Urban Watersheds
Water Quality in Allegheny County Pennsylvania
Ecology and Environmental Education
Reference Materials for Teachers
Grade 7 - 10 - 12

3 Rivers 2nd Nature
STUDIO for Creative Inquiry,
Carnegie Mellon University
Pittsburgh, PA

3 River 2nd Nature
Ecology and Environmental Education Reports
Phase 4 - 2004

Urban Watersheds / Water Quality in Allegheny County
Ecology and Environmental Education Report
Reference Materials for Teachers
Grade 7 -10 - 12

An Educational guide with curriculum materials
JoAnn Albert
Reiko Goto

Field studies, analysis and reports
Kathy Knauer
Mike Koryak
Linda Stafford

Classroom Activity: Interpreting Water Quality Data
Sasha Ottoson-Deal
Classroom Activity: Monitoring Our Watershed
Andrew Lee
Katherine Aerni

Source Materials:
3 Rivers 2nd Nature
STUDIO for Creative Inquiry
Carnegie Mellon University

Table Contents

3 Rivers 2nd Nature Education Program

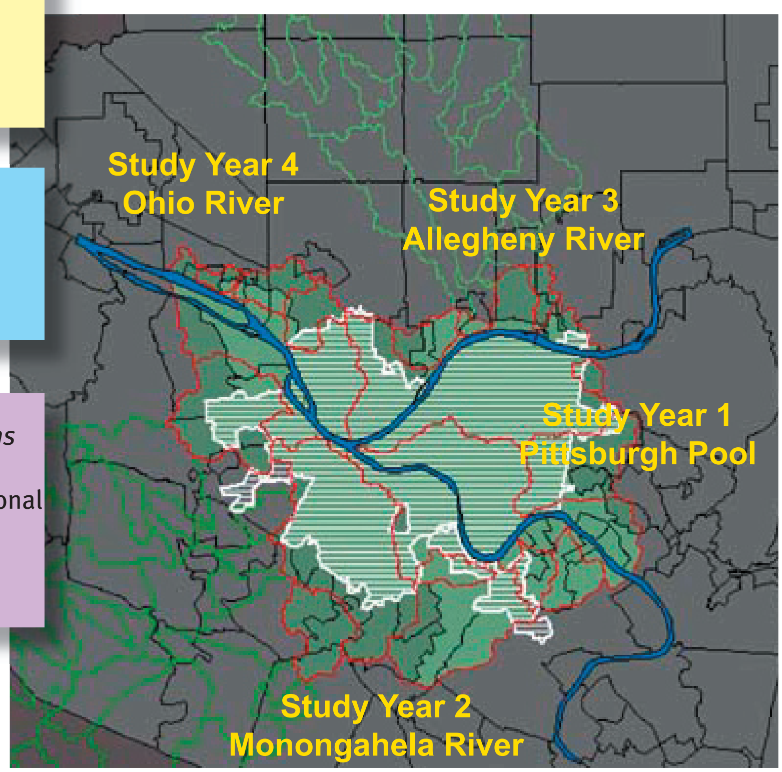
What is the 3 Rivers 2nd Nature Project?

3 Rivers 2nd Nature (3R2N) is an environmental study of the Allegheny River, the Monongahela, and the Ohio Rivers, and their adjacent riverbanks in Allegheny County Pennsylvania. There are 53 streams and 221 sub watersheds in our study area. We are partnered with 3 Rivers Wet Weather Inc. (3RWW). 3RWW works to resolve the gray infrastructure problems of our sewers while 3R2N works to illustrate the green and blue infrastructure opportunities of our rivers ecological systems. This project is funded by the Heinz Endowment as a five year study and is managed by the two full time research fellows Tim Collins and Reiko Goto at the STUDIO for Creative Inquiry, Carnegie Mellon University. The team consists of artists and collaborators in the natural sciences, history and design with university students. An educator JoAnn Albert has reviewed reports on water quality then she adapted and applied our research to a grade school educational context. JoAnn's work was able to weave many complicated issues together as one educational component; 3 River 2nd Nature study, background information, water quality testing standards, education standards, and classroom activities. We are prepared to develop educational materials on other components.

The primary research areas are:
- Water Quality in streams an rivers, Environmental Science and Biology
- Bank conditions along rivers, Botany and Geology

The secondary research areas are:
- History of Public / Private Uses of the Rivers

Community design and outreach programs include:
- River Dialogues to plan future recreational use of the rivers.
- An Education Program called "Urban Watersheds"



What is the education component in the project?

During the spring and summer members of the terrestrial and aquatic science teams spend time on the rivers doing field work collecting data. We analyze the data, create maps, graphs and other visual supplements, and produce what we call strategic knowledge, knowledge that helps us all understand the rivers in new ways. We organize community based workshops called river dialogues. The documentation of our activities are distributed on the internet Web site http://3r2n.cfa.cmu.edu. One of the most important communities we work with consists of educators, teachers and their students. We would like to create new information to help middle school and high school students understand our rivers from the past to the present, as opportunities rather than constraints. Through our program, we hope to provide tools and experiences for teachers, school children and families interested in participating in creating a living rivers vision for the future.

The Urban Watersheds educational guide and curriculum materials consists of three parts.

1) Urban Watersheds / Brownfield (year 2000)
2) Urban Watersheds / Water Quality (year 2002)
3) Urban Watersheds / Terrestrial (under development)

Urban Watersheds / Brownfield was developed during work on the Nine Mile Run Greenway Project. It is based on a single watershed, water cycle, water quality, soil and vegetation. The modules refer to grade between 7 and 10. The modules and activities were developed and tested in some public schools. Learning how each sub-watersheds and their tributaries function ecologically, and how they are affected by human activities mean understanding our rivers. The text is distributed on the internet, http://3r2n.cfa.cmu.edu/education/module.html

This Urban Watersheds / Water Quality educational guides was developed during the 3 Rivers 2nd Nature project. The topic corresponds with the new Pennsylvania education standards for grades 7 through 12. Our goal is to develop methods and information specific to the water quality problems and opportunities of this region. In this report we have addressed a brief local history, current conditions, water testing, and water testing standards. In the final chapter of this report, we introduce activities that include observation of a sub-watershed, testing local streams, and research approaches to local sub-watershed areas. In the near future we will demonstrate the activities in teacher training workshops.

The mission and goals of the education program?

Our goals are specific, we seek to:

- Integrate education into all aspects of the 3R2N project, by developing a pedagogical philosophy and method for the project.
- Make 3R2N studies and methods relevant to school teachers, and educators.
- Adapt and apply 3R2N studies and methods to interest and involve grades 7-12.
- Integrate 3R2N studies with the teaching environment and its standards.

- Teach concepts and methods that help us to care for, and nurture the natural environment.
- Share and reflect upon children's voices, and what they think about the rivers and their environment.
- Provide the knowledge, tools and experience that allow teachers, children and their families to participate in creating a vision for the future of the three rivers.
- Promote the idea that nature occurs in an urban setting, and we can choose to either ignore it or nurture it with either negative or positive effect.

Why water quality in urban watershed?

Three rivers: the Allegheny River, the Monongahela River, and the Ohio River define our region. Water quality is not only important for fishing or boating in a public places, but rivers are also the defining public-space element of our urban environment. The simple fact is that we have 90.5 miles of rivers and 2024 miles of streams in Allegheny County. Measuring, water quality in terms of physical chemistry, the ability to support life, in terms of biology to know what life is in the rivers, and in terms of pathogen indicators the affect of cities and sewers on rivers tells us how well we are caring for historic waters of the region. Water is always nearby, it is an essential element of the quality of life in our region. Water defines of our daily life and our travels.

Between the end of 1800's and the 1980's, industry and municipalities used the rivers as sources of water and as sinks for waste. Pollution was a way of life, some believe that it was a fair price to pay for a successful economy. Today, most of the mills have closed and nature has begun to restore herself. But pollutants from cities still impact the rivers. Today, rivers are very clean in dry weather and become sewers when it rains. (Streams are less improved in all weather conditions.1)

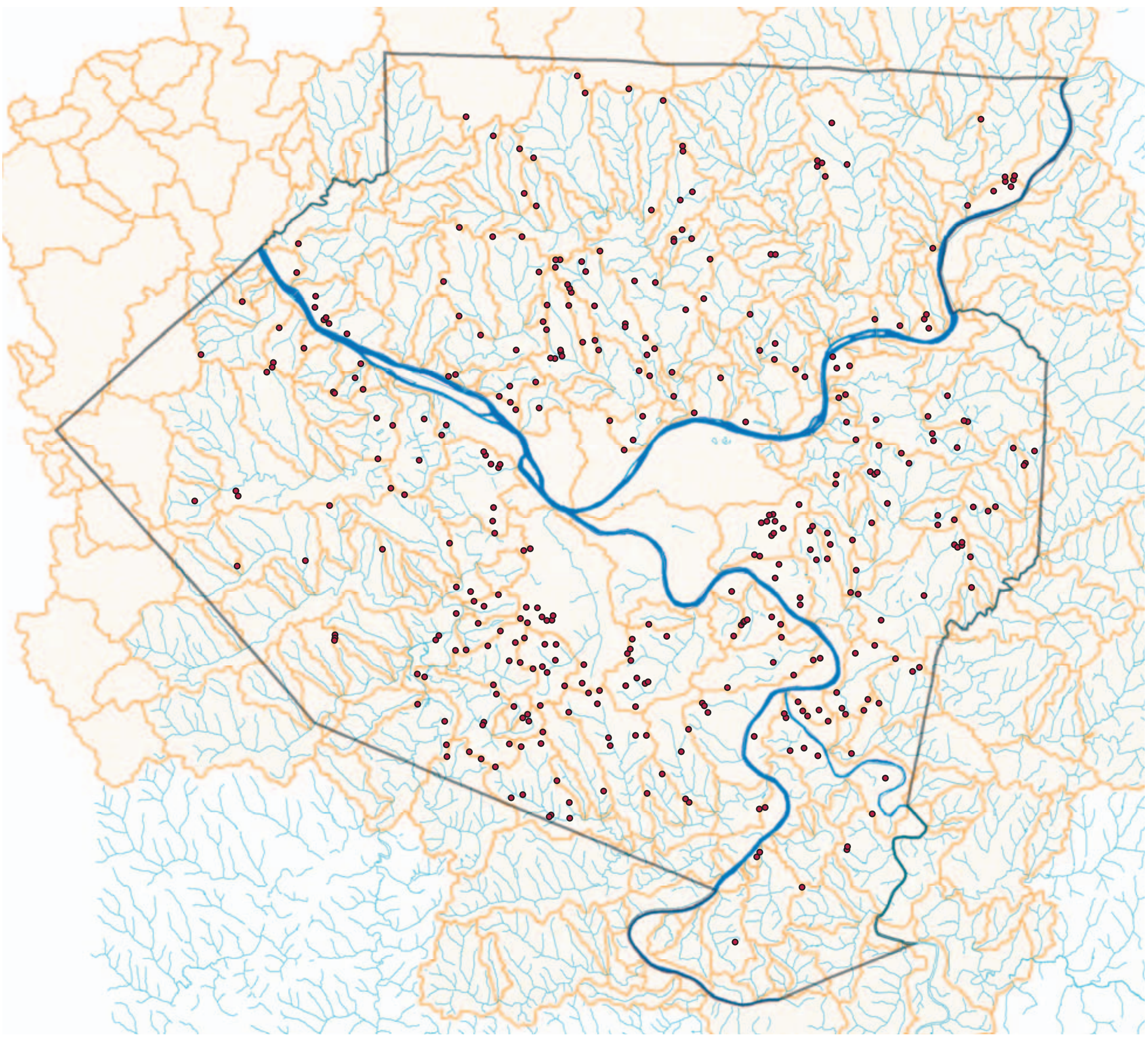
Human health and ecosystem health and water quality are all intertwined. That is why the Allegheny County Health Department issues CSO warnings (Combined Sewer Overflow) warnings each year during the recreational season. But we should all be able to understand the basic idea about water quality. When you think about the water quality in a river or stream, we suggest there are five important questions. First, does it look or smell clean? Second, can it support life? Third, is life in the body of water diverse? Fourth, does fecal mater affect the body of water? Fifth, do industrial pollutants affect the body of water? Casual observations can lead to identification of a source of pollution, but can only identify the type of pollution if a qualified water quality team is available to go on the water, take the appropriate samples and get those samples to an appropriate laboratory. We must all participate to achieve clean water.

Often our project has been asked by young people how they might get involved to to save and care for our rivers. The answer is we must all begin to understand the dynamic nature of our rivers and their relationship to the range of pollutants that wash off our streets and lawns as well as the problems that occur in older communities with combined sewer systems. Any student in Allegheny County can make a considerable contribution to what we need to know about water quality, by monitoring water quality in strategic stretches of streams throughout our region. Saving our rivers could start from one school monitoring any one of the 56 tributaries and sub-watersheds in Allegheny county. For more information about a strategic approach to water quality study of our regional streams see the following text, which is also available on the internet. http://3r2n.cfa.cmu.edu/Year4/reports/aquatic/stream/index.htm

-

(Footnotes)

[1] Finding of 3 Rivers 2nd Nature, water quality study in years 1, 2 and 3. See the water quality reports on 3r2n.cfa.cmu.edu.



This is the map of Allegheny county. There are about 53 streams and 221 sub watersheds. The red dots are school locations.

The confluence of the three rivers: the Allegheny, the Monongahela, and the Ohio River. The name "Monongahela" probably came from the Delaware Indian tribe, the name translates to "high banks breaking off and falling down to places." Allegheny is derived from the dialect of the Seneca Indian tribe, a remnant of whom are still living on the headwaters of the river. The word "Allegheny" signifies "fair watr." As the Indian word "Ohio," in other dialects, also means "fair water," it is thought that the one was merely the translation of the other, and that aborigines considered the two rivers to be, as in fact they are, one and the same stream.

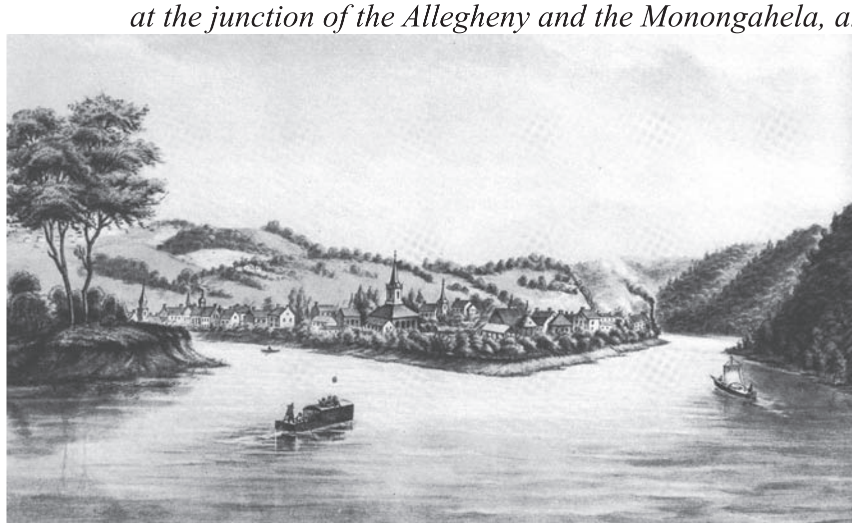
I. History of Pittsburgh's Riverfronts

Pittsburgh's greatest natural assets are its rivers. Throughout the city's history, the Allegheny, Monongahela, and Ohio River have played a contradictory role. While functioning as an aesthetic and recreational resource, they have also been the center of our region's commerce, transportation, and industry. Settlers and entrepreneurs built Pittsburgh at the confluence of the three rivers to take advantage of its military and commercial potential, while at the same time taking civic pride in this distinctive natural resource.

Pre-industrial visitors to the area were overwhelmed by what they saw. An eighteenth century British army captain named Harry Gordon described the confluence of the three rivers as "*the most healthy, the most pleasant, the most commodious, the most fertile spot of Earth known to European people.*" French explorers called the Ohio "*la belle riviere*" or "*the beautiful river*" and early explorer, Zadock Cramer went a step further and called it "*the most beautiful river in the universe.*"

Half a century later, in 1836, another visitor to Pittsburgh painted a very different picture. Peregrine Prolix published the following account of the area now called the Point:

> *Pittsburghers have committed an error in not rescuing from the service of Mammon, a triangle of thirty or forty acres at the junction of the Allegheny and the Monongahela, and*



Pittsburgh in 1817
Courtesy J. Mellon & Sons.

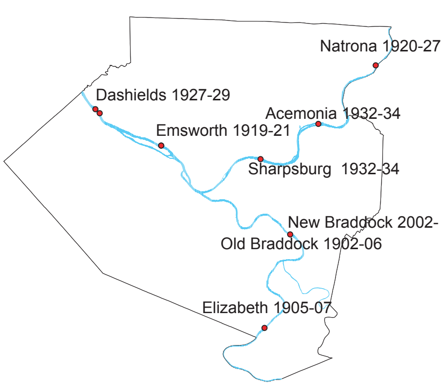
The Emsworth Locks and Dam.

unparalleled position for a park in which to ride or walk or sit…it is a spot worthy of being rescued from the ceaseless din of the steam engine and the lurid flames and dingy smoke of the coal furnace.

Pittsburghers had put their natural river resources to economic use from a very early date. By the early 1800's, the rivers supported the industries of cotton milling, glass manufacturing, coal and iron production, and boatbuilding. By 1811 steamboat building was one of Pittsburgh's major industries. The rivers provided a source of water for factories, transportation for industrial products, and a method to carry away their wastes.

At first, commercial use was limited by fluctuating water levels. In summer months and times of drought, the depth of the Ohio could be measured in inches and boats could run aground in the Monongahela. Dams were required to manage water levels and maintain a navigable channel. In the 1840's six privately owned toll locks and dams operated on the Monongahela. After Congress passed the Inland Waterways Improvement Act in 1824, the U.S. Army Corps of Engineers was charged with keeping the Ohio navigable. Construction of the first lock and dam on the Ohio began in 1878 at Davis Island. In 1897 control of the lock and dam system on the Monongahela was also handed to the Corps. By 1904 the Monongahela became the first American river that was completely navigable and by 1929 the entire Ohio was also canalized, turning both rivers into a series of slow moving pools.

It was during the Civil War that Pittsburgh industry really boomed. Its blast furnaces produced nearly 40% of the nation's annual iron output by 1870. Massive railroad yards lined the Ohio and Monongahela. By 1902 two railroad yards covered much of the lower Point. Smoke from the stern-wheelers and side-wheelers, from the ironworks, blast furnaces, and glass factories encased the river valleys and gave the city a reputation as the nation's dirtiest. According to one reporter, it looked like "hell with the lid off."



The location of the Pools and Lock and Dams in Allegheny County. The numbers indicate the construction dates.

During the mid-1870's to the 1930's Pittsburgh was one of the world's leading industrial centers. Historian Roy Lubove described the turn-of-the-century riverbank environment as follows:

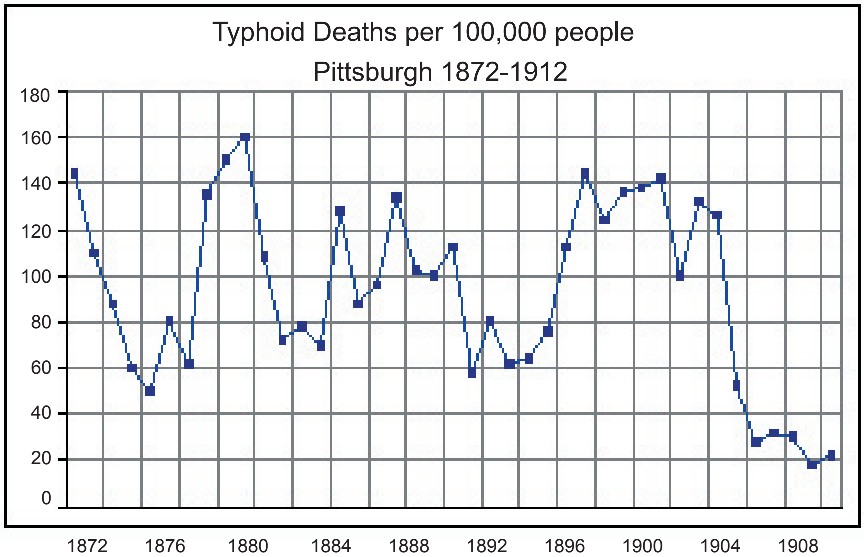
Most of the flatland fronting all three rivers was pre-empted by industrial and commercial enterprises. The desecration *of a superb natural environment – one of America's most spectacular in its combination of water-breaks, topography, and verdure – was total.*

Untreated municipal and industrial waste, mine drainage, and other pollutants lead to poor water quality and epidemics of waterborne disease. The conflicting uses of the river became deadly. Pittsburgh not only drew its water supply from the Allegheny and Monongahela, but discharged untreated sewage in them as well. Of the nation's large cities, Pittsburgh had the highest death rate from typhoid fever. From 1899 to 1907, the city had 130 deaths per 100,000 people, while the average for northern cities was 35 deaths per 100,000 people. This concentration of water and air pollution along the city's rivers, played a direct role in the suburbanization of Pittsburgh. Only those too poor to leave, and unable to afford daily public transport to their place of work, remained along the riverbanks in grungy, crowded housing.

In 1907 the city installed sand filters and began to chlorinate drinking water supplies and the typhoid rates began to drop. However, while treating its drinking water, the city continued to dump untreated sewage and industrial waste into the rivers. In 1948 less than 2% of the discharges to the Ohio River received any treatment at all. The Monongahela had no fish and ran red with acid mine drainage, steel mill effluent, and other pollutants.

World War II left Pittsburgh worn and dirty and in desperate need of a new image. Faced with declining industrial

On the new Beechwood Boulevard: one of the splendid views of Homestead and up the Monongahela River.



production, officials realized that to avoid a massive loss of population and industry, the Smoky City would need to clean up. Pittsburgh had entered the Renaissance period. City officials worked together to tackle smoke control and flooding issues, development of the Golden Triangle, and river clean-up.

Toward the end of the 1960's the Renaissance slowed. While building development continued along the riverfronts, the architecture did not allow for views of the rivers. Roads that were constructed to direct traffic around the city effectively cut off access to the rivers from downtown. The diversity of fish in the Ohio was at an all time low. Although major development projects were underway, the rivers were still suffering.

As steel and other heavy industries continued to decline, the city focused on attracting new types of business. The introduction of secondary sewage treatment and regulation of industrial discharges greatly improved water quality. By 1973 at least sixteen species of fish had returned to the Monongahela and today, there are more than fifty species of fish in the river. A second Renaissance in the 1980's worked on revitalizing neighborhoods, improving the quality of water and sewer lines, and reclaiming the city's natural assets. Efforts began to beautify the waterfronts and bring recreation back to the rivers. By this time 1980's Pittsburgh's image had improved enough to be named *America's Most Livable City* by Rand McNally.

Efforts to improve the waterfront continue, as people realize that the economic, cultural, and recreational value of the rivers is directly linked to their environmental health. Today, a new riverfront development plan focuses on bringing people back to the rivers by improving public access and adding green spaces along river edges.

