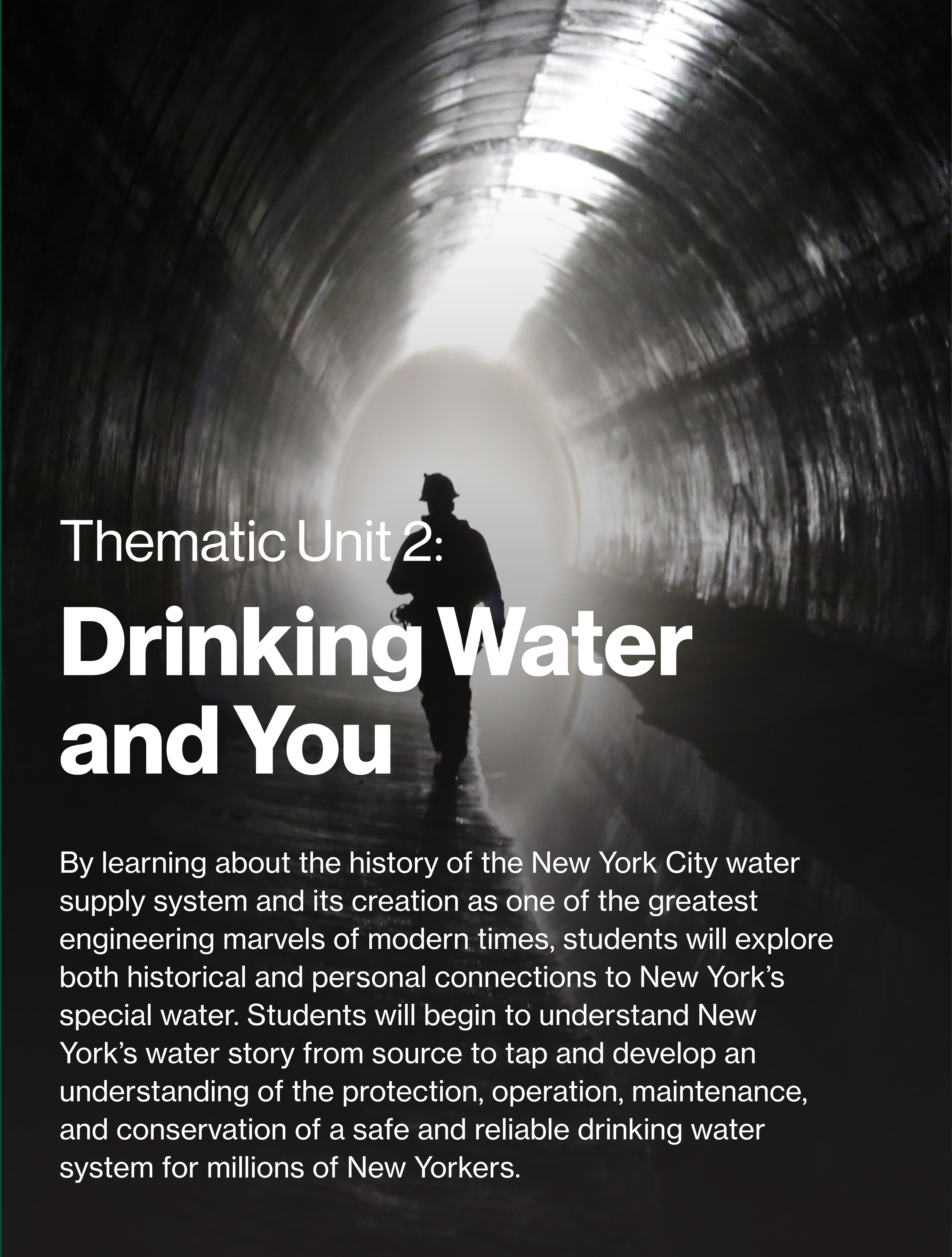


Thematic Unit 2:

Drinking Water and You

By learning about the history of the New York City water supply system and its creation as one of the greatest engineering marvels of modern times, students will explore both historical and personal connections to New York's special water. Students will begin to understand New York's water story from source to tap and develop an understanding of the protection, operation, maintenance, and conservation of a safe and reliable drinking water system for millions of New Yorkers.

What you should know:

The development of New York City's public drinking water supply system began in the 19th century and continues today with upgrades incorporating new technologies and innovations. Its history is a complex narrative of civic achievement, community sacrifice, scientific advancement, and brilliant engineering.

EARLY HISTORY

Indigenous populations, such as the Lenape tribal community, relied on abundant fresh water springs, streams, and ponds for a water supply close to where they lived. In what is now known as the borough of Manhattan, a primary source of water for both indigenous peoples and early Dutch colonists was a body of water called the Collect Pond. By the 1600s, early Dutch and British colonists relied on a growing number of public and private **wells** fed by groundwater. As New York's population grew these water supplies were contaminated by unchecked pollution from industry, livestock, and privies that either seeped into the ground, or was dumped directly into surface supplies.

In 1799, a New York State law entitled "An Act for supplying the City of New York with pure and wholesome water" granted a charter to the Manhattan Company to establish itself as the private water company for New York City. A special provision in the law, slipped in at the last minute by New York State Assemblyman Aaron Burr, also allowed the company to use its surplus money to start a bank. To keep its bank in business the Manhattan Company was obligated to supply water, which it did by pumping water from wells to a reservoir on Chambers Street, and then piping it to consumers. But Burr was more interested in running a successful bank than in solving New York City's water woes. In the end, this system was inadequate, supplying water from the same polluted sources and using inferior pipes, some made from hollowed out logs, that only reached parts of the city.

By this time, New York City's population had tripled from 33,000 in 1790 to nearly 96,000 in 1810. Through the early 1800s, diseases such as yellow fever, typhoid, and cholera killed thousands of people. Without reliable water pipes to fight them, large fires also destroyed entire neighborhoods. If the city was going to thrive (even survive), it was critical that we implement a public water supply system.

