Daylighting the Saw Mill River

A Curriculum on Green Design for Urban Ecology Enrichment and Resilience

Teacher Resources for Grades 3-8

22 Main Street Yonkers, NY 10701
www.groundworkhv.org

www.yonkersny.gov

This booklet was prepared by the Sustainability Education department at Groundwork Hudson Valley with funding support from the City of Yonkers. Additional research on Yonkers' cultural and industrial history, background on the Saw Mill River's historical uses, watershed, and water quality data, as well as engineering plans provided by the following partners:

- Philipse Manor Hall Historical Site
- Sarah Lawrence College Center for the Urban River at Beczak
- Yonkers Riverfront Library
- U.S. Fish and Wildlife Service
- Riverkeeper
- NYS Department of Environmental Conservation
- PS&S Engineering

Who are we?

Groundwork Hudson Valley is a non-profit founded in 2000, that convenes a coalition of government, community, and business leaders to change places and lives through environmental justice, sustainability education, and youth employment objectives.

The early vision for the Daylighting of the Saw Mill was built through these partnerships. The Daylighting of the Saw Mill River is a multi-phase project that includes a new urban river and parks through the center of downtown Yonkers, where the Saw Mill River was once buried beneath the City in the 1920s.

Phase I at Van Der Donck Park was completed in 2012, Phase II at Mill Street Courtyard was completed in 2016, and Phase III at New Main Street and Nepperhan Avenue by Chicken Island was completed in 2019.

The Urban River and Watershed Education

Teacher Background on the Saw Mill River Ecosystem and Daylighting.

You would not be able to judge the Saw Mill River's ecological significance, nor its influence to Yonkers' history by its size. Relative to the mighty Hudson River, the Saw Mill seems a mere trickle as it meanders through Westchester County before quietly reaching its end point as a small tributary. With the final stretch covered in a concrete flume and hidden from denizen's view for nearly a hundred years, it was all the less assuming. Yet, the Saw Mill River continues to shape the community as much as we have shaped its course over time.

Long before its rushing waters powered sawmills and gristmills to make Yonkers a booming industrial town, the Saw Mill River was used by the native Lenape people as a source for drinking water, cooking, fish trapping, irrigation, and transportation. When colonists arrived in the 17th and 18th centuries, they used metal tools, water wheels, and dams to bend the river to their needs. Industrialization and population growth continued to push the small river to its limits. Over time, because urban land was in short supply, the river was squeezed and covered over in places. Even though rivers were the life-blood of many communities across the country, providing power and water for living, they were abused by the dumping of industrial and human waste. Finally, in the 1920s, with odors and fears of water-borne diseases, the last bit of river in downtown was covered by a parking lot (named Larkin Plaza). It did not take long for the public to decry its mistake in burying the river. In the 1960s, industry started to move elsewhere, and by 2000, empty and boarded up buildings surrounded the parking lot and downtown.

From its source in Chappaqua to its mouth in Yonkers, the Saw Mill River is a great treasure—rich in history and integral to the environmental health of the region. The commitment by the City of Yonkers and local environmental organizations to "daylight" portions of its passage and turn them into park space reflect the core values of Yonkers: a resilient infrastructure and economy, recreational space for all, and a healthy environment. Though it took decades to come to fruition, once it was underway, the innumerable long-term benefits of the project quickly started to reveal themselves: developers and businesses started flocking to the area, fish and wildlife species that had long been absent returned, people congregated to enjoy festivals, music, or just take in the scenery, and awareness of our impact on water and air quality and our connection to the Hudson River deepened.

Still, increasing residents' knowledge and understanding of rivers and riparian zones is critical to preventing history from repeating itself. The more that people know about the history of the Saw Mill River, the life it supports, and the engineering principles behind its recent Daylighting, the better able they are to care for these ecosystems. This curriculum furthers that goal by connecting in-classroom lessons with self-guided field trips to the Daylighting Parks and facilitated excursions with local history and environmental education partners. When we introduce our young people to the river, we shape tomorrow's environmental stewards and build a more sustainable future.

Partners and Research Advisors

Groundwork Hudson Valley

- Jennifer Sloan, Director of Education 2012-2019—primary author
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PS&S Engineering

- Lisa DiGerolama

Saw Mill River Coalition

Philipse Manor Hall NY Historical Site

- Charles Casimiro

SLC Center for the Urban River at Beczak

Yonkers Public Library

- John Favereaux, Historian

US Fish and Wildlife Service

Yonkers Public Schools

Map of Daylighting Phase I, II, III Locations

Phase I: Van der Donck Park/Larkin Plaza

- Located by Yonkers Riverfront Library and Yonkers Metro North Train Station
- Completed 2012

Phase II: Mill Street Courtyard

- Entrance at Warburton Avenue across the street from Phase I
- Completed 2016

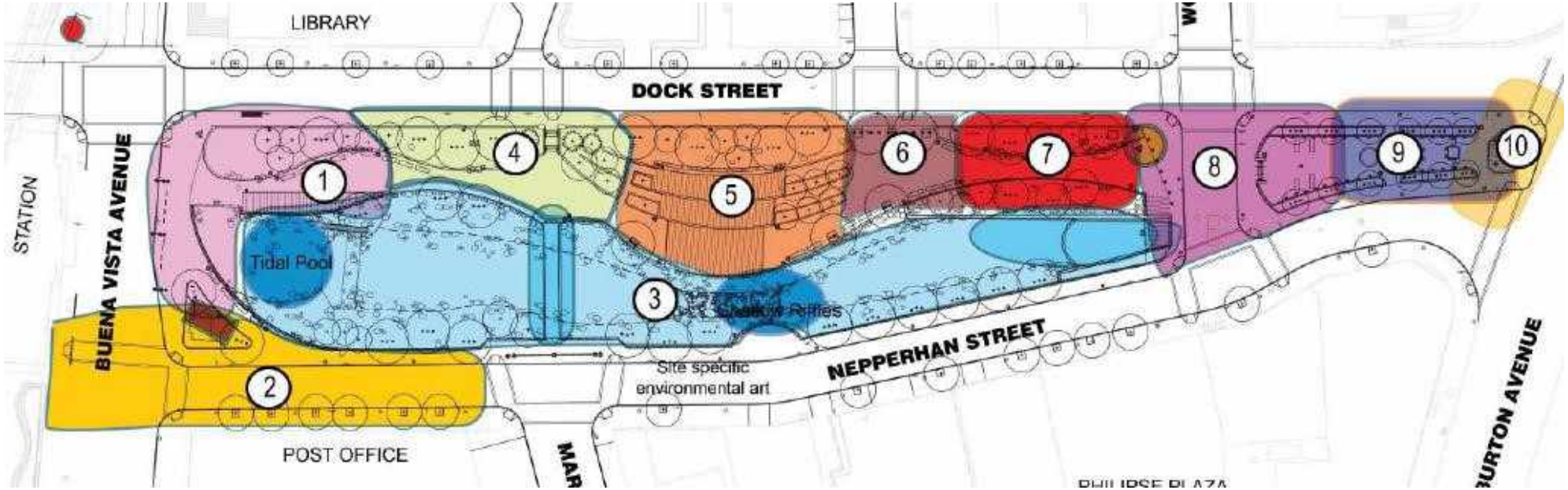
Phase III: Chicken Island/New Main Street

- Access along Nepperhan Avenue and New Main Street
- Completed 2019

Phase IV: Chicken Island/Nepperhan Avenue

- Planning in progress

Daylighting Phase I Map
Van der Donck Park at Larkin Plaza



1) Saw Mill River tidal pool
   Signage on ecological details

2) Gold Star Mothers Monument
   Native plantings and signage on Yonkers' industry and inventors

3) Pedestrian bridge
   Art & sound installations

4) Outdoor Classroom
   Eel mosaic & signage on fish migration and biodiversity

5) Outdoor Amphitheater
   Garden beds & river riffles.

6) Upper Plaza
   Signage on green infrastructure engineering

7) Upper freshwater pool
   Signage on Philipse Manor Hall

8) Netting Chamber
   Signage on Larkin Plaza history & Urban Wildlife Refuge

9) Overlook with flagpole
   Intercept chamber

10) Spanish-American War Memorial at Larkin Plaza

Curriculum Overview

This curriculum was developed for use by Yonkers schools as well as visiting classes from neighboring cities with an interest in river ecology, the impact of human activity on ecosystems, and green design principles. Though there is something for every age and learning level, the lessons here were geared toward grades 4-8, aligning with the Next Generation Science Standards (NGSS) presented in the right side bar. The first unit, featuring local history subjects, also covers many Common Core standards for social studies.

The curriculum is broken into 5 units covering the topics seen in the Table of Contents (to the right). Each unit offers: (1) background information for the teacher and/or students to read; (2) a resource page containing links to educational websites, videos, maps, and books/articles, field trip extensions, and key concepts; (3) a classroom instruction page featuring suggested activities targeted to different grade levels, key vocabulary definitions, and associated worksheet appendixes; and (4) a field trip activity suggestions page. Additionally, two of the units outline a Groundwork Hudson Valley special program in the Daylighting Parks. Though not essential, we highly suggest this program be booked with a Groundwork educator to facilitate. The curriculum can be used in full or as individual units. The different color stars throughout indicate the most appropriate grade range for each activity and corresponding standards.

- ★ Grades 3-5
- ★ Grades 4-6
- ★ Grades 6-8

NGSS Benchmarks

- 4-PS3 Energy
- 4-LS1 From Molecules to Organisms: Structures and Processes
- 4-ESS1 Earth's Place in the Universe
- 4-ESS2 Earth's Systems
- 4-ESS3 Earth and Human Activity
- 3-5-ETS1 Engineering Design

- 5-PS2-1 Motion and Stability: Forces and Interaction
- 5-PS3-1 Energy
- 5-LS2-1 Ecosystems: Interactions, Energy, and Dynamics
- 5-ESS2 Earth's Systems
- 5-ESS3-1 Earth and Human Activity
- 3-5-ETS1-2 Engineering Design

- MS-PS1-2 Matter and its Interactions
- MS-PS1-2 Matter and its Interactions
- MS-PS2-2 Motion and Stability: Forces and Interactions
- MS-PS3 Energy
- MS-LS1-4 From Molecules to Organism: Structures and Processes
- MS-LS2 Ecosystems: Interactions, Energy and Dynamics
- MS-ESS2 Earth's Systems

Table of Contents

The Saw Mill River

A Local History

Indigenous Period

For over 7,000 years, the lower Hudson Valley region was inhabited by native people. By the Age of Discovery (1400's-1600's), the Lenape Tribe were a thriving culture here. They had a rich traditional knowledge of the flora, fauna, and seasonal changes, and they lived in relative peace with the neighboring tribes. The Lenape north of the Delaware Water Gap spoke *Munsee,* a dialect of the Algonquian language group. Those settled along the area now known as Yonkers, called their village *Nappeckamack* ("fish-trapping place") They found rich agricultural soils and ample fisheries at the confluence of the *Muhheakantuck* ("the river that flows both ways"; a.k.a the Hudson River) and its tributary, the *Neperah* ("rapid moving stream"). Now we know that rapid stream as the Saw Mill River.

Source: www.accessgenealogy.com

Illustration of native Lenape using a fish-weir to trap shad fish.
Source: Chadds Ford Historical Society

SMR: A Local History (2/4)

Exploration and Colonization

The Age of Discovery brought a wave of European explorers to the Americas. Some sought religious expansion or freedom, while most had economic pursuits. In the early 1600's, the monarchies and corporations of England, France, and the Netherlands competitively sought an alternative trade route to the "East Indies" (Asia), after Spain and Portugal had already established dominance over the routes around Africa and South America. In 1609, the Dutch East India Company (DEIC) commissioned Henry Hudson to explore a possible northern passage to Asia. Chartering a small ship—the "Half Moon" - eastward, Hudson attempted to bypass the ice in the Arctic Ocean over Russia before setting sights on a fabled "Northwest Passage" through North America. Sailing along the continent's eastern shore, Hudson eventually discovered the wide mouth of a river along what we refer to as the New York harbor. Though it was not the passageway he sought for DEIC, Hudson took note of the rich natural resources of the area and the amicable native Lenape he traded with. He reported back that the area was perfect for colonization. Within the next few decades, the Dutch would establish many settlements from Manhattan to the north.

The European colonists greatly disrupted the native Lenape's way of life. Sometimes, what natives believed were land-access permits for hunting and trapping rights, were in actuality land-acquisition deeds. Corporate trade placed a high economic value on select natural resources, leading to over-hunting and over-fishing. Introduced diseases, like smallpox, and measles, devastated the Lenape people, who had no natural immunity. Eventually, initial distrust of the Europeans grew to outright hostility for many Indian clans. Over time, the Lenape that remained dispersed or emigrated west.


Adriaen van der Donck
Source: Wikipedia

In 1645, the Dutch West India Company granted Dutch settler, Adriaen van der Donck, a vast 24,000 acres expanse of land near the Neperah for his efforts in negotiating a peace between the Director-General of New Netherland, Willem Kieft, and the Lenape. His large new estate fetched him the name of "Jonkheer," meaning "young gentleman," which is how Yonkers got its name! He built a sawmill and a gristmill on that fast-moving stream that feeds the Hudson. Those and future mills established a strong economy in Yonkers, and gave rise to the name Saw Mill River.

SMR: A Local History (3/4)

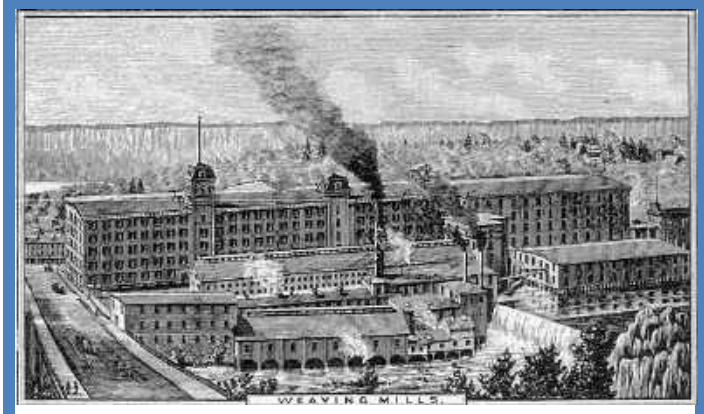
Though details of Adriaen van der Donck's untimely death in 1655 are scarce, we know his family continued to hold and manage the estate for over a decade.

Philipse Manor plantation.
Source: Enslaved Africans Rain Garden Website

Over the next two decades, the Dutch ceded much of their control over New Netherlands to the English—culminating with the 1664 seizure of New Amsterdam (the lower part of Manhattan island) by four English ships; the English subsequently renamed the colony "New York" after the Duke of York. Much of the van der Donck estate was eventually purchased by a Dutch immigrant named Frederick Philipse who later pledged himself to the British crown in exchange for manorship. Philipse became Lord of Philipseborough, building part of the Manor Hall located on the banks of the lower Saw Mill River in downtown Yonkers. Small farms and businesses leased land from Philipse, followed by blacksmiths and general stores. The downtown waterfront became a hub for both sloop and stagecoach as trade increased. Frederick Philipse and his wife, Margaret Hardenbroeck, were savvy but unscrupulous in their ambitions, amassing a great fortune and more land doing business with slavers and pirates among other merchants. By Frederick Philipse's death in 1702, Philipsburg Manor stretched from Croton to Spuyten Duyvil. Philipse's heirs continued to have wealth and influence until the American Revolution in 1777 when their lands were seized and the family exiled for remaining loyal to the British crown.

The Industrial Revolution and the Urban River

The Yonkers' economy continued to advance throughout the next century with the Saw Mill River still at its heart. As of 1813, there was a small wharf slightly upstream from the mouth where the sloops that carried river trade put in. Five small mills existed along the river above the village, all with their own dams, small mill ponds, and nearby tenements for the workers. The confluence of the Saw Mill and Hudson Rivers became a hub for commerce with and transportation to New York City during the age of the steamboat. More factories and



One of the Alexander Carpet Mill factories overlooking the Hudson River Palisades—circa mid 1800s.
Source: Westchester Historical Society

SMR: A Local History (4/4)

Flume construction to cover the final 2000 feet of the Saw Mill.
Source: PS&S Integrated Services—http://www.psands.com

businesses were built on the Saw Mill's banks, including extensive carpet mills, a chemical factory, and several ice houses. Additionally, the river was used for irrigation, fisheries, fire-fighting, and bathing. Of course, industrialization left a heavy mark on the Saw Mill River. By the turn of the 20th century, unchecked sewage and refuse discharge made the river stagnant and heavily polluted. Growing concern over exposure to this cesspool in downtown Yonkers in the early 1900s resulted in the decision to bury the last 2,000 feet of the Saw Mill River under a concrete flume. Construction lasted from 1917-1922, and the river would remain hidden under a park and parking lot for nearly a hundred years until its "daylighting" in 2011. We explore the impact of industrialization on the urban river more in Unit IV: Managing the Urban River.

