature in the Catskill Mountain Region of New York has warmed by 1.1° F since the 1950s along with an increase in average precipitation of over 13 centimeters per year. Studies have also indicated that the area can expect a warmer and wetter climate in the next century, but droughts will also occur, especially in the more developed parts of upstate regions (Burns, 2006). How might the following issues, com-

bined with the effects of climate change, affect the water supply system?

a. Increase in variability of stream runoff.
b. Potential for sea-level rise in coastal areas of NYC and potential negative impacts on wetlands and other natural flood-mitigation and water retention systems.
c. Human land use and development increasing vulnerability to climate change through increase in *impervious* surface coverage in the watersheds or further clearing of forested land.
d. Planning for the future needs of upstate and downstate customers.

Part II: Issues for Optional Analysis and Discussion

1) *Source to Sink Pollution Issues*

Most of the water that comes from upstate watersheds ends up in the various waterways that surround New York City (Figure 2). Interestingly, respondents to the American Museum of Natural History's survey mentioned above associated "water pollution" with urban and/or industrial areas such as New York and New Jersey. Indeed, pollutants such as total suspended solids, biological oxygen demand, pH, fecal *coliform* bacteria, oil, and grease can result from human activities. The effects of these pollutants can result in fish kills, oil slicks, and unusual colors or odors associated with the water. Such pollutants are under control throughout most of the NYC area. However, contaminants can be released during 'combined sewer overflows' (CSOs). CSOs constitute one of the most important point-source water pollution problems in New York City (Goldstein and Izeman, 1990, Beard et al., 1996; Solecki and Rosenzweig, 2001; Stoddard et al., 2002; Alfsen-Norodom et al., 2004). As little as 0.1 centimeters of rain in some portions of the NYC metropolitan area can initiate overflow conditions causing up to 10% of the city's raw wastes to enter the city's aquatic ecosystems through more than 540 overflow points (Beard et al., 1996). Increases in non-point sources of pollutants in urban areas have been shown to affect

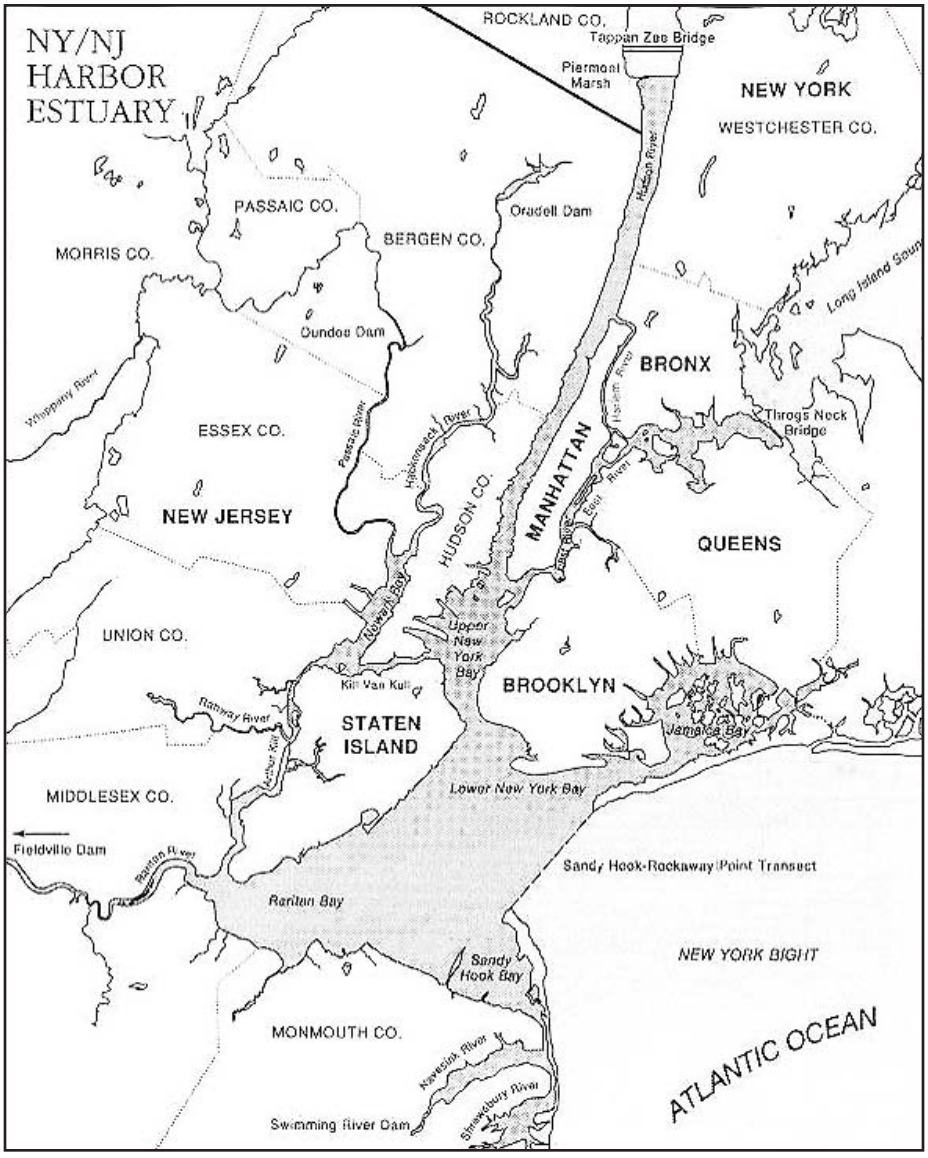

Figure 2. NY/NJ Harbor Estuary – Ultimate Recipient of Upstate Water (Source: USEPA)

water quality and aquatic biodiversity. Most of these effects are compounded greatly by vast stretches of *impervious* surface cover in urban areas that increase the velocity of stormwater and provide a continuous pathway along which many pollutants can be transported (Kennen and Ayers, 2002).