CROTON WATER SYSTEM

The Croton River, about 40 miles north of the city, was chosen as the best upland source of fresh water for a new water supply. Damming the river created a **reservoir**, or large basin, to store fresh water for use. Up to 90 million gallons of fresh water a day flowed from the reservoir into the Croton Aqueduct, traversing hills and valleys, and crossing the Harlem River over the High Bridge and into Manhattan. The **aqueduct** filled two reservoirs, a receiving reservoir between 79th and 86th Streets (now the site of Central Park's Great Lawn) and a distributing reservoir between 40th and 42nd Streets (today, the location of the New York Public Library). Engineering this water supply system was a massive and complex public works undertaking, built primarily by immigrant and migrant laborers, and unrivaled as one of the greatest engineering projects of its time.

On October 12, 1842, New Yorkers celebrated their new water supply with three consecutive days of festivities that included fireworks, cannon fire, church bells, and a five-mile-long parade. This only marked the beginning of a system that continued to expand to meet the demands of an ever-thirsty, ever-growing New York City population.

CATSKILL AND DELAWARE WATER SYSTEMS

Soon enough demand for water nearly outpaced supply. As the city industrialized, population continued to rise and the ways people used water began to change due to the introduction of indoor plumbing. In 1898, the boundaries of New York City were expanded into the five-borough city we know today. As pressure grew to provide more water, city leaders looked to expand the existing water system. An area 100 miles north of the city, on the west side of the Hudson River, was selected for what would become the new Catskill System. In 1905, the New York State Legislature passed the McClellan Act, creating a Board of Water Supply and allowing New York City to acquire property and develop reservoirs in the Catskills. The first drop of drinking water from the Catskills arrived on December 27, 1915, and by 1917, the new system was in full operation. Starting from the Ashokan Reservoir, the water traveled by gravity through the 92-mile Catskill Aqueduct, into the Bronx and through Manhattan, and under the New York Harbor to Staten Island. The scope of the new Catskill System eclipsed the engineering achievements of the Croton supply, and city leaders declared that it was now the greatest water supply in ancient or modern times.

People living in the Catskill Mountains at this time sacrificed a lot to make way for the new water system. Farms, cemeteries, and entire villages were removed from the region as we built large dams and flooded valleys to create new reservoirs. The city also required watershed communities to meet new sanitary standards that aimed to keep local farms and sewers from polluting the water supply. The forcible acquisition of land through **eminent domain** and the enforcement of watershed regulations would create a tension that lasted for decades between New York City and Catskill Mountain communities. Expansion of the water supply system, however, also meant that New York City had doubled its access to fresh water. The construction of both the Ashokan Reservoir (1915) and Schoharie Reservoir (1927) led some to promise that "water famine was now impossible." That promise proved to be untrue as our population doubled in the 1920s, forcing another expansion of the already vast water supply system. This time we looked westward toward the tributaries of the Delaware River. But this proposed expansion was contested in court by the State of New Jersey. In May 1931, the U.S. Supreme Court upheld the right of the City to build dams and reservoirs on the headwaters of the Delaware River. Initially, this new Delaware System included the Rondout (1950), Neversink (1954), and Pepacton (1955) reservoirs. Their waters were conveyed to the city through the 85-mile Delaware Aqueduct, which remains the longest tunnel in the world. After another interstate challenge was settled by the U.S. Supreme Court in 1954, New York City was allowed to build the Cannonsville Reservoir in 1967, which was the final reservoir in the Delaware System. Once again, entire communities were removed or relocated at each stage of construction for the Delaware System.

DRINKING WATER PROTECTION

The 1972 Clean Water Act and the 1974 Safe Drinking Water Act set important federal standards to ensure that drinking water is protected from contaminants. Further, the landmark 1997 Watershed Memorandum of Agreement formalized New York City's commitment to work in partnership with our upstate watershed neighbors to protect our drinking water at the source.

This partnership framework between New York City, New York State, the U.S. Environmental Protection Agency, watershed communities, and environmental advocates is considered a worldwide model for watershed protection, designed to both protect clean drinking water and the economic vitality of the Catskills. Due to these watershed protection programs and regulations, the Catskill and Delaware systems remain the largest unfiltered water supply in the United States today (filtered only by nature!). The agreement also provided economic development programs and other incentives to help the Catskills thrive by promoting projects that are consistent with protecting water quality. Many of these protected watershed areas are popular for outdoor recreation, such as fishing, hiking, and boating. By committing to watershed protection programs, New York City ensures safe drinking water quality today and into the future.

NYC'S WATER SUPPLY SYSTEM TODAY

Every day, New Yorkers use one billion gallons of fresh water! Altogether, the Croton, Catskill, and Delaware watersheds cover a vast 2,000-square mile area, collecting water in 19 reservoirs and three controlled lakes that store a total of 570 billion gallons at full capacity. Water flows from upstate reservoirs to the city by **gravity** through three large aqueducts. Water from the Catskill and Delaware systems is then delivered throughout the city by three large tunnels – City Water Tunnels No. 1, No. 2, and No. 3 – that connect to nearly 7,000 miles of underground pipes to deliver water to homes, schools, and businesses. Typically, water from the Croton System is delivered into the Bronx and Manhattan through the New Croton Aqueduct.

In most parts of the city, water is delivered by gravity alone. However, water must be pumped and stored in rooftop tanks to serve buildings that include more than six floors. Once the water is pumped into those rooftop tanks, gravity again takes over to supply the pressure for your shower, sink, and other fixtures. These wooden structures are an iconic sight along our New York City "roofscapes."

WATER FOR THE FUTURE

Today, our water supply faces new challenges. We are currently working on a $1 billion project to repair two leaks in the Delaware Aqueduct. It's the largest, most complex repair in the history of the system. The Delaware Aqueduct is leaking about 20 million gallons of water a day, mostly from a section of the tunnel on the west bank of the Hudson River. To fix the leak, we are building a 2.5-mile bypass tunnel that will be located 600 feet under the Hudson River. The bypass tunnel will be connected to structurally sound portions of the Delaware Aqueduct to convey water around the leaking section. To connect the bypass tunnel, we plan to shut down the Delaware Aqueduct for six to eight months, which will be the first time the tunnel will be shut down and drained since 1958.

Because the Delaware Aqueduct carries about 50% of our water each day, we need to take a number of steps to ensure all New Yorkers have an adequate, reliable supply of water during the shutdown. This involves some upgrades to the Catskill and Croton systems, which will be working at full capacity while the Delaware Aqueduct is out of service. Water conservation is also an important part of the planning for this project. Although New York City's population has grown by about 1.5 million people since 1990, our water consumption has dropped by about 35%. We are already a very water-efficient city.