View of Larkin Plaza in downtown, Yonkers. The Saw Mill River lies buried under concrete in this park/parking lot from 1922-2011.
Source: ny.curbed.com

Saw Mill River History Resources*

- Indigenous Period (Lenape History)
  - ◊ RiverKeeper, Inc.—"A Glimpse of the Lenape: The Night Before"
  - ◊ Lenape Lifeways— Research on website, books for sale, and program offerings.
- Exploration and Colonization
  - ◊ PBS Learning Media Library
    - * "Henry Hudson: A PBS World Explorers Video"
    - * "Henry Hudson" Video
  - ◊ New Netherland Institute— "New York's Colonial Dutch History": An Educational Resource From the New York State Archives
  - ◊ Yonkers Chamber of Commerce—"Early Yonkers History"
- Industrialization and the Urban River
  - ◊ "The Westchester Historian Volume 88 Number 4—"The Saw Mill River: An Environmental History". (Westchester Historical Society)

*Hyperlinks in Blue

Field Trip Extensions

- Philipse Manor Hall State Historic Site—offering tours relating to the history of the Saw Mill River, early Yonkers, and the Revolutionary War—with connections to the Philipse Family. See brochure for details.
- Clearwater Educational Sails—learn about Hudson Valley History and the environmental movement aboard the Clearwater Sloop or Mystic Whaler.
- Hudson River Museum—Tours and programs on Hudson River Art and History corresponding to changing seasonal exhibits.

Key Concepts

⇒ Native Americans lived in the Hudson Valley region for over 8,000 years. By the 1600's, the Lenape were the predominant culture in what is now Yonkers.

⇒ Dutch traders were the first Europeans to colonize the area, after Henry Hudson's exploratory sail up the Hudson River (named after him) in search of a northwest passage through North America to Asia.

⇒ Yonkers was named after landowner Adriaen van der Donck, the "Jonkheer," or young gentleman.

- ◊ Van der Donck built the first sawmill and gristmill along the Saw Mill River in 1649.

⇒ By 1664, the English gained control of the region and renamed New Netherlands, "New York."

- ◊ Dutchman, Frederick Philipse—pledged to the British crown—purchased most of Yonkers in 1672.
- ◊ Through the early 1700's, the Saw Mill River Basin developed into rich farmland, industrial mills, and factories, followed by many other businesses.
- ◊ The Philipse Family (of Philipse Manor Hall in Yonkers) remained loyalists to England in the years leading up to the American Revolution (1775-1783). They eventually fled to British held land.

⇒ In the 1800's the Industrial Revolution brought diverse food, manufacturing, and transportation industries to Yonkers; it also brought factory and human pollution to the Saw Mill River.

- ◊ Amid a cholera epidemic, the river was deemed unsafe and in 1917, the final portion was buried in a flume, underground, where it would remain until its "daylighting" in 2011.

Unit 1A Classroom Instruction:

The Saw Mill River—A Local History

Classroom Activity 1A:1: What's in a Name?

- Neperah, Nepperhan Creek, Sagh-kill, Saw Mill Creek… The Saw Mill River has had many names over its history given by the Natives, Dutch, and English. These names connote different uses of the river.
- Working in teams or solo, have students choose one of the names given to the Saw Mill River, the Hudson River, or Yonkers and research its meaning or origin, the period it was used, and then draw and caption how that place would have appeared at that time.
    - See Appendix 1A:1 Student Worksheet
- Potential research sources:
    - Unit 1 Teacher Background (from this curriculum)
    - Columbia University: History of Yonkers pdf
- Students should then present their findings at the front of the class.
    - Discuss how the nomenclature helps us to understand the ways Yonkers' landscape has been shaped by its residents over time.
- Alternative: Have students match the place name with provided pre-made meanings, time periods, and place descriptions.

Classroom Activity 2A:2 River Power and Industrialization

- Watch "Sawing Lumber with Water Powered Sash Sawmill at Leonard's Mill" video depicting the old fashioned sawmill shop similar to those used in the 1600s-early 1800s. (https://youtu.be/8DRKc10ZHKY)
    - How was flowing river water converted into mechanical energy in this old-fashioned sawmill? (Hint: describe a waterwheel)
    - How did water power affect the development of Yonkers?
- Watch "Sturgeons Saw Mill Draft3" video (13 mins) depicting an innovation on the saw mill that used a steam engine instead of a waterwheel, like the ones they used from the early 1800s-mid 1900s (https://youtu.be/2D3WTGrMTRQ)
    - Discuss how the industrial revolution changed the efficiency of manufacturing, related to lumber production.
    - How do you think improved efficiencies in lumber production affected other industries, or the cost of building businesses and homes?
    - How might this affect the trend of urbanization?

- **Lenape ("Leh-NAH-pay")** A Native American language group derived from Algonquian. The Lenni-Lenape, meaning "true people" of the northeastern woodlands were the predominant denizens of the Westchester region by the time of colonization.
- **Age of Discovery** Also known as the Age of Exploration, it is the period between early 1400s and early 1600s marked by extensive European exploration around the globe in search of trade routes, wealth, and precious resources.
- **Jonkheer** Dutch for "young lord," it was the nickname given to Dutch lawmaker Adriaen van der Donck, after he was gifted a large parcel of land surrounding the Saw Mill River. Yonkers is named after the term.
- **Saw Mill** A traditional saw mill used rapidly flowing water to power saws that cut tree logs into lumber. The Saw Mill River powered many saw mills and grist mills during colonial times.
- **American Revolutionary War (1775-1783)** The war for the independence of the 13 colonies from British rule. American colonists who remained loyal to the crown were known as "loyalists" or "Tories" whereas "Patriots" supported the revolution.
- **The First Industrial Revolution (1760-1840)** A period of technological innovation that advanced manufacturing processes, transportation, communication, and energy production. The steam engine, power loom, Bessemer process of steel production, sewing machine, telegraph, and telephone are key inventions that emerged.

KEY TERMINOLOGY

Appendix 1A:1—"What's in a Name"

Choose a place name from the box below to profile. Using the reading materials, research the name's meaning, and the time period it was used to refer to that place.

Muhheakantuck	Yonkers	Colen Donck
Sagh-kil	Nepperhan	Nappeckamack
Neperah	Saw Mill River	Hudson River

Place Name: _____

Meaning/Origin:_____

Period Used: _____ What is it called today? _____

Draw and caption a picture of how this place may have looked during that time period. You can include plants and animals, buildings, people, or anything that you think would help represent that period.

Caption: _____

_____

Unit 1B Field Trip Activities:

The Saw Mill River—A Local History

Field Trip Activity 1B:1 Local History Scavenger Hunt in Daylighting Park

Start students at Van der Donck Park, the home of the Daylighting Phase I. Students will walk through the park in chaperoned teams, answering questions on a guided scavenger hunt. See Appendix 1B:1 - Yonkers History

- Start off by giving a quick overview about the history of the Saw Mill River and why this portion was sealed up almost 100 years ago.
- Question students: Why were rivers so important to early settlements? How do you think the use of our rivers changed from the native Lenape to the colonists to modern day?
- Form small teams, each with a chaperone if possible, and distribute scavenger hunt materials to each team:
    - Clip-board, map of the park, scavenger hunt laminate with fill in the blank questions, and dry erase markers.
- Give students 20 minutes to explore the park and find answers to questions about local history using the interpretive signage.
- Key Topics for questions will include:
    - Lenape use and naming of the river
    - The Revolutionary War and the role of the local historical site Philipse Manor Hall
    - Famous Yonkers innovators (Otis Elevators)
    - The cholera epidemic leading to the capping of the river.
- Meet at the Outdoor Classroom by the large eel mosaic to review answers and discuss the role the river had in shaping Yonkers' history.

"Yonkers is a wonderful place to live... [with] four miles of Hudson River waterfront... and we have the new Daylighting project where they actually brought the Saw Mill River above ground." - Bob Walters, environmental advocate, and Yonkers' history enthusiast.

Field Trip Activity 1B:2 Yonkers' Labor Force and The Saw Mill River*

Start students at Mill Street Courtyard, the home of the Daylighting Phase II. Students will walk through the park, chaperoned, learning more about Yonkers' history and the labor force that helped make it the 4th largest city in New York. See Appendix 1B:2 worksheet and Yonkers Census information.

- Have students explore the Mill Street Courtyard, using tablets, etc. to take pictures of the artwork, exhibits, and historic artifacts (or sketch them).
- Ask students to choose one of the industries that shaped Yonkers, depicted in the "Tribute to Yonkers" interpretive sign and the metal sculptures depicting Yonkers' industry workers around the courtyard.
    - Students should write down their selection and begin to assume the perspective of a laborer in that industry to reflect on what Yonkers and the Saw Mill River was like back then, and how they might feel about its Daylighting today.
    - Optional: Cross Warburton Ave to Daylighting Phase I (Van der Donck Park) to research more about these industries.
- In class, have students write a short diary entry as their chosen worker describing their work day and view of Yonkers' development, and the Saw Mill River as it may have looked at that time.

*Programs offered by Philipse Manor Hall can greatly augment this lesson.

Yonkers History
Unearthed at the Daylighting Park

1. The Saw Mill River earned its name by hosting numerous mills that harnessed the power of fast flowing water for industrial use. The native Lenape people had already recognized the river's speedy flow and had named it _____, meaning "rapid running water."

2. Overlooking the park is a prominent historic building known as _____ Manor Hall that was originally owned by a family who was loyal to England during the _____ War. The family lost the building and their vast landholdings when the United States won its independence.

3. Many industries once flourished in Yonkers, powered by the forceful flow of the Saw Mill River. Most of these factories have moved on or switched power sources. However, in its sugar refinery, _____ _____ still utilizes water power.

4. Sailing ships were once the leading mode of transportation between upstate locations and New York City. These boats were replaced first by _____ and then by _____ which still form a critical link today.

5. Amidst health concerns caused by industrial pollution and urbanization, the final 2000 feet of the Saw Mill River was buried under a flume in a project that began in the year _____. It remained underground until its Daylighting in _____.

Yonkers History
Unearthed at the Daylighting Park

1. The Saw Mill River earned its name by hosting numerous mills that harnessed the power of fast flowing water for industrial use. The native Lenape people had already recognized the river's speedy flow and had named it _Neperah_, meaning "rapid running water."

2. Overlooking the park is a prominent historic building known as _Philipse__ Manor Hall that was originally owned by a family who was loyal to England during the _American Revolutionary____ War. The family lost the building and their vast landholdings when the United States won its independence.

3. Many industries once flourished in Yonkers, powered by the forceful flow of the Saw Mill River. Most of these factories have moved on or switched power sources. However, in its sugar refinery, _____Domino __Sugar_____ still utilizes water power.

4. Sailing ships were once the leading mode of transportation between upstate locations and New York City. These boats were replaced first by __steam boats__ and then by ___railroads____ which still form a critical link today.

5. Amidst health concerns caused by industrial pollution and urbanization, the final 2000 feet of the Saw Mill River was buried under a flume in a project that began in the year _____1917_____. It remained underground until its Daylighting in _2011_____.

Appendix 1B:2—"Yonkers' Labor Force and the Saw Mill River"

Name 3 Major Factories in Yonkers

Chosen Industry: _____

When was the business/factory founded or at peak production (approximate):_____

What would the job entail for someone working in this industry?:

_____

_____

Bonus: Describe any inventions or innovations important to this industry if possible.

_____

_____

How was the Saw Mill River important to this industry? _____

Use this section for various notes and sketches about your chosen industry/worker:

Additional research notes from class/homework: _____

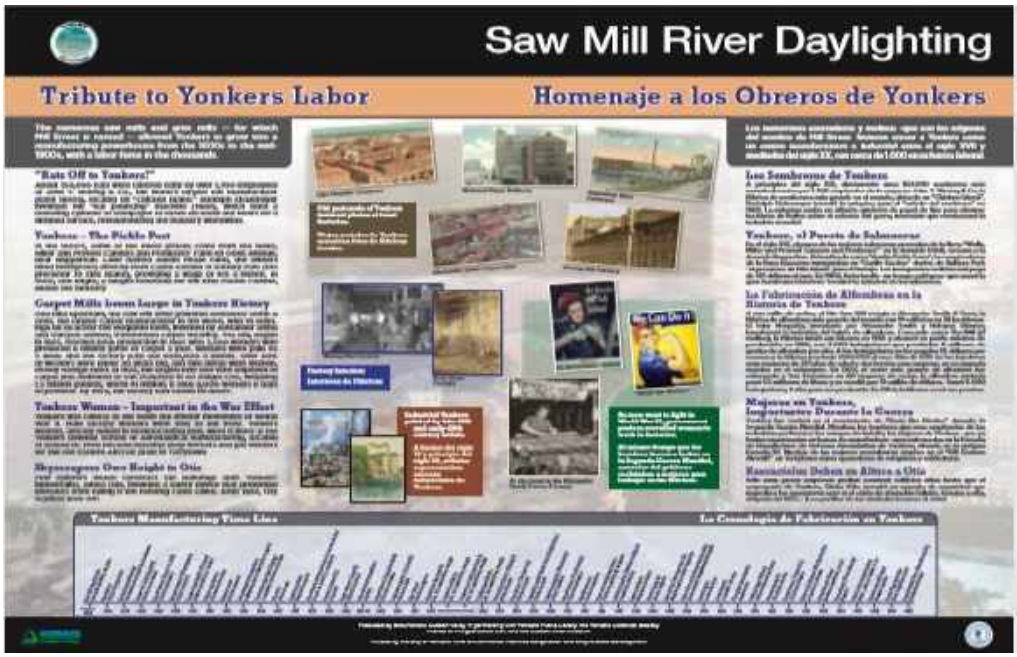
_____

_____

Assuming the role of a laborer in this industry, describe how you feel about Yonkers and the Saw Mill River: _____

_____

_____



Everyone Lives in a Watershed

What's Your H.U.C. (Hydrological Unit Code)?

Source: Saw Mill

What is a Watershed?

Over a landscape, peaks and valleys create a topography that affects the flow of water. Surface waters move downhill with gravity, collecting in temporary pools or flowing into streams and rivers that usually make their way to a lake or ocean. Through evaporation, precipitation, melting and flow, the "water cycle" keeps water in motion around the planet, connecting surface waters to the atmosphere (clouds), cryosphere (glaciers and snowpack), and hydrosphere (oceans). A watershed is simply an area of land, divided by ridges and hills, that drains all of the precipitation to a common outlet. Watersheds can be used to describe landscapes as small as your own backyard or as big as a continental coastline. Smaller watersheds can be a part of larger watersheds depending on the drainage outlet. The importance of watershed education is in recognizing how water flows and pools, always carrying runoff with it, and understanding that we are *all connected* by the water cycle.

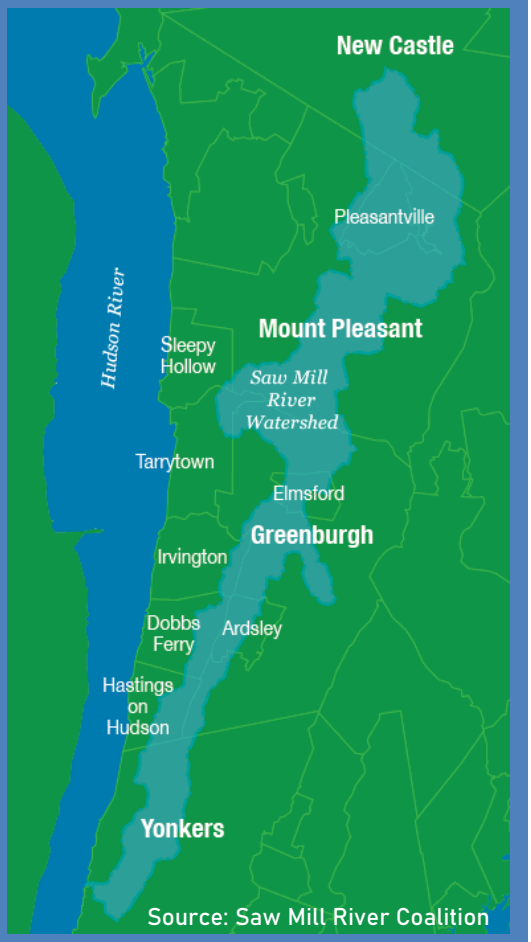
U.S.A. Watersheds Source: U.S. EPA

The source of water in a given watershed, known as the headwaters, is found at the drainage divide—or the

Everyone Lives in a Watershed (2/3)

highest peaks in the area. The place that headwaters connect is called the confluence and the end of the waterway, where it reaches its main body of water, is the mouth. As well as a "watershed," this system of converging headwaters pouring out the mouth of a stream into a river, lake, or ocean is often referred to as a drainage basin.