Pittsburgh's identity has always been tied to its rivers and both city and rivers have undergone many changes. Decisions affecting the rivers will require balancing environmental quality with economic and recreational development. If the rivers decline, the economic vitality and quality of life in Pittsburgh will also decline.

There were eighteen-rowing clubs between 1850 -1870 in Pittsburgh.

II. Urban Watersheds

Streams and Rivers

Streams and rivers are dynamic, ever-changing ecosystems. The diverse habitats found in or near a stream shelter distinct communities of plants and animals adapted to different conditions. Stream edges are frequented by many species, each with their own needs. Deer stop to browse or drink, kingfishers make burrows in the bank to nest, and salamanders hide in the leaf litter. Organisms living within the stream can have very specific needs. Many stream dwellers need specific oxygen and temperature requirements, vegetation and tiny animals to eat, and overhanging trees or submerged rocks and logs for shelter and reproduction. Vegetation along a stream's bank plays an important role in providing and maintaining appropriate habitat. It not only provides food and shelter to these creatures, it also cools the water with shade, filters pollutants, prevents erosion and slows flow during storms.

Streams and rivers also provide people with sources of drinking water, irrigation, transportation, cooling and supplies for industries, fishing, boating, swimming, and aesthetic beauty. However, human activities alter many natural stream characteristics. Over the last century many waterways have been dammed, channelized, and dredged to accommodate shipping and other commercial purposes. They have been used as sinks to dispose of sewage and industrial wastes. Removal of riparian vegetation and construction of impermeable surfaces like parking lots have increased runoff and added pollutants. While people have been the primary cause of these degradations to waterways, we can also take responsibility for protecting and restoring them.

Watersheds

A stream's health is dependent on the health of its watershed. Events within a watershed affect a stream's flow, shape, chemistry and biology. A watershed is the area of land from which runoff (from rain, snow, and springs) drains to a stream, river, lake, or other body of water. Its boundaries can be identified by locating the highest points of land around the waterbody. Streams and rivers function as the "arteries" of the watershed. They drain water from the land as they flow from higher to lower elevations. A watershed can be as small or as large as you care to define it. This is because several watersheds of small streams usually exist within the watershed of a larger river.

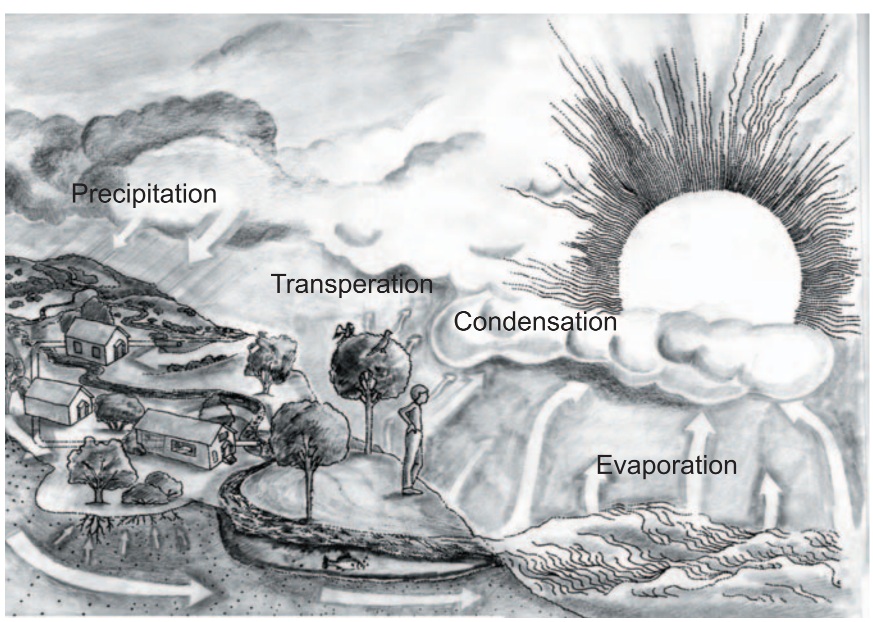
The Water Cycle

Individual watersheds are linked by the water cycle. The water cycle is the movement of water through the environment. It is through this movement that water in river systems is replenished. The main processes involved in the water cycle are evaporation, transpiration, condensation, and precipitation. The interactions between the water cycle, soils, and watershed define the natural water flow (hydrology) of any particular stream.

Natural Watersheds

When precipitation falls in a natural (undeveloped) watershed in the Mid-Atlantic States, about 40 percent will be returned to the atmosphere by evaporation or transpiration. Ninety percent of the water a plant takes up is released through transpiration.

Water reaching the ground will remain on the surface or be absorbed into the soil. Surface water will eventually run off into streams or lakes. Since the rainfall does not enter the waterway all at once, it helps prevent flooding. Water entering the soil may reach the ground water and ultimately discharge into the stream as a spring or seep. Ground water discharges to a stream are defined as its baseflow. At times when there is no surface runoff, the entire flow of a stream might be baseflow from ground water.



A water cycle diagram

Developed Watersheds

In developed watersheds, much of the vegetation and soils are replaced by impervious surfaces, such as parking lots, streets, and sidewalks. The rainfall that used to be absorbed by the soil, now travels along surface channels and into sewers.

Under these conditions less precipitation returns to the atmosphere, because it is quickly carried away from developed areas and is not allowed to stand in pools. Also, since natural vegetation is replaced by buildings and pavement, plants return less precipitation to the atmosphere through transpiration. Less water percolates through soil to the ground water, which can result in a lower water table and can affect baseflow. During storms, surface runoff increases and intensifies streamflow.

Impervious surfaces typically cover 40% or more of an urban watershed. Studies have shown that when the amount of impervious surfaces within a watershed reaches 10%, it results in stream channel instability and declines in aquatic biodiversity.

Urban streams

Urban streams and rivers seem to have a characteristic chemical makeup or "signature" that is different than those found in agricultural or other areas. The U.S. Geological Survey's National Water Quality Assessment (NAWQA) shows that in urban areas volatile organic compounds (VOC's) still occur widely in groundwater and streams have higher concentrations of total phosphorous, insecticides, and trace elements, such as lead and zinc. (Volatile Organic Compounds (VOC's) are organic chemicals that easily form vapors at normal temperature and pressure. This term is generally applied to organic solvents, certain paint additives, aerosol spray can propellants, fuels (such as gasoline, and kerosene), petroleum distillates, dry cleaning products and many other industrial and consumer products ranging from office supplies to building materials.)

Local streams and rivers in Allegheny County can suffer from a number of problems including:

- Acid mine drainage from past coal mining
- Leaking sanitary wastes from old and poorly maintained sewer systems
- Combined sewer overflows (CSO's)
- Deicing chemicals from airports and highways following winter thaws
- Filling, channelizing, and culverting

Many "CAUTION" signs are seen along urban streams.

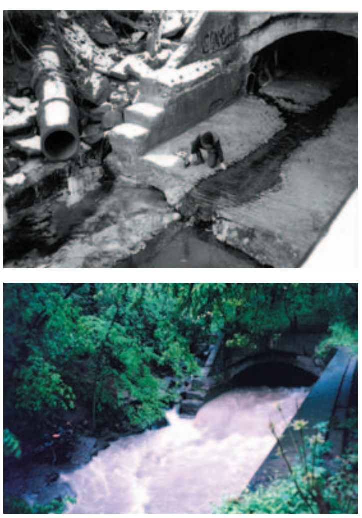
- o Lack of water in dry-weather from extensive drainage activities
- o Sudden storm surges from impermeable urban surfaces, such as parking lots.
- o Leaching alkaline materials from steel mill slag and road construction materials

Urban Runoff

Water runoff from impervious surfaces can carry significant amounts of pollutants, including fertilizers, oil, litter, animal waste, heavy metals, and pesticides. In the summer months, storm runoff from heated roads and parking lots can cause rapid increases in stream temperature that can kill fish. In winter months, runoff of sand and salt used to remove snow from roads can also contaminate streams. This runoff often goes directly into waterways.

In this area, leaching alkaline materials were a major urban signature in the water. The local geology includes formations of sandstone, shale and claystone with thin beds of coal and limestone. Water passing over exposed rocks becomes slightly acidic and mineralized, primarily from calcium sulfate. In urban area, cement, steel mill slag, and crushed limestone which are commonly used in parking lots and road construction contribute alkaline and calcium sulfate substances in local urban waters.

In winter months, another runoff problem affecting local waterways is deicing salts. The Pittsburgh area is located in a very hilly "ice belt," where salt is often used to melt icy roads. After a winter thaw, runoff from roads and parking lots can produce high salinity concentrations that result in osmoregulatory problems for susceptible aquatic organisms.


The photo [top] was taken in dry weather. The photo [bellow] shows the destructive flows at the same place in wet weather. Many urban streams suffer because of the impervious pavement and culverted tributaries.

Sewer Overflows

Water runoff that is channeled into sewers can enter either separated or combined sewer systems. While these systems help to prevent flooding of roads and parking areas, there can still be problems for waterways. (Figure 2-a)

Separated Sewer Overflows

In a separate sewer system, sanitary wastes (from toilets, washers, and sinks) are carried through sanitary sewers to a wastewater treatment plant. Separate storm sewers carry runoff from streets. Since the storm sewers discharge water directly into a river, any contaminants in the runoff enter the waterway.

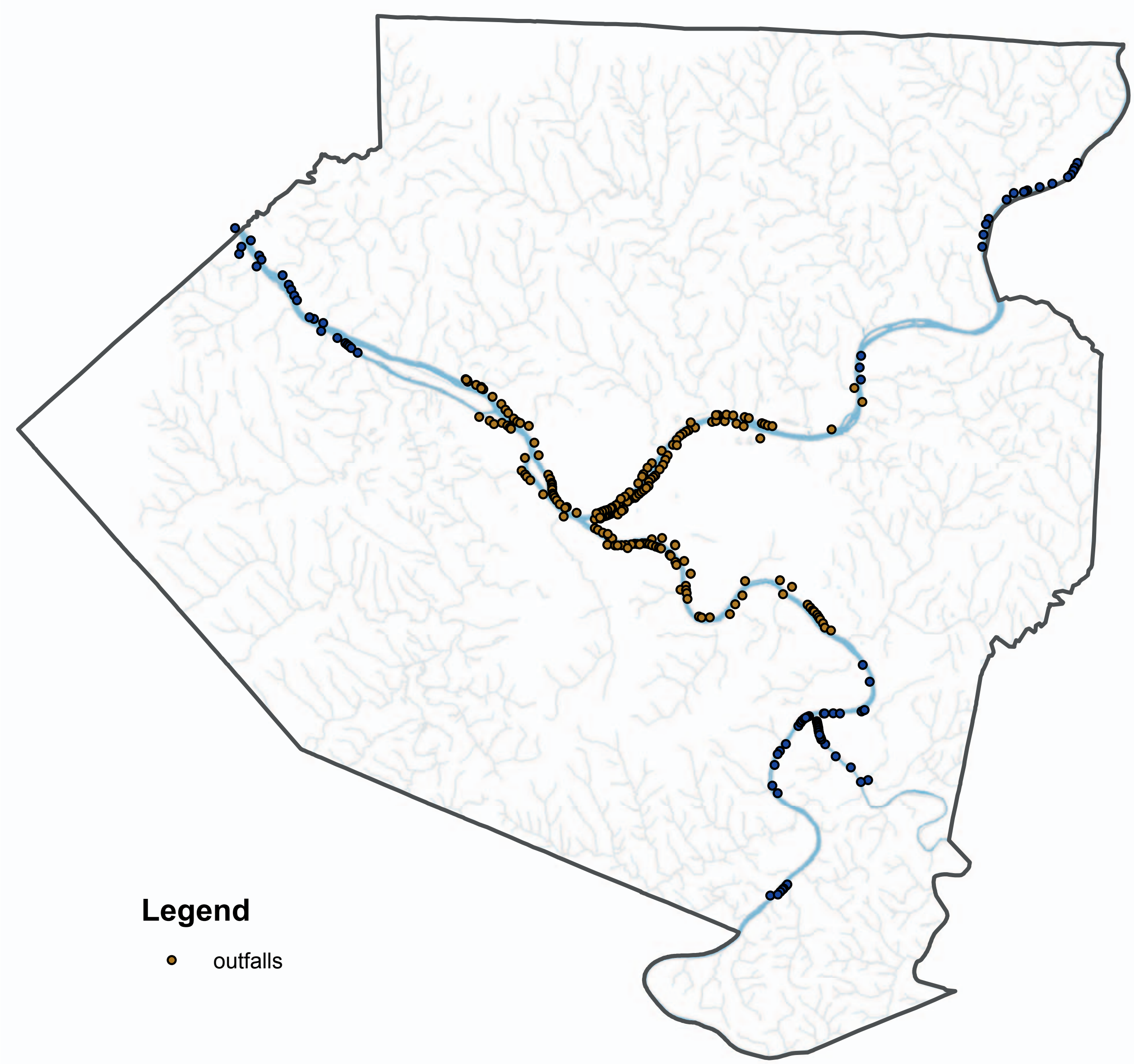
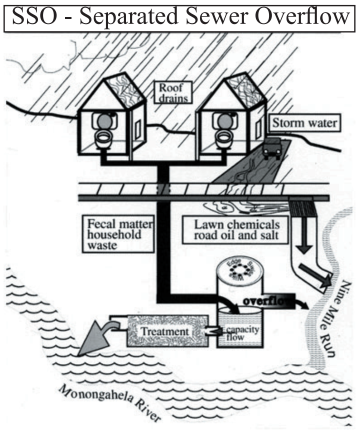
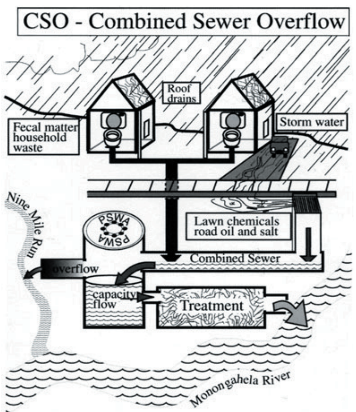


Figure II-a
Outfalls along the trhee rivers in Allegheny County
(The dots indicate the locations of outfalls)





They may also carry untreated waste from sanitary sewers that are improperly connected to storm sewers.

Combined Sewer Overflows

In a combined sewer system, both sanitary wastes and storm runoff are collected in the same pipe and carried to a wastewater treatment plant. Treated water is then released to a water body. However, after a heavy rainfall, the wastewater volume can exceed the capacity of the treatment plant. When this happens, combined sewer systems are designed to overflow and discharge excess wastewater directly into a waterway. These overflows contain contaminated runoff, untreated waste, and debris. Allegheny County has the most significant CSO's pollution problem in the U.S. at this point in time.

One solution that can help prevent sewer overflow is reducing the amount of storm water runoff by taking advantage of natural processes. These processes include tree planting, green space development and use of porous pavements in parking lots and walkways which allow water to filter into the ground instead of going into sewers.

Acid Mine Drainage

Acid mine drainage (AMD) occurs when materials that are normally buried underground become exposed to air and water. Pyrite, or Fool's Gold, is a mineral commonly associated with coal seams that contains iron and sulfur. When oxygen and water react with pyrite, sulfuric acid is formed. The acid in turn dissolves minerals and metals into the water.

Pennsylvania has mined coal for over 200 years. In fact Pittsburgh was the site of the state's first coal production, which occurred in 1761 at Coal Hill, what is now Mt. Washington. Historically, coal fueled iron furnaces, glass works, and steam engines. Today, while it still supports a variety of industries, most coal is used to generate electricity. Pennsylvania is the third largest coal consumer in the country and 90% of our electricity is fueled by it.


An acid mine drainage (AMD) site.

Unfortunately our mining history has left Pennsylvania with over 250,000 acres of abandoned mine lands, refuse piles, and mine shafts. Acid mine drainage from these sites is the primary source of water quality degradation in Pennsylvania, impacting over 3200 miles of streams. Acid mine drainage is characterized by low pH and elevated levels of sulfates, iron, and other metals. It typically has a reddish color from iron precipitates, but can also be milky colored if aluminum is present. Some mine drainage is crystal clear, which indicates water so acidic that metals remain dissolved.

Buried Streams

Originally, Pittsburgh was covered by a network of creeks, brooks and streams draining into the larger rivers. As the city grew, this network became a convenient way to dispose of sewage and storm water. Early plumbing systems were simply routed to streams and carried away by the rivers. Culverting, or piping, streams became an attractive solution that hid an unattractive problem. With the development of roads, buildings and parking areas, additional streams were diverted, straightened, piped, and confined in channels. Most Pittsburghers are unaware of the number of buried streams that they walk or drive over daily. (Figure 2-b)

Today, area streams continue to disappear into culverts and sewers as a result ofdevelopment. Channeling stream water to Pittsburgh's sewer system can overwhelm treatment plants, especially during storms, and contribute to the CSO problem. Removing streams from the surface also removes many benefits. Meandering, open streams slow runoff and prevent erosion, reduce flooding, improve water quality, create aquatic and riparian habitats, beautify landscapes, and provide recreational and educational opportunities.

Solutions

Many efforts are underway in Pennsylvania to improve waterways that are impacted by acid mine drainage. New passive treatment technologies have been developed that rely on natural chemical and biological processes to treat mine drainage. This drastically reduces the cost of operation and maintenance that is normally associated with active treatment. The make-up of mine discharges can vary greatly. Different types of passive technologies are often used in conjunction with each other to best address the type of discharge. Some passive treatment technologies are:

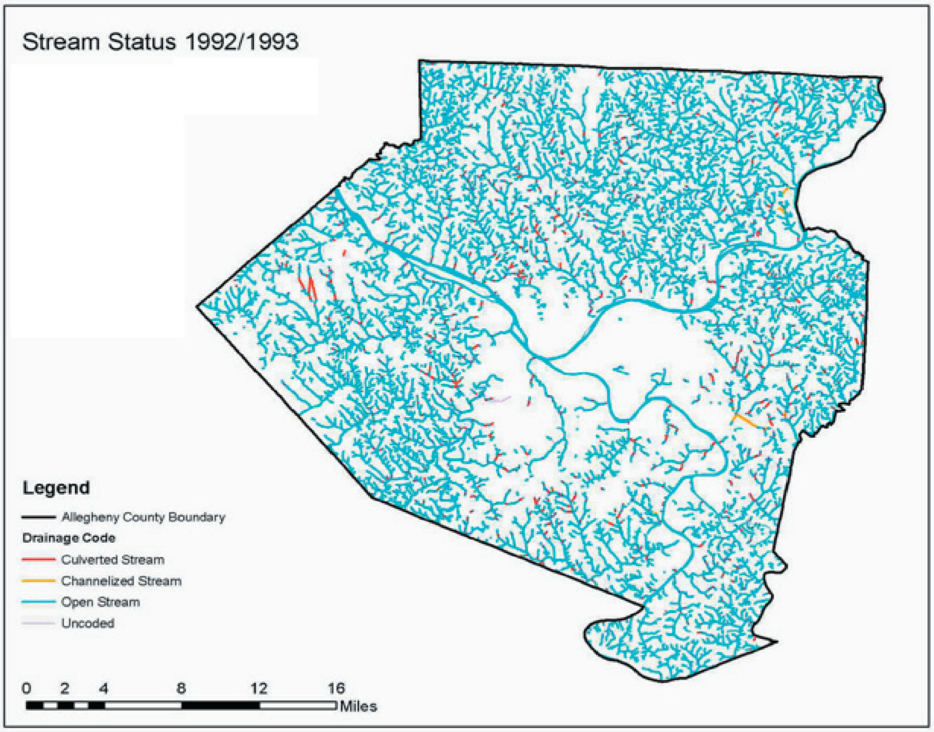
- **Constructed wetlands** – a shallow wetland designed to slow flow and remove metals through oxidation. This method works best on discharges with low acidity and high alkalinity.

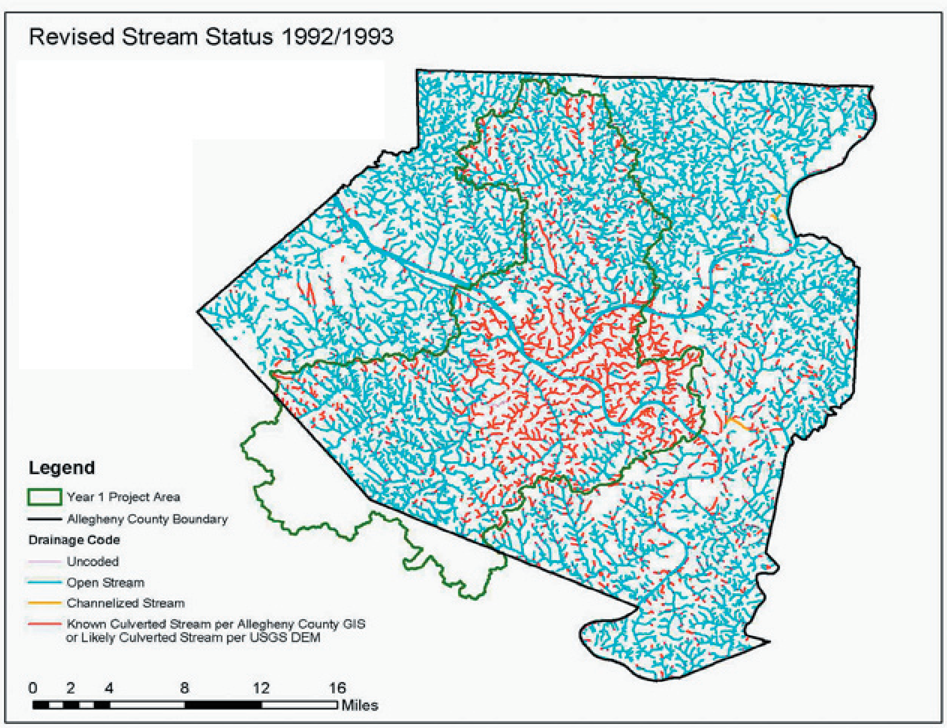
- **Open limestone channels** – a swale lined with limestone used to treat acidic drainage.

A constructed wetland

Figure II-b

“Stream Status 1992/1993,” shows rivers, open streams, channelized streams, and culverted streams. The most notable feature of this map and its underlying data is the lack of almost any stream lines for the core of the county, in the cith of Pittsburgh and surrounding older communities. “Revised Stream Status 1992/1993,” shows the complete stream coverage. 3R2N used DEM (Digital Elevation Model) to leveal the missing streams on GIS (Geological Information System) map.





A daylighting project: before (photo top) and after (photo below).

- **Anoxic limestone drains** – a limestone channel buried under clay which prevents oxygen from reaching the drainage. The lack of oxygen reduces the chance that metals will oxidize and armor the limestone, which makes it ineffective. A settling pond after the drain collects the metal precipitate before treated drainage enters the stream.

- **Vertical flow system** – a pond that forces water to flow down through a layer of decaying organic material and limestone. The organic material consumes oxygen as it decays, creating an anoxic environment; produces carbon dioxide which dissolves the limestone; and provides habitat for anaerobic bacteria which produce alkalinity in their waste. A settling pond is also recommended with this method.