But what else can we do to conserve our precious resource? This is a great opportunity for your students to brainstorm ideas that can make a difference and spread the word about making a more water-resilient New York!

Sequence of Lessons

1. My Daily Water Use Log
2. Water for New York City: Creating a Public Water Supply System
3. Technology and Innovation: Engineering New York City's Water Supply System
4. Clean Water and Public Health: Consider the Source
5. Drinking Water Treatment Explained
6. Testing the Waters: Making it Safe
7. Water for the Future: The Big Fix

L1 My Daily Water Use Log

Most American cities enjoy abundant clean water resources for drinking, cooking, and bathing, yet severe drought, water quality concerns, and other circumstances in many parts of the country and the world have made us even more aware of the value of clean water. There is no doubt that the seemingly endless supply is, in fact, a finite resource. The simple act of tracking and logging personal gallons used each day will enlighten, inform, and perhaps modify how we use water and what we take for granted.

ESSENTIAL QUESTION

How much water do you use each day?

VOCABULARY

Hygiene *(noun)*
The conditions or practices (as of cleanliness) conducive to health.

Drought *(noun)*
A prolonged period of dryness when there is very little or no precipitation.

SUGGESTED IDEAS AND ACTIVITIES

a. Discuss how we use water every day and make a list. Put these uses into larger categories (e.g., bathing, cooking, cleaning, recreation). Research how many gallons our typical water activities use, including a 5-minute shower or flushing the toilet. Use beans or another item to represent gallons and count up how many gallons we each use, create different piles or even “buckets” of total gallons used each day.

b. Have students calculate their average daily water use using DEP’s Water Use Calculation Worksheet. Consider which daily activities were not included and discuss how this would change students’ total daily amount. With your students, develop a water use log sheet to be completed in a 24-hour time period for all water activities. Discuss the difference between low-flow, high-efficiency plumbing fixtures and older, less-efficient fixtures.

c. Use bar graphs, pie charts, and other visual displays to track water use data. Now, ask students to complete a weeklong log of their water use activities. Determine average daily use from the data collected. Compare water usage of cities in the United States by population, geography and climate, type of supply (surface water or groundwater), and access to supply (source water). Compare usage globally.

d. Discuss what it means to use water “indirectly” or “virtual water” (e.g., for food, materials, energy) and ask students to brainstorm everything in their lives that requires water. Research, collect, and compare data related to how much water we use indirectly, by assigning a particular item or material to each student (e.g., a hamburger, a carton of almond milk, a new pair of jeans).

e. Pass around a full gallon of water as you discuss how much we use on a daily basis, and define what it means to measure our “water footprint.” Have students look up their water footprint, including their direct and indirect water use activities, by using the online Water Footprint Calculator. Discuss results and next steps for reducing our water footprints.

f. Interview family members about their water use, and pose questions about other countries or places they have lived or traveled to where availability of clean water and water use activities may have been different.

CONSIDER AND DISCUSS

- Have a conversation with students about where their water comes from. How aware are they of how much water they use, compared to other students in the class, other cities, or other countries?
- Discuss how much water is required to make different foods or products that students like. Are students surprised? How does our water footprint affect the environment?
- Why is water conservation important? Consider the different ways we can save more water at home and at school; share with families and friends.

ASK THE EXPERT

Natural Resources Conservation Manager - a professional who ensures that all land-related activities comply with government regulations in order to balance the need to use resources with the health of an ecosystem.

L2 Water for New York City: Creating a Public Water Supply System

New York City's water supply comes from three watersheds called the Croton, Catskill, and the Delaware that span nearly 2,000 square miles, both east and west of the Hudson River. The creation of our water supply system began in the 1830s with the construction of the Croton Reservoir and Croton Aqueduct, and the system continues to advance today, nearly 200 years later. Its ongoing protection requires strong community partnerships with a mutual understanding and appreciation of the importance of clean water.

ESSENTIAL QUESTION

Why should keeping our drinking water clean and safe be a public responsibility?

VOCABULARY

Civic *(adjective)*
Of or relating to citizen, a city, citizenship or community affairs.

Eminent Domain *(noun)*
A right of a government to take private property for public use.

SUGGESTED IDEAS AND ACTIVITIES

a. Have students select a photograph or drawing from the large archival collection of images documenting the design and construction of our water supply system (see DEP's "Out of the Archives" albums for examples). Compare features of the image with today. Write a caption, a poem, or a fictional story about the image. Make sure students also select images that include people.

b. Have each student or groups of students research the life and work of one of the many people (architects, engineers, stone masons, or construction crews) who worked on our water supply system, or the history of the immigrant and migrant communities that contributed to the building of the system. Create an exhibit, present to each other and to other classes.

c. Explore and discuss present day public works projects in your neighborhood or in the city. Visit and photograph them several times throughout the school year. Research recent large-scale projects like the construction of Water Tunnel No. 3, the Croton Water Filtration Plant, or the repairs to the Delaware Aqueduct.

d. Watch the film *Deep Water* to hear firsthand and historical accounts of the building of the Ashokan Reservoir, part of the Catskill System. Discuss what eminent domain is and how it greatly shaped watershed communities during the development of the water supply. Discuss the positive and negative impacts of the development of the Catskill System. Consider the different stakeholders and hold a mock town hall to recreate how decisions affected all of the communities involved.

e. Meet with librarians and educators at the central Public Library within your borough to search for, and learn from, primary source documents such as articles, images, and maps depicting New York City's water story over time. Discover research skills to help find, understand, and decipher archival sources.

f. Take a field trip to Central Park to learn about the history of the Croton System while walking around the Central Park Reservoir. Connect with NYC H2O for a guided school program or plan a self-guided walking trip. Refer to a historical map to find the location of the original receiving reservoir, just south of the current body of water. Ask students how many gallons they think fill the reservoir (it's about one day's supply – one billion gallons!).