Pollution prevention and appropriate land management planning are some of the most effective methods currently being employed to reduce diffusive environmental contamination in urban areas (Wakeman and Themelis, 2001). New York State's statewide non-point source management program focuses on reducing input from agricultural, urban, and onsite disposal systems (Beard et al., 1996). One example of the application of *non-point source* management to reduce ocean pollution and improve ecosystem health is the Long Island Sound Study. Currently in Phase III, this comprehensive management plan seeks to reduce nitrogen loading into Long Island Sound in order to mitigate *eutrophication* and resultant *hypoxia*. The strategy for meeting nitrogen reduction targets relies on aggressive control of point and non-point sources via land use decisions at the local level. At the scale of the watershed, the plan implements stormwater detention ponds, streetsweeping, and habitat protection and restoration. As a result of such actions, upgrades to sewage treatment plants have decreased nitrogen discharges to the Sound by 25% from peak years in the early 1990s and the severity of hypoxia has decreased (Long Island Sound Study, 1998).

2) *Challenges of Maintaining a Large Metropolitan Water Supply System*
   a. Ongoing construction of NYC water tunnel No. 3 to be completed in 2020 at a cost of almost $6 billion. See resources on progress (NYCDEP, 2006a) and the story of the sandhogs (urban miners) working to dig the tunnel (Levay, 2005).
   b. The importance of water conservation and initiatives to reduce water consumption such as: leak detection, water metering, incentive programs and education programs such as a toilet rebate program to encourage use of water-saving models (NYCDEP, 2005e).

3) *New Techniques to Identify Threats to Watershed and Drinking Water Quality*
   The use of landscape analysis and *Geospatial Information Systems (GIS)* to determine risks to water resources as a result of watershed landscape change in the EPA's "A Landscape Analysis of New York City's Water Supply (1973-1998)" (Mehaffey, 1998).

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Glossary

Buffer Zones: A defined land area adjacent to a water body on which activities that may impact water quality are regulated or restricted.

Coliforms: A group of related bacteria whose presence in drinking water may indicate contamination by disease-causing microorganisms.

Disinfection By-products: Products formed when disinfectants used in water treatment plants react with bromide and/or natural organic matter present in the source water. Different disinfectants produce different types or amounts of disinfection byproducts. Disinfection byproducts include trihalomethanes, haloacetic acids, bromate, and chlorite.

Downstate: A term for the southeasternmost portion of New York State, in contrast to Upstate New York.

Ecosystem Services: Benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services that affect climate and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as nutrient cycling.

Eminent Domain: Power of state entities to take private property for public use with compensating payment to the owner.

Eutrophication: The increase of chemical nutrients, typically compounds containing nitrogen or phosphorus, into a water body, oftentimes resulting in excessive plant growth and decay and subsequent reductions in water quality.

Filtration: Slowly filtering drinking water through clean sand or a simi¬lar filtering medium to eliminate contaminants and make the source water potable.

Filtration Avoidance Determination: An agreement between the EPA and local and state governments that waives the federal requirement to filter drinking water known as the Surface Water Treatment Rule.

Giardia: A protozoan parasite that infects the gastrointestinal tract and causes the disease giardiasis.

GIS (Geographic Information System): A computer system for capturing, storing, querying, analyzing and modeling geospatial data.

Groundwater: Water beneath the Earth's surface, beneath saturated soil and rock, that supplies springs and wells.

Hypoxia (also oxygen depletion): A phenomenon that occurs in aquatic environments as dissolved oxygen is reduced to a point detrimental to aquatic organisms.

Impervious surfaces: Hard surfaces (rooftops, sidewalks, driveways, streets, parking lots, etc.) that do not allow rain water to infiltrate into the ground. Instead, the rain water runs off these surfaces, picking up heat and other water pollutants that can be transferred to streams, rivers, and lakes, creating water quality problems.

Microbial Contamination: Concentrations of microbial *pathogens* such as viruses, bacteria, *Giardia lamblia* and *Cryptosporidium* spp.

Non-Point Source Pollution: Pollutants from many unidentifiable sources such as agricultural runoff. Non point source pollution is from a more diffuse source than point-source pollution.

Pathogen: A disease-causing organism.

Point Source Pollution: Pollutants that are emitted from a specific point of discharge or a concentrated originating point like a pipe from a factory. One example of point source pollution from stormwater runoff is NYC's combined sewer overflows described above in 'Part II: Issues for Optional Analysis and Discussion Topic 1."

Runoff: The flow of water from rain, snowmelt or other sources over the land surface in the form of rivers, lakes and streams to the oceans.

Source Water: Water in its natural state, prior to any treatment for drinking.

Stakeholder: Any entity dependent on the use and management of specific resources. Stakeholders may belong to different socially and politically defined units but all have an interest or 'stake' in the same resource.

Surface Waters: Water that is on the Earth's surface, in streams, rivers, lakes, and reservoirs.

Turbidity: Cloudy appearance of water caused by the presence of tiny particles. High levels of turbidity may interfere with proper water treatment and monitoring.

Upstate: A term generally referring to the Northernmost region of New York State, outside of the core of the New York Metropolitan area.

Watershed: The region draining into a river, river system, or other body of water.

Wetlands: A general term applied to land areas which are seasonally or permanently waterlogged, including lakes, rivers, estuaries, and freshwater marshes.