Many urban water quality problems can be improved by reducing storm water runoff and sewer overflows. A number of strategies are available that reduce runoff and restore natural processes. They include:

- **Reuse of rain water** - capturing roof runoff in tanks allows it to be used for lawn and garden irrigation, preventing the runoff from being part of peak flows during storms and infiltrating it into the soil during dry weather Disconnecting pavement and roof drainage from sewer lines and directing it to adjacent vegetated soil or infiltration basins are other related strategies available to reduce peak runoff.

- **Infiltration basins** – carefully engineered depressions in the landscape, “water gardens”, dry wells, and subsurface recharge beds collect runoff from roofs and pavements and percolate it into the soil.

- **Tree plantings** - intercept a portion of rain water.

- **Soil rehabilitation** – aeration, the addition of organic matter and dense vegetation increase infiltration rates and pollutant-neutralizing microbial activity in soil

A daylighting project: before (photo top) and after (photo below).

- **Reduction of impermeable surfaces -** reconfiguring driveways, parking lots, and streets to reduce unnecessary pavement turns more of a site over to pervious, vegetated soil.

- **Porous pavement** – special varieties of asphalt, concrete, masonry, and other materials have open pores that detain runoff, filter pollutants and allow water to pass through to the soil.

- **Vegetated swales –** as alternatives to pipes, routing runoff through vegetated surface channels or "swales" slows its velocity, removes pollutants, and allows it to infiltrate into the soil.

- **Daylighting** – restoring or replacing historic streams by excavating culverts and creating naturalized open channels slows the velocity of runoff and brings the flow into contact with the soil, vegetation, air, and sunlight, allowing the natural ecosystem to treat and infiltrate the running water.

III. Water Quality Parameters

To understand what makes a healthy stream, we must explore a variety of stream components. Streams and rivers can be measured to determine the physical structure of the stream channel, the physical and chemical quality of the water, the presence of pathogenic organisms, and the type of biotic community they support. Examining these parameters and how they interact can be used to assess the overall condition of a waterway.

Physical, chemical, and bacterial testing can indicate water quality, land uses, and specific pollutants that may be affecting a waterway. These parameters measure the stream's ability to support aquatic life and whether the water is potentially harmful to humans. These measurements are "snapshots" in time and may vary from day to day or even hour to hour. They indicate current conditions or what is in the water at the time of sampling.

Sources and Associated Pollutants: Volunteer water quality monitoring

Source	Common Associated Chemical Pollutants
Cropland	Turbidity, phosphorus, nitrates, temperature, total solids
Forestry harvest	Turbidity, temperature, total solids
Grazing land	Fecal bacteria, turbidity, phosphorus, nitrates, temperature
Industrial discharge	Temperature, conductivity, total solids, toxics, pH
Mining	pH, alkalinity, total dissolved solids
Septic systems	Fecal bacteria (i.e., Escherichia coli, enterococcis), nitrates, phosphorus, dissolved oxygen / biochemical oxygen demand, conductivity, temperature
Sewage Treatment plants	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total solids, and toxics
Construction	Turbidity, temperature, dissolved oxygen and biochemical oxygen demand, total solids, and toxics
Urban runoff	Turbidity, phosphorus, nitrates, temperature, conductivity, dissolved oxygen and biochemical oxygen demand

Rather than the snapshot view of conditions provided by physical, chemical and bacterial parameters, biological testing is a measure of stream health over time. By examining populations of aquatic organisms, biological assessments provide a holistic view of the conditions and stresses affecting the stream community. These organisms are called the "canaries of the stream" because their presence, abundance and diversity can reflect changes in the stream environment.

Water quality parameters should be measured over a period of time, at different sampling points, and under different weather conditions in order to analyze impacts and detect changes to water quality and provide the information needed to maintain a healthy ecosystem.

Bacterial Parameters

Bacterial assessments measure the presence of bacteria that are potentially harmful to humans. Fecal bacteria are naturally found in the feces of humans and other warm-blooded animals, but are rare or absent in unpolluted waters. As a result they are a good indicator of sewage or fecal contamination in water.

Fecal bacteria are found in the intestines of humans and animals and aid in the digestion of food. When people or animals defecate, some of the fecal bacteria pass out of their bodies with the waste. Fecal bacteria usually do not cause sickness, but their presence can indicate the presence of other pathogenic intestinal organisms.

Pathogenic organisms are bacteria, viruses, and parasites that cause diseases and illnesses. A number of these diseases are waterborne. Cholera, typhoid, and dysentery are examples of waterborne diseases that were serious problems for people before the effective treatment of wastewater and drinking water.

Pathogens are difficult to detect in water because they are usually scarce and can't survive for very long outside a human or animal body. However, if intestinal pathogens are present in an individual, they will be found along with fecal bacteria. If fecal bacteria levels are high in a river, there is a greater chance that pathogenic organisms are present and a greater probability of contracting an illness from the water.

These bacteria enter waterways directly from domestic or wild animals, from agricultural and storm runoff carrying animal waste, and from human sewage. Cities sometimes contribute fecal waste to rivers through their sewer systems. Sewer overflows after a heavy rainfall can result in high levels of fecal coliforms downstream from the discharge point. Bacteria levels are strongly correlated to rainfall and natural bacteria levels in streams can vary significantly.

Fecal bacteria are used as indicator organisms to monitor the safety of water for specific uses, such as drinking or swimming. Fecal bacteria tests tell us the amount of bacteria in the water, but do not identify whether the source of the contamination is from humans or other animals. Fecal bacteria can be traced to the specific organism through DNA testing, but the cost is usually prohibitive.

The path of delivery of bacteria to a waterway varies with the source. For instance, if the source is human, the pollution can often be traced to faulty septic systems, faulty sewer systems, or sewer overflows. If the source is wildlife or pets, it can be much more difficult to pinpoint. In this case the bacteria would be carried in runoff that could enter a storm sewer or flow directly into a waterway.

The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli (E. coli)*, fecal streptococci, and enterococci. Except for *E. coli* which is a single species in the fecal coliform group, they are all groups of bacteria that contain a number of species. Which bacteria you test for depends on what you want to monitor.

- Total coliforms are a widespread group of bacteria that are found in humans, animals, soil, and other places outside the human body. They are used as the standard test for drinking water, because they indicate an outside source of contamination.

- Fecal coliforms, a subgroup of total coliform bacteria, are more fecal specific. However, fecal coliforms include a species of bacteria that is not fecal in origin. It enters waterways in discharges from textile, pulp, and paper mill wastes. Fecal coliform bacteria is the main water quality indicator used in Pennsylvania and a large amount of historical fecal coliform data exists for the region's rivers.


A student is using pH testing equipment at a stream.

- *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. Because *E. coli* is more specific, the U.S. EPA has recently begun recommending it, instead of fecal coliforms, as a better indicator of health risk from water contact in recreational waters.

- Fecal streptococci are usually found in the digestive system of humans and other warm-blooded animals. In the past, a test that measured the ratio of streptococci to fecal coliforms was used to determine whether fecal contamination was of human or nonhuman origin. This test is not onger considered reliable.

- Enterococci are a subgroup of the fecal streptococcus group. Enterococci are more human-specific and have an ability to survive in salt water. In recreational waters they are considered a useful indicator in freshwater and the best indicator of health risk in salt water.

Sampling for bacteria is a more complicated process than other water quality parameters. To measure coliform bacteria, water samples must be collected in sterilized containers. The samples are filtered and incubated for a specific amount of time. The colonies of bacteria that form during incubation are counted and recorded as colony forming units (CFU).

Fecal coliform levels for drinking water are the same for all states and are required by the EPA. Standards for swimmers and other recreational uses are set by the states. Bacteria levels for recreational waters are measured as a monthly geometric mean during the recreational season of May to October. In Pennsylvania for recreational swimming, fecal coliform are not to exceed 400 CFU/100ml in more than 10% of samples at a given site in a month or have a maximum monthly geometric mean of 200 CFU/100 ml with a minimum of 5 samples/month/site. Acceptable levels of *E. coli* bacteria for recreational uses are recommended at 240 CFU/100 ml for any single sample and a monthly geometric mean of 130 CFU/100 ml with a minimum of 5 samples per month .

Physical and Chemical Parameters

Chemical testing measures the concentration of dissolved or suspended substances in the water. Physical parameters, such as temperature, volume of flow, and velocity, can indicate what type of aquatic organisms the stream will support. The physical and chemical make-up of a stream is affected by soil, geology, precipitation, vegetation and land use in the watershed. These parameters can change from day to day. They indicate conditions in the water at the time of sampling and can increase or decrease with the quantity of runoff.

Physical and chemical parameters help determine the type of pollution that may be affecting a waterway and can provide some clues as to the sources. Water quality is good if naturally occurring substances are present at levels that support aquatic life. Problems occur when activities alter natural levels or introduce substances that are toxic to aquatic life.

pH

Water is made up of hydrogen (H+) and hydroxyl (OH-) ions. The pH test measures hydrogen ion concentration to determine if a liquid is acidic or basic. As H+ ion concentration increases, pH decreases.

The pH scale runs from 0-14. A solution with a pH of 7 is neutral, less than 7 is acidic, and greater than 7 is basic. A neutral solution would contain balanced amounts of H+ and OH-, an acidic solution would contain more H+ than OH-, and basic solution would contain more OH- than H+. The pH scale is logarithmic, which means that each number on the pH scale represents a ten-fold change in acidity. For example, a pH of 6 is ten times more acidic than a pH of 7 and a pH of 5 is one hundred times more acidic than a pH of 7. (Figure 3-a)

Changes in pH

The pH level can be affected by several factors, including soil and bedrock, respiration and decomposition, and some forms of pollution. Some types of soil and bedrock can affect pH by providing buffering capacity. Limestone bedrock neutralizes acid and would raise the pH of a body of water, but granite bedrock provides little neutralizing capacity and little effect on pH. Drainage from forests and marshes is often slightly acidic, due to the presence of organic acids produced from decaying vegetation.

Carbon dioxide enters water from a variety of sources, including release from bacteria and aquatic plants and animals during respiration and decomposition. When carbon dioxide combines with water it forms carbonic acid. Although this is a

Figure III-a: pH of common substance and
lethal pH limits for aquatic organisms

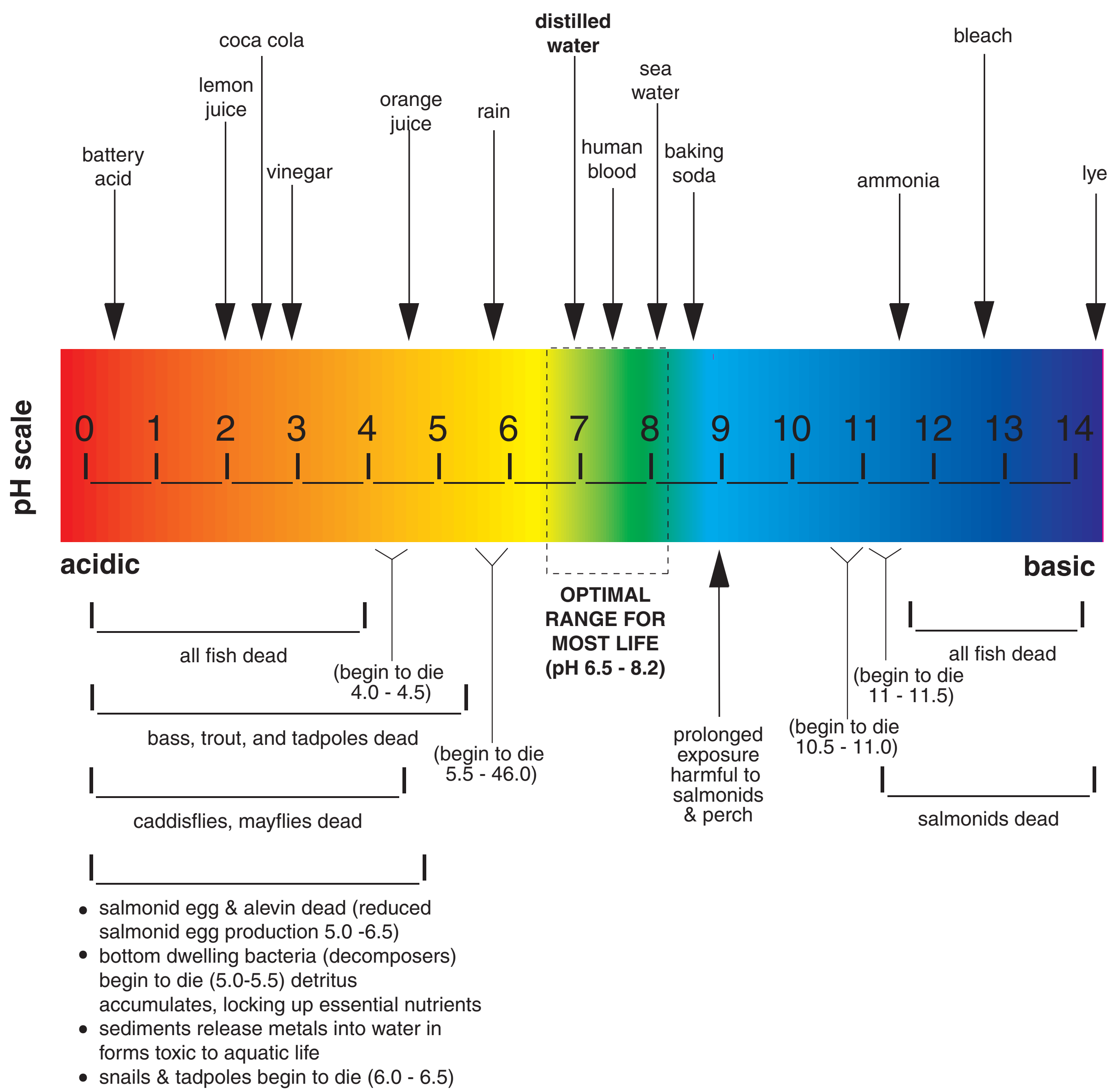


*Figure III-a
Compiled from Campbell, G. and Widberger. 1922. The Monitor's Handbook. La Motte Company, Chestertown, MD and MacDonald, L.H. with A.w. Smart and R.C. Wissman. 1991. Monitoring Guidelines to Evaluate effects of Forestry Activities on Streams in the Pacific and Alaska. U.S. Environmental Protection Agency, Region 10, Seattle, WA.

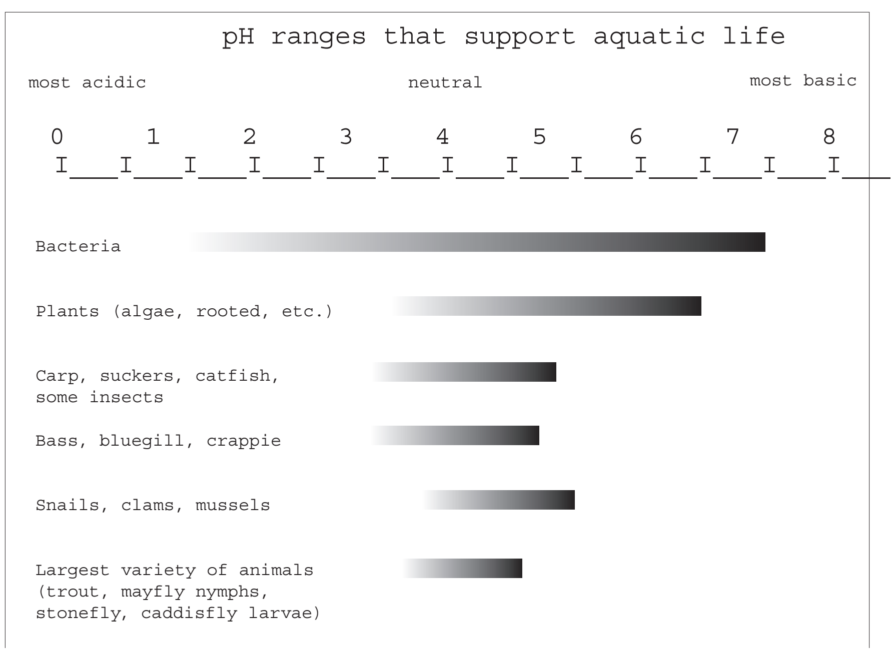
weak acid, large quantities of it can lower pH. Acids can also be produced when nitrogen oxides and sulfur dioxide, primarily from cars and coal-fired power plants, are released into the atmosphere. As a result nitric acid and sulfuric acid are formed and enter waterways when they return to the ground as acid precipitation.

The greatest source of water pollution in Pennsylvania is acid mine drainage. The major source of this pollution is abandoned coal mines. When iron sulfide or pyrite, a mineral associated with coal seams, is exposed to water, oxygen, and sulfur oxidizing bacteria it forms sulfuric acid and ferric hydroxide. Sulfuric acid can dramatically lower the pH of a stream.

Effects on aquatic life

Aquatic organisms function best within a given pH range. Most organisms can survive within a pH range of 5 to 9, although a pH of 6.5 to 8.2 is optimal. Immature stages of aquatic organisms are generally more sensitive to low pH levels and some sensitive species will not be present in water with pH values below 6. The absence of these organisms in the foodchain can have serious effects on an ecosystem.

Changes in pH levels can also affect aquatic life by indirectly altering other aspects of water chemistry. Highly acidic waters can release heavy metals, such as aluminum, copper or iron, into the water. These metals can affect gill function in fish and cause deformities in young fish. Water with low or high pH levels can become more toxic when combined with certain metals and



chemicals.   A fish that can usually survive a pH as low as 4.8 will die at a pH of 5.5 if the water contains 0.9 ml/L of iron. At high pH levels, smaller amounts of ammonia are needed to reach a level toxic to fish.

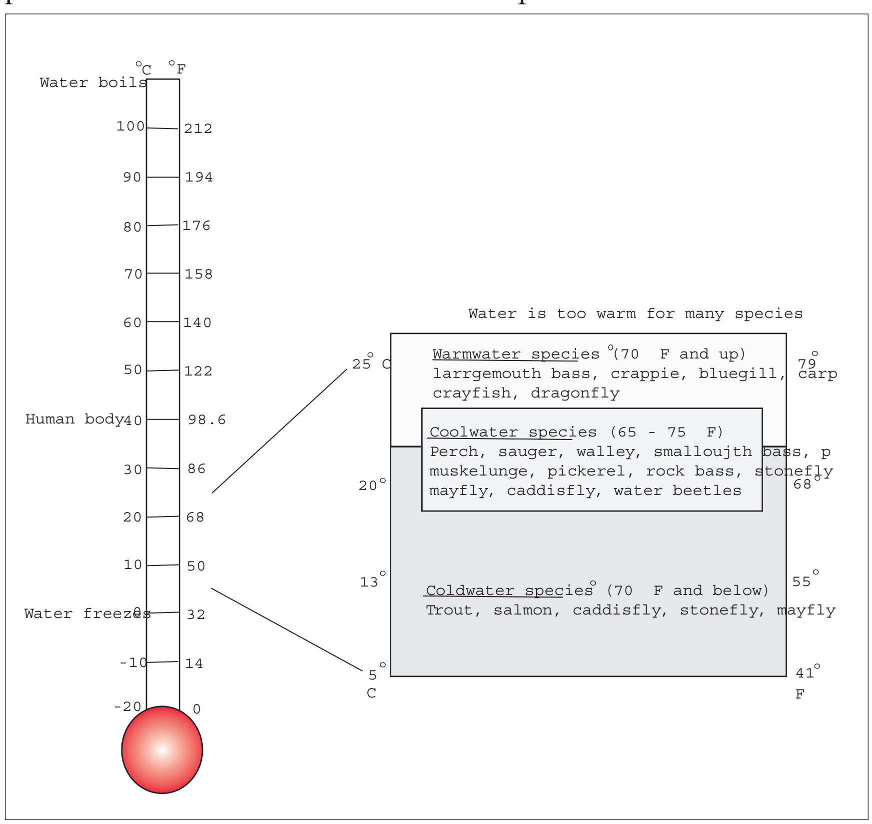
Temperature

Temperature affects many of the physical, chemical, and biological characteristics of a waterway. It affects the amount of dissolved oxygen, rate of photosynthesis, metabolism of organisms, and species that can live there.

Changes in Temperature

Water temperature can change seasonally or even daily in smaller streams. However, changes caused by climate are buffered by other factors, including the velocity and volume of water, the source of the water, and the amount of sunlight reaching the water. Deeper, fast moving waters are less affected by the sun's heat than shallow, slower moving streams. Stream temperatures will also be lower if they are fed by groundwater from springs.

Trees overhanging a river bank shade the water from sunlight, which keeps the water cooler. Soil erosion from the removal of shoreline vegetation, construction, or poor farming practices can increase the amount of suspended solids in the water.



Water with high levels of suspended solids becomes dark colored or cloudy and absorbs more heat.

Thermal pollution causes increased water temperature by adding warm water to a waterway. Industries may cause thermal pollution by discharging water that was used to cool machinery. It may also be caused by return flows from irrigation systems and stormwater runoff that has traveled across heated surfaces like streets, sidewalks, or parking lots. Get sentence from Tim about Pool 3 on Mon and add here.

Effects on aquatic life

Aquatic plants and animals are surrounded by water, so their "climate" depends on the temperature of water instead of air. Their body temperature, metabolic rate, and life cycles are all influenced by the temperature of the water in which they live. Because fish and aquatic insects are "cold-blooded," they assume a body temperature similar to the surrounding water. These organisms are adapted to have a specific range of temperatures in which they can live. Within this range is a narrower temperature range that is optimal for survival, growth, and reproduction. Some prefer cooler water, such as trout and mayfly nymphs, while others thrive in warmer conditions, such as dragonflies and bass. Not only do different organisms have different requirements, but optimum temperature ranges may also change for various stages of life. Fish larvae and eggs usually have narrower temperature requirements than adult fish.

Decreasing temperatures slow respiration and growth of aquatic organisms and may limit reproduction. Increasing temperatures raise the metabolic rate of aquatic organisms, resulting in higher oxygen requirements. Since warm water holds less oxygen, the need for more comes at a time when less is actually available. The life cycles of aquatic insects can speed up in warmer water, which may affect animals that depend on their emergence at a particular time. Temperatures also affect the sensitivity of organisms to toxic waste, parasites, and disease, either due to the stress of warmer temperatures or the decrease in dissolved oxygen.

Dissolved Oxygen (DO)

Most plants and animals need oxygen to live. Nearly all of the oxygen we breathe is produced by green plants. In fact, three-fourths of the earth's oxygen comes from aquatic plants in the oceans, called phytoplankton. Oxygen becomes dissolved in water through diffusion from the atmosphere; by aeration as water tumbles over rocks and waterfalls; and as a by-product of photosynthesis. Most aquatic organisms have specialized features, like gills, that allow them to extract oxygen that is dissolved in water.

Changes in Dissolved Oxygen

Temperature is one of the most important factors affecting dissolved oxygen levels. Oxygen dissolves easier in cold water than warm water. As temperatures increase, oxygen levels decrease. Critically low oxygen levels can occur during hot, dry summer months, when capacity is decreased due to low water and organisms have a higher demand. Slower moving bodies of water generally have lower DO levels as well, because they tend to heat up more quickly. Removal of riparian vegetation can also result in lower oxygen levels due to increased water temperatures and greater amounts of suspended particles from erosion.