The Saw Mill River Drainage Basin



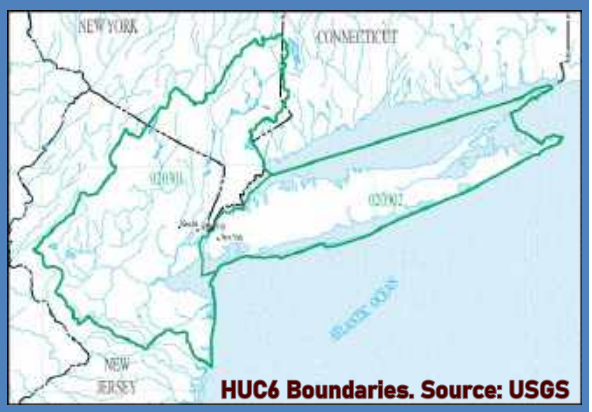
Source: Saw Mill River Coalition

The Saw Mill River has a 20-mile journey from Chappaqua to Yonkers, but its drainage basin extends beyond that—nearly 27 square miles. When the glaciers of the last ice age receded, they left their mark behind: large striations among the hard bedrock that formed many ridges and valleys running north to south. The ridges surrounding the Saw Mill River, often steep, form its drainage divide. Natural gullies and creeks carrying soil and fallen leaves feed into it. Impermeable roadways and buildings redirect rainwater, channeling trash, leaked oil, and other runoff into it. Hoses from homes and gardens wash away soaps and excess fertilizers into it. These confluences have a stacking effect, bringing life-giving detritus and nutrients downstream alongside life-taking pollution. As such, the mouth of the Saw Mill River, where it reaches the Hudson, has alternated between being a nursery and a graveyard for fish and wildlife over the past 400 years. The deciding factors between the two have been the rules that govern our use and abuse of the water resources in our watershed, and the cooperation and monitoring of the watershed by its citizens.

Hydrologic Unit Code (H.U.C.) - HUC8-02030101

Because the Saw Mill River empties into the Hudson River, its watershed is part of a larger watershed, known as the Lower Hudson Drainage Basin. Hydrology scientists who study how water moves over the land use unique addresses to keep track of these drainage basins. This helps them to more accurately monitor *current* conditions and predict *future* conditions such as erosion, storm surge, flooding, changes to marine habitat, pollution, landslides, and water shortages. We call these addresses Hydrologic Unit Codes, or HUCs for short. The Lower Hudson sub-basin HUC is 02030101.

Everyone Lives in a Watershed (3/3)



HUC6 Boundaries. Source: USGS

Broken into components on the United States Geological Survey (USGS) National Map, our unique water resource HUC8 looks like this:

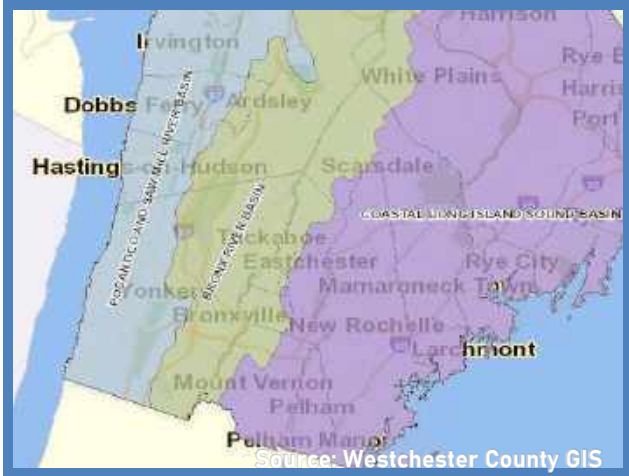
⇒ Mid-Atlantic Region (HUC2-02), which eventually connects to the Atlantic Ocean

⇒ Lower Hudson-Long Island Sub-region (HUC4 -0203)

⇒ Lower Hudson River Basin (HUC6-020301), which is entirely tidal, and finally…

⇒ Lower Hudson Sub-basin (HUC8-02030101)

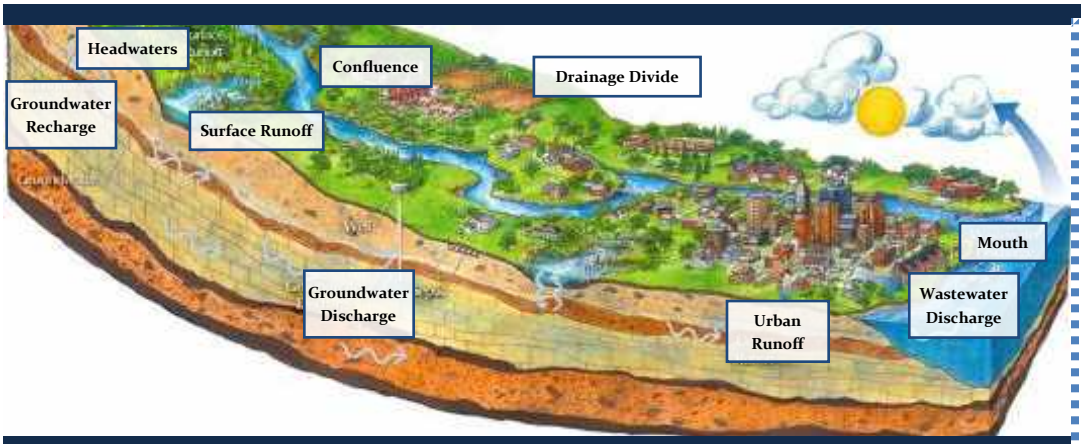
Considered this way, it is easy to trace human impact on water quality and marine habitat in the Atlantic Ocean back to us. What we do here matters all the way down the line—sometimes permanently. The changes our ancestors made to the Saw Mill River drainage basin during colonization and industrialization still affect the hydrology of the region today. Though many of these changes to land use, water flow, waste management, and biodiversity adversely affected our water resources, there are some choices available that can improve conditions. For instance, terracing steep land, adding buffer zones along streams, restoring coastal wetlands, and promoting mass transit and bike paths (reducing vehicles on the road) can reduce erosion rates and runoff pollution in a watershed. Knowing our watershed boundaries also helps environmental scientists pinpoint where runoff is coming from. When pollution can be traced to a single source, such as a factory or broken sewer line, it is referred to as point source pollution. When the pollution is diffuse, such as *many* lawns, vehicles, or buildings, it is referred to as nonpoint source pollution.



Source: Westchester County GIS

Yonkers Watersheds

Yonkers topography of many hills actually puts it into two *distinct* watersheds: the Pocantico & Saw Mill River Basin to the west, and the Bronx River Basin to the east. Both, however, converge where the East River meets the Hudson as part of the Lower Hudson-Long Island Sub-region (HUC: 0203). This is still important to note , especially when working with Yonkers students. In researching their home watershed, they may fall into either.



Field Trip Extensions

- SLC Center for the Urban River at Beczak (CURB)— Watershed, marine pollution, and estuary literacy programs.
- Groundwork Hudson Valley—Saw Mill River clean-up activities, tours of the Saw Mill Daylighting Parks from the Science Barge, and programs on water management at home (EcoHouse location).
- Clearwater Educational Sails— Hudson Valley history and environmental movement programs aboard the Clearwater Sloop or Mystic Whaler.

WaterShed Education Resources*

- What is a Watershed?
  - ◊ Waves, Wetlands, and Watersheds: California Coastal Commission Science Activity Guide—"Chapter 5: Water, Water, Everywhere"
- The Saw Mill River Drainage Basin
  - ◊ Westchester County GIS Map—Saw Mill River Watershed
  - ◊ USGS Science in Your Watershed— "Water Resources for Links for HUC 02030101—Lower Hudson" Maps and data links on watersheds.
- Hydrologic Unit Codes (HUC)
  - ◊ CoCoRaHS Educational Series—"Watersheds" video reviewing watersheds, HUCS, and hydrology data collection and uses.
  - ◊ USGS video tutorial: Using Hydrologic Unit Codes (HUCs) within the Watershed Boundary Dataset (WBD)
- Yonkers Watersheds
  - ◊ "Three Rivers of Yonkers"—SLC CURB Curriculum for 4th/5th Grade

*Hyperlinks in Blue

Key Concepts

⇒ Everyone lives in a watershed! Yonkers has two: the Saw Mill River and Bronx River drainage basins.

⇒ A watershed is an area of land that drains all the water running under and over it to a single point or larger body of water. Small watersheds combine into larger watersheds.

- ◊ Watersheds are comprised of drainage divides at the highest ridges in that area, headwaters or source precipitation along those high points, tributaries which are smaller streams that empty into larger streams at confluences, and the mouth, or the point from where all the water drains to a larger stream, lake, aquifer, or ocean.

⇒ The Saw Mill River is about 20 miles in length, originating in Chappaqua and ending at the confluence with the Hudson River.

⇒ The Saw Mill River's narrow drainage basin is about 27 square miles in area.

⇒ Pollution from multiple upriver sources accumulates downstream as runoff.

- ◊ Runoff oil, chemicals, fertilizers, and physical trash lowers water quality, which in turn severely affects river organisms as well as the health of the surrounding environment.

⇒ Hydrologic Unit Codes (HUCs) are like addresses that hydrologists use to identify specific watersheds and drainage areas.

- ♦ Hydrologists study how water moves through geological features in a given landscape.

Unit 2A Classroom Instruction:

Everyone Lives in a Watershed—What's Your H.U.C.?

Classroom Activity 2A:1: Water Cycle Review

- Watch "The Water Cycle" video by CoCoRaHS Educational Series (https://youtu.be/ZzY5-NZSzVw)
- Review the complete water cycle diagram using the USGS image in Appendix 2A:1. Interactive digital version found here: https://water.usgs.gov/edu/watercycle-kids-int.html
- Watershed Charades—Create cards with key water cycle terms. Split class up into 2 teams. Students must come up to the front of the class, draw a card, and either act out or draw on the whiteboard their chosen term, trying to get their team to guess correctly within the time limit.

Classroom Activity 2A:2: What's Your HUC?

- Watch "Watersheds" video by CoCoRaHS Educational Series (https://youtu.be/2pwW2rlGIa8) to introduce watershed and HUC topic.
- What's Your HUC? - In a Computer Lab or using classroom tablets, have students determine the HUC8 "address" for the Saw Mill River Drainage Basin. Use the US Geologic Survey National Map found here: https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View
  - First select "All Subcategories" box in left-side Datasets window
  - Then click "Show Preview" for the Watershed Boundary Dataset (WBD). HUC2 boundaries should display on the national map,
  - Finally, interact with the map by either searching for their specific address in the Search Bar above the right-side map, or by zooming in (double-clicking) on our region until you have found Yonkers.
  - Record the HUC8 sub-basin or even HUC12 sub-watershed number for the selected location.

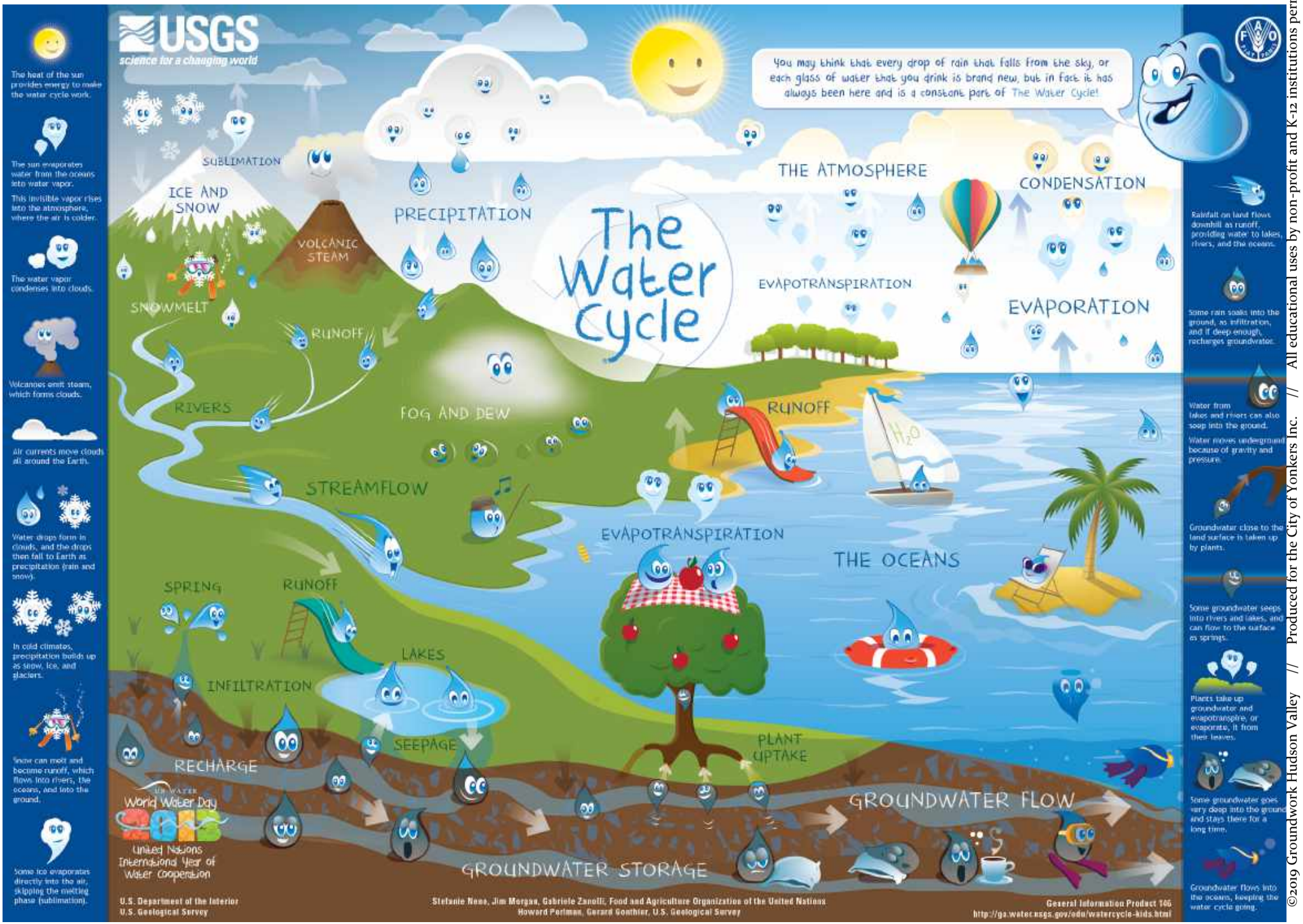
Classroom Activity 2A:3: Saw Mill River Watershed—Map Data w/ GIS

- In a computer lab setting, have students go to "Mapping Westchester County"—Geographic Information Systems: https://giswww.westchestergov.com/gismap/default.aspx?ActiveId=Drainage+Divides&Query=NAME%3d%27SAW+MILL+RIVER+BASIN%27&QueryZoom=Yes#
- Follow the Appendix 2A:3 worksheet and use the interactive map identify threats to the watershed and environmentally vulnerable areas.
- Background information packets: https://www.riverkeeper.org/wp-content/uploads/2019/03/2018-Entero-Report-SAW-MILL-Final.pdf

KEY TERMINOLOGY

- **Condense** To change from gas or vapor to liquid form.
- **Evaporate** To change from liquid into gas
- **Precipitate** The falling of water to the Earth as rain, sleet, hail, or snow.
- **Watershed** An area of land that drains to a single body. Also known as a **drainage basin.**
- **Runoff** Water that flows off land into lakes and streams, carrying debris, soil, nutrients, and pollution.
- **Drainage Divide** Elevated ridgeline that separates one watershed from another.
- **Hydrology** Study of how water moves through and over the land.
- **HUC** A Hydrologic Unit Code, or unique "address" given by hydrologists to a water source, such as a river basin or watershed.
- **Point Source Pollution** Pollution that is traceable to a single source.
- **Nonpoint Source Pollution** Pollution that accumulates in the environment from many different sources.

Appendix 2A:1—Water Cycle Review



Appendix 2A:3—Saw Mill River Watershed—Map Data with GIS

On your computer, go to "Mapping Westchester County"—Geographic Information Systems
Follow the steps below to identify features of the watershed as depicted on the map.
Note: if a map feature doesn't load, you may have to click the link next to it to download it.

1) On the right-hand bar, select "Show Additional Data on Map" at the bottom.
2) Click the + next to "Environmental Features" to expand the menu options.
3) Scroll down to "Watersheds" and toggle it on by clicking the checkbox. Note colors.
   Q: What larger basin does the watershed area outlined in black fall in?

   A: _____
4) Toggle on the "Steep Slopes" feature by clicking the checkbox. Note the red lines that appear. Zoom in on the map using the plus icon on the top left to get a closer look.
   Q: In what direction do most of the steep slopes or ridges run? (N-S, E-W, NE-SW, etc.)

   A: _____
   Q: How do you think that effected the size/shape of the drainage basins in the region?

   A: _____
5) Toggle off "Watersheds" and "Steep Slopes" and toggle on "Flood Plains." Note the colors for 100-year and 500-year flood events. Scroll to the top of the right-hand bar and expand the "Facilities and Services" menu by clicking the + next to it.
6) Toggle on important human health and social service icons, and scroll through the map to see which ones are in a 100 or 500 year flood zone in the Saw Mill River basin. List 2 different examples here and their approximate location.

   _____

   _____

   List 1 major roadway that overlaps with a 100 or 500 year flood zone.

   _____
7) Go back to "Environmental Features" and toggle on features that are potential environmental hazards one at a time. (ie: stormwater outfalls, hazardous waste sites, farms/stables/nurseries, and petroleum bulk storage)
   Q: Which city has the highest concentration of each in the *Saw Mill River Watershed*?
   A: stormwater outfalls: _____ hazardous waste: _____
   farms/stables: _____ petroleum bulk storage: _____

Unit 2B Field Trip Activities:

Everyone Lives in a Watershed—What's Your H.U.C.?