CONSIDER AND DISCUSS

- Explore DEP's NYC Watershed Virtual Tour for video interviews, maps, and more activities on the history of our water supply.
- Speculate as to why the dams, reservoirs, and other structures were designed to be both beautiful and functional. Compare to similar types of functional public buildings like libraries, railway stations, or public schools then and now.
- What is eminent domain? Think about how past policies and plans shaped both New York City's growth and that of the watershed towns.

ASK THE EXPERT

Historian – an academic researcher who studies events of the past, related to a particular time period, geographical region, or social phenomenon.

L3 Technology and Innovation: Engineering New York City's Water Supply System

From the late 1700s to the early 1800s, the exponential growth of our population drove the search for a reliable source of drinking water beyond the city limits. Innovative engineering and technology played an integral role in developing this remarkable system. Many of the original above-ground structures, such as bridges and gatehouses built in the mid-1800s to support the system, are now historic landmarks. Some are even enjoyed by the public as recreational attractions (past and revived), such as the High Bridge across the Harlem River.

Today, aqueducts, tunnels, and pipes of different sizes and materials carry drinking water mostly by gravity across long distances from the watersheds to the city. Once drinking water goes underground, we can only imagine the vast system of pipes that convey water to every building, or to the "surface" as it enters one of the iconic wooden water towers. None of this would be possible without the tools, materials, and expertise of the engineers and the hands of those who labored to build the system.

ESSENTIAL QUESTION

What are the necessary skills, information, and technology required for developing a water supply system?

VOCABULARY

Engineering *(noun)*
The application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people.

Aqueduct *(noun)*
A conduit, or structure, designed to carry water over a long distance, usually by gravity.

Technology *(noun)*
A manner of accomplishing a task especially using technical processes, methods or knowledge.

SUGGESTED IDEAS AND ACTIVITIES

a. Set up a model joining two watertight containers with a flexible tube. Fill one of the containers and raise it up to a higher elevation to regulate the flow into the empty container at a lower elevation. Play with the heights and distance between the two containers to consider how water travels from upstate watersheds to the city. This demonstrates the fundamentals of a gravity-fed water system.

b. Add to the above activity by introducing the source water component (surface, stream, and ground) and its accessibility. Demonstrate and/or fabricate a simple pump that draws water from a low spot to a high spot; devise a model of a dam that holds back and creates a pool of water behind it (impounds the water into a reservoir).

c. Review New York City's Water Story: From Mountain Top to Tap map (shown on page 43), including the corresponding slides and teacher's guide. Ask students to locate their borough and nearby waterways, then have them trace the path their drinking water took from the watershed to the city. Use the scale to calculate the distance water travels. Write stories of the journey from the perspective of a drop of water. Contact DEP's Education Office to receive a class set of student maps and a wall map to display in your classroom.

d. Read *The Lowdown on the High Bridge* by Sonia Manzano. Take a trip to the High Bridge in northern Manhattan (shown on page 37). Make observations and consider the skilled labor and the people involved in designing and constructing the bridge that spans nearly 1500 feet across the Harlem River. Illustrate what you think once happened above, within, and below the bridge. Discuss how the construction of the city's first bridge impacted a growing city.

e. Illustrate and caption, on separate cards, component parts of a water system such as a reservoir, aqueduct, water tank, pipes, and faucet. Arrange sequentially. Introduce the concept of systems thinking to students and determine the important interconnections within the water supply system (use DEP's Discovering the New York City Water Supply System lesson).
f. Continue researching the important stories of the laborers and specialists hired to build our water system, including where and how they lived, what jobs they had, and their long-term settlement patterns. Introduce the Sandhogs, the urban miners who constructed much of the city's underground infrastructure. Find videos online that share their stories.
g. Research and report on other public works projects related to water such as canal systems (e.g., Erie, Morris, Champlain) or public baths in ancient Rome. Challenge the class to convey water (or a ping pong ball or marble) across the room by constructing a channel or pipe; introduce the concepts of velocity and slope related to distance.
h. Collect photographs of New York City's iconic water towers and ask students to "wrap" one in their own design. Share photos of actual artwork displayed on water towers. Make an exhibit.
i. Make a cross-section drawing or model illustrating both an above and below ground view showing the path of water from the pipes under the street through your school building to one of the bathroom fixtures. Discuss infrastructure and plumbing.

CONSIDER AND DISCUSS

- Discuss comparable public engineering projects such as roads and bridges (transportation systems).
- Learn more about John B. Jervis, the Chief Engineer for the Croton Aqueduct. Consider his career and compare to how engineers play a role in planning and designing infrastructure projects today.
- If you were developing a city today, would you still use similar techniques and technology to supply water to residents? How would you design a sustainable water system?

ASK THE EXPERT

Civil Engineer – a professional who conceives, designs, constructs, and maintains infrastructure projects.

WHAT IS A SANDHOG?

This is the common name given to generations of New York City's underground construction workers responsible for the tunneling and excavation of our underground infrastructure. Sandhogs have played a key role in the construction of New York City's water system, including City Water Tunnels No. 1, No. 2, and No. 3.

L4 Clean Water and Public Health: Consider the Source

Supplying quality drinking water is an essential part of protecting public health, and it all starts at the source. Every day, one billion gallons of drinking water are delivered to the taps of New York City, serving residents, commuters, and tourists as well as over 70 New York State communities along the path of the water system north of the city. New Yorkers value the world renowned reputation of their drinking water, which is attributable in large part to its source among the dense forests and protected natural creeks and streams that feed into large lakes and reservoirs, up to 125 miles away. Farmers, foresters, residents, business owners, and many partner organizations and communities living and working in the watershed help protect our water at its source – this is what makes up the living watershed.

ASK THE QUESTION

How are we connected to the source of our drinking water?

VOCABULARY

Potable *(adjective)*
Safe or suitable for drinking.