Turbidity from suspended solids can lower dissolved oxygen levels because cloudy water absorbs more heat and blocks light penetration which prevents photosynthesis. Dissolved solids also affect DO levels, because oxygen dissolves easier in water with low levels of dissolved solids. Urban runoff and erosion can add salts, sediment, and other pollutants that increase levels of dissolved or suspended solids in water.

D.O. Requirements for some aquatic Species

(Levels required for spawning, growth and well-being)

Some Native Fishes / Insect Larvae	D.O. in ppm or mg/L
Salmon, trout, caddisfly, stonefly, mayfly	6 ppm and above
Bass, crappie, catfish, carp	5 ppm and above

Aquatic plants affect dissolved oxygen levels through photosynthesis and respiration. Waters with abundant plant growth can have large daily fluctuations in dissolved oxygen. Due to photosynthesis, the oxygen levels rise during the day and peak in late afternoon. At night when photosynthesis stops, plants and animals continue to consume oxygen through respiration. Dissolved oxygen levels are at their lowest at dawn and some can drop to minimum levels at this time. This situation is more common in lakes and ponds, which tend to have larger numbers of rooted aquatic plants.

Decreased DO levels may indicate high levels of bacteria from untreated sewage or agricultural runoff. Fertilizers can also stimulate overabundant plant growth. When the plants die, they are decomposed by increased numbers of bacteria which use large amounts of dissolved oxygen.

Effects on Aquatic Life

Most aquatic organisms have specific oxygen requirements and are unable to live in water that does not meet their needs. The amount of DO an organism needs depends on its species, the temperature of the water, pollutants, and the state of the species (adult or young, active or dormant). Cold-blooded animals require more oxygen at higher temperatures because their metabolic rate increases. A trout needs five to six times more oxygen when the water temperature is 24° C (75° F) than when the water temperature is 4° C (41° F).

A healthy stream generally has a higher DO level than the minimum required by aquatic life to buffer against changes in DO from temperature, drought, or contaminants. The minimum dissolved oxygen level required to support a diverse fish population is 4-5 ppm, although higher levels may be required for growth and spawning. Dissolved oxygen levels above of 6.5 ppm for warm water streams and above 7 ppm for cold water streams are considered good.

Conductivity

Conductivity is a measure of the ability of water to conduct an electrical current. This ability depends on the presence of ions of dissolved compounds. Ions come from the breakdown of compounds and conduct electricity because they are negatively or positively charged when dissolved in water. Conductivity is an indirect measure of the presence of dissolved solids and can be used as an indicator of water pollution.

Solutions of inorganic compounds are relatively good conductors. Inorganic dissolved solids include chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron. Solutions of organic compounds like oil or sugar conduct electricity poorly and have low conductivity.

Changes in Conductivity

Some ions occur naturally as water flows over certain types of rock or soil. Calcium and carbonate ions dissolve into water when calcite containing rocks, like limestone and shale, are present.

Human activities also influence conductivity. Acid mine drainage can add iron, sulfate, copper, cadmium, and other ions if minerals containing them are exposed to air and water. Sewage and farm runoff can raise conductivity due to the presence of nitrate and phosphate. Runoff from roads can also carry salts and other materials that contribute ions to water.

Effects on Aquatic Life

Dissolved solids are necessary for aquatic life. They help to regulate the flow of water in and out of cells and are building blocks for molecules. Low concentrations can limit the growth of aquatic life. Phytoplankton are very dependent on nitrates and phosphates that are dissolved in water. On the other hand, high concentrations can cause water balance problems for organisms and result in lower DO levels, because oxygen dissolves easier in water with low levels of dissolved solids.

Conductivity is measured in micromhos per centimeter. It is abbreviated umho, which is a unit of current or the flow of electricity. A conductivity range between 150 and 500 umhos/cm in streams generally supports a healthy fish population.

Alkalinity

Alkalinity is a measure of the buffering capacity of water or the ability of bases to neutralize acids. It is important in determining a stream's ability to neutralize acidic pollution. Alkalinity does not refer to pH, but instead refers to the ability to resist change in pH.

Alkalinity is naturally added to water if it passes through soil and bedrock containing materials that are high in carbonates (CO_3^{2-}), bicarbonates (HCO_3^-), and hydroxides (OH^-). Streams with limestone, for example, have high alkalinity and good buffering capacity. Other rock types, such as granite, do not have minerals that contribute to alkalinity. Treated sewage effluents can also add alkalinity to a stream.

If increasing amounts of acid are added to water, buffering capacity will eventually be consumed. However, the natural buffering materials will slow the decline in pH to around 6. Then a rapid drop in pH will occur as bicarbonate buffering capacity is used up. A solution with a pH below 4.5 contains no alkalinity because there are no buffering materials left.

Effects on Aquatic Life

Alkalinity helps to protect aquatic life from acid wastes and acid precipitation by regulating the pH of a body of water. Alkalinity can also remove toxic metals, such as lead, arsenic, and cadmium, by precipitating the metals out of solution.

Alkalinity levels of 20-200 mg/l are typical of fresh water. A total alkalinity of 100-200 mg/l will stabilize pH levels in a stream.

Hardness

Most people associate water hardness with the ability to lather soap – the harder the water, the less lather. However, water hardness primarily represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions. Iron, aluminum, and manganese may also contribute to hardness, but large amounts of them are not usually present.

Like alkalinity, the geologic makeup of an area usually determines the level of hardness. Soft water is often seen in areas with igneous rocks, like granite, which don't release many ions. Hard water is often seen in areas with calcite rich soil or rock, such as limestone, which releases calcium when exposed to slightly acidic water. Mine drainage also contributes calcium, magnesium, iron, manganese and other ions if minerals containing them are present and exposed to air and water. Treated sewage effluent and industrial discharges may also contribute to the hardness of water.

Effects on Aquatic Life

Stream organisms use calcium to build shells and bones. Aquatic plants use calcium in cell walls and magnesium as a nutrient and component of chlorophyll.

Hard water helps keep fish from absorbing metals such as lead, arsenic, and cadmium into their bloodstream through their gills. Also, nonmetals such as ammonia, phenols and certain acids seem to be more toxic in soft water than hard water.

Total Hardness (mg/l $CaCO_3$)	
0-60	Soft water
61-120	Moderately hard water
121-180	Hard water
181 and higher	Very hard water

There are no general standards for hardness and it can range from zero to hundreds of milligrams per liter. Some common hardness values are shown in the chart above.

Ammonia and Nitrate

Nitrogen is required by all organisms for growth and reproduction. It is very common and is found in many forms in the environment. Organic nitrogen (nitrogen combined with carbon) is found in proteins and other compounds. Inorganic nitrogen may exist as nitrogen gas (N_2) in the free state, as nitrite (NO_2) or nitrate (NO_3) when combined with oxygen, and as ammonia (NH_3) when combined with hydrogen. Nitrogen is most abundant in the environment as a gas. However, most organisms can not use nitrogen gas and depend on other organisms to convert it to another form.

During decomposition bacteria break down protein molecules into ammonia. Ammonia is then oxidized by specialized bacteria to first form nitrite and then nitrate. Nitrates are then reduced to nitrogen gas. Blue-green algae are able to use N_2 directly and convert it to ammonia and nitrates, which are forms of nitrogen that plants can take up through their roots and use for growth.

Fertilizers and sewage are the main source of ammonia and nitrate in water. They can enter waterways from farm and lawn fertilizer runoff, livestock and animal waste, leaking septic tanks, sewer overflows, and wastewater treatment plants.

Nitrate is generally the form of nitrogen used as an indicator fertilizer or sewage in stream sampling. This form is used because nitrates end up in rivers and streams more quickly than other nutrients, like phosphorus, because they dissolve more readily in water. Also, ammonia is the least stable form of nitrogen in water and is easily converted to nitrate in waters containing oxygen.

However, water that is polluted with nitrogen-rich organic matter, may show low nitrate levels. This is because the decomposition of organic matter lowers the dissolved oxygen level, which slows the rate at which ammonia is oxidized to nitrite and nitrate. Under these conditions it may be necessary to also monitor for ammonia, which is considerably more toxic to aquatic life than nitrate.

Effects on Aquatic Life

Ammonia is nitrogen rich, ammonia and nitrate act as fertilizers and can speed the eutrophication of waterways. Dramatic increases in aquatic plant growth can affect dissolved oxygen, temperature, and other indicators.

Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at concentrations of 10mg/l or higher under certain conditions. Unpolluted water generally has less than 1 mg/l of nitrate.

Even at low levels, ammonia is toxic to aquatic organisms. It can affect hatching and growth rates in the early life stages of fish and cause tissue changes in the gills, liver, and kidneys during development. When ammonia levels reach 0.06 mg/l, fish can suffer gill damage and levels greater than 0.1 mg/l usually indicate polluted waters. Ammonia becomes more toxic at higher pH levels, low dissolved oxygen levels, and warmer water temperatures. The natural level of ammonia or nitrate in surface water is typically low, but in the effluent of wastewater treatment plants it can range up to 30 mg/l.

Iron

A primary source of iron is from mine discharges. Pyrite or iron sulfide is a mineral associated with coal seams that can form acid mine drainage. When pyrite is exposed to oxygen and water it releases sulfuric acid and dissolved iron. Sulfuric acid lowers the pH and can dissolve other toxic metals into the water. The metals stay in solution until the pH rises to a level where precipitation occurs. At higher pH values iron forms ferric hydroxide, a precipitate commonly referred to as “yellowboy.” This precipitate forms a yellowish orange residue that settles to the bottom of a stream.

Effects on Aquatic Life

When iron precipitates form they clog the gills of fish and suffocate bottom dwelling invertebrates. Maximum allowable levels for dissolved iron are 0.3 mg/l.

Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is a term applied to the material left behind after a water sample is filtered and evaporated. TDS is a measure of material dissolved in water such as carbonate, bicarbonate, chloride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and other ions.

Dissolved solids enter water naturally as it flows over rock or soil that releases ions easily (see Conductivity). Treated sewage effluents and run off from streets containing salts, fertilizers, and other material also add dissolved solids to waterways. In addition, as plants and animals decay, dissolved organic particles are released and can contribute to the TDS concentration.

Effects on Aquatic Life

A certain level of these ions in water is necessary for aquatic life. Changes in TDS concentrations can be harmful because the water density determines the flow of water in and out of an organism's cells. If TDS concentrations are too high or too low, growth of aquatic life may be limited and death may occur.

High concentrations of TDS may also reduce water clarity, contribute to a decrease in photosynthesis, lead to an increase in temperature, and transport toxic compounds and heavy metals.

Rainwater contains less than 10 ppm TDS. Rivers may contain between 100 and 2,000 ppm. Maximum allowable levels range from 750 ppm to 1500 ppm. The specific allowable level is determined by the type of waterway – warm or cold water stream – and the type of fish it should support.

Turbidity

Turbidity is a measure of the cloudiness of water. It is caused by suspended solids and plankton, which scatter light as it passes through water.

High turbidity is an indicator of either runoff from disturbed or eroded soil or plankton blooms from excess nutrients. Very clear water is typical of the open ocean or oligotrophic lakes, which support little plant and animal life. Moderately low levels of turbidity with enough plankton to support the foodchain are ideal for a healthy ecosystem.

Effects on Aquatic Life

High levels of turbidity can cause several problems for aquatic systems. It can result in low dissolved oxygen levels by preventing photosynthesis by blocking sunlight and raising water temperature by absorbing more heat from the sun.

High turbidity is damaging to gills and can bury eggs and benthic invertebrates when particles settle. Suspended particles may also carry nutrients, pesticides, and bacteria throughout waterways.

Turbidity is measured in Nephelometric Turbidity Units or NTU's. NTU refers to the way a nephelometer, the instrument used for the test, estimates how light is scattered by particles suspended in water. The measurement provides a good correlation with the concentration of particles in water that affect clarity. Turbidity levels for aquatic life should not exceed 100 NTU.

Biological Parameters

Biological monitoring provides an indication of stream health over time, because it measures aquatic organisms and their responses to changes in their environment. The presence, diversity, and abundance of certain types of organisms can provide information on stream health, because they react differently to changes in water quality. Biological surveys can be used to identify the impact of pollution and pollution control activities, to rank stream health, and identify water quality trends. The most common organisms studied are fish, algae, and macroinvertebrates. This study focuses on macroinvertebrates.

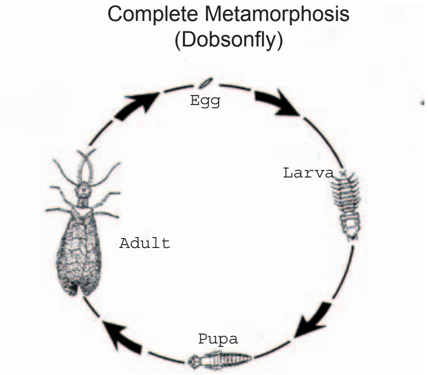
Macroinvertebrates are animals that can be seen with the unaided eye and have no backbone. Those that live on stream bottoms are called "benthic" organisms, which means bottom-dwelling. Aquatic insects, clams, worms, leeches, and snails are examples of benthic macroinvertebrates.

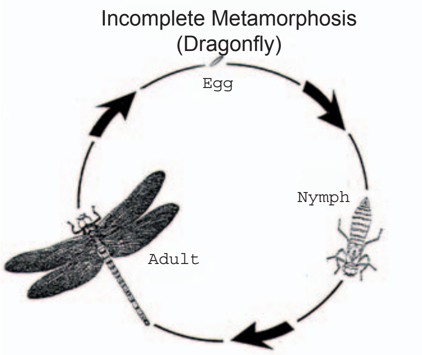
Life Cycles

Many aquatic macros are immature or larval forms of insects. Throughout their life cycle insects pass through several structural changes, a process known as metamorphosis. Insects that undergo complete metamorphosis begin as eggs, deposited in the water by a winged adult. The eggs hatch into tiny larva, which grow until they gradually enter into a pupal stage. The pupa is generally encased and non-mobile, like a cocoon. In the pupa the insect undergoes drastic changes in anatomy and emerges as an adult. The adults are often very different in appearance from their larval forms. Examples of insects that go through complete metamorphosis are caddisflies, beetles, and dobsonflies.

Life cycle of Cadisfly

Insects that undergo incomplete metamorphosis pass through a simpler set of changes. These insects begin their lives





as eggs that hatch into nymphs. As the nymph grows, it slowly transforms into the adult. Nymphs resemble their adult forms much more than larva that undergo complete metamorphosis. Mayflies, stoneflies, and dragonflies are examples of insects that go through incomplete metamorphosis.

Habitats and Adaptations

Each type of macro has a preference for certain living conditions that its water habitat must provide for it to survive. These different habitats are formed as a stream or river progresses from headwaters to mouth, where it empties into another body of water.

The headwaters are typically narrow, rocky, and shaded. Since little sun reaches the water, the primary food source consists of plant material from outside the stream, such as leaves, twigs, and other organic debris. Further downstream in the middle reaches, the stream becomes wider and deeper. The water alternates between slower, deeper pools, and faster, rocky riffles. The canopy no longer covers the entire stream, which allows sunlight to reach the stream bottom. Algae grow on the rocks and add another food source to the stream. The wide lower river is characterized by slow-moving, turbid water with a silt, sand, or gravel bottom. Vegetation is found only at the edges and most of the water is unshaded, although turbidity might prevent sunlight from reaching the bottom. Fine particles of organic debris and algae are a major food source.

Macroinvertebrates are adapted to the physical conditions and food base of their preferred habitat. Shredders are a group of macros with large chewing mouthparts which let them feed on large pieces of organic matter. Shredders are usually most abundant in in headwaters and other areas with canopy covered edges. They play an important part in providing finer food particles that can be used by other types of macros. Shredders include stonefly nymphs, scuds, and cranefly larvae.

Scrapers or grazers feed on algae that are attached to rock or other substrates. Water pennies and some caddisfly larvae are scrapers. Since their food is often in areas with a swift current, many scrapers have adaptations for holding on, such as flat bodies or suction disks. They are more common in the middle river, where enough sunlight reaches the stream bottom to support algal growth.

Collectors feed on fine particles of decomposing organic matter. Filtering collectors strain tiny particles from water. They have specialized nets or sticky hair-like brushes that they use to capture food as it flows past them. Filtering collectors include black fly larva and net-spinning caddisflies. Gathering collectors feed on dead organic material that has settled to the stream bottom and many are adapted for burrowing into bottom sediments. Mayfly nymphs, some caddisfly larvae, and midge larvae are gathering collectors. Collectors are found in all parts of the stream, but make up a larger portion of the lower reaches where fine particles accumulate.

Predators have adaptations to catch and consume other macroinvertebrates, such as large pincer-like jaws for biting and chewing, spear-like mouthparts for piercing, or large forelegs for grasping. Dragonfly nymphs, damselfly nymphs, and dobsonfly larva (hellgrammites) are predators. They are found in all parts of the stream, but because of the large number of prey needed to support them, they are usually present in smaller numbers.

Indicators of Water Quality

Macroinvertebrates are useful indicators of stream quality for a number of reasons.

- They are affected by the physical, chemical, and biological conditions of the stream.
- They are relatively sedentary and cannot easily escape pollution, so their populations reflect the overall health of the stream.
- Some are very intolerant of pollution.
- They may show impacts from habitat loss.
- They are a critical part of the aquatic food web.
- Many macros spend over a year in the water.
- They are easy to sample and can be monitored any time of the year.

Good water quality indicators; Mayfly larvae (photo top) and Gammarus (photo bottom)

Macroinvertebrate studies are based on an organism's ability to tolerate pollution. Some macroinvertebrates are capable of surviving in a wide range of conditions and are more tolerant of water quality declines, while others are sensitive to even subtle physical and chemical changes in their environment.

Macroinvertebrate communities in polluted streams are dominated by a small number of pollution tolerant species, such as sludge worms, and lack organisms that are pollution intolerant. On the other hand, healthy streams have a high diversity of organisms, including pollution intolerant species like mayflies.

The advantage to a biological assessment is that it indicates when the stream is impaired due to pollution or habitat loss. A stream filled with a variety of life is obviously healthier than a stream with only a few types of organisms. The disadvantage of a biological assessment is that it does not identify the reason why certain organisms are present or absent. For example, stonefly nymphs are aquatic organisms that are sensitive to most pollutants and to low dissolved oxygen levels. If stoneflies are absent from a stream, it may indicate a problem but not the cause of it. Reasons could range from low water and warm temperatures, to pollutants, to habitat degradation. For this reason physical and chemical water quality parameters are usually measured when a biological assessment is conducted.

Selecting Metrics

In a biological survey, a variety of measurements or metrics can be used to interpret and analyze biological data. Metrics translate raw data (lists of organisms) into relevant biological information about the health of a stream. To be useful, metrics must be shown to respond to stream impacts in predictable ways. When selecting metrics, it is critical to choose those that are appropriate to your region.

Individual metrics provide valuable information, but many studies use a multi-metric approach that combines several metrics into a total condition score to summarize data. Metrics that are commonly used in rocky bottom streams fall under four general categories:

1. Taxa richness and composition
2. Pollution tolerance and intolerance
3. Feeding ecology
4. Population attributes

When surveying a number of streams, a reference stream may be included in the study. The reference stream is used for comparison and should be a high quality, non-impaired stream that is in the same ecoregion.

1

2

3

4

The water quality team: An Environmental scientist Kathy Knauer (photo 1), the director of the 3 Rivers 2nd Nature Tim Collins (photo 2), and Biologists Linda Stafford (photo 3) and Mike Koryak (photo 4), from the Army Corps of Engineers.

IV. The 3R2N Study

Overview

The 3R2N water quality study focused upon surface water sampling to understand the potential for recreational uses There is a documented recovery of life (fish) in the rivers, there is less information about the streams. The Rivers are believed to be more affected by urban wet weather affects, so we sampled the rivers in both wet and dry weather conditions for the potential to support life and the impacts of an urban setting. We tried to understand the baseline condition in dry weather and the changes in wet weather. There is very little information about streams, so we sampled dry weather with the intention of understanding the potential for life, the existing life and the dry weather impacts of an urban setting. Rivers and streams in an urban setting are typically affected by stormwater the water that drains off urban lands, roads, roofs etc., and/or combined sewer overflows, (CSO's) stormwater mixed with sewage which overflows in wet weather.

Sample sites and methods

Wet/Dry conditions

The 3R2N water quality study included river sampling in both wet and dry weather conditions. Dry weather sampling measured the general water quality with a specific interest in recreational uses. Wet weather sampling measured how contaminated the water became with bacteria when it was raining and how quickly the water returned to dry weather conditions.

Dry weather samples were taken after a minimum of three days of dry weather to insure that there was no effect from rain. Wet weather samples were taken after a steady rain of at least ¼ inch fell throughout the region. Wet weather samples were collected for three consecutive days after this rainfall.

Chemical and Biological Sampling

Studies indicate that biological diversity and ecosystem health in the rivers are improving, with fish species increasing by as much as 400% over the last 20 years. However, little information is available on bacteriological indicators, a potential impact from urbanization and aging sewer systems. Since the study was concerned with recreational use of the rivers, bacteriological indicators were a primary focus.

River Sampling

River sampling included bacteria and basic physical chemistry parameters such as temperature, pH, and dissolved oxygen. River monitoring sample sites were chosen near public access areas, like marinas, and streams that flowed into the main rivers. River samples were taken at three points in a straight line across the river (50-100' from each bank and midstream). This would indicate whether water quality is different in the center of the river than along the edges, where people are more likely to come in contact with water. Samples were taken at approximately one foot below the surface, because people usually swim in the top one to three feet of water.

Stream Sampling

There is little information about water quality in the tributary streams that run through our communities and feed into the rivers. For every mile of river in the Pittsburgh Pool, there are twenty miles of streams which feed into those rivers. Benthic surveys and additional chemical tests were conducted on the tributary streams, in order to gain a better understanding of their water quality.

Streams were sampled in the first riffle area upstream from the mouth of the river. This was to insure that no backflow from the river would affect the samples and to provide a good macroinvertebrate sampling location. Since stream samples were gathered at the furthest point downstream, they reveal stresses that occur throughout the watershed. Bacteriological sampling was taken only in dry weather conditions, because of the physical difficulty and costs of monitoring streams in wet weather.

The benthic survey followed Rapid Biological Assessment protocols developed by the U.S. Environmental Protection Agency with appropriate modifications for local conditions. Pine Creek was selected as the reference stream, because it reflected the urban/suburban environment in the study, is classified as "Approved Trout Waters" and had a relatively healthy invertebrate community.

The selection of metrics considered that sewage was of major interest to the study and is known to be a problem in many Allegheny County streams. However, three new metrics were designed to address the influence of other local conditions, such as combinations of sewage, salt runoff, acid mine drainage, and urban alkaline leachates.

Summary of Data

1. Bacteria levels in dry weather for river and stream sampling sites (Figure IV-a, IV-b, IV-c, IV-i)
2. Chemical testing data in dry weather for river and stream sampling site (Figure IV-a, IV-b, IV-c, IV-d, IV-e, IV-f, IV-g)
3. Example of bacteria levels in wet weather (including how bacteria level changes in time) and its river sampling sites (Figure IV-d, IV-e, IV-h, IV-i)
4. Biological chart showing condition scores and its sampling sites (Figure IV-j, IV-k)

Bacteria

Rivers

- In dry weather most of the river sample sites along the Monongahela River were within the recommended 200 CFU/100ml levels for fecal coliform

- In wet weather recommended levels were exceeded at many river sampling sites, having higher concentrations of fecal coliform than would be expected in this region due to CSO problems.