Field Trip Activity 2B:1—Watershed Clean Up

Start students at Van der Donck Park, the home of the Daylighting Phase I. Students will walk through the park in chaperoned teams, looking for and safely cleaning up trash. *Note: parent waivers may be necessary.*

- Starting at the Outdoor Classroom by the large eel mosaic, review key concepts:
    - What is a watershed?
    - What larger drainage basin is the Saw Mill watershed a part of?
    - What is point source pollution and non-point source pollution? Give examples of both.
- Split students into small teams. Give every student work gloves, give each team a large construction grade garbage bag, trash-grabber tools, and a clip board with a blank piece of paper and pencil. Optional: have students wear reflective vests or bright color T-shirts.
- Share clean-up rules:
    - Do not pick up broken glass, medical waste (needles, band-aids, etc.)
    - Do not cross any roads.
    - Do not impede pedestrian or bicycle traffic (move to the side).
    - Do not step over the rope barriers or rails.
    - When in doubt, ask a chaperone.
- Have students take turns (5-10 mins each) in their team collecting, bagging, and documenting trash. Collectors should use trash grabbers. Small wrapper, chip bags, and empty plastic bottles can be picked up by hand, if student is wearing gloves.
    - The student with the clipboard can tally how many wrappers, chip bags, pieces of Styrofoam, plastic grocery bags, plastic bottles, and aluminum cans are found.
    - Students should note any signs of other runoff, such as oil slicks, soap bubbles, paint, excess nutrients (indicated by lots of algae growth), etc.
- Meet back at the outdoor classroom to consolidate trash, consolidate numbers and discuss what was found.
    - What was the most common item found?
    - How do you think the trash might affect wildlife here and downstream? How do you think it affects the environmental health of a community?
    - What were examples of non-point source pollution? Were there any *potential* point source pollution examples?

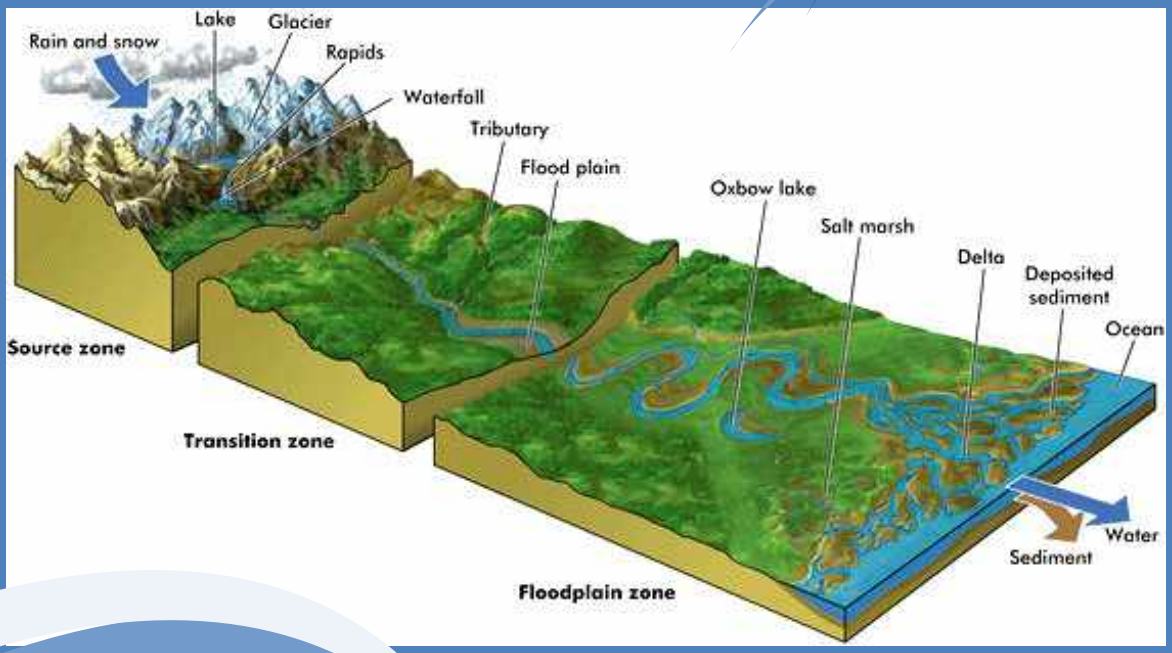
"A River is the report card for its watershed" ~ Alan Levere, Connecticut Department of Environmental Protection

"We forget that the water cycle and the life cycle are one" ~ Jacques Cousteau, marine scientist

Groundwork HV hosts the Great Saw Mill River Cleanup every year around Earth Day. Volunteer groups welcome!

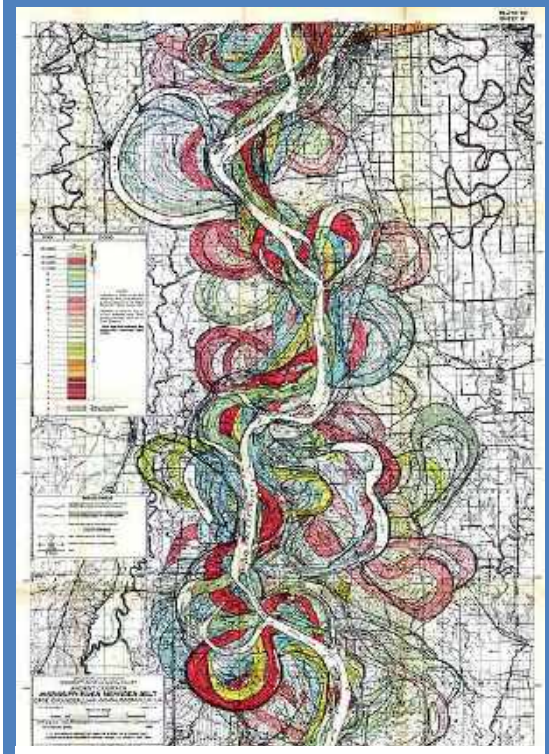
River Features & Ecology

Riparian Zones and Biodiversity in the River



A River Runs Through It

As it traverses the topography, a river bends and dips to find the path of least resistance. Because of the unique chemical qualities of H_2O (hydrogen bonding), water can even rush around objects to meet together again. The interaction between the flowing waters and the landscape forms unique features, each with their own set of dynamics and ecosystem. The tug-of-war between gravitational potential energy and kinetic energy in movement constantly shifts the velocity and trajectory of the river.

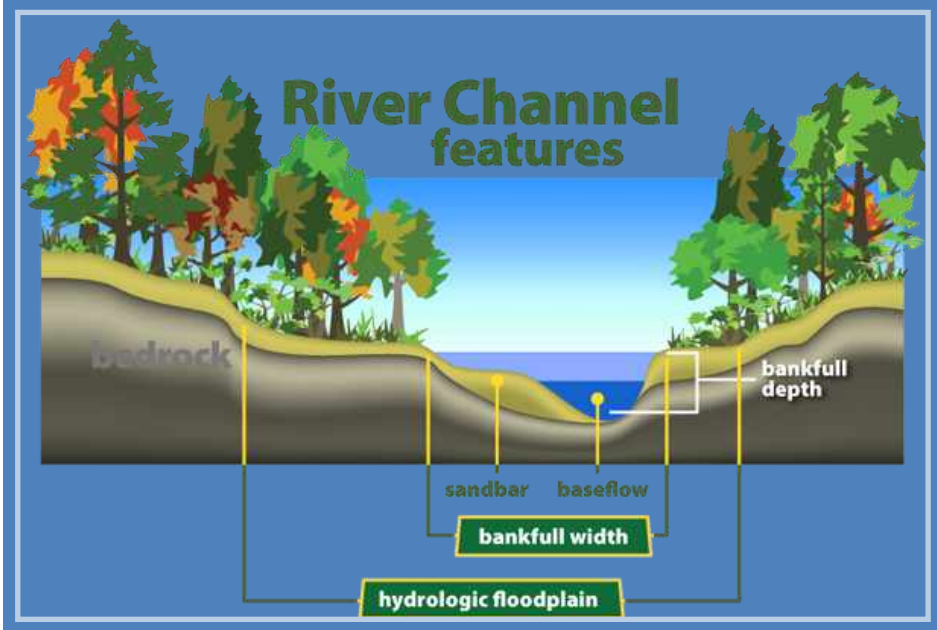


1944 map illustrating the various meandering courses of the Mississippi River over time. Source: Army Corps of Engineers

Humans have long seized upon these dynamic forces to move large objects, generate power, enrich and irrigate the soil, and develop fisheries. At times, we have even bent rivers to our will, dammed them, filled them, channeled them, and covered them, but sometimes rivers have a will of their own! Flooding rains, powerful erosion, drought, and sheer force can let a river reclaim the areas around it. Rivers may bring life, but living with them requires understanding them.

River Features and Ecology (2/4)

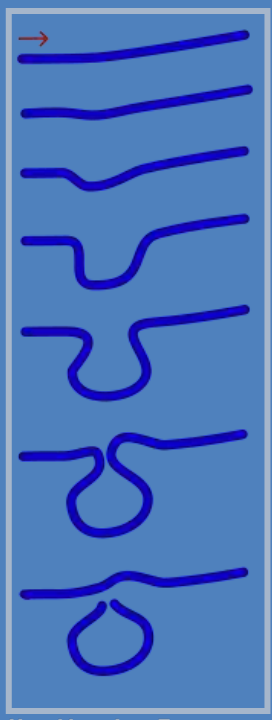
Rivers 101



A river courses through three distinct zones: the source zone, which channels melting snow and glaciers, rainwater, and mountain lakes swiftly down steep gradients, eroding rock and soils; the transition zone where neighboring streams form tributaries that merge together in broad valleys to become wider and deeper rivers; and the floodplain zone or deposition zone, where rivers often meander through flatter topography and heavy rains cause the river to flood over its banks, depositing sediment and nutrients, thus enriching the soil. The floodplain culminates at the mouth of the river. When a river empties out into another body of water, there is often a rapid decrease in velocity, causing a lot of sediment to be deposited at the mouth. This results in a landform known as a delta. Deltas fan out from the mouth of the river, and can create rich ecological zones.

When looking at the mouth of the Saw Mill River, you'll notice that it is artificially channeled by barrier walls, changing how sediment is deposited into the Hudson River. Still, you may spot a large sand bar along the northern wall of the channel, which is fully exposed at low tide. Another one, just beyond the wharf, typically stays submerged. It is here where waterfowl like cormorants, herons, geese, ducks, and seagulls congregate to look for food.

Whenever a river slows, it deposits sediment. As a river naturally bends to the harder bedrock, the water begins to erode the outer bank while depositing sediment on the inner bank further downstream. The outer bank begins to form deeper pools allowing it to move even faster, while sediment collecting on the inner bank creates shallow riffles that further slow the flow. Over time, the alternating erosion and deposition accentuate the curves and create meanders. If the meander exaggerates to the point of breeching, it forms an oxbow lake (see right).



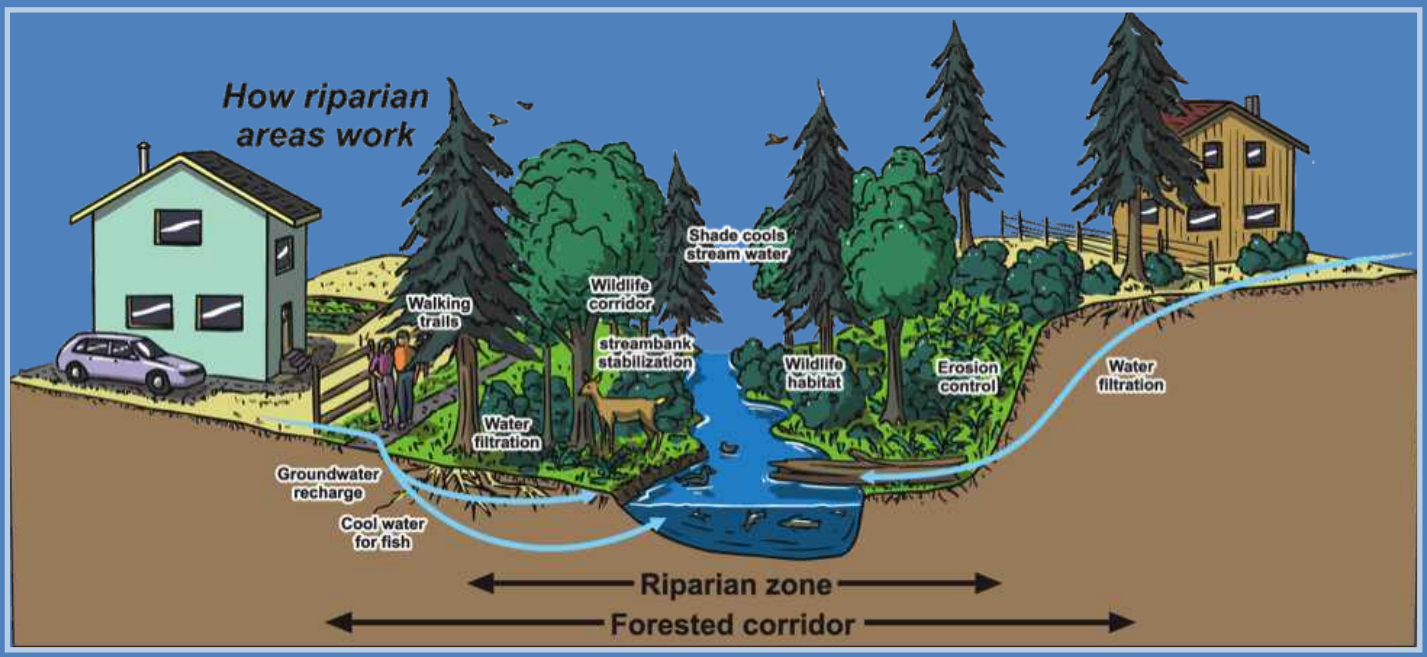
How Meanders Form. Source: Wikipedia Commons

River Features and Ecology (3/4)

Riparian Zone Ecosystems

Google Map "Street View" image of the mouth of the Saw Mill River, where it empties into the Hudson River. Note the straight, walled channel and the sand bar on the right

The intersection of the river and the land is called a riparian zone. When intact, this natural habitat is characterized by hydrophilic (water loving) plants, rich soils, clean waters, diverse animal communities, and strong food webs. Along the Saw Mill River, pin oaks, dogwood, black willows, speckled alders, and staghorn sumac trees are most common, and many species of frog, turtle, snake, duck, woodpecker, and songbird call it home. You can even find mammals such as muskrats and beavers dipping in and out of the stream. A detailed list of documented species can be found on the Saw Mill River Coalition website.



While meandering rivers and floodplains are natural features that enrich riparian zone ecosystems, they can become disruptive to our system of roads and urban/suburban buildings. The Saw Mill River, while small and sleepy compared to some rivers, has still eroded into property lines, flooded over bridges and into highways, and caused damage to our built infrastructure. Removing invasive vines that choke out trees and shrubs, and planting riparian buffers of fast-growing native trees help to stabilize the Saw Mill's banks and reduce the risk of flooding. Community organizations, public officials, and citizen volunteers have partnered up to form the Saw Mill River Coalition to restore and protect this critical ecosystem and help to mitigate inevitable issues around erosion and

River Features and Ecology (4/4)

flooding. Groundwork Hudson Valley, the parent organization for the Saw Mill River Coalition, hosts many vine-clearing projects throughout the year as well as the *annual* Great Saw Mill River Cleanup event where hundreds of volunteers pull literal tons of trash from the river and its banks!

Biodiversity in the Saw Mill River

River systems provide habitat and other resources to support an abundance of species. Species richness in an area is a measure of its biodiversity. The more biodiversity in a given ecosystem, the stronger its food web, or web of life, is. Runoff fertilizers and pollution, degradation or elimination of riparian zones due to overdevelopment, and the introduction of invasive ornamentals that out-compete native species are examples of how humans can adversely affect biodiversity.

Even with urbanization, the Saw Mill River has been a refuge for many fish, crustaceans, insects, and other visitors. Most importantly, studies have proven nature's resilience here: the more the river is restored, the more life returns. Still, climate change leaves a lot of uncertainty regarding the resilience of our surrounding ecosystems *and* infrastructure. According to the theory behind reconciliation ecology, as urbanization continues, people must be intentional about offsetting our footprint on nature while we adapt for future challenges by creating habitats throughout our cities and suburbs. Phase One of the Saw Mill River Daylighting is a great example of reconciliation ecology in action. Uncovering the river and adding features like a fish ladder for migrating fish, riffles to oxygenate the water, and lots of native plants along the banks bring a functional habitat back to a busy city hub.

Groundwork HV student volunteers seining the Saw Mill River to study fish populations post-Daylighting in 2012.
Source: Saw Mill River Coalition

In 2015, post-Daylighting, the Saw Mill in Yonkers was designated an "Urban Wildlife Refuge" by the U.S. Fish and Wildlife Service. The "Daylighting Park" in Van der Donck Plaza is now home to a wide range of species, including the American eel, river herring, tessellated darter, painted turtles, mallards, muskrat, and threatened birds, such as the American Phoebe. White sucker fish, snowy egrets, night herons, double crested cormorants, salamander larva, and a beaver have also been spotted frequenting or migrating through! Did you ever expect to find so much wildlife in the heart of Yonkers?!