SUGGESTED IDEAS AND ACTIVITIES

a. Read various fables, such as Aesop's Fable *The Crow and the Pitcher,* and other stories about wells and drinking water with magic powers. Discuss how we keep ourselves healthy. Write a fable or other kind of story about a source of drinking water with special properties. Discuss how these properties help all living things.

b. Interview the physical education teacher, biology teacher, or school nurse about the importance of hydration before, during, and after physical activity. How much of your body is made up of water? Which parts of your body only function when you are hydrated?

c. Discuss concepts related to drinking water and our public health, such as contagion, epidemics, and water-borne illnesses, as well as prevention and immunization. Discuss the importance of ensuring safe drinking water quality for water consumers.

d. Research and present information that compares different public water systems in various locations throughout the United States; identify their drinking water source. Compare to rural, suburban, and other urban communities. How is water quality protected?

e. Read *The Magic School Bus: At the Waterworks (NYC Edition)* to trace the source of our drinking water, and understand how the entire water supply system is maintained and protected each day. Create a large mural depicting the flow of water from mountain top to tap to replicate how Ms. Frizzle's class traveled through New York City's water cycle. Contact DEP's Education Office for a class set of books.

f. Refer back to lessons in Unit 1 about the relationship between trees and water quality in a watershed. How do forests filter water naturally? Research New York City's watershed protection programs that support the preservation and sustainable development of forests. Plan a trip to the watershed to plant trees along a watershed stream through the Watershed Agricultural Council's Trees for Tribs (tributaries!) program.

g. Connect with watershed neighbors to learn about our living watershed. Research important industries and activities in watershed communities (past and present), including farming, forestry, tourism, outdoor recreation, and more. Participate in the Watershed Agricultural Council's Green Connections program to connect with students and teachers in watershed communities; plan a trip to visit each other.

h. Plan a field trip to the East- or West-of-Hudson supply systems to experience the Croton Dam, Kensico Dam, Cross River Reservoir, or Ashokan Reservoir, to name a few. Consider applying for a Watershed Forestry Bus Tour grant from the Watershed Agricultural Council or a Watershed Education Grant from the Catskill Watershed Corporation to help plan and pay for your trip. While in the watershed, visit nearby environmental education and recreation centers or cultural and historical sites, such as the Time and the Valleys Museum, the Ashokan Center, Frost Valley YMCA, and the Green Chimneys' Clearpool Education Center. Consider planning a longer watershed trip with Operation Explore, a special three-day program at Taconic Outdoor Education Center and Stony Kill Farm.

CONSIDER AND DISCUSS

- Discuss the relationship of the sources of your drinking water to the water that flows from your tap. Consider how far water needs to travel and by what conveyance; is technology needed?
- Discuss the important relationship between watershed communities and New York City.
- How do forests and vegetation act as natural filters in a watershed? Does the land surrounding our source water play a role in providing for clean water?

ASK THE EXPERT

Epidemiologist – a public health professional who investigates patterns and causes of disease and injury in humans.

L5 Drinking Water Treatment Explained

Today drinking water is regulated under the federal Safe Drinking Water Act to keep tap water safe. The New York State Department of Health and the U.S. Environmental Protection Agency also set regulations to protect our water. It is an important responsibility to provide and distribute potable water, and each year water utilities are required to provide an annual consumer report (Drinking Water Supply and Quality Report) to the public.

Water from the Catskill and Delaware systems, approximately 90% of our daily supply, is filtered only by nature and not required to be filtered by technology. New York City has been granted a Filtration Avoidance Determination from the federal government because drinking water quality meets the criteria to remain unfiltered and our rigorous and comprehensive watershed protection program works to ensure nature can effectively filter it now and into the future.

In 2015, a filtration plant for the Croton supply began operating to remove impurities from the water and ensure it met all the regulatory standards. As parts of the Croton watershed have changed from rural to more densely populated suburban areas, the risk of contaminants reaching the water has increased.

ESSENTIAL QUESTION

How is our drinking water treated?

VOCABULARY

Disinfection *(noun)*
The process of introducing a chemical or other added product to remove or inactivate disease-causing organisms.

Filtration *(noun)*
The act of capturing impurities from the water as it passes through a medium like sand and/or charcoal.

DRINKING WATER TREATMENT PROCESS

Most of New York City's drinking water passes through the Catskill/Delaware Ultraviolet Disinfection Plant before it is distributed throughout the five boroughs. Located north of the city in Westchester County, the plant is the largest of its kind in the world.

- **Chlorine -** Water is disinfected with chlorine which is a common chemical disinfectant added to kill germs and stop bacteria from growing on pipes.
- **Ultraviolet (UV) Light -** Exposure to UV light inactivates potentially harmful microorganisms, including Cryptosporidium and Giardia, which are often tolerant to chlorine disinfection. UV treatment does not change the water chemically, as nothing is added except energy.
- **Fluoride -** Added to drinking water to improve dental protection, it is effective in preventing cavities at a federally approved level of 0.7 mg/L.
- **Sodium Hydroxide -** Added to raise the pH, it reduces corrosion of household plumbing.
- **Food Grade Phosphoric Acid -** Added because it creates a protective film on pipes that reduces the release of metals, such as lead, from service lines and household plumbing.

Water from the Croton System is filtered by the Croton Water Filtration Plant, located underground in the Bronx. After filtration, the Croton water goes through the same steps in the disinfection process described above.

- **Coagulation -** Chemicals are added to the untreated water, causing particulates to bunch together (or coagulate) and become larger particles called floc.
- **Dissolved Air Flotation -** Air bubbles are injected into the water to help float the floc to the top of water tanks where it is skimmed off.
- **Sand Filtration -** The water flows through a bed of sand, slowly removing any remaining particles.

SUGGESTED IDEAS AND ACTIVITIES

a. Introduce your students to the idea of scientific experimentation. Introduce turbidity and sedimentation, investigate by using coffee grounds, tea leaves, and powdered drink mix. Do some float to the top, some sink to the bottom, and others stay suspended? Predict, observe, and record what happens in a clear glass container. Use a magnifying glass.

b. Discuss and define local rocks and minerals. Investigate the relationship of geology and drinking water. What does it mean to have hard water? Make a solution of baking soda and water. Measure alkalinity and hardness. Talk about how minerals can dissolve in nature. Next, make a supersaturated solution of baking soda and water. Have students paint on black paper with the solution. Do they see anything? Let it dry. What happened?

c. Review DEP's annual Drinking Water Supply and Quality Report with your students. Research online water departments or agencies in different regions, and compare and contrast data included in their water quality reports. Are methods and technologies the same in different regions (why or why not)? Which DEP employees work to provide your safe and clean drinking water each day and what is their background (career path, education, training)?

d. Learn more about the treatment process to remove pathogens like Cryptosporidium and Giardia from drinking water. Which cities have been affected? Discuss UV treatment and how innovative science and technology has advanced water treatment processes to ensure safe drinking water.

e. In small groups, build natural filtration models using various materials of different texture, size, and porosity (sand, gravel, soil, coffee filters), or fun materials like different types of candy. Create a water solution with high turbidity (using clay or soil, or cocoa mix) and hypothesize how clean the water will be after seeping through the filter.