- Sample areas further upriver from the city showed less impact and had a shorter recovery time. There are fewer CSO's in these areas.

- **The study indicates that there is a relationship between highly urbanized areas and wet weather water quality problems.**

Streams

- Many streams showed high levels of bacteriological indicators and were more impacted by fecal coliform in dry weather than the main rivers.

- Streams most and least impacted by bacterial contamination

  Allegheny River Tributaries

  - Most impacted – Sipes Run, Pine Creek, Girtys Run

  - Least impacted – Guyasuta Run, Heths Run

Monongahela River Tributaries

- Most impacted – West Run, Streets Run, Becks Run

- Least impacted – Nine Mile Run

Ohio River Tributaries

- Most impacted – Saw Mill Run

- Least impacted Chartiers Creek

- **Many streams have high levels of bacteria in dry weather when there would be no storm water runoff or combined sewer overflows. This is a significant issue.**

Chemical

- Chemically, the study streams tended to be alkaline, hard, and mineralized. Concentrations of ammonia and metals, especially iron and aluminum, were elevated at a number of stations. The pH, alkalinity, conductivity, and hardness values would be considered very high in local non-urbanized streams.

- **These results indicate a widespread influence of leaching alkaline mill slag, highway deicing salts, sewage contamination, and at some locations, acid mine drainage from coal mines.**

Biological

- The biological assessment showed that all of the 35 stream sample stations were impaired to various degrees
  - ~ 42.8% severely impaired
  - ~ 37.2% moderately impaired
  - ~ 20% slightly impaired

- Note that a stream with poor bacteriological conditions, such as Pine Creek and West Run, can have good biological conditions.

- Over 15,000 invertebrate organisms from 67 different taxa were collected.

- **While all streams were impaired to some extent, the number of streams that were moderately or slightly impaired is encouraging. Also, the diversity of aquatic life found in these streams exceeded what might have been expected from historical views of these urban waterways.**

Conclusion

The water quality team in the 3 Rivers 2nd Nature has taken samples from each testing site once a week in dry weather, for a period of more or less than six weeks. We sample three consecutive days during specific wet weather events. Our scientists identify the sites and protocols for sampling. They run the laboratory tests, then carefully enter the data into databases which is then transfered into a geographic information system (GIS) which associates spatial-geometric features with the database records. We want to understand three types of water quality, the ability to support life, the impacts of urbanization and the life in streams. We want to understand our results in relation to time, in relation to weather and in relations to specific locations on the river.

The question of water quality is like asking about the weather. Give it a minute and it can change. Watch it over a year, and it can have different chemical, physical and biological personalities at different times of the year.

Water is a dynamic entity which touches everything, most things can be either dissolved or transported by it. Understanding water quality requires a caring relationship, an interest in the stream or river over time. We have just begun to listen to our rivers and heed the signs that tell us of their ability to support life and provide access for recreation.

We know very little about streams, water quality studies of streams are easy to do, and easy to access. For every mile of river we have 20 miles of streams in Allegheny County. Ride, pedal, skate or walk downhill and you will find your own urban stream, that needs to be studied and cared for.

Mike Koryak who does the biological assessment for 3R2N has said, “Water quality has improved, we have gone from a river with very few fish, to a river of many fishes in less than 30 years.”

Appendix IV: Summary of Data

Figure IV-b:Dry Weather Bacteria Testing in the Pittsburgh Pool

Monongahela River	E Coli (CFU/100ml)
Becks Run	1987
Streets Run	1944
West Run	2420
Nine Mile Run	204
Homestead Run	2047
Allegheny River	E Coli (CFU/100ml)
Girty's Run	2420
Pine Creek	1997
Sipes Run	~
Guyasuta Run	395
Ohio River	E Coli (CFU/100ml)
Saw Mill Run	1888
Chartiers Creek	829

Figure IV-c: Dry Weather Bacteria Testing of Streams on the Upper Monongahela RiverPool

Upper Monongahela River	E Coli (CFU/100ml)
Turtle Creek	1388
Thompson Run	1856
Crooked Run	2420
Youghiogheny	337
Sandy Creek	234
Pine Run Creek	1761
Peter's Creek	935
Coursin Run	381
Wiley Run	527
Fallen Timber Run	754
Lobbs Run	972
Perry Mill Run	142
Kelly Run	202
Bunola Run	379
Mingo Creek	369
Dry Run	2246
Pigeon Creek	1206
Sunfish Run	1372
Beckets Run	845

Figure IV-d: Dry Weather Physical Chemistry Testing in the Pittsburgh Pool

(Average of six tests during the summer of 2000)

Monongahela River	Temperature (°C)	pH	DO (ppm)	Conductivity (umhos/cm)
MP0.23-R	24.00	7.5	7.86	345
MP0.23-M	22.98	7.4	8.46	422
MP0.23L	23.31	7.5	7.73	451
MP2.82-R	23.90	7.4	7.33	305
MP2.82-M	22.27	7.5	8.03	402
MP2.82-L	22.37	7.5	8.05	417
MP5.66-R	22.98	7.4	8.22	446
MP5.66-M	22.78	7.4	8.26	453
MP5.66-L	22.38	7.4	7.98	454
MP10.21-R	22.65	7.3	8.03	369
MP10.21-M	22.35	7.3	8.18	364
MP10.21-L	22.08	7.2	8.03	362
Allegheny River	Temperature (°C)	pH	DO (ppm)	Conductivity (umhos/cm)
AP0.18-R	18.60	7.5	10.59	300
AP0.18-M	20.32	7.4	10.61	262
AP0.18-L	20.30	7.4	10.38	279
AP2.26-R	19.20	7.5	9.94	280
AP2.26-M	19.13	7.5	10.60	280
AP2.26-L	18.85	7.4	10.42	279
AP4.57-R	19.43	7.5	10.99	271
AP4.57-M	19.33	7.5	10.73	287
AP4.57-L	19.10	7.5	10.53	281
AP6.1-R	19.08	7.4	10.54	283
AP6.1-M	19.02	7.4	10.51	281
AP6.1-L	18.92	7.4	10.49	293
Ohio River	Temperature (°C)	pH	DO (ppm)	Conductivity (umhos/cm)
West End Bridge-R	21.42	7.4	8.83	292
West End Bridge-M	21.12	7.5	9.03	331
West End Bridge-L	21.20	7.4	9.29	321
Brunot Island-R	21.26	7.4	9.16	285
Brunot Island-M	21.12	7.4	9.56	287
Brunot Island-L	21.28	7.4	9.28	301
Below Chartiers Creek-R	21.30	7.4	9.61	274
Below Chartiers Creek-M	21.66	7.4	9.74	279
Below Chartiers Creek-L	27.10	7.3	9.63	224
Upper Neville Island-R	19.69	7.3	9.79	256
Upper Neville Island-M	21.24	7.4	9.52	302
Upper Neville Island-L	22.08	7.5	9.26	320

MP=Monongahela in Pittsburgh Pool, AP=Allegheny Pittsburgh Pool, OP=Ohio Pittsburgh Pool
* R=Right, M=Middle, L=Left

Figure IV-e: Dry Weather Physical Chemistry Testing on the Upper Monongahela River

(Average of six tests during the summer of 2001)

Upper Monongahela River	Temperature (°C)	pH	DO (ppm)	Conductivity (umhos/cm)
M11.5-R	23.08	7.5	7.88	299
M11.5-M	23.18	7.5	7.82	301
M11.5-L	23.11	7.5	7.70	305
M14.3-R	23.70	7.5	7.78	312
M14.3-M	23.31	7.5	7.78	315
M14.3-L	23.54	7.5	7.58	311
M16.7-R	24.01	7.5	7.45	316
M16.7-M	24.23	7.5	7.44	321
M16.7-L	24.03	7.6	7.40	334
M23.2-R	24.09	7.3	7.23	300
M23.2-M	24.14	7.4	7.52	299
M23.2-L	23.90	7.4	7.33	305
M24.3-R	26.12	7.4	7.07	286
M24.3-M	25.97	7.4	7.41	284
M24.3-L	25.19	7.6	6.83	674
M27.8-R	24.45	7.7	7.53	282
M27.8-M	24.43	7.5	7.44	281
M27.8-L	24.71	7.4	7.29	285
M31.7-R	23.46	7.4	7.62	260
M31.7-M	23.62	7.5	7.74	262
M31.7-L	23.53	7.7	7.54	266
M35.0-R	23.46	7.4	7.52	243
M35.0-M	23.49	7.4	7.57	242
M35.0-L	23.56	7.5	7.52	241

Figure IV-f: Dry Weather Physical Chemistry Testing of Streams in the Pittsburgh Pool

(Average of six tests during the summer of 2000)

Monongahela River	Temperature (oC)	pH	DO (ppm)	Conductivity (umhos/cm)	Ammonia (mg/l)	TDS (ppm)	Turbidity (NTU)	Alkalinity (mg/l)	Hardness (mg/l)	Iron (mg/l)
Becks Run	19.75	7.9	9.51	1181	0.049	656	0.43	51	232	0.095
Street Run	17.95	7.5	6.12	1659	1.551	963	2.32	108	371	0.485
West Run	18.55	7.7	6.72	1181	0.171	652	0.85	99	201	0.071
Nine Mile Run	18.13	10.0	6.24	1299	0.171	859	0.23	73	245	0.021
Homestead Run	16.43	7.4	1.82	1288	0.537	645	1.04	173	257	0.204
Allegheny River	Temperature (oC)	pH	DO (ppm)	Conductivity (umhos/cm)	Ammonia (mg/l)	TDS (ppm)	Turbidity (NTU)	Alkalinity (mg/l)	Hardness (mg/l)	Iron (mg/l)
Girty's Run	14.93	8.4	12.09	1581	0.030	722	0.45	139	226	0.079
Pine Creek	14.95	8.1	11.40	792	0.070	508	0.68	105	139	0.162
Sipes Run	~	~	~	~	1.479	743	1.63	175	251	
Guyasuta Run	14.66	8.1	9.90	765	0.033	643	0.23	174	246	0.015
Ohio River	Temperature (oC)	pH	DO (ppm)	Conductivity (umhos/cm)	Ammonia (mg/l)	TDS (ppm)	Turbidity (NTU)	Alkalinity (mg/l)	Hardness (mg/l)	Iron (mg/l)
Saw Mill Run	17.62	7.7	8.50	818	0.230	883	0.60	95	221	0.142
Chartiers Creek	18.60	7.8	8.82	1101	0.020	960	1.07	134	282	0.832

Figure IV-g: Dry Weather Physical Chemistry Testing of Streams on the Upper Monongahela River

(Average of six tests during the summer of 2001)

Upper Monongahela River	Temperature (°C)	pH	DO (ppm)	Conductivity (umhos/cm)	Ammonia (mg/l)	TDS (ppm)	Turbidity (NTU)	Alkalinity (mg/l)	Hardness (mg/l)	Nitrate (mg/l)	Iron (mg/l)
Turtle Creek	18.06	7.42	7.60	1021	0.117	697	1.55	73	227	1.5	0.877
Thompson Run	18.71	9.43	7.24	1214	1.675	909	1.65	78	288	2.3	0.447
Crooked Run	17.93	7.26	2.09	758	9.572	477	8.38	126	143	0.7	0.533
Youghiogheny	20.52	7.61	7.40	289	0.055	195	1.54	33	63	0.6	0.440
Sandy Creek	16.19	7.76	8.65	1483	0.058	1175	0.32	81	402	0.3	0.092
Pine Run Creek	16.10	7.57	9.00	1162	0.071	852	0.50	54	262	1.7	0.192
Peter's Creek	19.73	7.63	8.62	-	0.199	797	1.33	97	262	2.4	0.938
Coursin Run	14.59	7.97	9.15	743	0.054	546	0.51	157	238	0.6	0.116
Wiley Run	16.32	7.42	7.23	1338	0.069	1095	0.48	78	380	0.3	0.279
Fallen Timber Run	15.59	7.76	8.56	1208	0.066	918	0.50	153	316	0.3	0.225
Lobbs Run	19.47	7.65	6.29	3021	1.140	2141	1.28	130	275	0.7	0.579
Perry Mill Run	19.83	7.72	8.20	843	0.042	806	1.14	232	214	0.3	0.290
Kelly Run	18.98	7.49	7.90	826	0.061	686	1.10	156	261	0.4	0.377
Bunola Run	18.21	7.40	7.91	845	0.070	711	1.54	100	286	0.9	0.465
Mingo Creek	18.69	7.85	7.66	1205	0.066	914	1.05	196	227	0.3	0.294
Dry Run	20.02	7.65	7.26	763	0.117	617	3.37	198	214	0.5	0.460
Pigeon Creek	19.31	7.73	7.03	2470	0.103	1828	2.26	175	292	0.3	0.634
Sunfish Run	15.84	7.83	8.97	1772	0.513	1346	1.67	276	259	1.0	44.700
Beckets Run	18.28	7.40	9.08	605	0.053	635	1.17	186	188	0.6	2.920

Figure IV-i: Bacteria Testing of Streams in Wet Weather and Dry Weather in the Pittsburgh Pool and Upper the Monongahela River

Wet Weather Bacteria Levels (CFU/100ml)			Dry Weather Bacteria Levels (CFU/100ml)
Pittsburgh Pool	1st day after wet weather event (9/25/2000)	2nd day after wet weather event (9/26/2000)	Average
MP0.23-R	1553	1203	311
MP0.23-M	435	579	65
MP0.23-L	548	1733	123
MP2.82-R	2420	2420	46
MP2.82-M	2419	1553	68
MP2.82-L	2419	2420	84
AP0.18-R	1046	2420	63
AP0.18-M	980	2420	42
AP0.18-L	488	2420	48
AP2.26-R	2420	2420	113
AP2.26-M	548	1733	48
AP2.26-L	613	2420	41
West End Bridge-R	435	2420	342
West End Bridge-M	579	2420	334
West End Bridge-L	548	2420	414
Brunot Island-R	1733	2419	309
Brunot Island-M	921	2420	215
Brunot Island-L	613	2420	262

Wet Weather Bacteria Levels (CFU/100ml)			Dry Weather Bacterial Levels (CFU/100ml)
Upper Monongahela River	1st day after wet weather event (9/26/2001)	2nd day after wet weather event (9/27/2001)	Average
MP14.3-R	365	816	668
MP14.3-M	96	179	71
MP14.3-L	87	157	54
MP16.7-R	85	179	92
MP16.7-M	113	179	107
MP16.7-L	108	313	115
MP27.8-R	104	31	64
MP27.8-M	42	35	58
MP27.8-L	55	47	61
MP31.7-M	26	49	409
MP31.7-R	31	23	66
MP31.7-L	23	19	62

*R = Right, M = Middle, L = Left

Figure IV-j: Bacteria Level Chaanges in Time

Average Fecal Coliform Data from Select Sites along the Monongahela, Allegheny and Ohio Rivers during Wet Weather from October 15-18, 2001

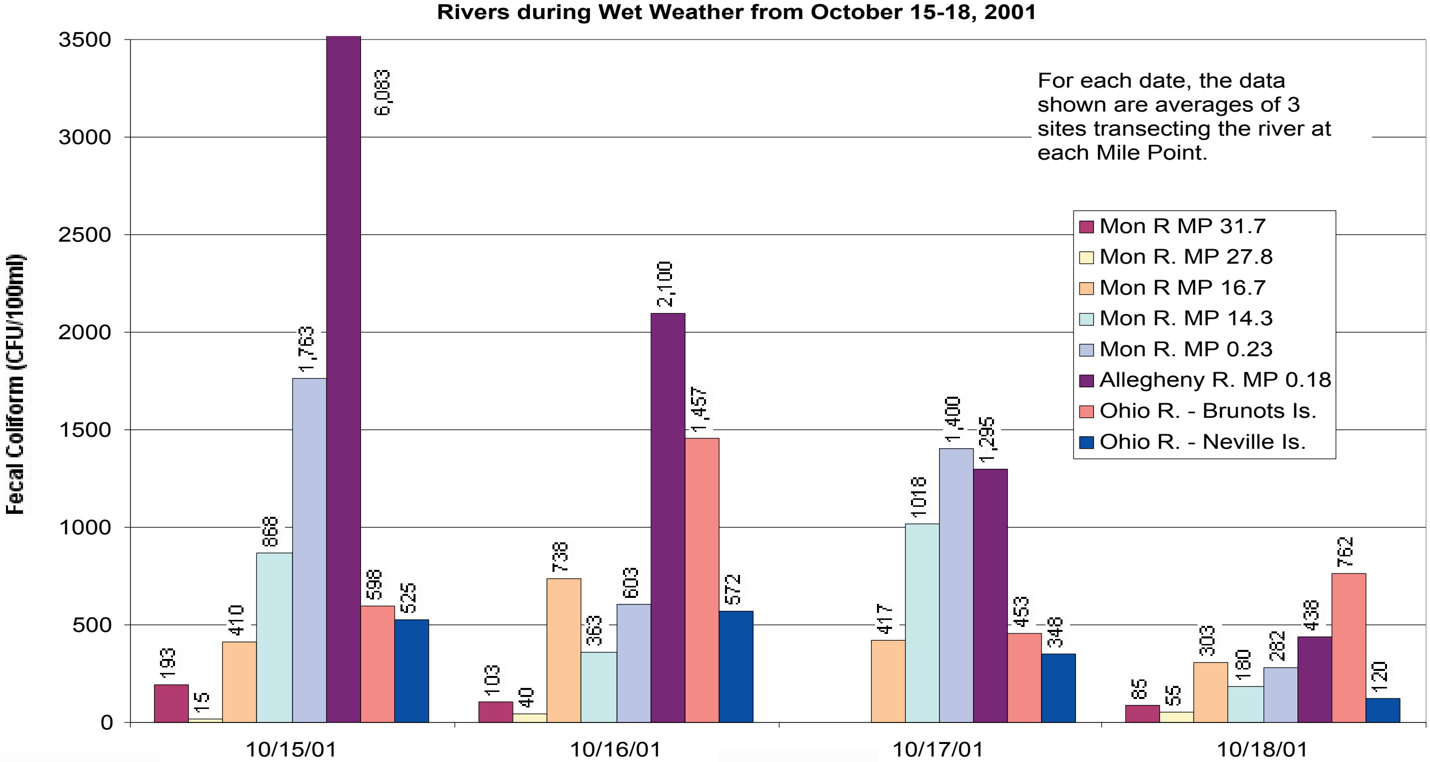
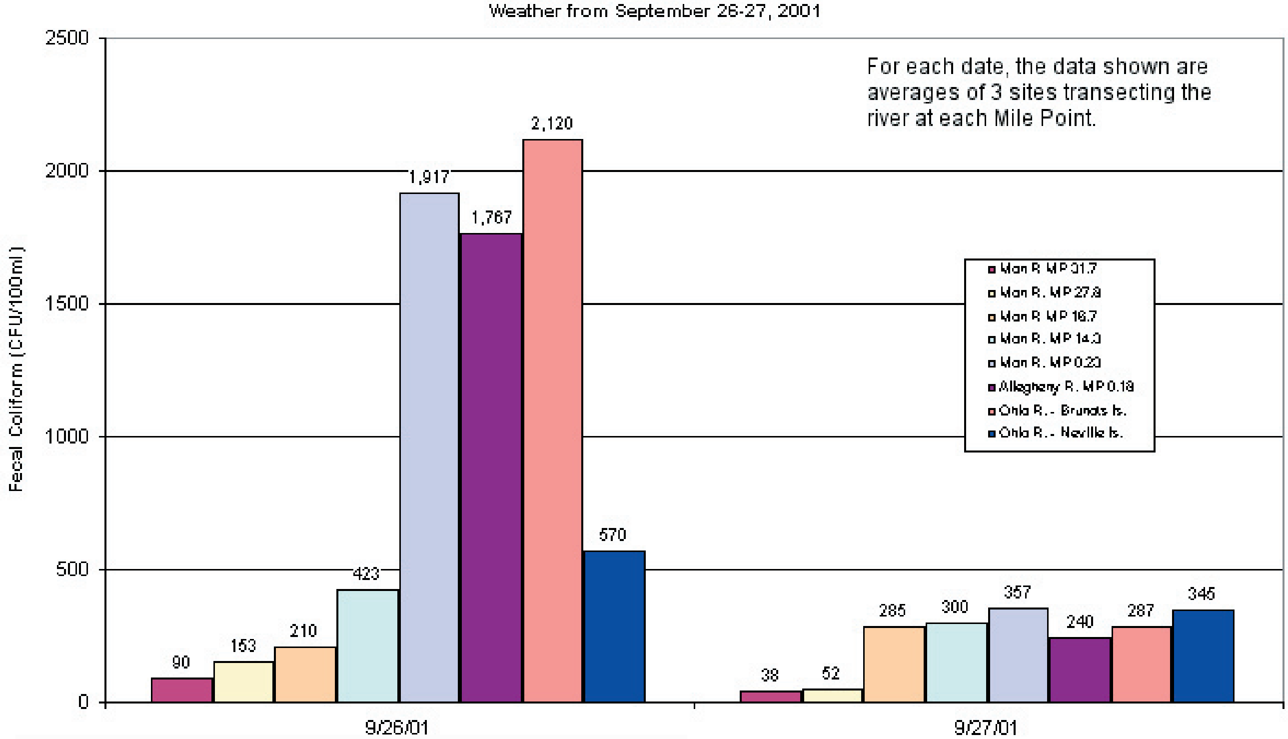
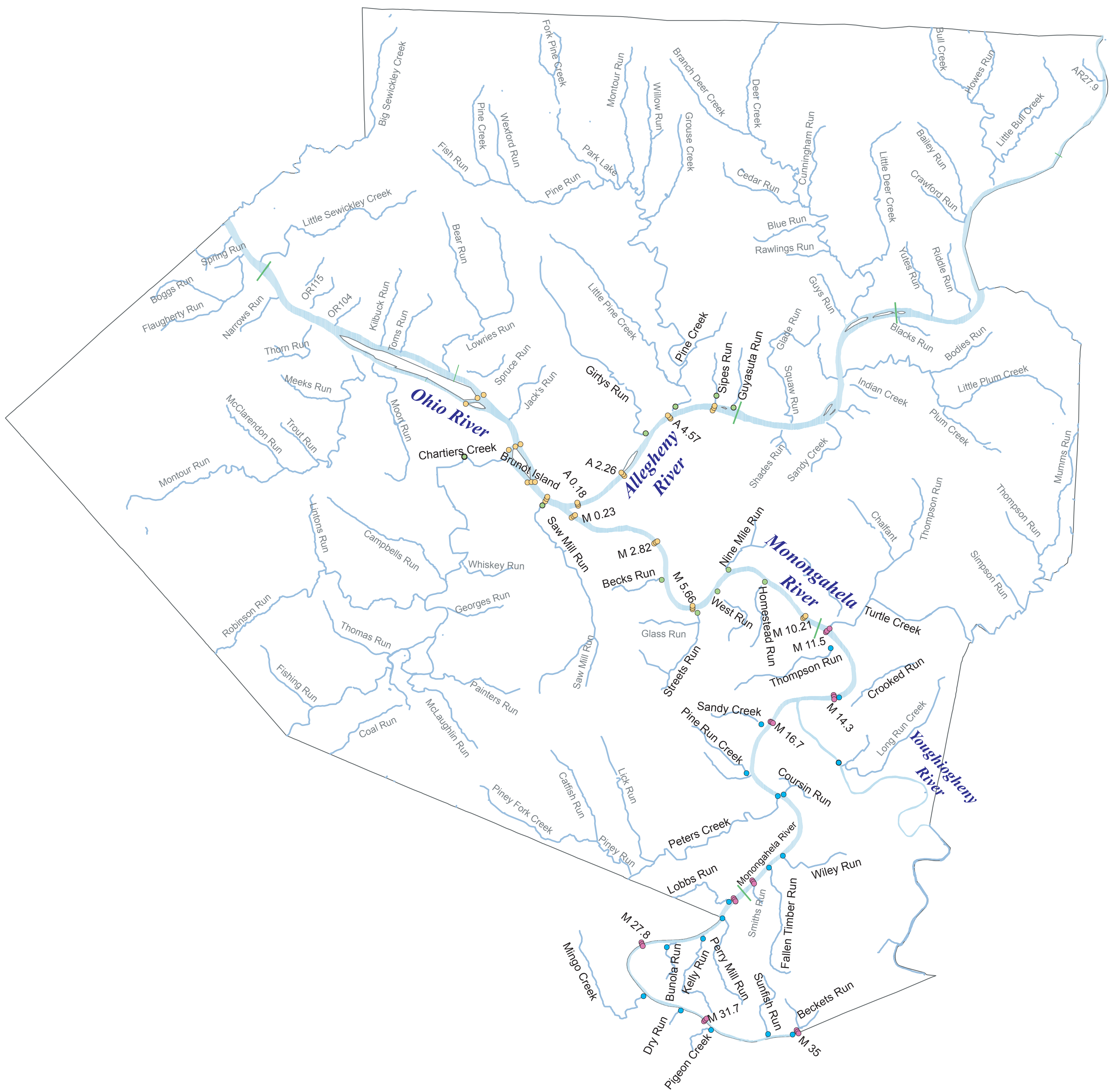