River Ecology Education Resources*

- A River Runs Through It
  - ◊ American Prairie— Research on website, books for sale, and program offerings.
- Rivers 101
  - ◊ Three Rivers of Yonkers—SLC CURB Curriculum for 4th & 5th Grades
  - ◊ Teachearthscience.org—"Rivers: Teacher Background" pdf
- Riparian Zone Ecosystems
  - ◊ USDA Natural Resource Conservation Service—Riparian Areas Environmental Uniqueness, Function, and Values.
- Biodiversity in the Saw Mill River
  - ◊ There's Something Fishy about the Saw Mill River—Presentation by Raquel Romero, Bio student at Saunders High School, 2012
  - ◊ Saw Mill River Coalition Website

*Hyperlinks in Blue

Field Trip Extensions

- Groundwork Hudson Valley Science Barge—Daylighting tours and ecology programs offered as either stand alone or extension activities of the Science Barge tour.
- Saw Mill River Audubon—customized, guided field trips about aquatic and wildlife habitats, trees, or bird identification at one of their select sites along the Saw Mill River.
- SLC Center for the Urban River at Beczak—comprehensive river and tidal estuary literacy programs. SLC CURB also does water testing research in the Saw Mill and Hudson rivers.

Key Concepts

⇒ Humans have used rivers for transportation, irrigation, fishing, and industry over our history. Often our uses required manipulating the rivers flow and course.

⇒ As modern sources of energy replaced urban rivers, we have often relegated them to the background, sometimes even narrowly channeling them in alleys, or under buildings and roads.

⇒ Rivers can be separated into three zones, each with distinct features:

- ◊ The source zone where headwaters form from rains as it channels through mountains and between stone ridges.
- ◊ The transition zone where many tributaries meet
- ◊ The floodplain or deposition zone where the river broadens and slows on flatter terrain until it reaches the mouth or delta. It is here that the river is most likely to meander.

⇒ Riparian zones are natural buffers and important habitat where water loving plants and animals thrive.

⇒ Urban waters often eliminate the riparian zone altogether, severely compromising biodiversity.

⇒ Reconciliation ecology principles state that traditional methods of creating separate nature preserves is inadequate if we want to prevent a mass extinction of species.

- ◊ Only by creating habitat space and resource access for plants and animals *within* our cities and suburbs, will we avoid global ecosystem collapse.

Unit 3A Classroom Instruction:
River Features and Ecology

Classroom Activity 1: Diagram of a River

- Review river basics using the Appendix 3A:1 worksheet
    - First, diagram the major components of a river system.
    - Next, complete the Match Game of key functions at the bottom.
- Discuss the importance of riparian zones in maintaining biodiversity in and around rivers. Use the educational resources listed on the previous page as well as the Unit 3 background information to help come up with examples of species found in riparian zones.
    - What would students expect to find in a healthy Saw Mill River riparian zone in terms of flora and fauna? A: Native trees, shrubs, grasses, and other hydrophilic plants, northeastern amphibians, waterfowl, mammals, insects, and fish.
    - What sorts of things threaten the richness of species and quality of water? A: Pollution, invasive species, development, deforestation.
- Introduce the idea of reconciliation ecology. Have students draw a picture of how the Saw Mill River would look in Yonkers if it was meeting the needs of both city inhabitants and wildlife.
- Extension: Use Unit 2, Lesson 3 on Biodiversity from "Three Rivers of Yonkers: A Curriculum for 4th and 5th Grades," by SLC CURB.

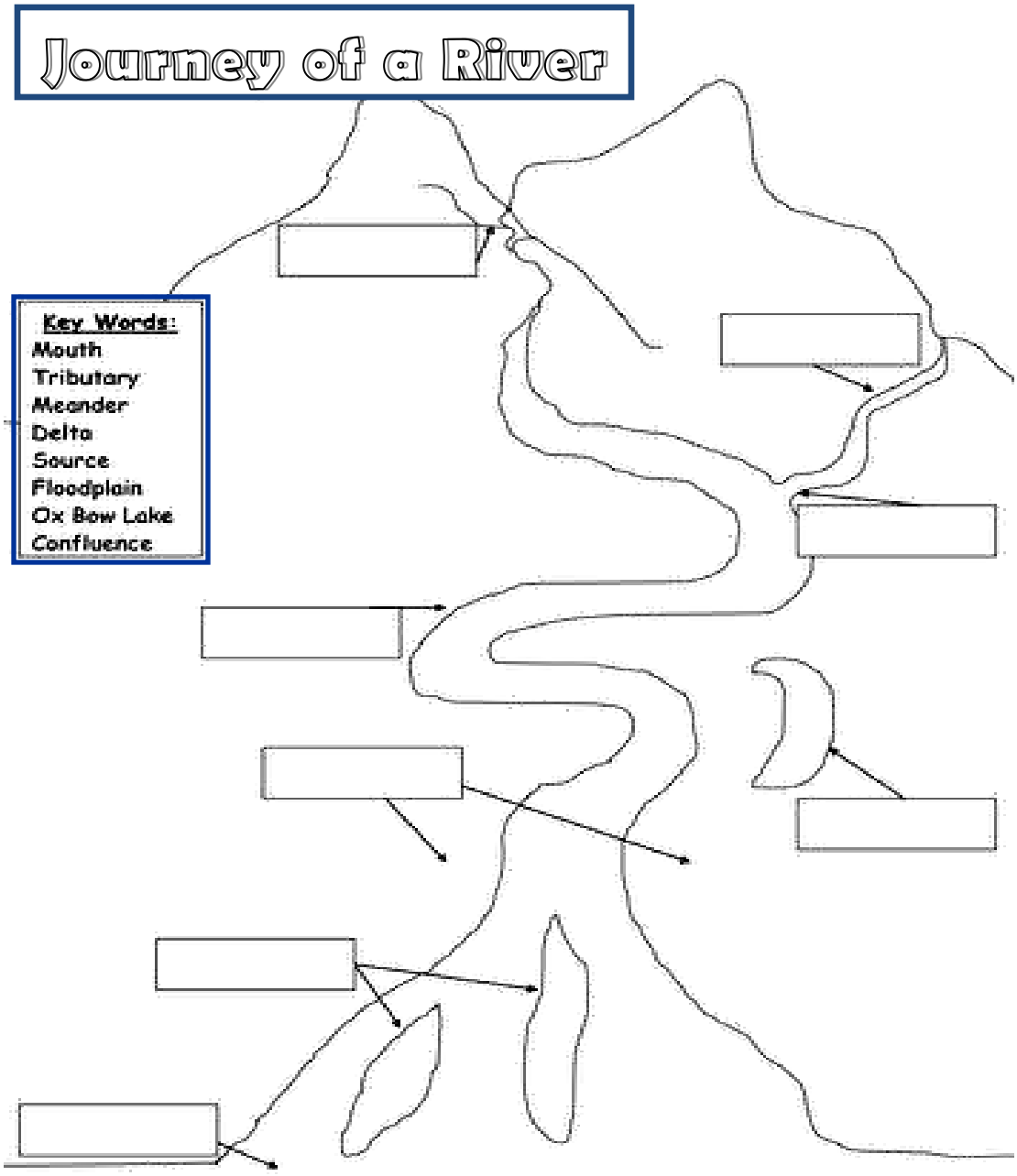
Classroom Activity 2: NASA Images of Change

- Rivers are not static features of geography. Both natural and manmade processes can greatly affect both the course and water quality of a river over time. Scientists use satellite and imaging technology to gain insights on erosion, sedimentation, flooding, drought, climate change, and other changes to river ecosystems and the impact on rural, suburban, and urban settlements around them.
- Go to NASA's Images of Change: https://climate.nasa.gov/images-of-change?id=674#674-flooding-along-mississippi-river
    - Use the controls on the top right of the page to select Gallery View. Make sure you are on the "Water" tab on the top bar.
    - Scroll through examples of bodies of water around the world and how they have changed due to flooding or other natural events. How might climate change also play a role?
    - Now go to the "Human Impact" tab. Scroll through examples of how deforestation, damming/dam removal, urbanization, and wetland restoration have impacted the environment.
- Optional: Have students choose a river or region and profile the natural and anthropogenic changes made to it over time, as documented in this gallery.

- **Source Zone** Highland headwaters of a river, including melting snow, rainwater, and mountain lakes.
- **Transition Zone** Where rapid-flowing source waters collect from tributaries to a larger stream and begin to slow.
- **Floodplain Zone** The area of land adjacent to a river, generally downstream in a valley, that experiences more frequent flooding. A healthy floodplain allows rivers to spread out, slow down, and deposit nutrient rich sediment.
- **Meander** When uneven erosion and deposition along the river banks begins to create large curves along the river's route.
- **Delta** The point where a river meets a larger body of water, slowing to create a large fan-shaped area of sediment deposition.
- **Riparian Zone** The area extended beyond the river's banks that includes plants and animals, soil, and manmade structures.
- **Biodiversity** Richness in species within a given area.
- **Reconciliation Ecology** The study of land-use trends and species-area relationships to determine ways to encourage biodiversity in human-dominated ecosystems.

KEY TERMINOLOGY

Appendix 3A:1 —"Diagram of a River"



MATCH GAME: Match the terms on the right with their correct description on the left.

1) When fast-moving river wear away rock and soil from their beds and banks _____

2) When a river slows down and the suspended particles settle out. _____

3) The buffer zone of plant and wildlife habitats surrounding the river. _____

4) The area of land between ridges where all the water drains to a larger body. _____

5) All of the precipitation and melted snow pack that forms the river at its source. _____

A) Headwaters

B) Sedimentation

C) Watershed

D) Erosion

E) Riparian

Unit 3B Field Trip Activities:

River Features and Ecology

Field Trip Activity 3B:1—Biodiversity at the Daylighting Park

- Students will start at Van der Donck Park, site of Daylighting Phase I, and perform a guided scavenger hunt. Note: They should not cross any streets.
- Review the terms habitat and biodiversity. Include things like plant species, food sources, shelter, access to mates, and clean water.
- Use the maps across from the library, to show the Saw Mill River's path from Chappaqua to Yonkers, emptying into the Hudson River on the other side of the train station.
- Split students up into small groups, each with a chaperone if possible, and give each team a clip-board, map of the park, and scavenger hunt sheet.
    - Tell students they have 15-20 minutes to find signs/art around the park to help answer questions about biodiversity.
    - Use both sides of Appendix 3B:1—Biodiversity Scavenger Hunt

Field Trip Activity 3B:2—Citizen Science: Eel & Arthropod Study*

This activity requires permission from the DEC and pre-placement of an eel mop at least 48 hours in advance. The American Eel migrates in early spring. Find access to a secure location along the Saw Mill River, such as Van der Donck Park. Be sure to label your class name on the attached line and carefully secure it to a fixture above the riverbanks. A tutorial on making them can found here: http://www.dec.ny.gov/docs/remediation_hudson_pdf/eelmop.pdf

- First teach students about the life cycle and migration of the American Eel from the salty Sargasso Sea to freshwater streams in the northeast.
- Use a bucket on a rope to get enough river water to fill a large basin and small observation tray. This is what the eels and arthropods will end up in.
- Students will observe as they pull up the eel mop and swish it thoroughly in the large water basin until they are confident they have dislodged any glass eels and bugs taking residents in the eel mop.
- Finally, strain the water out by pouring it through a fishnet to reveal any glass eels or other organisms that might be hidden in the sludge and water. Pass any eels or bugs around in the observation trays with a magnifying glass.
- Alternative: Use a Leaf Pack Experiment Stream Ecology Kit to perform an arthropod study using staked leaf packs placed 3-4 weeks in advance.

"Have you also learned that secret from the river; that there is no such thing as time? That the river is everywhere at the same time: at the source and the mouth, at the waterfall, at the ferry, at the current, in the ocean and in the mountains, everywhere—and that the present only exists for it, not in the shadow of the past nor the shadow of the future."
Hermann Hesse, Siddhartha

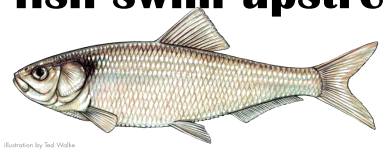
Yonkers' students watch the final reveal of an eel mop pulled from the Saw Mill River, housing glass eels and aquatic arthropods:

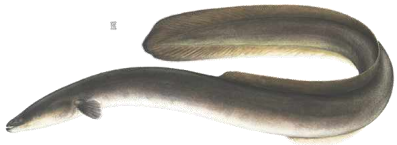
*It is *strongly* recommended that you book this activity with Groundwork Hudson Valley's Science Barge *or* the SLC Center for the Urban River at Beczak (CURB)

Biodiversity at the Daylighting Park
Scavenger Hunt

1) A _____ is a stream that flows into a larger stream, just like the Saw Mill River flows into the Hudson.

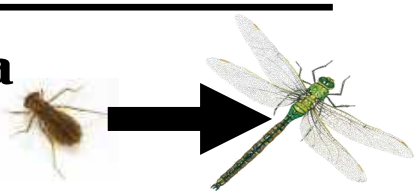
2) A FISH LADDER was put in by the waterfall to help these two fish swim upstream:





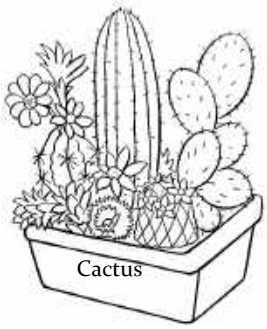
_____ _____

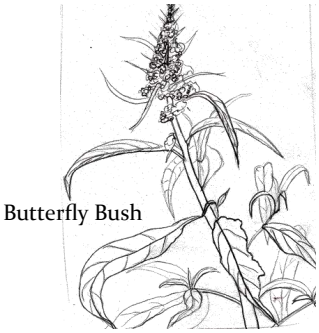
3) Which predatory insect is also known as a "mosquito hawk?" (species name, 3 words)



_____ _____ _____

4) After you've toured the whole loop, CIRCLE the TWO plants below that you CAN find at the Daylighting Park:





5) Order the different life stages of the American Eel 1-6:

_____ _____ _____ _____ _____ _____

ART is LIFE!

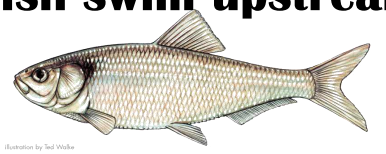
Circle all of the animals that are represented in the tile mosaics in the Daylighting Park. Believe it or not, all of these animals can claim the Saw Mill River or its *riparian zone* as habitat—if we keep it clean. Bonus: Try to label them all!

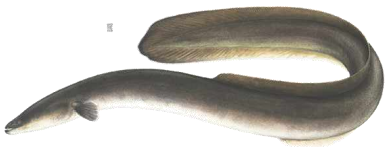
Biodiversity at the Daylighting Park

ANSWER SHEET

1) A __tributary_____ is a stream that flows into a larger stream, just like the Saw Mill River flows into the Hudson.

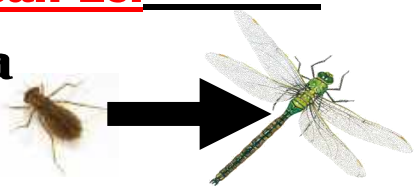
2) A FISH LADDER was put in by the waterfall to help these two fish swim upstream:





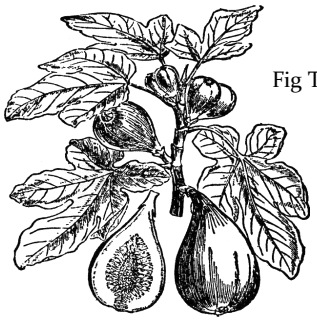
_____Alewife_____ _____American Eel_____

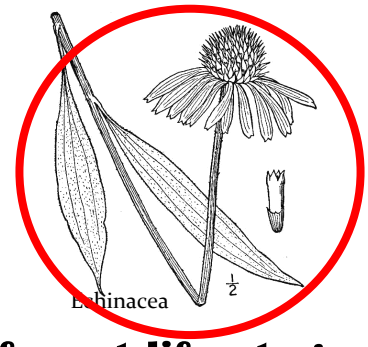
3) Which predatory insect is also known as a "mosquito hawk?" (species name, 3 words)

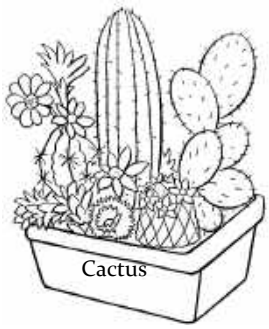


____Common__ _____green_____ _____darner_____

4) After you've toured the whole loop, CIRCLE the TWO plants below that you CAN find at the Daylighting Park:







5) Order the different life stages of the American Eel 1-6:

_3__ __5_ __6_ _1__ __2_ _4__

ART is LIFE! ANSWER SHEET

Circle all of the animals that are represented in the tile mosaics in the Daylighting Park. Believe it or not, all of these animals can claim the Saw Mill River or its *riparian zone* as habitat—if we keep it clean. Bonus: Try to label them all!