CONSIDER AND DISCUSS

- Explore DEP's NYC Watershed Virtual Tour for video interviews, maps, and more activities on watershed protection and the drinking water treatment process.
- How is New York City able to maintain a drinking water supply that is mostly filtered by nature? Compare our water treatment methods to other U.S. or global cities. Which other cities have received a Filtration Avoidance Determination and how are they protecting water quality?
- What regulations determine public health safety related to drinking water? What other regulations protect public health?

ASK THE EXPERT

Environmental Health & Safety Officer – a professional who develops and implements health and safety plans, through data capture and ongoing analysis, for the operation of water and wastewater facilities.

L6 Testing the Waters: Making it Safe

Beyond meeting the necessary federal and state water quality standards, New York City is one of only a few cities in the country that also monitors and tests its source water in order to ensure the highest water quality. DEP monitors water throughout the distribution system, as well as in upstate reservoirs and watershed streams that feed into these larger bodies of water. We test for more than 250 potential contaminants every day to protect the quality of our drinking water. These potential contaminants are monitored by scientists who conduct more than 1,200 tests daily, 37,000 monthly, and more than 450,000 annually, in our distribution system, including at nearly 1,000 sampling stations throughout the five boroughs. That's in addition to the more than 260,000 tests performed in the watershed...and they all have to pass!

To increase our ability to monitor this mostly unfiltered water source, DEP also conducts two million tests performed by a network of robotic monitoring stations that provide real-time data on the quality of the water as it moves across the reservoirs.

ESSENTIAL QUESTION

What tests are performed on our drinking water to make sure it is safe to use?

VOCABULARY

Chemistry *(noun)*
A science that deals with the composition, structure and properties of substances, and the transformations that they undergo.

SUGGESTED IDEAS AND ACTIVITIES

a. Scientists conduct taste and odor tests at their central labs. Have your students conduct their own taste and odor tests using a few different samples of tap water collected from various locations. Set up a testing procedure including observation, hypothesis, prediction, experimentation, and conclusion.

b. Conduct a blind taste test for tap water versus bottled water. Label the samples by A, B, C, and so on. Allow students to taste the different samples, make observations, and then vote. Consider including multiple samples from different kinds of bottled water or tap sources.

c. Investigate the differences between tap water and bottled water. Ask students what types of bottled water have they bought in the past? Research where this water comes from and discuss the resources needed to collect, manufacture, and transport bottled water. Have students share what they learn by creating PSAs or posters to display around school, in the cafeteria, and near water fountains.

d. Using store bought water test strips and several "mystery" water samples, have students predict which sample is tap water and why. Demonstrate an experiment using four sample cups of water. For example, 1: tap water; 2: tap water with a drop or two of vinegar (pH); 3: tap water with a drop or two of chlorine bleach (chlorine); 4: tap water with dissolved antacid tablet (alkalinity or hardness). Record data and determine which one is tap water based on the data collected.

e. Further investigate DEP's annual Drinking Water Supply and Quality Report with students, by reviewing the different potential contaminants or water quality concerns (pathogens, nutrients, turbidity) and where they come from. Research water supply systems for other cities to determine different water quality challenges.

CONSIDER AND DISCUSS

- Discuss the many parameters that are used (required) to determine if water is safe to drink. What are these parameters? Why do they matter?
- Discuss how technology has changed in the field and in the lab. What kind of new techniques are used to deliver accurate sampling information about water quality? (Hint: robotics)

ASK THE EXPERT

Chemist - a scientist engaged in chemical research or experiments.

L7 Water for the Future: The Big Fix

In 1990, it was discovered that a section of the Delaware Aqueduct, the longest tunnel in the world, has been leaking about 20 million gallons a day into the Hudson River. New York City and parts of four adjacent counties depend on this aqueduct for drinking water, as it delivers about 50% of our daily water. The Delaware Aqueduct Repair Project requires years of planning, design, and construction to make the necessary repairs. We are building a bypass tunnel, and connecting it to structurally sound portions of the aqueduct, to eliminate the largest leak by conveying water around it. This work will require shutting down the Delaware Aqueduct for 6-8 months in 2022. During this time, conservation will help us get through the shutdown while we rely on water from the Catskill and Croton supplies.

ESSENTIAL QUESTION

Why is it important to conserve water?

VOCABULARY

Conservation *(noun)*
The careful preservation and protection of Earth's natural resources.

Bypass *(noun)*
A secondary channel, pipe, or connection to allow a flow when the main passage is closed or blocked.

SUGGESTED IDEAS AND ACTIVITIES

a. What does it mean to conserve? Discuss some simple ways to conserve water at home and at school. Compile a list on the board. Learn how New York City is conserving water on a larger scale, including by replacing toilets in schools and adding timers to spray showers in parks. Investigate if any of these changes have occurred in your school or neighborhood.