Figure 9: Average Fecal Coliform Data from Select Sites along the Monongahela, Allegheny and Ohio Rivers during Wet Weather from September 26-27, 2001





Legend

- Dry Weather Transect Testing Sites in the Pittsburgh Pool
- Dry Weather Single Testing Sites in the Pittsburgh Pool
- Dry Weather Transect Testing Sites Upper the Monongahela River
- Dry Weather Single Testing Sites Upper the Monongahela River
- Locks and Dam

Figure IV - a
Dry Weather Testing Sites
in the Pittsburgh Pool and upper the
Monongahela River

3Rivers 2nd Nature
Art Ecology Community
The STUDIO for Creative Inquiry Carnegie Mellon

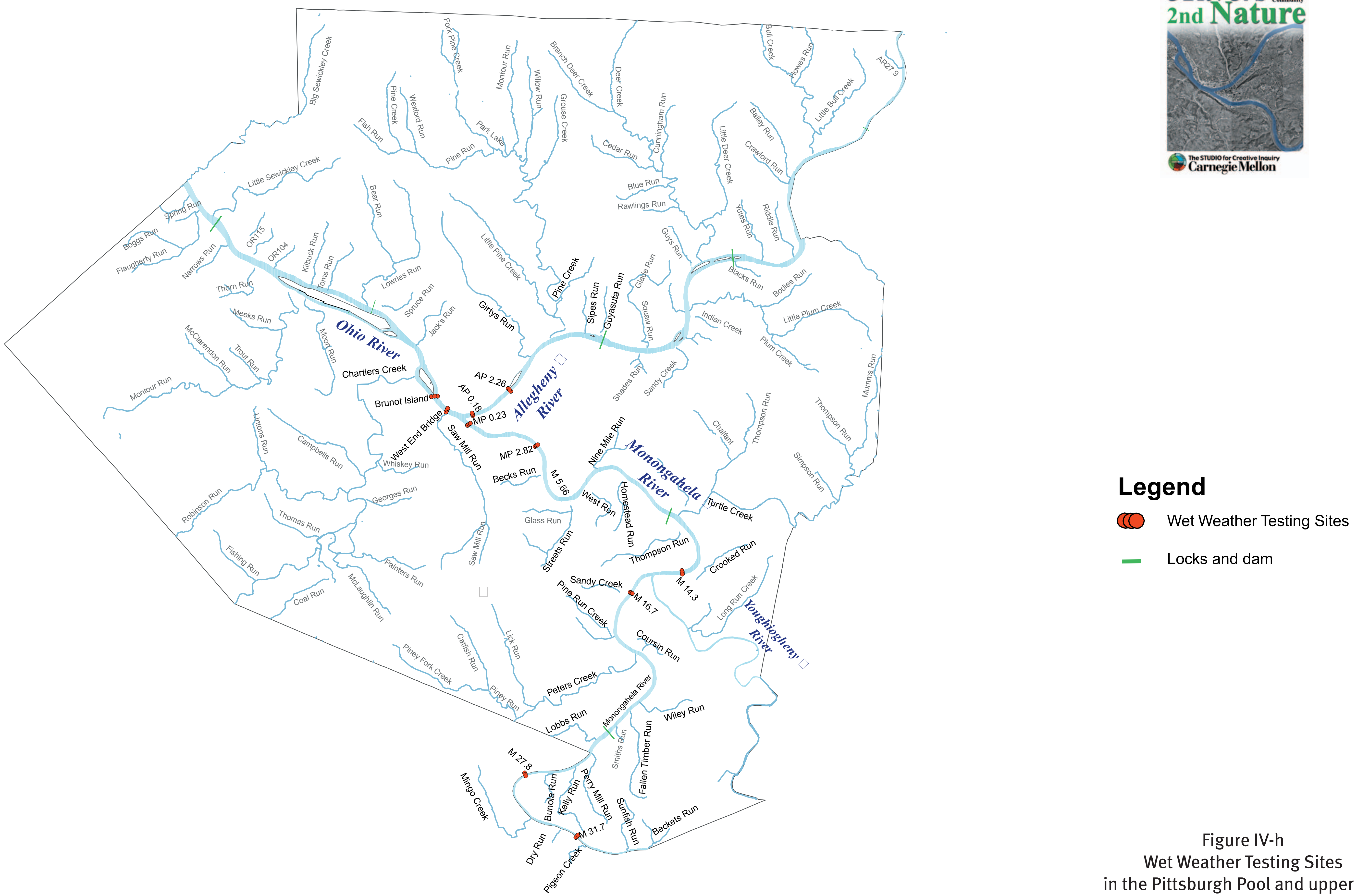


Figure IV-h
Wet Weather Testing Sites
in the Pittsburgh Pool and upper the
Monongahela River

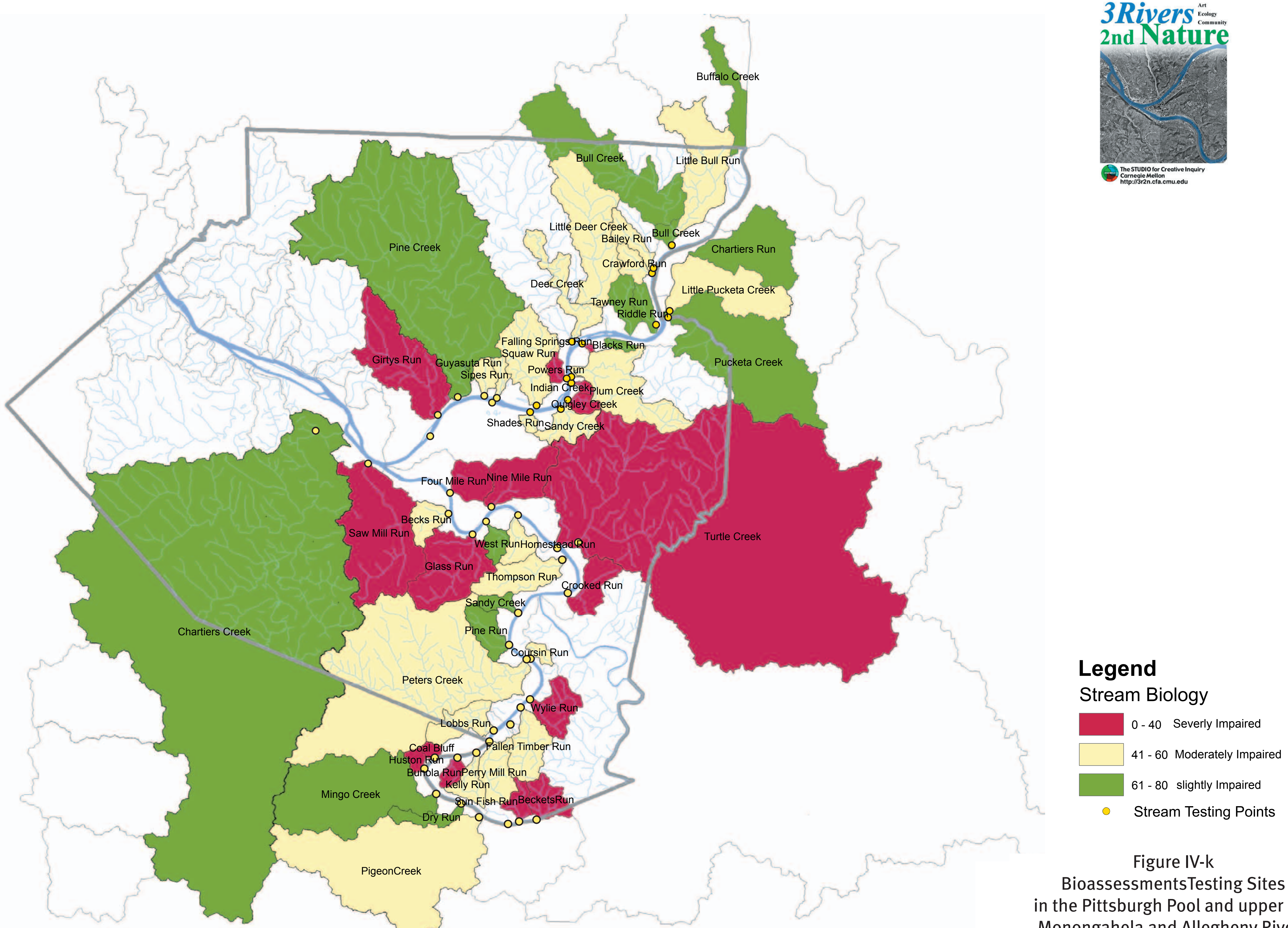


Figure IV-k
BioassessmentsTesting Sites
in the Pittsburgh Pool and upper the
Monongahela and Allegheny Rivers

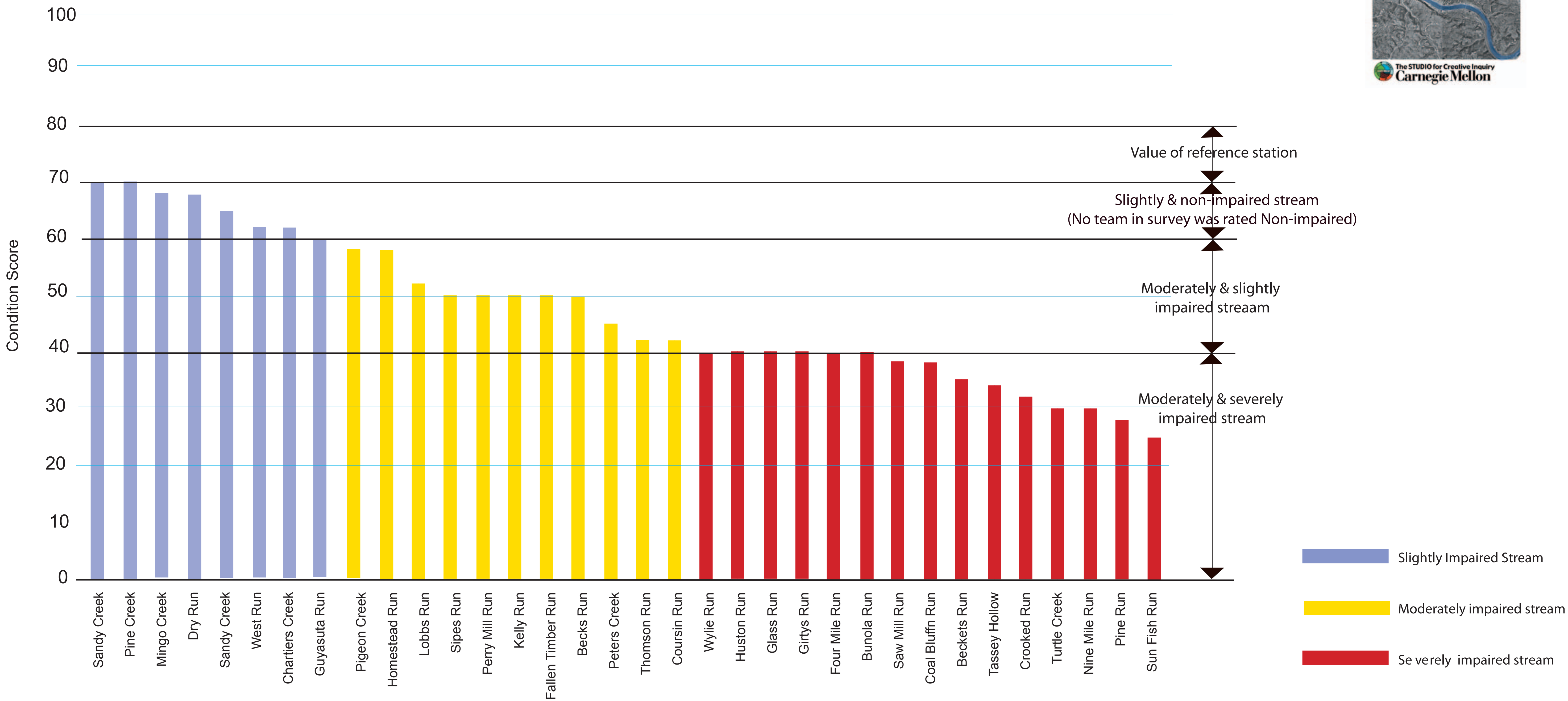


Figure IV-l
BioassessmentsTesting Results
in the streams of the Pittsburgh Pool
and upper the Monongahela River

V. Classroom Activity 1: Awareness of Our Rivers

Overview:

This activity introduces students to their local river(s). They will create a concept map* about the past, present and future of the local rivers. Students begin by sharing their experience and memories about the river.

This guided inquiry will help students recognize the multiple issues that can affect their understanding of their local river and its relationship to the environment, the economy and society. The second part of this activity focuses on the history of the local rivers. After researching a particular historic topic or time period, students will present their information in the classroom.

*concept map: A concept map consists of nodes or cells that contain a concept, item, and question. The form could look like a web diagram. Each element is also linked or labeled to denote directional relationships between the nodes with an arrow symbol. The links explain the relationship between the nodes. A concept maping could be used to represent complex ideas or knowledge, it can also be an excellent tool for gathering and sharing information.

Objectives:

Students will:

- Describe the issues and events in the history of Pittsburgh's rivers.
- Explain the effects of natural events and human uses on the rivers.
- Discuss what should be considered when making decisions on the use of river resources.

PA Education Standards for Environment and Ecology :

Watersheds and Wetlands

Watershed 4.1.10. E

Identify and describe natural and human events on watersheds.

- Describe how natural events affect a watershed (e.g., drought, food.)

4.3.7.A. *Identify environmental health issues.*

- Identify various examples of long-term pollution and explain their effects on environmental health.
- Identify diseases that have been associated with poor environmental quality.

4.3.7.B. *Describe how human actions affect the health of the environment.*

- Identify land use practices and their relation to environmental health.
- Identify residential and industrial sources of pollution and their effects on environmental health.

4.3.10. E. *Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices.*

- Explain how human practices affect the quality of the water and soil.
- Analyze data and explain how point source pollution can be detected and eliminated.

Humans and the Environment

4.8.7.C. *Explain how human activities may affect local, regional and national environments.*

- Explain how a particular human activity has changed the local area over the years.

4.8.10. C. *Analyze how human activities may cause changes in an ecosystem.*

- Analyze and evaluate changes in the environment that are the result of human activities.
- Compare and contrast the environmental effects of different industrial strategies (e.g., energy generation, transportation, logging, mining, agriculture.)

Preparation

Student materials:

- Local or school library resource books
- Web site
- Resource contacts
- Maps of sample sites and land uses (urban, rural, etc.), sewer & stream outflows

Estimated duration:

Interview...1-2 days outside of class to conduct interview, 1 class period to present interviews

History...2-3 days for research, 1-2 class periods for presentations and timeline development

Lesson Plan

Class Setting

Key Questions:

1. Have a general discussion about rivers.
   - *How are rivers important?*
   - *Why are so many cities located near rivers?*
   - *How would you describe the Three Rivers in Pittsburgh?*
   - *How have the three rivers affected the Pittsburgh area? How have the rivers been affected by Pittsburgh?*

2. Have each student interview two people who have had personal experiences with the river. Students should interview them for general information on the river, their remembrances and experiences, the importance of the river in their lives, and their view of the river today. Discuss possible candidates for the student's interviews. This may be as open-ended or guided as desired. Interviews may include people who live or work on the river, family or friends, etc. Encourage students to interview people in different age brackets to represent different time periods.

3. Have students write a report comparing the two interviews. Discuss the following:
   - *What information from your interviews was the most interesting for you?*
   - *Were people's comments regarding the rivers positive or negative? How did people's personal experiences affect their views of the rivers today?*
   - *Aside from personal experience, what other things may have affected how people view the rivers?*
   - *Did you notice any variation in views among age groups? If so, how would you explain it?*

4. Divide students into groups. Tell them they will be researching more about the rivers and their role in Pittsburgh's history.

5. Have each group research a certain time period in the history of Pittsburgh's rivers from the 1700's to present.
   - Tell students that their group should gather river-related information for their time period on the following topics:
     - o Historical events
     - o Population growth and settlement patterns
     - o People related to the river
     - o Uses of the river and their effects
       - transportation/navigation
       - industry
       - recreation
       - security
       - others
     - o Environmental conditions/changes – water quality, public health,

   - Assign each group a time period and due date for completion of the research. (*Some of the important issue/events for each time period are listed for the teacher's information.)*
     - o 1700-1800
       - Native Americans
       - European settlement – French/ British –early wars, forts
       - Why did people fight over this area?
       - Gateway to the west

     - o 1800—1850
       - Early industries – boat building, salt works, glass, mills, iron, coal
       - River travel – riverboats, sidewheelers, flatboats, steamboats
       - Settlement – where people lived in relation to the rivers

     - o 1850-1900
       - Poor water quality – waterborne diseases, waste disposal, drinking water
       - Settlement – where people lived in relation to the rivers

- Population
- Industrial growth – effect of Civil War, steel
- Dams & bridges

o 1900-1950
- River canalization (dams)
- 1936 flood
- Poor water quality, little aquatic life
- Early drinking water treatment
- Steel industry

o 1950-present
- Water quality improves over this period
- Wastewater treatment
- Waterfront development/renovation
- Focus of industry changes
- Recreational use & access

6. Have each group prepare and present short reports on the rivers during their time period. After the presentations are finished, discuss the following:
   - o *What were the main issues/events during each time period?*
   - o *What do you think may have influenced people's decisions when determining the uses of the rivers in each time period?*
   - o *How did these decisions affect the rivers?*
7. As a class, have students develop a visual timeline that demonstrates river-related changes and issues. Use a long piece of butcher paper. The timeline can be done in a number of ways. You may want to spark some ideas then let students determine the format of the timeline. Two possible options are listed below:
   - o List the time periods along the top of the paper. List important events below the appropriate time– such as when fish disappeared and returned, best/worst water quality, peaking of specific industries, floods, dams, bridges, etc.
   - o Draw a river over time that visually shows how the rivers changed, including physical changes from natural banks to industrial development, population growth, environmental changes (lots of fish in the water, no fish, discharges entering

the water), various types of boats, addition of dams or bridges, etc.

8. After the project is completed, discuss the following.
    - *What are the most dramatic changes you see on the timeline? Are there any trends or connections you can see?*
    - *Which issues of today would you focus on?* (To spark discussion, quickly review some of the issues if necessary.)
    - *How would you address these issues? What changes would you recommend for the rivers today? What impact do you think your changes/decisions would have?*
    - *What things should people consider when making decisions regarding uses or changes to the rivers?*
    - *How might decisions on the river-related issues we are facing today affect future generations?*
    - *Have your original views of the rivers changed as a result of this project? Do you think you have a role in the future of the rivers?*

Variation:

1. Give each group one topic area and have them research that topic over the entire time period from 1700-present. Have each group present their topic information. Discuss how each topic affected other topics – i.e. industrial development and environmental conditions.

VI. Classroom Activity 2: Interpreting Water Quality Data

Activity : Interpreting water quality data

Overview:

This is designed to familiarize students with water quality interpretation before going into the field to do original research. Students will analyze water quality data, make correlation between different water quality indicators, and predict stream conditions and wildlife. Students will also use maps for spatial analysis and to visually represent their conclusions. The activity emphasizes the interdependence of water quality indicators. The goal of this exercise is for students to think critically about water quality and to make predictions about stream conditions, not just to report whether a particular indicator is "good" or "bad" at a given test site.

Objectives:

Students will

- Examine specific water quality parameters
- Identify primary pollutants for each site and explore the interactions between them
- Predict stream conditions, wildlife habitat, human use, pollution source
- Create symbols to represent conclusions visually on maps
- Understand the interconnection of biological and chemical characteristics of streams

PA Academic Standards for Environment and Ecology:

Watersheds and Wetlands

4.1.12.C. *Analyze the parameters of a watershed.*

- ◆ Interpret physical, chemical and biological data as a means of assessing the environmental quality of a watershed.

Environmental Health

4.3.7.B. *Describe how human actions affect the health of the environment.*

- ◆ Identify land use practices and their relation to environmental health.

- Identify residential and industrial sources of pollution and their effects on environmental health.

4.3.10. E. *Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices.*

• Explain how human practices affect the quality of the water and soil.

Humans and the Environment
4.8.7.C. *Explain how human activities may affect local, regional and national environments.*

- Explain how a particular human activity has changed the local area over the years.

4.8.10. C. *Analyze how human activities may cause changes in an ecosystem.*

• Analyze and evaluate changes in the environment that are the result of human activities.

Background Information

See chapter III: Water Quality Parameters

<u>Preparation</u>

Student materials:

- Parameter guidelines (Figure VI-a)
- Maps (Figure VI-b, c, d, e, f, g, h, i)
- Data tables: Dry weather Pittsburgh pool (Figure IV-b), Dry weather upper Monongahela River (Figure IV-c), and Wet weather (Figure IV-e.)
- Colored pencils

Set up

Review Chapter 3. Explain the relationship between the maps and the data sheets. Divide the class into groups if desired and assign test sites. Each student can also be assigned a specific parameter if desired.