Managing the Urban River

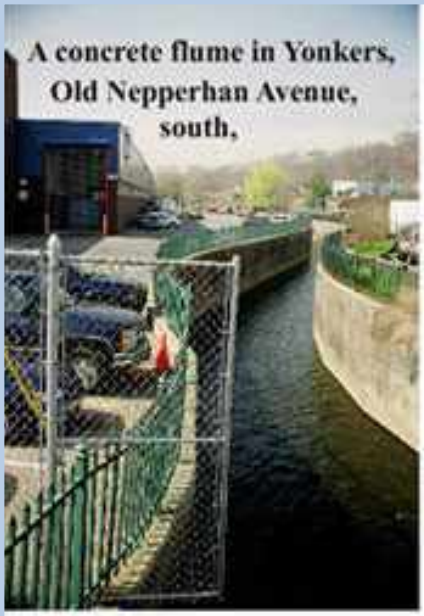
Rethinking Our Approach to Urban Waters

A Tale of Two Rivers

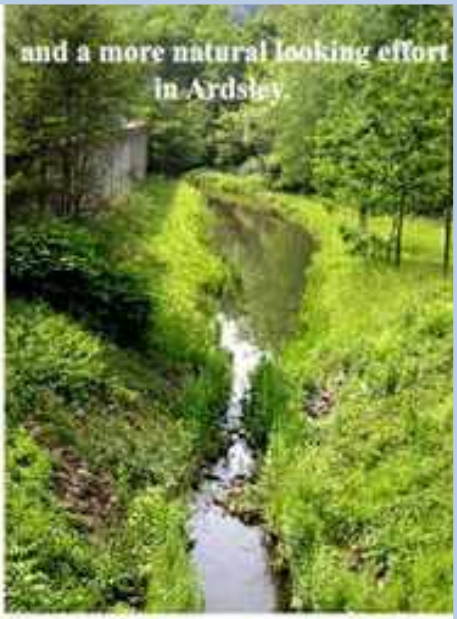
Picture a wild and scenic river, twisting and turning, carving through mountains and foot hills, surrounded by alluvial forest and prairie ecosystems teeming with life, enrichened by the river's very own floodwaters. Now imagine a narrow channel of water sandwiched between cement walls, littered with trash, poisoned with runoff oil, chemicals, and fertilizers, and obscured by buildings, bridges, and old factories. The truth is, all over our country, these two descriptions often apply to the same river. Most large cities across the United States and the world are on a coast; they border some body of water. These waterways granted better access for transport and trade, not to mention food and water. As we have learned in previous units, rivers were particularly useful as they also provided a source of freshwater, rich soils in the floodplains, and usable energy. The same streams that inspire us in their untamed beauty, self-purification, and ability to steadily carve through the landscape are also the ones that beleaguer us when they flood into our highways, destroy our bridges, erode our property, or disgust us with toxic pollution—even if we polluted it. That does not *have* to be the case, though. We have choices on how we manage the urban river.

The Saw Mill River Parkway flooded after Hurricane Sandy's heavy rain breached the river banks.

Managing the Urban River (2/4)



Yonkers



Ardsley

The Urban River

Rivers are dynamic systems; in a blink of geologic time, they can form, mature, and even dry up as tectonic plates shift and Earth's climate changes. The Hudson River is relatively young, for instance, at an estimated 13,000-26,000 years old. The Saw Mill River is likely a fair bit younger than that! Still, compared to the history of human civilization, it may seem eternal. As such, we tend to take the urban river's existence for granted.

The long period of industrialization was unkind to the Saw Mill River—many dams and millponds were constructed in the early 1800's to take advantage of the river's kinetic energy; as population swelled in the mid 1800's, houses, factories, and roads were built directly over the river; by the late 1800's, residents used it increasingly to discharge sewage, and factories illegally used it to dump refuse. Its flow impeded, its purity compromised, its recreational uses stripped, the Saw Mill was pushed to the background and largely ignored. Even as the health of the river's lower portion waned, it still provided passage for many migratory fish species and the waterfowl that preyed upon them. But water stagnation and pollution brought an onslaught of health concerns, and population growth required a super-highway for commuters.

In the early 1900s, even as dams were being removed from the Saw Mill, more sections of the river—including its last 2000 feet—were culverted and covered, and long stretches of the river were dredged to make room for the Saw Mill River Parkway. These alterations fragmented the habitat, impeding fish migration, and prevented aquatic reptiles, crustaceans, and insects from burrowing into the riverbed. It also hid the ongoing dumping of oil, paint, and heavy metals from factories. A 1990's United States Geological Survey (USGS) study reported that the Saw Mill River tributary was the biggest source of pollution in the Hudson River, and had some of the highest levels of PCBs and cadmium, mercury, copper, and zinc in the nation!

Across the world, urbanization and population growth has resulted in the "death" of many

Managing the Urban River (3/4)

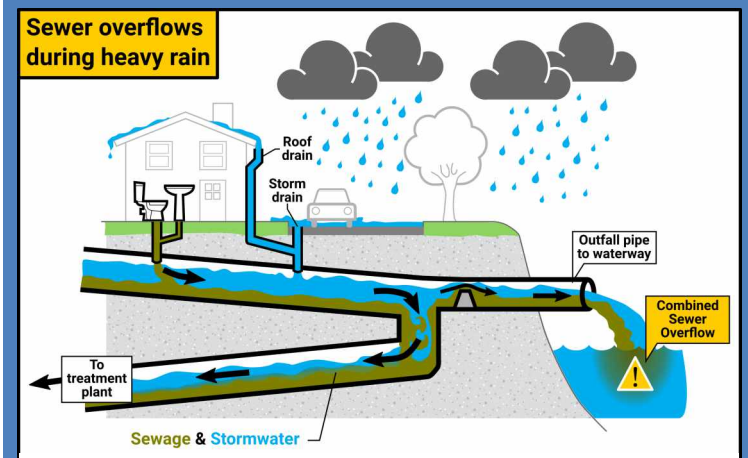
rivers - meaning they ceased to serve any ecological function. Pollution, ever-encroaching infrastructure, overuse, and climate change have been the common causes. The Saw Mill River seemed vulnerable to a premature death if proactive measures were not taken.

Runoff oil and street litter that make their way to storm drains empty out into our rivers as pollution.

Traditional Stream Management

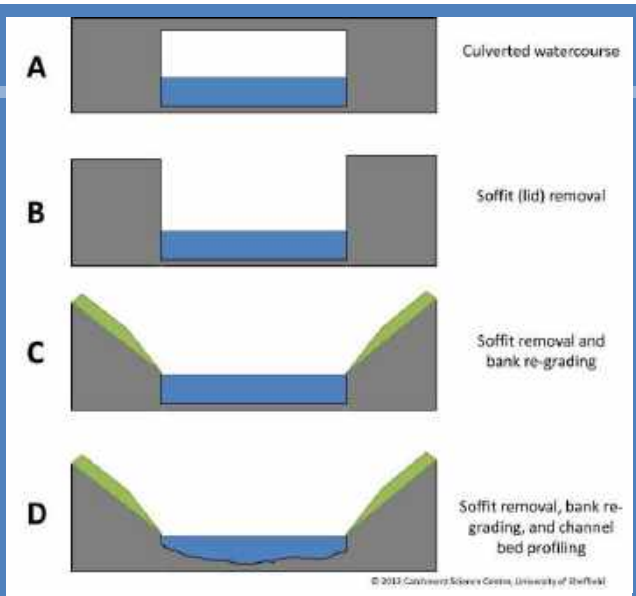
The changeability of streams makes them a nuisance for development. Though they may be older than our cities, streams and rivers are constantly maturing. It is *normal* for them to meander, flood and ice over—but those processes are quite destructive to roads, bridges, and buildings. As such, stream management techniques have traditionally included straightening, channeling, culverting, dredging, and building dams. These are examples of hard engineering, as they involve the use of heavy machinery to move material in the river bed and banks, as well as concrete and metal structures to divert, bury, or bridge the water. Though these techniques are designed to mitigate regular flooding, they can actually lead to more devastating floods during extreme weather events. The increased flowrate and reduced buffer zones also greatly contribute to downstream environmental degradation.

Lined, straightened channels—lacking in rocks and riparian vegetation—expedite river flow and discharge. Moreover, urban stormwater management typically involves transferring water off of roads and into streams as quickly as possible. This increased volume and velocity creates more powerful forces of erosion downstream, which has the potential for being *more* damaging. It can also make the river vulnerable to combined sewage overflows (CSOs). In our old cities, sewage lines and stormwater drains joined together in underground pipes where a weir, or mini-dam, would divert regular flow to a waste water treatment plant. However, during heavier rain events, the excess flow would be able to crest over the weir and discharge a mixture of untreated sewage and rainwater into nearby bodies of water.



Combined Sewage Overflow (CSO). Source: ECOSS.org

Managing the Urban River (4/4)



The process known as "daylighting" is when previously culverted rivers are unearthed. It can be completed in multiple stages ranging from just removing the culvert lid (soffit), to creating a new river bed profile altogether.

Green Design Alternatives

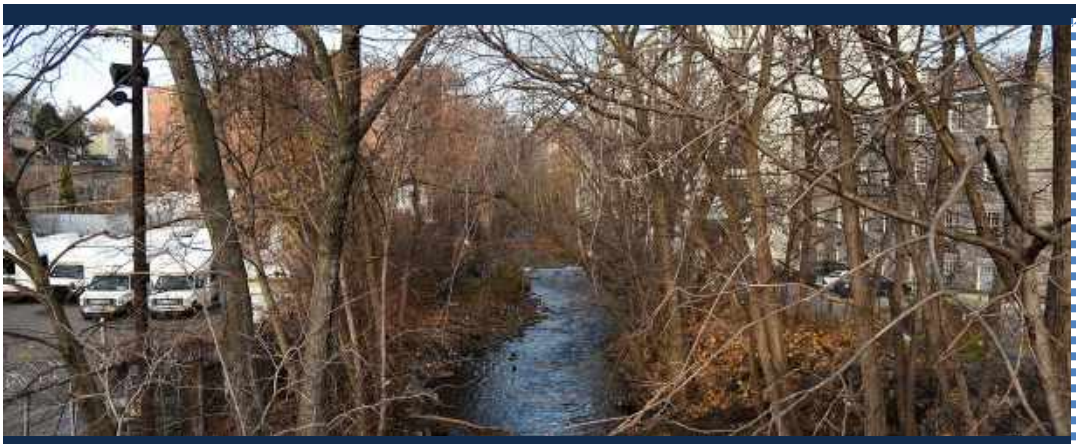
The conventional hard engineering approach to stream management used in the past has proven insufficient time and again. Flood damages and water scarcity still alternately plague these waterways, and the effects of climate change on the water cycle are only exacerbating this. Additionally, the aging infrastructure is deteriorating rapidly in many places, necessitating ongoing and costly repairs.

In response, a new approach focusing on river restoration has emerged in the past few decades. This new paradigm involves integrating our understanding of the *geology, hydrology, and biology* of a river system to design truly sustainable engineering solutions. From the Netherlands to Bangladesh to Texas, cities and suburbs are beginning to make "room for the rivers," by removing culvert lids, re-grading banks, adding riparian zone buffer vegetation, and creating public parks that double as temporary floodplains. According to American Rivers, in addition to filtering runoff and providing habitat ,"an acre of wetland, saturated with water 1-foot deep, can hold 330,000 gallons of water—equivalent to the amount that would flood 13 homes thigh-high."

Rendering of "Branch Waters Network" development plan for Trinity River in Dallas, Texas by Kevin Sloan's Studio.

In addition to creating more greenspace, cities can also make use of more permeable pavements, green roofs, bioswales, and ample tree plantings to slow runoff and water infiltration. Furthermore, when aging culverts are removed, it provides the opportunity to create sanitary sewer lines separate to stormwater drainage systems, eliminating the health hazard that CSOs present.

Sanitary sewage system (SSS). Source: SRFC Consulting



Urban River Education Resources*

- A Tale of Two Rivers
  - Saw Mill River Coalition— Slideshow
  - "11 Rivers Forced Underground" - National Geographic Slideshow
- The Urban River
  - "Lost Rivers"—2012 movie documentary by Catbird Productions featuring the Saw Mill River Daylighting. Available at Yonkers Library
- Traditional Stream Management
  - "Stream Processes: A Guide to Living In Harmony with Streams" by Chemung County Soil and Water Conservation District (Aug 2006)
- Green Design Alternatives
  - Making Room for Rivers: A Different Approach to Flood Control—article by Columbia Water Center.
  - Global, Local, Coastal Distance Learning Module—A comprehensive climate curriculum by GWHV. Unit 4 Chapter 2, Unit 5 Chapter 4

*Hyperlinks in Blue

Field Trip Extensions

- SLC Center for the Urban River at Beczak—river and tidal estuary literacy programs as well as water quality, pollution, and coastal climate resilience programs.
- Groundwork Hudson Valley—special tours of the Daylighting Parks (inquire with the Sustainability Education department for details) and Science Barge extension activities on urban runoff, climate resilience, and biomimicry/green design.

Key Concepts

⇒ Most large cities around the world were built on the coasts of a waterway. Rivers provided transport and trade access as well as a resource for food and water.

⇒ Industrialization and urbanization created competition for space, leading to many urban rivers being culverted, covered over, diverted, or dammed.

⇒ Even while old dams were being removed along the Saw Mill River, other portions of it were being covered over to make room for parkways, development, and for sanitation purposes.

⇒ Burying the river did nothing to improve the quality of the water. A 1990s study by USGS reported some of the highest concentrations of heavy metals such as cadmium, mercury, copper, and zinc for a waterway in the country!

⇒ Yonkers' old infrastructure included underground pipes that brought both water from storm drains and sewage to water treatment facilities. During heavy precipitation, the mixture of untreated sewage and stormwater would overflow ("combined sewage overflow") directly into the Saw Mill and Hudson Rivers.

⇒ Hard engineering, involves the use of artificial structures such as concrete walls and channels, levees and dams to control water flow, protect coasts/riverbanks and mitigate flooding.

⇒ Green infrastructure uses ecological principles to work with nature while protecting coasts—restoring floodplains/wetlands, riparian zones, and river beds, and adding more permeable surfaces in cities.

Unit 4A Classroom Instruction:
Managing the Urban River

Classroom Activity 4A:1— Lost Rivers—Part 1

- Watch the first half of "Lost Rivers," a 2012 film documentary by Catbird Productions about disappeared waterways around the world, including the Saw Mill River Daylighting. Total run time: 72 minutes. Part 2 covered in Unit 5.
    - Available for purchase, or streaming at Docuseek with registration. Alternatively, request to borrow it from Groundwork Hudson Valley.
    - Teacher background for film found here: https://misc.icarusfilms.com/press/pdfs/lr_pk.pdf
- Have students write a short essay/reaction paper about the topic, including:
    - Why were so many rivers were covered up in the first place?
    - How do you think hiding away urban rivers affects us, *culturally*?
    - What are the challenges that aging culverts and hidden urban rivers face in the age of climate change?
    - How do lost rivers and daylighting projects generate global interest?
- Profile a "lost river" using the National Geographic slideshow, "11 Rivers Forced Underground" - https://www.nationalgeographic.com/environment/photos/underground-rivers/
    - Students should use Appendix 4A:1 Profile a "Lost River."

Classroom Activity 4A:2— Another Saw Mill Daylighting Story

- Watch this 2016 video about the proposal to daylight the Saw Mill River…. in Halifax, Nova Scotia, Canada: https://youtu.be/MIhtv-Tv8Vo
- Discussion Questions:
    - How is the river covered? Why does it need repairs? What is the cost of repairing the old system?
    - What were some of the challenges to daylighting the river?
    - What are some of the advantages of daylighting presented?
    - How is this project alike and different from the Saw Mill River daylighting in Yonkers?
    - Can Yonkers serve as an example? Defend your answer.

- **Combined Sewage Overflow** (CSO) The discharge into rivers and streams that occurs after heavy rain or snowmelt from a combined sewer system exceeds the capacity of the pipe that leads to the wastewater treatment facility. Combined sewers collect both domestic sewage and industrial wastewater in the same pipe as stormwater runoff, leaving them vulnerable to CSOs.
- **Green Infrastructure** An approach to water management that protects, restores, or mimics the natural water cycle. It includes wetland restoration, tree planting, increasing surface permeability, daylighting culverted streams, and protecting riparian buffers.
- **Culvert** A tunnel carrying a stream that allows water to flow under a road, trail, or building. It may be made from a metal pipe, or concrete.
- **Permeable Pavement** A method of paving vehicle and pedestrian pathways that enables infiltration of stormwater runoff.
- **Bioswale** A sloped retention area landscaped with native grasses, perennials, shrubs and/or trees used to channel, collect, infiltrate, and filter stormwater.
- **Green Roof** A living roof of a building that includes waterproof membrane, root barrier, growing medium and vegetation intended to reduce stormwater runoff, improve air quality, and mitigate urban heat island effect.

KEY TERMINOLOGY

Appendix 4A:1—Profile a "Lost River"

Use with National Geographic Slideshow: "11 Rivers Forced Underground"

Chosen Waterway: _____

City/State/Country: _____

Population of City above it (requires additional research):_____

Where does it flow to?: _____

Last seen (decade): _____

Why was it covered up? _____

_____

How was it covered up (materials/methods)?: _____

_____

Environmental issues for waterway today (additional research required): _____

_____

_____

Additional Research Notes or Sketch:

Unit 4B Field Trip Activities:

Urban River Management

Field Trip Activity 4B:1—Pollution and the Urban River

Start group at the Outdoor Classroom in Van der Donck Park, the site of Daylighting Phase I. Buses can drop off students at the intersection of Dock Street and Buena Vista Avenue, by the library. Map on pg. 4 of this book.