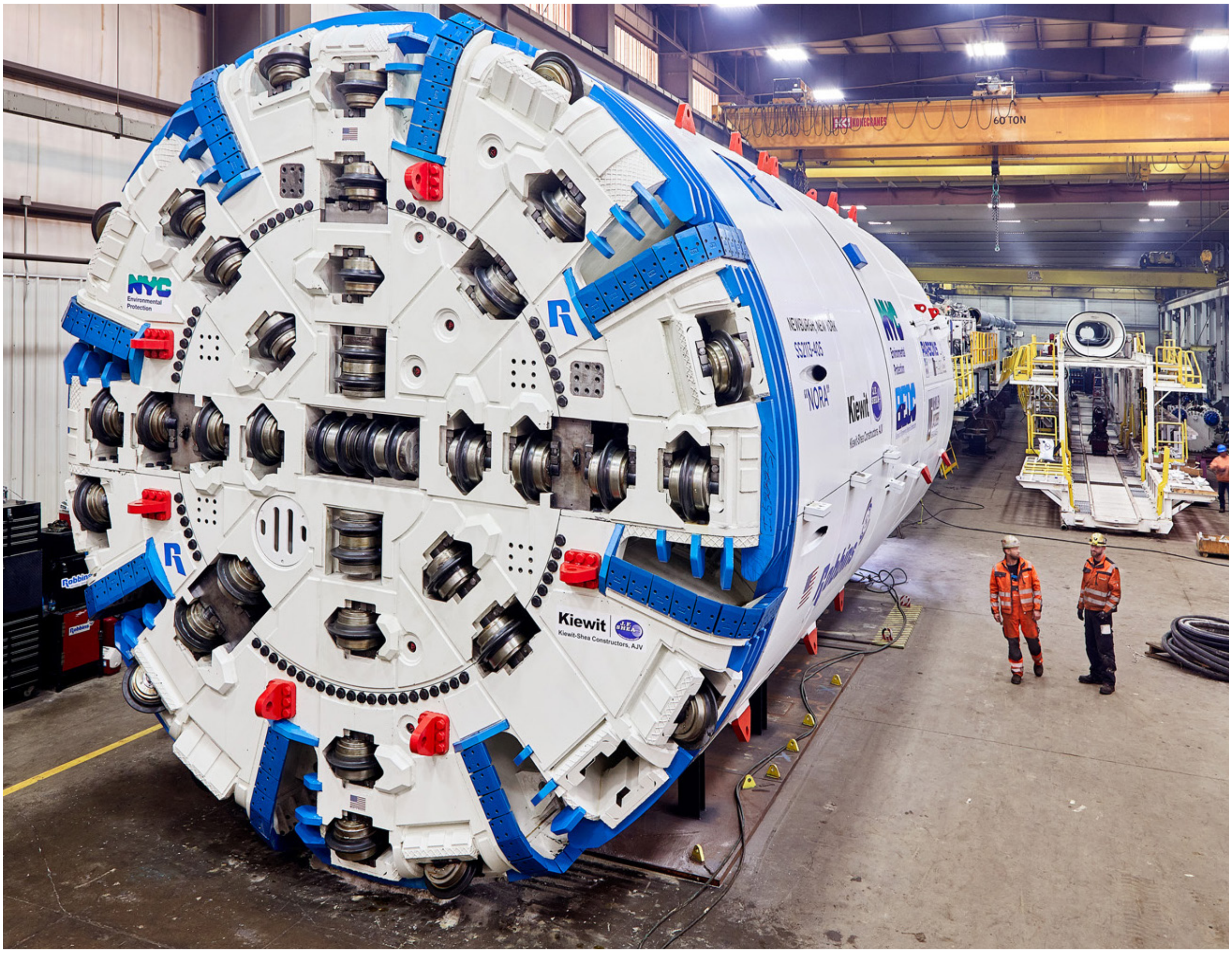
b. Using their "Water Use Logs" from the Lesson 1 activity, challenge your students to reduce their water use for a period of one week by either a number or a percentage. Make it a competition. Discuss which activities were easy to alter water use for and which were difficult.

c. Learn more about Nora Stanton Blatch DeForest Barney, the first and only woman engineer to work on the Catskill System. Look up images of the tunnel-boring machine (shown on page 42), named after Nora, used for excavating the new bypass tunnel in the Delaware Aqueduct. Research other types of cutting edge engineering technologies being used today (e.g., Autonomous Underwater Vehicles). Design and build a model for a fictional invention that replaces a difficult or unpopular chore or task.

d. Further explore the New York City Water Story: From Mountain Top to Tap map (shown on page 43) by investigating where the leaks are occurring. Locate where the Delaware Aqueduct passes underneath the Hudson River. For younger students, create an overlay and have them trace over the map. What does the picture resemble (e.g., branches of a tree)? Make a list of all the names of the aqueducts, tunnels, lakes, and reservoirs and discuss their origins. Visit DEP's website for a map teacher's guide with more suggested activities.

e. Create a watershed timeline to understand the size and sequence of the components in the water supply system. Research the history of each watershed, reservoir, and aqueduct. In a large space indoors or outdoors, use cups of water and containers to measure out the size of each reservoir (proportionally!). Map out the entire system, using rope as the aqueducts and tunnels connecting all of the pieces together.

f. Examine historical flyers and PSAs used by New York City in the past to encourage New Yorkers to conserve water. Discuss media that students could use today to share similar messages of water conservation.