- Follow the procedure as outlined in Appendix 4B:1
- Alternative: Book a tour guide for this activity by contacting Groundwork Hudson Valley.

Field Trip Activity 4B:2—Citizen Science: Water Testing

This activity requires purchase of one or more Water Monitoring test kits, such as this low-cost one by LaMotte and a refractometer. Find access to a few secure location along the Saw Mill River, such as the mouth of the river, Van der Donck Park, Chicken Island, or even upriver at Woodlands lake, etc.

- Review the scientific method, and give some basic instructions on water testing procedures (safety, sample collection, reading a test tube, using a refractometer, how to develop test tabs, etc). Provide background information on each test used. Tests include: pH, phosphates, nitrates, salinity, dissolved O_2, fecal coliform, and temperature, and turbidity.
- Citizen science allows for more ample testing and quicker response to pollution. Riverkeeper maintains databases for water testing results collected by citizens in our watershed. View the Saw Mill River data here: https://www.riverkeeper.org/water-quality/citizen-data/saw-mill-river/
- Collect samples using a bucket on a rope. Follow instructions for each test in LaMotte booklet, using pipettes to fill the test tubes (Note: different tests may require different volumes of water). Label the site location and test being done for each test tube.
    - Use visual observations to form a hypothesis about which site will have the best or worst water quality.
    - After conducting tests, record and analyze results to compare water quality among sites.
    - Was your hypothesis correct? In your conclusion, discuss potential reasons for the differences. Extension: Compare results with those on Riverkeeper's website.
- Alternative: Consult or book a program with SLC Center for the Urban River at Beczak on water quality testing. Be sure to specify it is for the *Saw Mill River*.

"The good life of any river may depend on the perception of its music, and the preservation of some music to perceive." - Aldo Leopold, conservationist

Samples of the Saw Mill River for water testing conducted by SLC Center for the Urban River at Beczak.

Appendix 4B: 1—"Pollution and the Urban River" Field Trip Procedure 1/3

PROGRAM LENGTH: 90 MINUTES TO 2 HOURS

MATERIALS:

CHEMICAL POLLUTION: 6 test tubes, lemon, vanilla, and strawberry extracts, acetone, slips to cover test tubes, marker to mark test tubes, student worksheets or dry erase board to record answers

OIL RUNOFF: Two bowls, water to fill both, ¼ cup of vegetable oil, 2 cheesecloths

PHYSICAL WASTE: Funnel, two balloons, two small containers, barley, Styrofoam pieces

DAYLIGHTING PARK TOUR: Clipboards with park map, markers or pens for students.

OBJECTIVES:

⇒ Students will learn about how chemical pollution affects fish behavior, among other things, by blocking their sense of smell; how physical pollution, such as Styrofoam can affect their diet; and how oil in the river affects aquatic animals' ability to breathe and thermo-regulate.

⇒ Students will understand the difference between point source pollution and nonpoint source pollution and identify potential examples of both.

⇒ Students will understand that the Saw Mill River drainage basin empties at its confluence with the Hudson River and that the accumulation of all upstream runoff discharges here.

⇒ Students will be able to identify vulnerabilities for pollution along the Saw Mill River in downtown Yonkers.

LOCATION:

Van der Donck Park, home of Daylighting Phase I. Downtown Yonkers by Riverside Library and Metro North train station. Part 1, 2, and 3, can be performed with the whole class, or in a round robin with 3 smaller groups, depending on the number of facilitators.

PART 1: CHEMICAL POLLUTION (20 minutes)

Introduction: Did you know fish can smell their way home? Not only that, fish also detect odors to find food, avoid predators and prepare for mating! Recently, scientists discovered that chemical pollution, like cadmium and copper from factories that end up in our waterways can endanger the sense of smell in fish, even eliminating an animal's recognition of important olfactory triggers. That means some migratory animals might never find their way home. Others may have a hard time reproducing. Perhaps most disturbing, some animals might not detect the scent of danger — and pay for it with their lives!

Preparation (setup at Outdoor Classroom):

1. Gather materials. Prepare six "smelling" test tubes: 2 will be filled halfway with vanilla extract, 2 with lemon extract, and 2 with strawberry extract (other extracts can be used).

2. One of each scent will be "*uncontaminated*" and should be filled the rest of the way with pure water. The other set of scents will be "*contaminated*" and should be filled the rest of the way with acetone (if using nail-polish

Appendix 4B: 1—"Pollution and the Urban River" Field Trip Procedure 2/4

remover, be sure it is unscented).

3. Mix up the test tubes and mark the plugs/corks with a letter A-F. Be sure to note which is which on an answer sheet. Test tubes should be covered in foil so the contents (and the color of the liquid) cannot be seen.
4. Set up a worksheet grid or dry-erase board with columns: "Lemon," "Vanilla," and "Strawberry." Set up rows: A-F

Procedure:

1. Split students into teams of 3 or 6. Each team represents a school of fish. They can create team names based on fish species if they like.
2. Have teams send up a representative to participate in each round. Uncap a test tube and ask the team representatives to gently smell the sample, without speaking. After all representatives have had a chance to smell the sample, ask them to vote on a private sheet what they think they had: vanilla, lemon, or strawberry. They can also indicate if they think the sample is *pure* or *contaminated*.
3. Repeat Step 2 for each test tube. Teams of 6 will go once, whereas teams of 3 will go twice.
4. You can also tally the total votes for each scent at the front of the class.
5. Reveal the answers. Typically, there are far more wrong answers on the contaminated samples than the pure samples. Tell students that every wrong answer that their team got represents a fish lost from their school. How many fish do they have left?

Discussion Questions:

- How do they think chemical pollution may affect fish populations?
- Do they think chemical pollution is more likely a form of point-source pollution or non-point source pollution?
- Can you always *see* chemical pollution in the water? If not, how do we know it is there?
- Later, tour the Daylighting Phase I park and determine the most likely sources of chemical pollution in the Saw Mill River, past and present. Mark them on the map provided with an "X"

PART 2: OIL RUNOFF (20 minutes)

Introduction: Oil leaking from factories and automobiles as well as oil spills can runoff into river systems. Oil coats the scales and clogs the gills of fish, suffocating them. Oil also introduces toxins to fish that can cause disease, birth defects and death. In marine mammals, the oil damages the protective ability of the skin to thermoregulate. In waterfowl, it can prevent their down feathers from keeping them warm and stop them from flying.

Preparation (setup at Amphitheater):

1. Set up two basins: fill one halfway with pure water and the second halfway with water, adding a

Appendix 4B: 1—"Pollution and the Urban River" Field Trip Procedure 3/4

splash of vegetable oil to represent motor oil.

2. Place a pre-moistened cheesecloth or other fine membraned cloth or sieve by each basin.

Procedure:

1. Have the students look at both basins. Students should note the properties of the oil. Does it sink or float on the water? Why is this? (Density)
2. Tell them that the folded cheesecloth represents the porous gills of a fish. Water should flow through it easily to allow for oxygen exchange.
3. Call up a volunteer. Tell them to hold the cheesecloth by two sides and dip the center into the pure water, and then pull it out. Students should come up and observe, noting how the water moves through the cheesecloth and does not collect on the surface or "clog the pores." (some water may remain due to hydrogen bonding)
4. Call another volunteer. Next, have that volunteer dip the cheesecloth into the bowl with the water and oil (be sure to go through the oil level. Once removed, have students come up and note the "pores" and if there is residue on the surface.

Discussion:

- If oil and water do not mix, but oil sticks to the gills of fish, how might this affect a fish's ability to breathe?
- How might an oil coating affect the ability of a bird to thermoregulate? (Cannot get warm b/c down feathers are compromised)
- A mammal? (Cannot cool off because skin's pores are blocked and excess heat cannot escape)
- Where do they think most of this oil comes from? What regulations might prevent this from happening? (ie: car inspections, illegal dumping sites, laws against pouring motor oil down drains).
- Later, tour the Daylighting Phase I park and determine the most likely sources of oil runoff in the Saw Mill River, past and present. Mark them on the map provided with a "circle" and be sure note to what they are.

PART 3: PHYSICAL WASTE (20 minutes)

Introduction: Plastic bottles, food containers, and toys take hundreds of years to fully biodegrade but splinter into pieces and remain in waterways for a long time. Fish can mistake plastic pieces for food sources and eat them. When ingested, plastic can cause a blockage in the digestive system and starve or choke the fish. Marine animals can also get caught in lost fishing line, discarded 6-pack rings, and plastic bags, which are mistaken for jellyfish underwater.

Metal cans are mistaken for fish by predator waterfowl, such as cormorants, egrets, kingfishers, and herons. While hunting, the can get stuck on aluminum cans or lacerated by their sharp edges. An aluminum can may take up to 500 years to biodegrade.

Appendix 4B:1—"Pollution and the Urban River" Field Trip Procedure 4/4

Preparation: (setup by Pedestrian Bridge)

1. Set-up 2 clear funnels on a stand and attach a red balloon to the bottom end of each.
2. Make two "fish food" containers: one with just barley, and one with barley mixed with tiny Styrofoam beads, or foam dots.

Procedure:

1. "Styrofoam is sticky! Plastics do not pass!" Talk about how Styrofoam can clog up the digestive system of an animal and leave little room for actual foods.
2. Call up a student volunteer. Ask them to pour food container #1 with just barley down one funnel. The barley should easily slide down the funnel, and collect in the balloon. Remove the balloon and pass it around. This represents the normal digestion of a fish, food passing through the stomach of a fish.
3. Call up another volunteer. Now have them pour food container #2 w/ the barley and Styrofoam beads into the funnel. The mix should get stuck to the funnel. When the flow of materials finally slows to a halt, carefully remove the balloon and pass it around. This represents the impeded digestion of a fish that has consumed too many plastic pieces. It is malnourished or starved.

Discussion:

- Why do you think marine animals often mistake plastic for food?
- Why does plastic waste starve marine animals?
- How does so much litter make its way into waterways? Hint: consider watersheds, urban infrastructure, flood events, and waste management.
- Later, tour the Daylighting Phase I park and look for areas with the highest concentration of trash both on the banks and in the Saw Mill River. Mark vulnerable areas on the map provided with diagonal lines/shading. List the types of trash spotted.

PART 4: DAYLIGHTING PARK TOUR (30-45 minutes)

Introduction: The Saw Mill River was clogged with industrial waste and raw sewage in the early 1900s. Amidst health concerns, the last 2000 feet of the river was culverted in a concrete tunnel and buried underground in 1917. This did little to prevent illegal dumping, road runoff, and trash from making its way to the mouth of the river and into the Hudson. If anything, being hidden made the water quality worse; there were no plants, decomposers, or sunlight to purify it and no way to notice what was going into it. In 2012, after a long public discussion and planning process, the Saw Mill was exhumed.

Procedure:

- Give students a map of the park and writing utensil. Working in chaperoned teams, they should locate and mark the sources of pollution discussed in Parts 1-3, and label what they find.
- Return to the Outdoor Classroom after 30 minutes to share answers.

Daylighting the Saw Mill River

A Restoration and Resilience Story in Three Phases

The Decision to Daylight

Though a movement to revitalize badly degraded surface streams in our cities and suburbs using green infrastructure techniques has gained considerable popularity, daylighting a buried river is a bit more complicated. Daylighting can involve everything from actually *locating* the hidden river channel to demolishing buildings and moving roadways. Other challenges to completing such a project include severe space constraints, raising capital (money), dealing with buried sewage lines, overcoming public fears of unsafe open waterways, and gaining enough political will.

Creating a groundswell of interest in liberating the Saw Mill River took many partners many years. After gaining approval from the U.S. Army Corps of Engineers as a valid restoration project (1992), daylighting got support from an upstart community environmental organization, Groundwork Hudson Valley (1999). Early on, the effort included tours of the river's underground flume for public officials and other interested parties, which garnered a commitment from local developers to build

Underground tour of Saw Mill River flume at Larkin Plaza.
Source: Saw Mill River Coalition

The Saw Mill River Daylighting (2/5)

A charrette to discuss daylighting plans, organized by Groundwork Hudson Valley. Source www.groundworkhv.org

housing, offices, and commercial space along the river's path. This put daylighting the Saw Mill River into a larger context: downtown waterfront revitalization. By the turn of the century, the downtown district had become overwhelmed with abandoned factories and businesses and was home to an aging population. Attracting more young residents, as well as the businesses to employ them, was key to Yonkers' future economic sustainability. Adding a new Daylighting Park seemed like a worthy investment towards that goal.

For over a decade, Groundwork Hudson Valley and its offshoot, The Saw Mill River Coalition, led the effort to exhume the Saw Mill River. With the help of Scenic Hudson, river advocates convinced New York Governor George Pataki to allot $34 million to the plan. It was important to Groundwork and its partners that the end product be something that would be shared and enjoyed by the entire community. For this reason, a Community Benefits Agreement (CBA) was established, and from 2005 through 2010 many charrette sessions were held. Funded by Scenic Hudson and the Hudson River Foundation, these roundtable discussions "involved Yonkers students, teachers, artists, community groups, businesses, and local officials as well as architects and ecologists in the planning process. Their ideas have had a major impact on the cultural, environmental, and recreational elements of the daylighting and the new park" (Groundwork Hudson Valley website). Finally, on November 15, 2011, the Saw Mill River began to flow *aboveground* in downtown Yonkers for the first time in over 90 years!

Phase One: Van der Donck Park

A view of Daylighting Phase I at Van der Donck Park. Source: PS&S

Completed in September 2012, Daylighting Phase I established an open air riverbed as part of a 13,775 square foot aquatic habitat. Instead of removing the entire concrete flume, PS&S engineers diverted the river and gave it a new channel with a more naturally-graded bank lined with a buffer of native grasses, perennial flowers, and hydrophytic trees. The old flume now serves as an overflow channel for flood

The Saw Mill River Daylighting (3/5)

waters, preventing more combined sewage overflows from occurring in this strip. At the point where the river first emerges, a netting chamber was installed to trap trash and debris that could otherwise clog or pollute the river near its confluence with the Hudson.

Restoring ecosystem services for this impaired waterway was a high priority. As such, the design included several freshwater pools and a tidal pool as habitat for larger fish, such as the American eel and carp, and a fish ladder to facilitate upstream passage for smaller fish between the pools. Riprap (rocks) and a staircase waterfall add both ambiance and life-supporting oxygen to the water as the water bubbles over, and the surrounding park space includes permeable pavers and many garden beds to serve as an emergency floodplain during storm surge events (when winds push the brackish Hudson River up into the Saw Mill). Colorful mosaics, an outdoor classroom, benches, and a foot-bridge with a sound installation add cultural and educational value to the park.

Phase Two: Mill Street Courtyard

Straddled by several dilapidated buildings and flanked by trash-strewn alleys, the whoosh of the Saw Mill River could be *heard*, but catching a glimpse of it between dips underground Mill Street was a challenge. With Daylighting Phase II, the City sought to unearth a 100-foot portion of the Saw Mill River and create an open public courtyard. However, given space constraints, the river's increased velocity through this corridor, and the presence of many active buildings, the river could not be given a natural bed. Done in the style of a "woonerf" (meaning living street) or vehicular-pedestrian street found in the Netherlands, the Mill Street Courtyard provides an accessible throughway connecting the Saw Mill River daylighting at Van der Donck Park to both New Main Street

The Saw Mill River Daylighting (4/5)

and North Broadway. Public artwork lines the walkways, including metal sculptures designed by Yonkers artist Haifa Bint-Kadi, honoring the labor force that built and defined the city in the 19th and 20th centuries. Other installations include a three-story mural ('Wildfire') painted by a Dutch artist Eelco Van Den Berg and a mirrored glass pole ('As We Reflect') - also created by Haifa—that reflect the animal and cultural diversity of Yonkers respectively. Appropriately, a 150-year old mill stone that was uncovered during construction and believed to be from the historic Yonkers Flouring Mill was also incorporated into the park. Bioswales, or cutaways connecting the paved walkway with garden beds, help to retain excess stormwater and purify runoff before it reaches the river. Phase II opened to the public in 2016.

Phase Three: Chicken Island

Source: PS&S Engineering

At the site of Phase III, the Saw Mill River makes a sharp bend from its north-south course to an east-west direction. Though already partially above ground here, the Saw Mill was initially hidden behind old storefronts and lined with crumbling retaining walls. Severe flooding during a Nor'easter storm in 2009 demonstrated the area's precarious state. As such, plans for channel restoration by "Chicken Island" were drafted even before Daylighting of Phase I was underway. The process started with the removal of the old store fronts in 2016. From 2016-2017, the river banks were reinforced with stone armor and the surrounding area was re-graded to create a flood zone and park space. In November 2018, a new 18 million dollar design by PS&S, funded by several New York State agencies and grants, was unveiled. The 1.25 acre water themed park includes a throwback to the Saw Mill's history in the form of an undershot

Source: City of Yonkers website

The Saw Mill River Daylighting (5/5)

water wheel. The water pressure needed to turn it is aided by an underwater dam-like structure called a weir. The water wheel also serves to generate electricity for the park's efficient LED lightposts. To weather 100-year flood events, a hard-engineered retaining wall and sloped riprap (rocks) hug the sharp bend in the river. The surrounding lawn, garden beds, permeable paver walkways, and plaza double as a spillover zone for extreme flood events, as well as a moderate riparian buffer. As with Phase I, buried sewage lines were separated from stormwater drain pipes to prevent overflows.