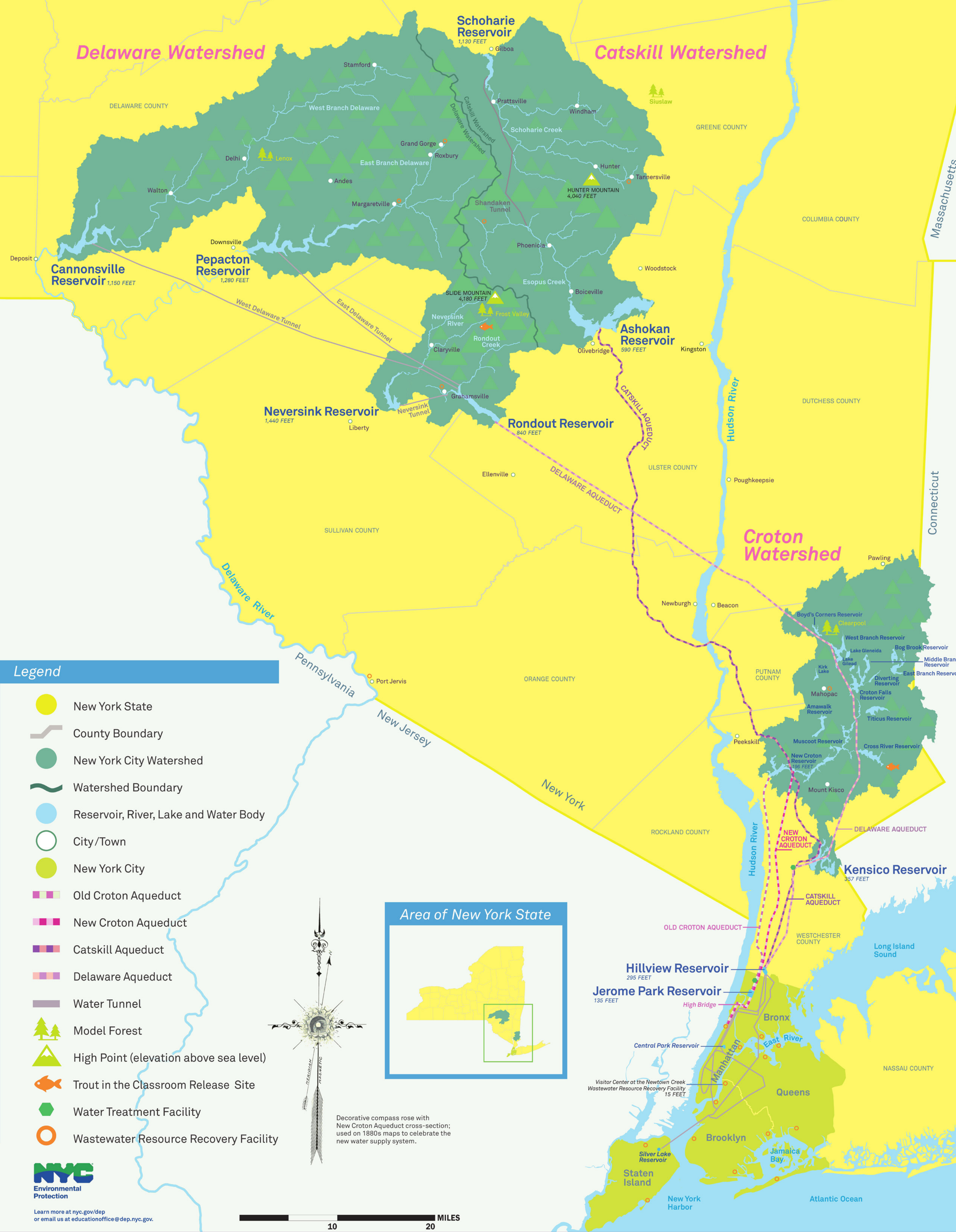
g. Facilitate a mock town hall in which students take on the different roles of stakeholders and decision-makers involved in a similar situation based on the Delaware Aqueduct repairs. How do large-scale projects like this one affect various communities? Who is involved in the repairs and how were the project plans decided on?

CONSIDER AND DISCUSS

- Consider what other organisms need clean water to survive. Discuss the importance of water conservation and protection for all living things.
- How has technology changed the way we manage our water supply?
- How can New York City plan and prepare for changes to its water supply system? Consider citywide sustainability initiatives. What are other cities doing to become more sustainable?

ASK THE EXPERT

Robotics Engineer – a professional who designs and maintains robots, develops software applications, and conducts research to determine how robotics can help systems function.



Delaware Watershed
Catskill Watershed
Croton Watershed
Schoharie Reservoir
1,130 FEET
Gilboa
Stamford
DELAWARE COUNTY
West Branch Delaware
Catskill Watershed
Delaware Watershed
Prattsville
Windham
Schoharie Creek
Siuslaw
GREENE COUNTY
Grand Gorge
Roxbury
Delhi
Lenox
East Branch Delaware
Hunter
Tannersville
Andes
HUNTER MOUNTAIN
4,040 FEET
Walton
Margaretville
Shandaken Tunnel
COLUMBIA COUNTY
Massachusetts
Downsville
Phoenicia
Deposit
Cannonsville Reservoir
1,150 FEET
Pepacton Reservoir
1,280 FEET
Woodstock
Esopus Creek
SLIDE MOUNTAIN
4,180 FEET
Boiceville
West Delaware Tunnel
East Delaware Tunnel
Frost Valley
Neversink River
Ashokan Reservoir
590 FEET
Rondout Creek
Claryville
Olivebridge
Kingston
Grahamsville
Neversink Reservoir
1,440 FEET
Neversink Tunnel
Liberty
Rondout Reservoir
840 FEET
CATSKILL AQUEDUCT
Hudson River
DUTCHESS COUNTY
ULSTER COUNTY
Ellenville
DELAWARE AQUEDUCT
Poughkeepsie
Connecticut
SULLIVAN COUNTY
Pawling
Delaware River
Newburgh
Beacon
Boyd's Corners Reservoir
Clearpool
West Branch Reservoir
Bog Brook Reservoir
Lake Gleneida
Middle Branch Reservoir
Lake Gilead
East Branch Reservoir
Kirk Lake
PUTNAM COUNTY
Diverting Reservoir
Pennsylvania
Port Jervis
ORANGE COUNTY
Mahopac
Croton Falls Reservoir
Amawalk Reservoir
Titicus Reservoir
New Jersey
Peekskill
Muscoot Reservoir
Cross River Reservoir
New Croton Reservoir
196 FEET
New York
Mount Kisco
ROCKLAND COUNTY
DELAWARE AQUEDUCT
NEW CROTON AQUEDUCT
Hudson River
Kensico Reservoir
357 FEET
CATSKILL AQUEDUCT
OLD CROTON AQUEDUCT
WESTCHESTER COUNTY
Long Island Sound
Hillview Reservoir
295 FEET
Jerome Park Reservoir
135 FEET
High Bridge
Bronx
Central Park Reservoir
East River
Manhattan
Visitor Center at the Newtown Creek Wastewater Resource Recovery Facility
15 FEET
Queens
NASSAU COUNTY
Brooklyn
Silver Lake Reservoir
Jamaica Bay
Staten Island
New York Harbor
Atlantic Ocean
Legend
New York State
County Boundary
New York City Watershed
Watershed Boundary
Reservoir, River, Lake and Water Body
City/Town
New York City
Old Croton Aqueduct
New Croton Aqueduct
Catskill Aqueduct
Delaware Aqueduct
Water Tunnel
Model Forest
High Point (elevation above sea level)
Trout in the Classroom Release Site
Water Treatment Facility
Wastewater Resource Recovery Facility
Area of New York State
MERIDIAN
MAGNETIC
Decorative compass rose with New Croton Aqueduct cross-section; used on 1880s maps to celebrate the new water supply system.
MILES
10
20
NYC Environmental Protection
Learn more at nyc.gov/dep
or email us at educationoffice@dep.nyc.gov.