With Phase IV across the Chicken Island parking lot already in development, Yonkers Mayor Mike Spano had this to say about the ongoing work to daylight the Saw Mill River: "Yonkers is recognizing that the new generation of our workforce desires walkability, wants convenience to work, home and leisure. I believe we are accomplishing that here in Yonkers – attracting millennials with each new development and innovative project."

Only time will tell if the daylighting of the Saw Mill River will stand up to the environmental pressures that river maturation, human population growth, and climate change pose. As a bold step towards green infrastructure, urban resilience planning, and environmental restoration, it certainly has attracted developers to the region and earned global interest and praise. Though initial water quality and biodiversity studies have been somewhat promising, it is still up to Yonkers' residents and businesses to be diligent and responsible environmental stewards if we hope to preserve this waterway for many future generations. Perhaps the greatest value conveyed from daylighting the Saw Mill River is that we are forced to consider it daily—never taking it for granted.

Daylighting Education Resources*

- The Decision to Daylight
  - ◊ "Lost Rivers"—2012 movie documentary by Catbird Productions featuring the Saw Mill River Daylighting. Available at Yonkers Library
  - ◊ Daylighting: A New Life for Buried Streams—Rocky Mountain Institute/U.S. Environmental Protection Agency
- Phase One: Van der Donck Park
  - ◊ American Rivers Website—"What Exactly is Stream Daylighting?"
  - ◊ Groundwork USA Website— "Daylighting the Saw Mill River."
  - ◊ Urban Waters Learning Network - Storymaps: Green Spaces for Urban Communities, Part II—"Reclaiming Urban Waters"
- Phase Two: Mill Street Courtyard
  - ◊ PS&S Integrative Services—Mill Street Courtyard rendering
- Phase Three: Chicken Island
  - ◊ LoHud article—"Yonkers Opens New River Park Downtown" -

Field Trip Extensions

- Groundwork Hudson Valley—special tours of the Daylighting Parks (inquire with the Sustainability Education department for details) and Science Barge extension activities on urban runoff, climate resilience, and biomimicry/green design.
- Philipse Manor Hall State Historical Site—offering tours relating to the history of the Saw Mill River, Yonkers history and industrialization, and the Daylighting. See brochure for details.

Key Concepts

⇒ Daylighting refers to the process of unearthing buried rivers and removing it's culverts so they are open-air

⇒ The challenges of daylighting a stream vary by location, but can include locating the stream, removing buildings, bridges, and roadways to gain access, diverting old sewer lines, raising capital, and getting public support.

⇒ Given space constraints, available capital, flood concerns, and public access, planners must decide between a hard engineering design, green infrastructure, or a hybrid approach.

- ◊ Each phase of the Daylighting presented different engineering challenges as well as different public use options.

⇒ Daylighting the Saw Mill River at Larkin Plaza (now van der Donck park) took over a decade of convening partners, planning, preparation, and fundraising to come to fruition.

- ◊ Phase I at Van der Donck Park was completed in 2012.
- ◊ Phase II at the Mill Street Courtyard was completed in 2016.
- ◊ Phase III at Chicken Island was done in stages but completed in 2019.

Unit 5A Classroom Instruction:
Daylighting the Saw Mill River

Classroom Activity 1: Lost Rivers—Part 2

- Watch the second half of "Lost Rivers," a 2012 movie documentary by Catbird Productions about disappeared waterways around the world featuring the Saw Mill River Daylighting. Full run time: 72 minutes
    - Available for purchase, or streaming at Docuseek with registration.
    - Teacher background for film found here: https://misc.icarusfilms.com/press/pdfs/lr_pk.pdf
- Have students form debate teams, taking different community stakeholders positions for or against daylighting the Saw Mill River. Stakeholders in favor of the daylighting plan include:
    - New developers who believe the project might attract new residents and shoppers to the area.
    - Environmentalists who champion the improved water quality and habitat expansion they hope will result from project.
    - Residents in favor of new greenspace and parks.
    - City officials who believe green infrastructure is the resilient city planning of the future.
- Stakeholders opposed to the daylighting plan include:
    - Current local business owners who are afraid they will lose customers during construction or from lack of parking.
    - Local residents who are concerned about noise and increased rents or taxes.
    - City officials who believe hard engineering is a safer, less expensive option with fewer variables to consider.
- After debating the pros and cons of Daylighting, have students draft a plan that takes *all* stakeholders into consideration.

Classroom Activity 2: Blue Design Challenge

- Watch this video of the 2007 Noreaster's impact on the Saw Mill River at Chicken Island. https://youtu.be/oYFigHl7IVY
- Optional: Video slideshow of Chicken Island from 1930s-2018 Daylighting. https://www.youtube.com/watch?v=qi6chCi7Dlg
    - Video slideshow of Daylighting the SMR at Mill Street before and after (2008-2018)
    - Video slideshow of Daylighting Phase I of the SMR/Nepperhan at Larkin Plaza (2008-2012) https://youtu.be/kX8vb9Qkx78
- Cut out scenarios from Appendix 5A:1 and place them in a container. Have teams of students select 1 scenario and work together to solve the engineering challenge, sketching their plan or design.

KEY TERMINOLOGY

- **Daylighting** A process of removing obstructions that cover a river or drainage way to restore it to either its natural or open-channeled state.
- **Green Design** The philosophy of designing objects, systems, and infrastructure with the goal of mitigating or eliminating negative environmental impact.
- **Urban Resilience** The capacity of a city, its systems and its inhabitants to recover quickly from shocks and stresses and adapt to change sustainably.
- **Renewable Energy** A power source that is not depleted when used, such as wind or solar power
- **Weir** An underwater barrier constructed to regulate water pressure downstream. Can be narrow or broad crested.
- **Retaining Wall** A concrete and/ or stone structure that holds back earth or water.

Appendix 5A:1 —"Blue Design Challenge"

Scenario 1

A major parkway and important commuter thruway hugs the course of the Lotic River for several miles. More powerful storms are increasing the frequency of floods along the natural river, leading to road damage, vehicular accidents, and excessive traffic. There is no buffer between the river and the parkway, but the area adjacent to the far side of the parkway is undeveloped.

Using green infrastructure principals, design a solution to flooding along the Lotic River.

Scenario 2

An open-air river in Little Town is constantly flagged as an impaired waterway due to excessive counts of fecal coliform—a dangerous bacteria. This is worse after heavy rain events, keeping fishers and recreational visitors away. The combined sewage system of Big City, which is just upriver, is the likely culprit.

Find a collaborative solution between Big City & Little Town to improve water quality and make it safe for recreational use and wildlife again.

Scenario 3

An old industrial city, Sleepyville is home to many abandoned factories and in need of a new boost to attract businesses and residents to the area. An idea to daylight the buried Invigorate River has been floating around for decades in the hopes it will bring tourism and new families to Sleepyville. The river has several sharp bends in its culvert and can have a high flow rate.

Design a daylighted portion of the Invigorate River that is safe but attractive to new residents.

Scenario 4

The Abundance River used to be rich with biodiversity and home to the anadromous American Eel and catadromous shad fish. Several dams and weirs along the urbanized portions of the river prevent migratory passage for these species and more. The riparian zone is also compromised with invasive vines that choke out the native trees and shrubs.

Create a plan/design that will restore the ecosystem functions of the Abundance River.

Scenario 5

The Pristine River is not living up to its name. Sandwiched between streets and buildings, it is full of trash, dog feces, and vehicle runoff, such as oil that have seriously compromised the water quality. The storm drains that empty in to the river are seemingly always clogged with debris.

Using at least one green infrastructure idea, create a plan/campaign that will increase awareness about river pollution and reduce the amount of waste making its way into the Pristine River.

Scenario 6

Channeled by a concrete floor and walls, the Forgotten River is often neglected by the people of Busy Village. Without eyes on the river, it has become vulnerable to illegal dumping or source-point pollution. The walls around it are also beginning to crumble and need to be replaced, or the river banks may begin to erode.

Using at least one hard engineering and one green infrastructure method, design a plan to re-channel the Forgotten River & discourage illegal dumping.

Unit 5B Field Trip Activities:

Daylighting the Saw Mill River

Field Trip Activity 5B:1—Green Engineering Tour of Daylighting

Start students at either Van der Donck Park, the home of Daylighting Phase I, *or* Chicken Island, the home of Daylighting Phase III. Working in chaperoned teams, students will walk through one, two, or all three Daylighting parks, depending on time. Each area should take about 30-45 minutes to answer all questions on the worksheet, with 10 minutes of walking time between sites.

- Each team should receive a clip-board, map of the parks, and the 3 Green Engineering worksheets with fill-in-the-blank questions.
    - Use Appendix 5B:1a for Phase I, Appendix 5B:1b for Phase II, and Appendix 5B:1c for Phase III.
    - Students should look for the interpretive signs in each park to find the answers to questions.
- Alternative: Book a tour guide for this activity by contacting Groundwork Hudson Valley.

"Our 'lost rivers' and other lost natural resources--in it's rebirth --can save our cities and make them sustainable and livable again. Nature is a powerful ally and needs to be unleashed again in these very dense post-industrial cities, helping create more walkable community plazas, encouraging activities. Reconnecting people to their rivers is magic." ~Ann-Marie Mitroff, environmentalist.

Green Engineering at the Daylighting Tour Questions—Phase I, Van der Donck Park

1) By 1892, the river had become so polluted with human and industrial waste, they began to take down the dams and mills and fill parts of it, for fear of an outbreak of this disease: _____

2) The last stretch of the river, near its confluence with the Hudson, was encased in a concrete _____ by the City of Yonkers (1917-1922) and then paved over, creating a parking lot and small park, called Larkin Plaza.

3) A _____ _____ is an area of deeper water to allow the daily ebb and flow of saltwater from the tides while mitigating flood risks.

4) Both the American eel and the alewife are Saw Mill River "signature species." This device was built to allow these fish to migrate up and downstream, providing places to rest between "jumps." A: _____ _____

5) If someone throws a plastic water bottle along the South County Trailway in Hawthorne, NY it will eventually wash down the Saw Mill to Yonkers and out to the Hudson River. That is why a _____ chamber was installed to trap garbage. A _____ allows fish to pass through the chamber, unobstructed.

6) Riffles of jumbled rocks and narrowing of the river create turbulence which add _____ to the water.

7) The old flume was left intact after the river was daylighted, serving as what type of storm-water system to ensure that when it rains, no sewage goes into the river? A:_____

Green Engineering at the Daylighting Tour Questions—Phase II, Mill Street Courtyard

1) According to the map at the Mill Street Courtyard entrance, approximately what percentage of the Saw Mill River still remains buried downtown? (visually estimate using the map and key) A: _____%

2) At this Mill Street location, in the late 1800s, P. F. Peek Yonkers Flouring Mills drew water power from _____ _____ that were created by dams or weirs to create more water pressure.

3) Though daylighted, the Saw Mill River remains channeled by concrete and stone at Phase II. Observe the river from the bridge. Compare how it flows here to the more nature river bed in Phase I at Van der Donck Park.

A:_____

_____

What factors contribute to this difference?

_____

_____

4) The Mill Street Courtyard features two methods to reduce stormwater runoff from polluting the river. Considered "green infrastructure," the _____ _____and the _____ act as bio-filters.

5) During the daylighting project, old _____ pipes were discovered that still discharged waste into the river. By fixing these pipes during daylighting construction, water quality was improved. If left untreated, _____ (same as above) can contribute to eutrophication, or nutrient loading of our waterways.

Green Engineering at the Daylighting Tour Questions—Phase III, Chicken Island

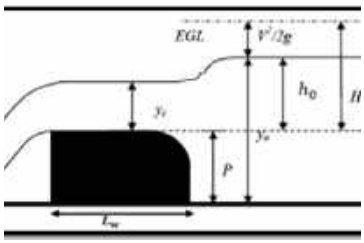
1) How does precipitation infiltration percentage differ in a natural environment versus a developed environment? _____% pre-development. _____% post development.

2) A throwback to the use of water energy to power saw mills and grist mills along the Saw Mill River, this feature was installed to provide electricity that runs park lights at night— working even in low velocity current. (3 words)
A: _____ _____ _____

3) Name two challenges that traditional urban design has presented for managing the urban river, and one that climate change presents:

a. _____
_____
b. _____
_____
c. _____

4) During industrialization, the Saw Mill River's path was altered via a channel that hooks sharply by Yonkers Avenue and New Main St. With the old retaining wall beyond repair after years of erosion and flooding still a concern, a higher concrete wall was installed with the sloping lawn and plaza serving as a small _____ buffer.



5) To ensure sufficient base flow to the water wheel (40 cfs), engineers diverted flow to a narrow channel that passes over a *weir*. A weir is a _____-like underwater barrier that creates more water pressure by letting water back up behind it.

Green Engineering at the Daylighting Tour Questions—Phase I, Van der Donck Park

1) By 1892, the river had become so polluted with human and industrial waste, they began to take down the dams and mills and fill parts of it, for fear of an outbreak of this disease: __Cholera___

2) The last stretch of the river, near its confluence with the Hudson, was encased in a concrete __flume__ by the City of Yonkers (1917-1922) and then paved over, creating a parking lot and small park, called Larkin Plaza.

3) A __tidal___ __pool_____ is an area of deeper water to allow the daily ebb and flow of saltwater from the tides while mitigating flood risks.

4) Both the American eel and the alewife are Saw Mill River "signature species." This device was built to allow these fish to migrate up and downstream, providing places to rest between "jumps." A: ___fish_____ __ladder_____

5) If someone throws a plastic water bottle along the South County Trailway in Hawthorne, NY it will eventually wash down the Saw Mill to Yonkers and out to the Hudson River. That is why a ____netting____ chamber was installed to trap garbage. A ____special channel_ allows fish to pass through the chamber, unobstructed.

6) Riffles of jumbled rocks and narrowing of the river create turbulence which add ____oxygen____ to the water.

7) The old flume was left intact after the river was daylighted, serving as what type of storm-water system to ensure that when it rains, no sewage goes into the river? - A:___sanitary sewage system OR separate sewer system_____

Green Engineering at the Daylighting Tour Questions—Phase II, Mill Street Courtyard

1) According to the map at the Mill Street Courtyard entrance, approximately what percentage of the Saw Mill River still remains buried downtown? (visually estimate using the map and key) A: _____60_____%

2) At this Mill Street location, in the late 1800s, P. F. Peek Yonkers Flouring Mills drew water power from ___mill___ __ponds_____ that were created by dams or weirs to create more water pressure.

3) Though daylighted, the Saw Mill River remains channeled by concrete and stone at Phase II. Observe the river from the bridge. Compare how it flows here to the more nature river bed in Phase I at Van der Donck Park. A:___The flow rate__ is much greater, the river is faster and more forceful.__ What factors contribute to this difference?

__The channel is narrow, straight, and smooth, so there is not friction from rocks and bends to slow it down.__

4) The Mill Street Courtyard features two methods to reduce stormwater runoff from polluting the river. Considered "green infrastructure," the _permeable_ __pavers_____and the ___bioswales_____ act as bio-filters.

5) During the daylighting project, old _sewage_____ pipes were discovered that still discharged waste into the river. By fixing these pipes during daylighting construction, water quality was improved. If left untreated, ___sewage_____ (same as above) can contribute to eutrophication, or nutrient loading of our waterways.

Green Engineering at the Daylighting Tour Questions—Phase III, Chicken Island

1) How does precipitation infiltration percentage differ in a natural environment versus a developed environment? ____50___% pre-development.
_____15_____% post development.

2) A throwback to the use of water energy to power saw mills and grist mills along the Saw Mill River, this feature was installed to provide electricity that run park lights at night—working even in low velocity current. (3 words)
A: ____undershot____ ____water_____ ___wheel_____

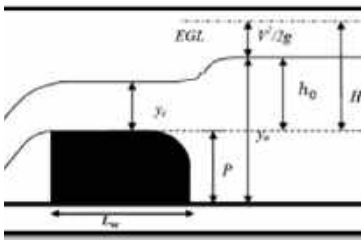
3) Name two challenges that traditional urban design has presented for managing the urban river, and one that climate change presents:

a. Too many impermeable surfaces=poor rainwater infiltration_____

b. Straightened, channeled rivers flow faster and cause more erosion/destruction__

c. warmer climate = more evaporation and heavier rain = more flooding

4) During industrialization, the Saw Mill River's path was altered via a channel that hooks sharply by Yonkers Avenue and New Main St. With the old retaining wall beyond repair after years of erosion and flooding still a concern, a higher concrete wall was installed, with the sloping lawn and plaza serving as a small ____floodplain OR riparian_____ buffer.



5) To ensure sufficient base flow to the water wheel (40 cfs), engineers diverted flow to a narrow channel that passes over a *weir*. A weir is a _____dam_-like underwater barrier that creates more water pressure by letting water back up behind it.