Estimated duration

Introduction…30 minutes

Data analysis and discussion within groups…30–45 minutes

Presentation and discussion…30 minutes

Lesson Plan

Key questions:

- *Which parameters are interesting or indicative for each particular site?*
- *Why is it important to test for these particular parameters?*
- *How do these parameters interact with each other?*
- *Where do the data values fall in relation to the acceptable range for this parameter?*
- *What effect is this difference (or lack thereof) likely to have on the plants and animals living in/around the water?*
- *What sources might have caused this particular condition?*
- *Looking at the map, how does this test site relate to the rest of the stream system?*
- *Compare results with other groups - is there a relationship between one test site and the next?*

1. Use chapter 3 and the data tables: Dry weather Pittsburgh pool(Figure IV-b), Dry weather upper Monongahela River (Figure IV-c), and Wet weather (Figure IV-e.) Review each testing parameter to be analyzed before beginning this activity.

2. Decide which area to focus on, i.e. stream in the school district, or transects on a familiar portion of river. Divide the class into small groups (3-4 students) and assign two test sites to each group. Students may choose to use all available data or to focus on 2 or 3 primary indicators for those sites.

3. Using the summary chart (Figure VI-a,) have students evaluate the data for their sites. Have each group do the following:
    - Determine the acceptable range for each parameter using the chart: i.e. pH between 6.5 and 8.2, Nitrates below 1 mg/1, etc.
    - Examine the actual stream/river data. *Is it within the acceptable range?*
    - Compare both sites: *is the data similar? Is one site more polluted and the other healthier? What might be different about the sites to cause this?*
    - Think about possible sources of pollution: i.e. E. coli contamination from sewer overflow, high Nitrates from

farm runoff, high temperature from urban runoff, etc.

- Identify interactions between parameters. For example, high turbidity increases temperature, and high temperature lowers dissolved oxygen.
- Evaluate the water quality and make predictions about stream/river conditions – plants, wildlife, and human contact. *What do you think each stream looks like? What type of organisms could live in the stream? Would you swim there?*
- Show conclusions on the maps with symbols/color/numbers/etc. (Maps: Figure VI-b, c, d, e, f, g, h, i)

4. After the groups have analyzed their sites, have the students discuss their findings as a class. They should characterize each stream/river site and explain the similarities and differences between their two study sites. After each group presents their conclusions, have the class collaborate to create a composite map of the entire study area. They should look for patterns across the entire system: *Does water quality improve upstream? Or are upstream sources of pollution diluted over the length of the river?* If each group is looking at a different stream, they can discuss the effects each stream has on the river into which it flows.

Appendix V:

Figure VI-a: Parameter guidelines

Testing parameter	Acceptable range	Possible sources	Additional information
Temperature	Depends on species and time of year Warm water species: 21°C and up Cool water species: 18 - 23°C Cold water species: 21°C and below	Tree shade, sunlight, water depth, farming/grazing, forestry, industry, septic systems, sewage treatment, construction, urban runoff	Warm water: largemouth bass, crappie, bluegill, carp, crayfish, dragonfly Cool water: perch, sauger, walley, smallmouth bass, pike, muskellunge, pickeral, rock bass, stonefly, mayfly, caddisfly, water beetles Cold water: trout, salmon, caddisfly, stonefly, mayfly
pH	6.5 - 8.2	Soil, bedrock, decomposition, industry, mining	Alkaline vs acidic Bacteria can survive widest pH range, plants and mollusks more tolerant of basic levels than fish
Dissolved oxygen	5 ppm and above 8 ppm and up is ideal	Septic systems, sewage treatment, construction, urban runoff	High temperature/turbidity/dissolved solids = low oxygen level
Conductivity	150 - 500 umhos/cm	Bedrock, industrial, urban runoff	
Ammonia	0.06 mg/l and below	Sewage treatment	Interacts with pH, temperature, DO
Total Dissolved Solids	1500 ppm and below or 750 ppm and below (depending on aquatic species)	Farming, forestry, industry, mining, sewage treatment, construction	Fish species/fisheries designation
Turbidity	100 NTU and below	Farming/grazing, forestry, sewage treatment, construction, urban runoff	Affects DO and temperature, damages fishes' gills
Alkalinity	20 - 200 mg/l 100 and up is ideal	Bedrock, sewage, mining	Regulates pH
Hardness	Soft water: 0-60 mg/l Moderately hard water: 61-120 mg/l Hard water: 121 - 180 mg/l Very hard water: 181 mg/l and up	Bedrock, mining, industry, sewage	No safety standards Hard water keeps fish from absorbing heavy metals and other toxins
Nitrate	1 mg/l and below	Farming/grazing, sepic systems, urban runoff	High nitrates increase plant growth, toxic to warm-blooded animals at >10mg/l
Iron	0.3 mg/l and below	Mining	Interacts with pH
E. coli bacteria	240 CFU/100ml and below (for a single sample)	Septic systems, combined sewer overflow	Effects on non-human animals

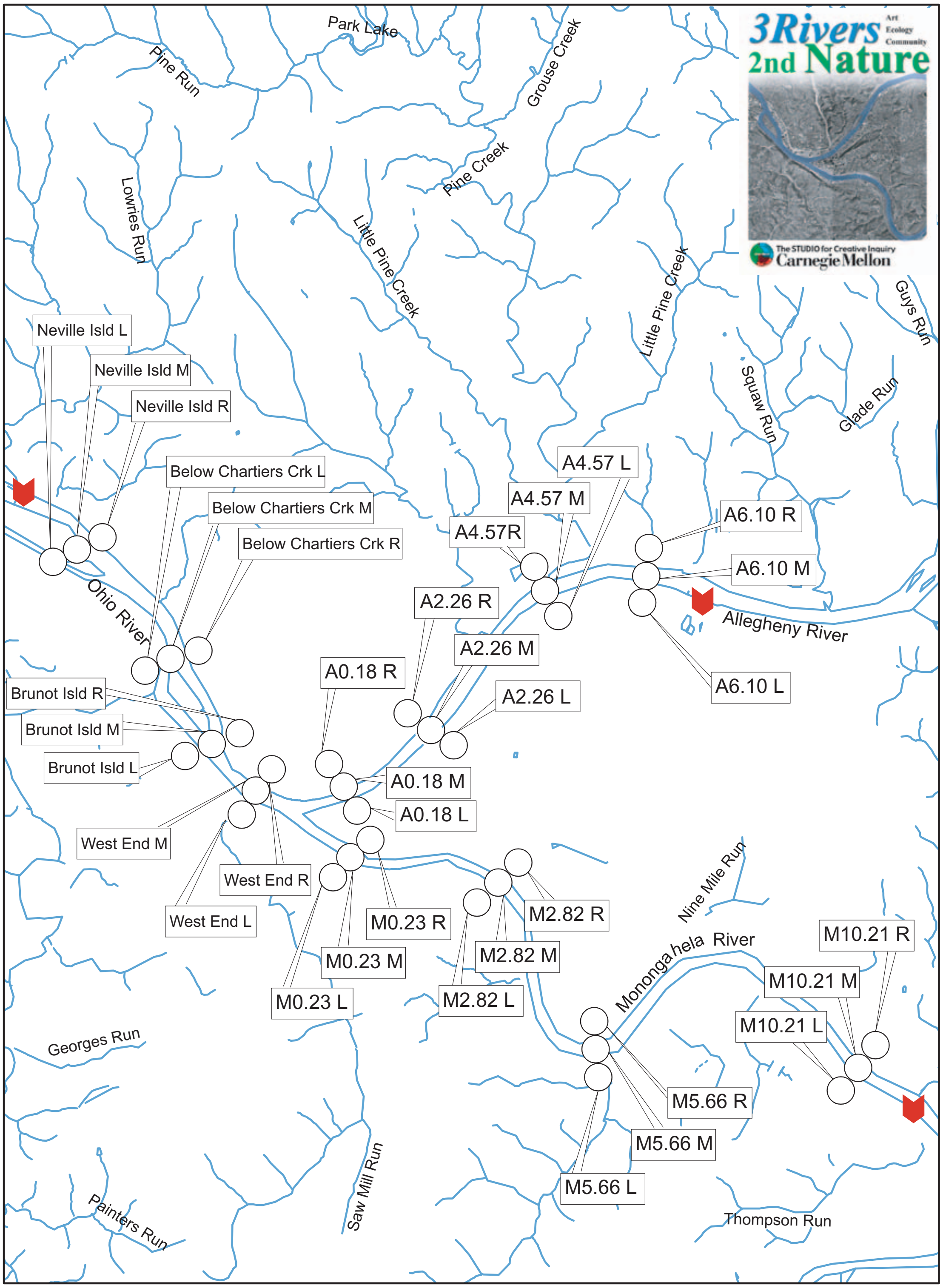


Figure VI-b:

River Chemistry Comparison Map
Pittsburgh Pool

Use colors to indicate impairment levels from data sheet

Legend

River Chemistry Test Sit

Lock and dam

Streams

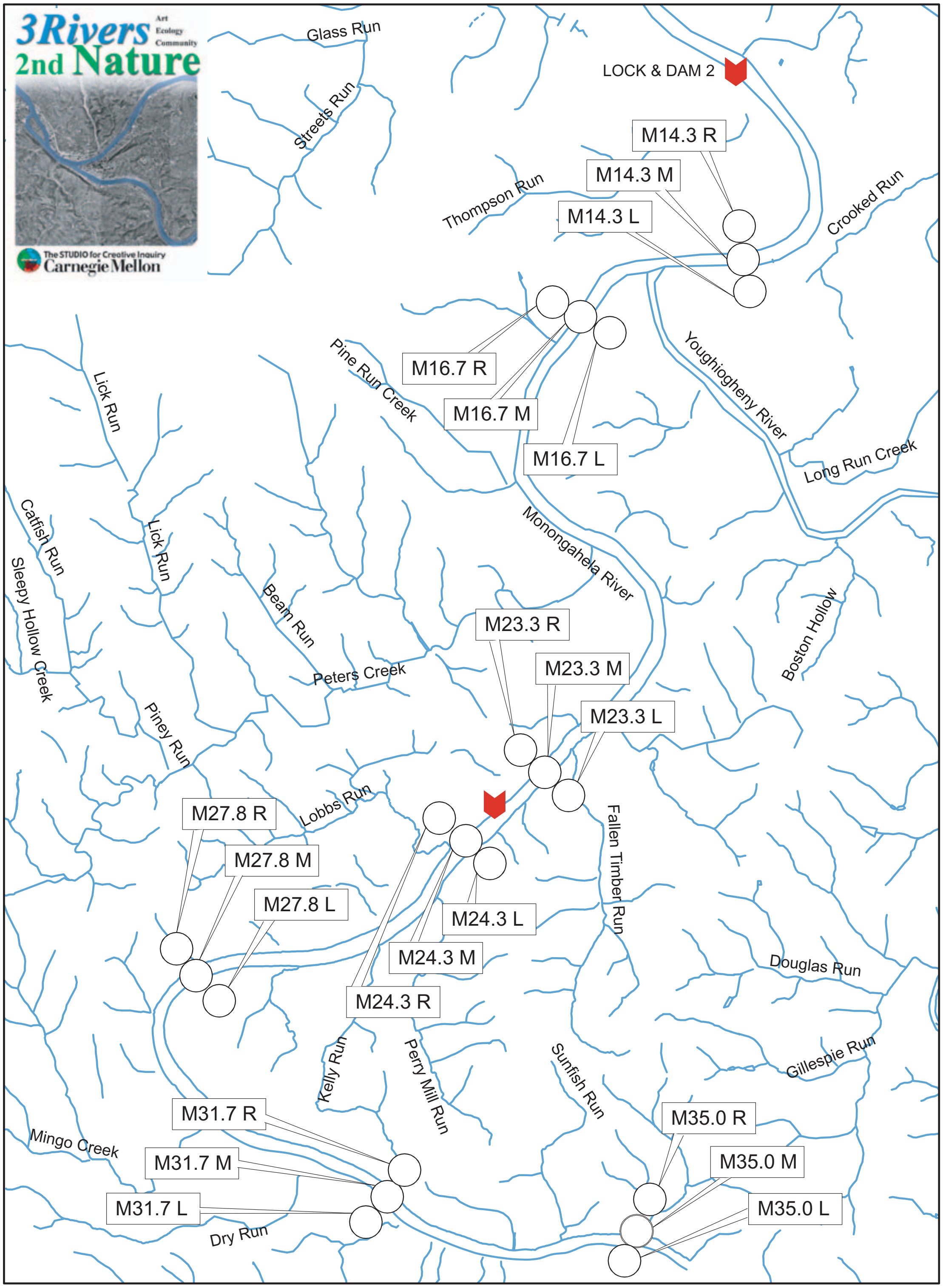


Figure VI-c:
River Chemistry Comparison Map
Upper Monongahela River

Use colors to indicate bacteria levels from data sheet

Legend

- Chemistry Test Sites
- Lock and dam
- Streams

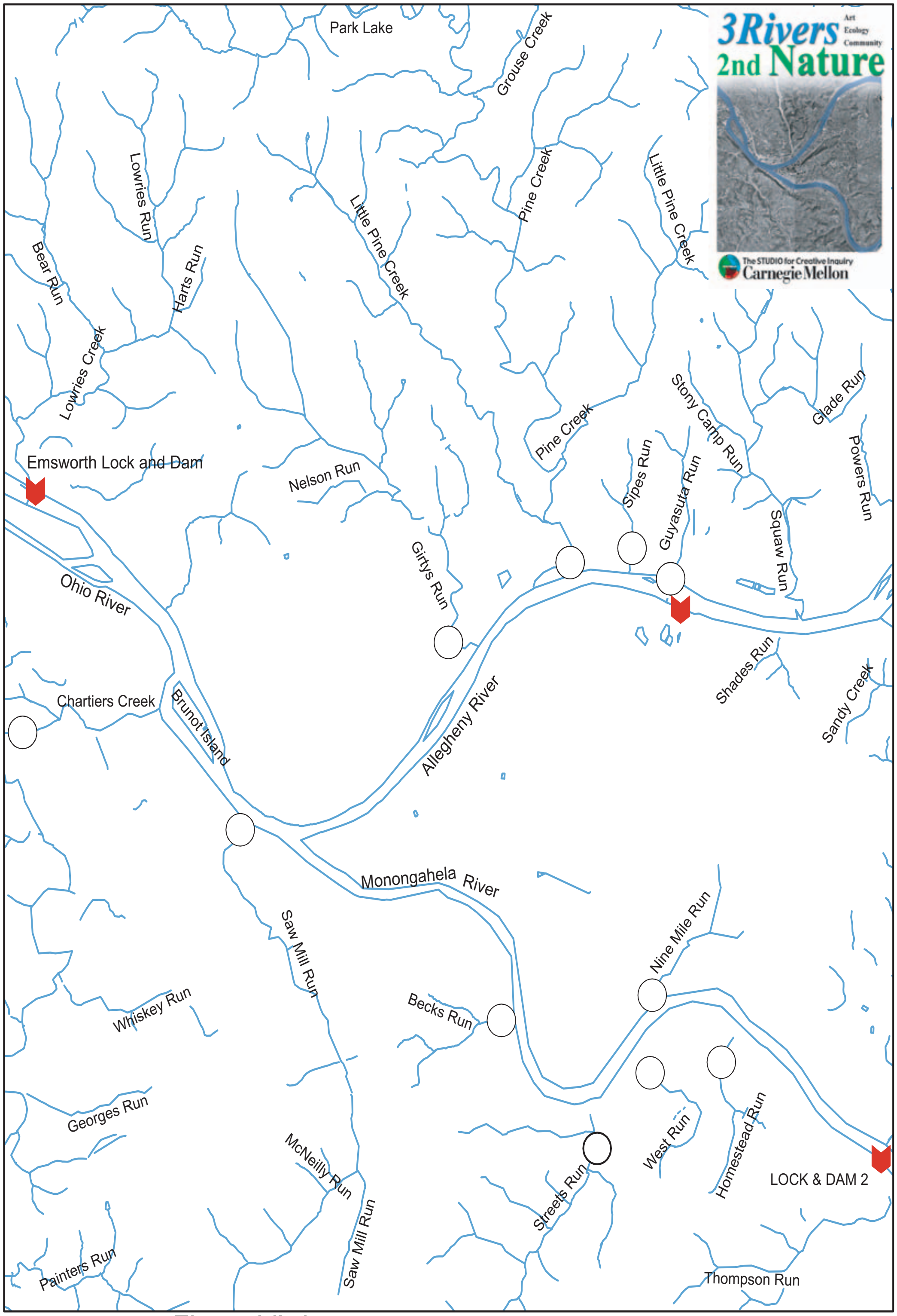


Figure VI-d:
Stream Chemistry Comparison Map
Pittsburgh Pool

Use color to indicate impairment levels from data sheet

Legend

- Chemistry Test Sites
- Lock and dam
- Streams

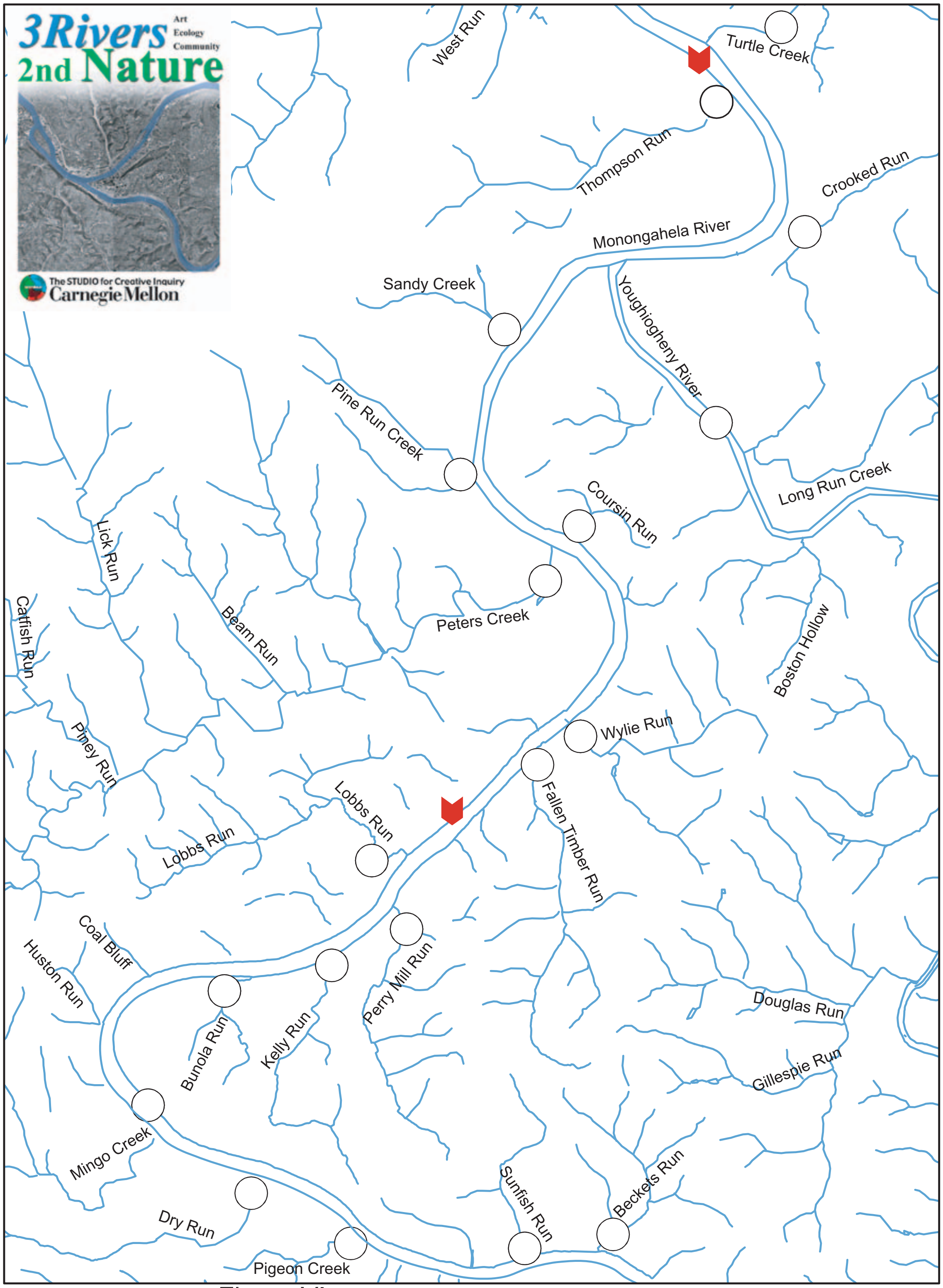


Figure VI-e:

Stream Chemistry Comparison Map

Upper Monongahela River

Use color to indicate impairment levels from data sheet

Legend

- Chemistry Test Sites
- Lock and dam
- Streams

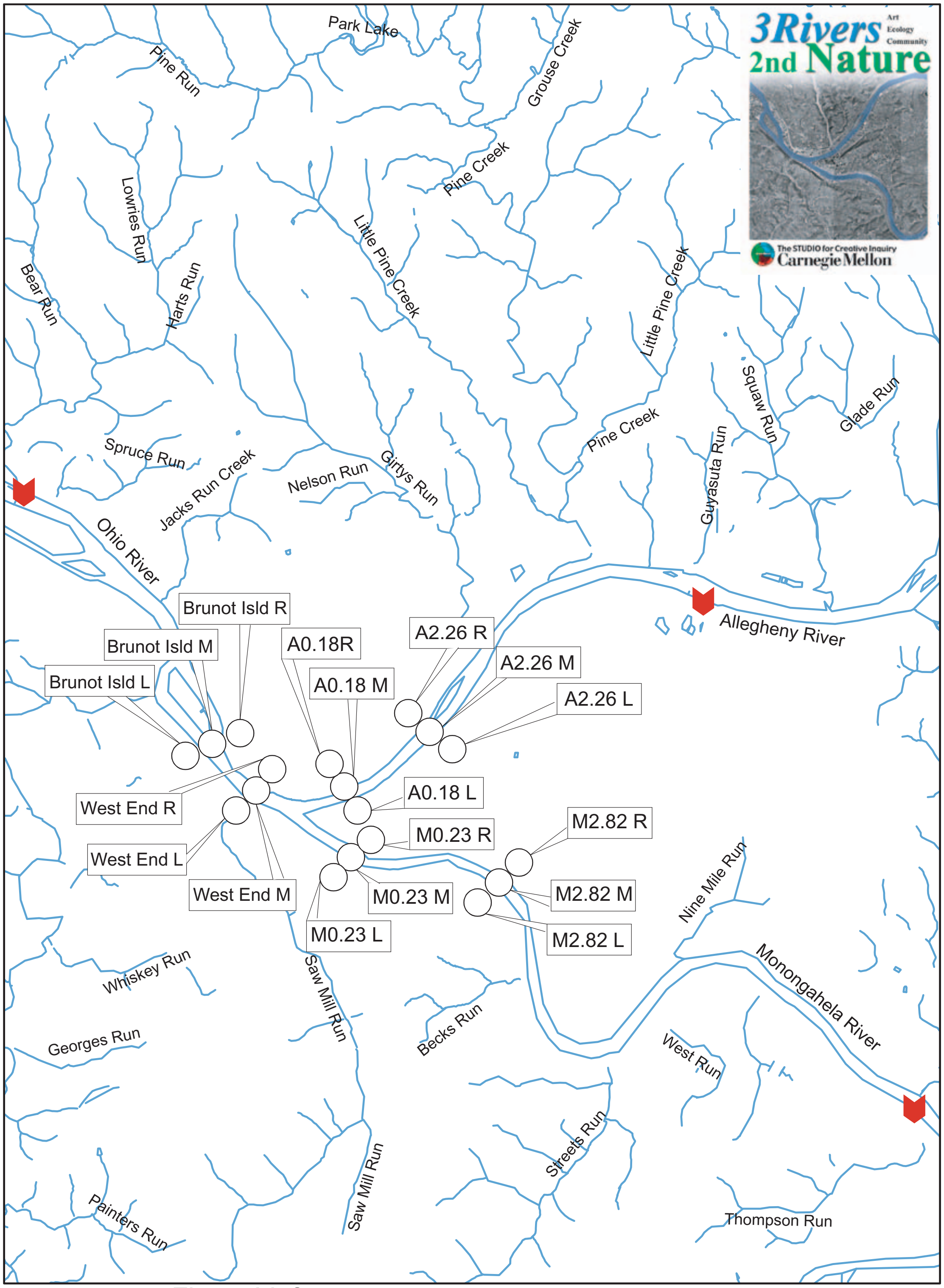


Figure VI-f:

River Bacteria Comparison Map

Pittsburgh Pool

Use colors to indicate values from data sheet

Legend

Bacteria Test Sites

Lock and dam

Streams

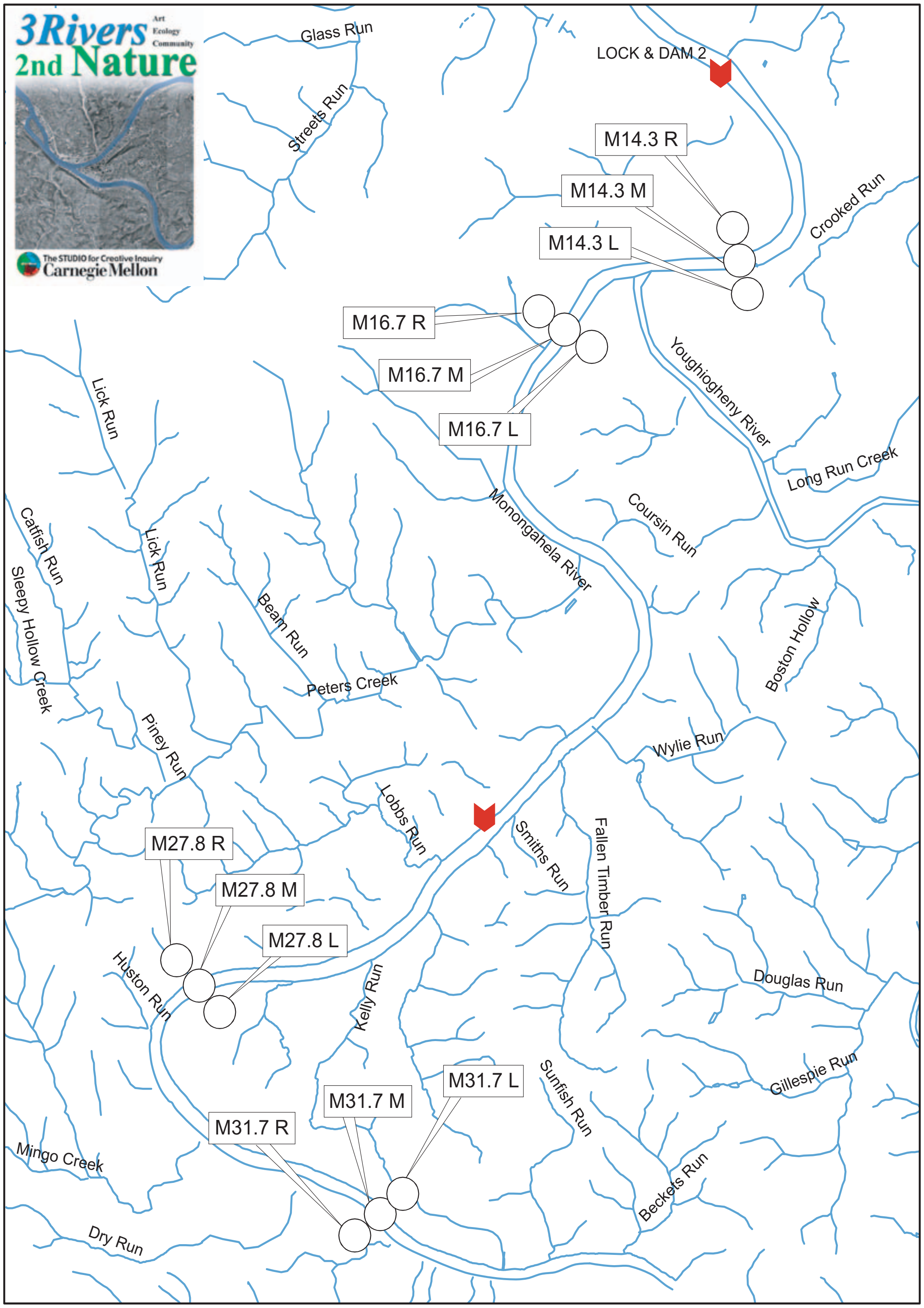


Figure VI-g:
River Bacteria Comparison Map
Upper Monongahela River

Use colors to indicate values from data sheet

Legend

- Bacteria Test Sites
- Lock and dam
- Streams

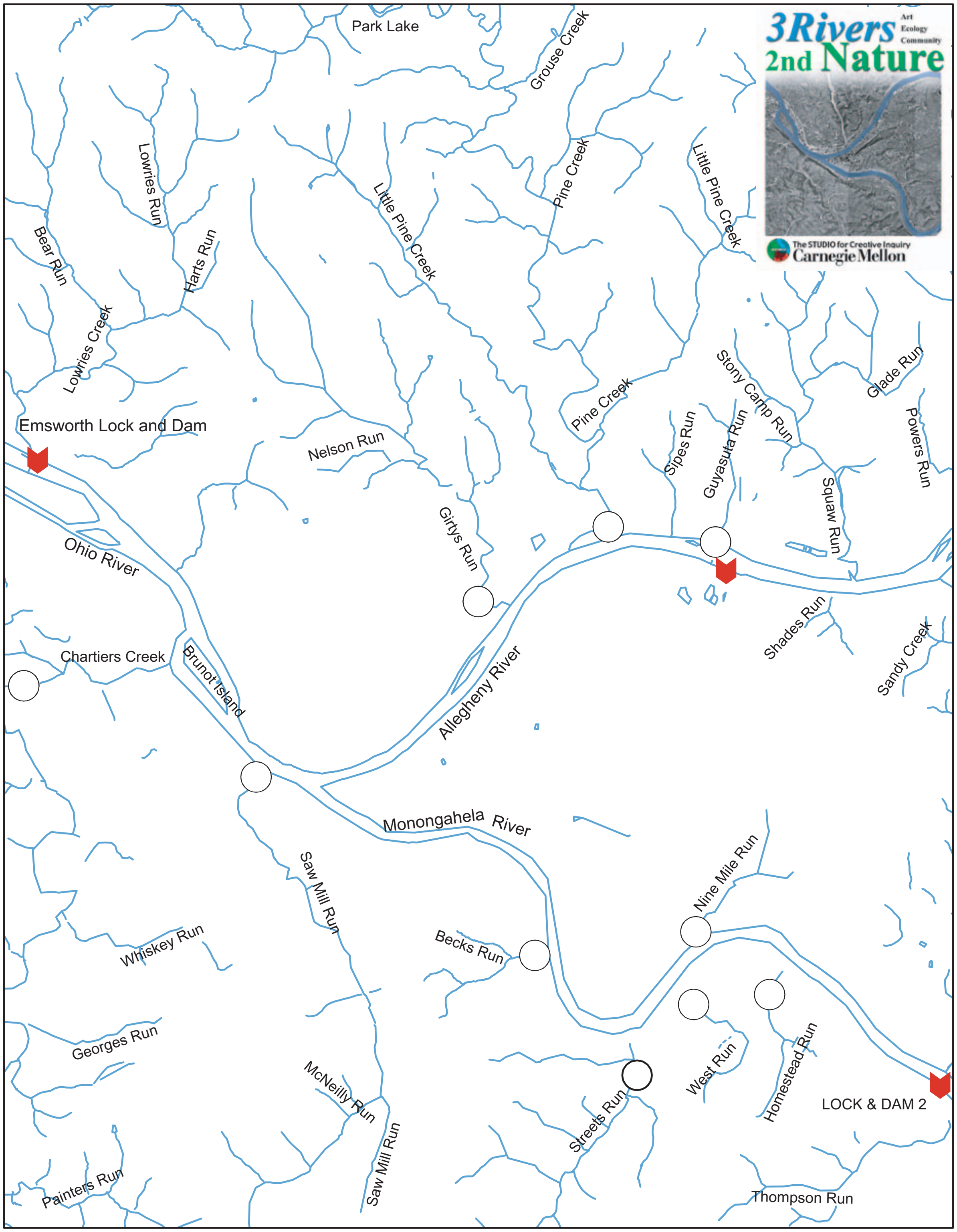


Figure VI-h:

Stream Bacteria Comparison Map
Pittsburgh Pool

Use color to indicate values from data sheet

Legend

- Bacteria Test Sites
- Lock and dam
- Streams

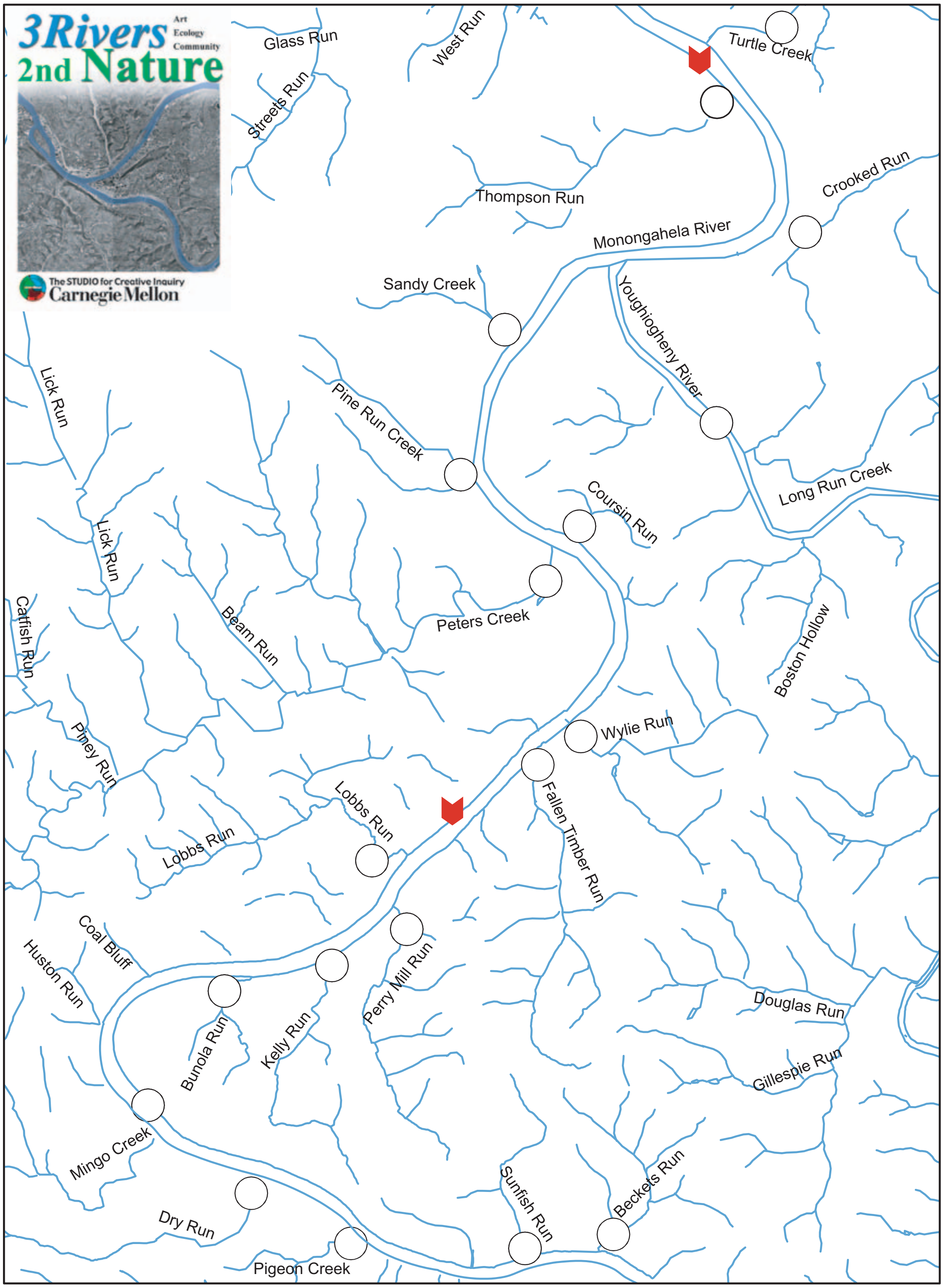


Figure VI-i:
Stream Bacteria Comparison Map
Upper Monongahela River

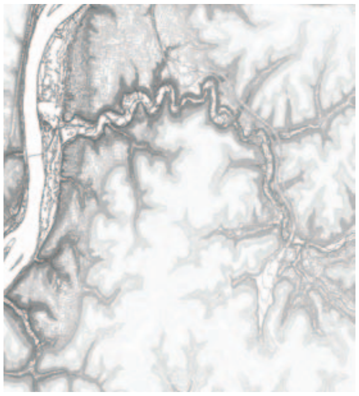
Use color to indicate values from data sheet

Legend

Bacteria Test Sites

Lock and dam

Streams



This contour map shows a river consists of different sizes of streams. (The Allegheny River and Plum Creek)

VII. Classroom Activity 3: Monitoring Our Watersheds

Overview:

In this activity students will collect critical data at selective testing sites and analyze urban watershed quality. Effective watershed analysis can include a wide variety of tests and analyses depending on the location and characteristics of the local watershed.

Objectives:

Students will be able to:

- Survey a small local watershed and its water quality.
- Develop observation and assessment skills.
- Test physical, chemical, and biological parameters of a stream. Collect data and analyze the results.
- Observe and describe each testing sites in scientific manner.
- Identify areas of the stream that affect the water quality in other parts of the watershed.
- Identify the type(s) of pollution or other problems in the waterway.

PA Academic Standards for Environment and Ecology

Watersheds and Wetlands

4.1.7.B. *Understand the role of the watershed.*

- ◆ Identify and explain what determines the boundaries of a watershed.
- ◆ Explain factors that affect water quality and flow through a watershed.

4.1.7.C. *Explain the effects of water on the life of organisms in a watershed.*

- ◆ Explain how the physical components of aquatic systems influence the organisms that live there n terms of size, shape and physical adaptations.

4.1.10. A. *Describe changes that occur from a stream's origin to its final outflow.*

- Describe changes by tracing a specific river's origin back to its headwater including its major tributaries.

4.1.10. B. *Explain the relationship among landforms, vegetation and the amount and speed water.*

- Analyze a stream's physical characteristics.

4.1.10. C. *Describe the physical characteristics of a stream and determine the types of organisms found in aquatic environments.*

- Describe and explain the physical factors that affect a stream and the organisms that live in a watershed.
- Identify aquatic organisms that live in a watershed.
- Categorize aquatic organisms found in a watershed continuum from headwater to mouth.
- Identify the types of organisms that would live in a stream based on the stream's physical characteristics.

4.1.10. E. *Identify and describe natural and human events on watersheds.*

Identify the effects of humans and human events on watersheds.

4.1.12. A. *Categorize stream order in a watershed.*

- Explain a concept of stream order.
- Identify the order of watercourses within a major river's watershed (a sub watershed.)
- Compare and contrast the physical differences found in the stream continuum from headwater to mouth.

4.1.12. C. *Analyze the parameters of a watershed.*

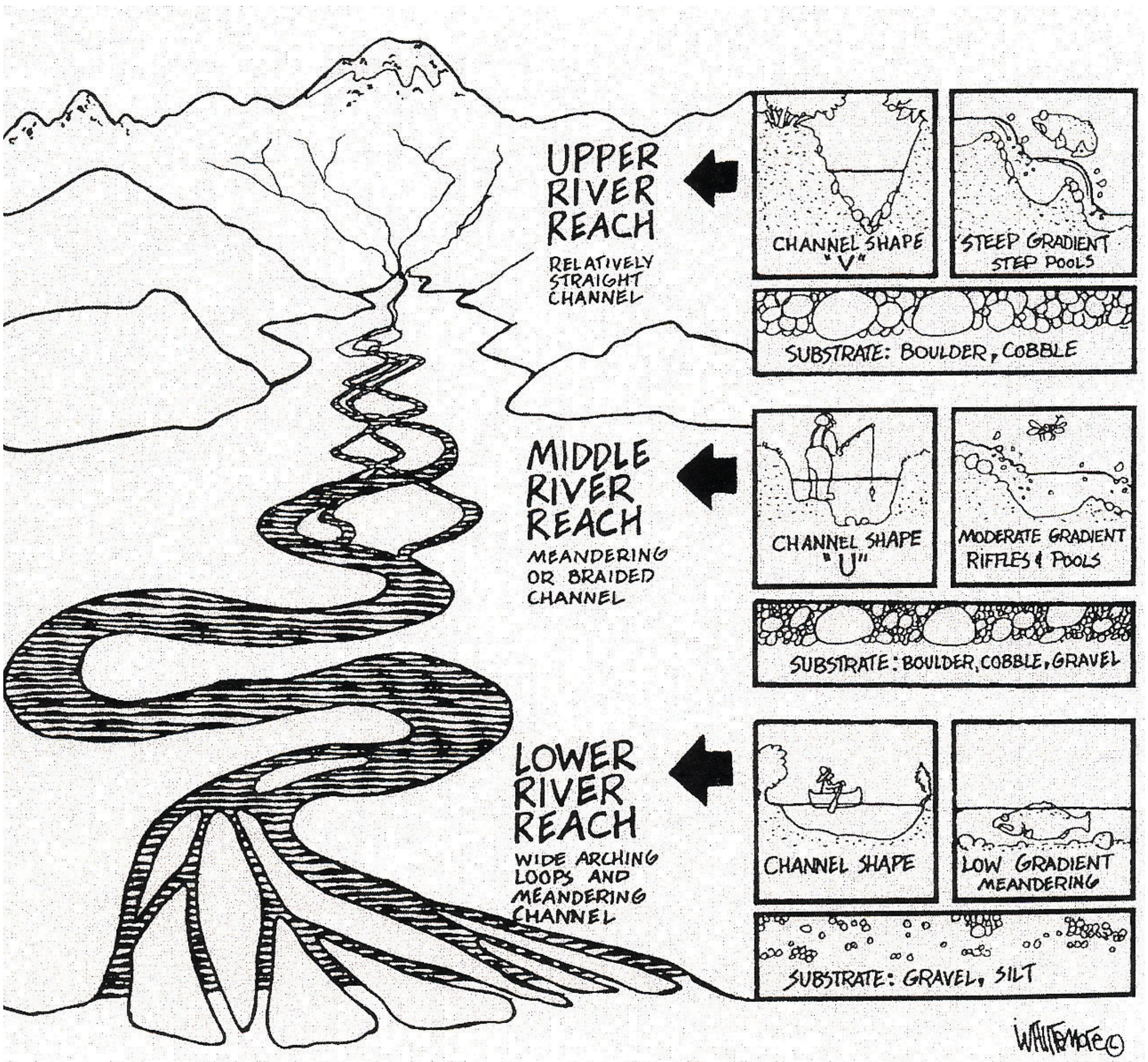
- ◆ Interpret physical, chemical and biological data as a means of
  assessing the environmental quality of a watershed.
- Apply appropriate techniques in the analysis of a watershed.

<u>Background Information</u>

A River Continumm:

- As streams move through different orders they can be thought of as progressing from youth to old age.
- The headwater is generally the youngest stage, and the mouth of the river is considered the most mature.
- As a stream meanders through this continuum, it changes physically, chemically, and biologically.

The River Continuum



The Upper Reaches:

- A 1st or 2nd order stream formed from various sources such as precipitation, snow melt, surface runoff, or ground water.
- No more than a few feet wide with a steep gradient, a stair-step appearence.
- Stream channel is “V” shaped and narrow.
- Stream bottom is comprised of large boulders with cobble and gravel filling in around them.
- Water tumbles over boulders to form deep plunge pools.
- The riparian zone almost completely covers the stream with its canopy, therefore very little sun gets to the stream.

- The plant matter that enters this stream comes from outside the stream, consisting of leaves, needles, and woody stems (organic debris.)
- This debris provides food and habitat for the small organisms which are the primary consumers of the stream.

Middle Reaches:

- A third or fourth order stream due to the addition of tributaries that have added to flow.
- Stream is now wider and deeper, the gradient is not as steep.
- Stream channel is "U" shaped, and banks have been eroded.
- Stream bottom is comprised mostly of gravel and cobbles.
- Water flows between pools and riffles.
- The canopy of the riparian zone no longer covers the entire stream, therefore more sun is able to penetrate the stream. Organic debris still falls into the stream.
- The sunlight allows photosynthetic algae to grow and become the base of the food chain.
- Due to the change in the food chain base, different organisms are able to live in the middle reaches of a river.

Lower Reaches:

- More streams have entered and added more flow thus creating a mainstream river.
- The channel is very wide and deep with no gradient.
- As the river flows, the load of sediment grows beyond the river's capacity to continue carrying it and they are deposited on the river bottom. Therefore, the bottom consists mainly of sand, gravel, and mud.
- The sediment and debris form a delta which forces the river to split, following different paths.
- The riparian zone only covers the sides of the channel leaving most of the water unshaded and allowing maximum sunlight. However, due to the high turbidity from suspended sediments, sunlight is unable to reach the bottom.
- Fine particles replace both organic debris and algae as the food source for primary consumers.

Preparation

Student Materials:

- Topographic map of stream site
- Tape measure and meter stick
- Floating object (orange, cork ball)
- Watch or stop watch
- Water testing kits (see the section of "Notes for Teachers")
- E-coli testing bottles
- Thermometer and pH meter
- Recording materials (clipboard, pencil, data sheets)
- Clean water to rinse the equipment
- Container for waste
- Surgical gloves
- Eye protection
- Boots
- Physical, chemical, and biological data sheets

Set up

Review safety and use of the test kits and other sampling equipment.

Estimated Duration
- Data collection...3 hours
- Data analysis and discussion...1.5 hours

Lesson Plan

Class Setting

Site selection for sampling:

Determining sampling sites depends greatly on the focus of your study. If your concern is overall watershed assessment, then regular test points evenly spaced throughout the watershed area would be desirable. If your goal is to determine problem areas, and sources of certain perceived problems, then more strategic planning of test sites will greatly simplify and accelerate your search.

Select sites along the main channel of the stream. For example, make the first observations at the last point that the stream maintained a channel before becoming culverted or emptying into another stream or river. Continue upstream from

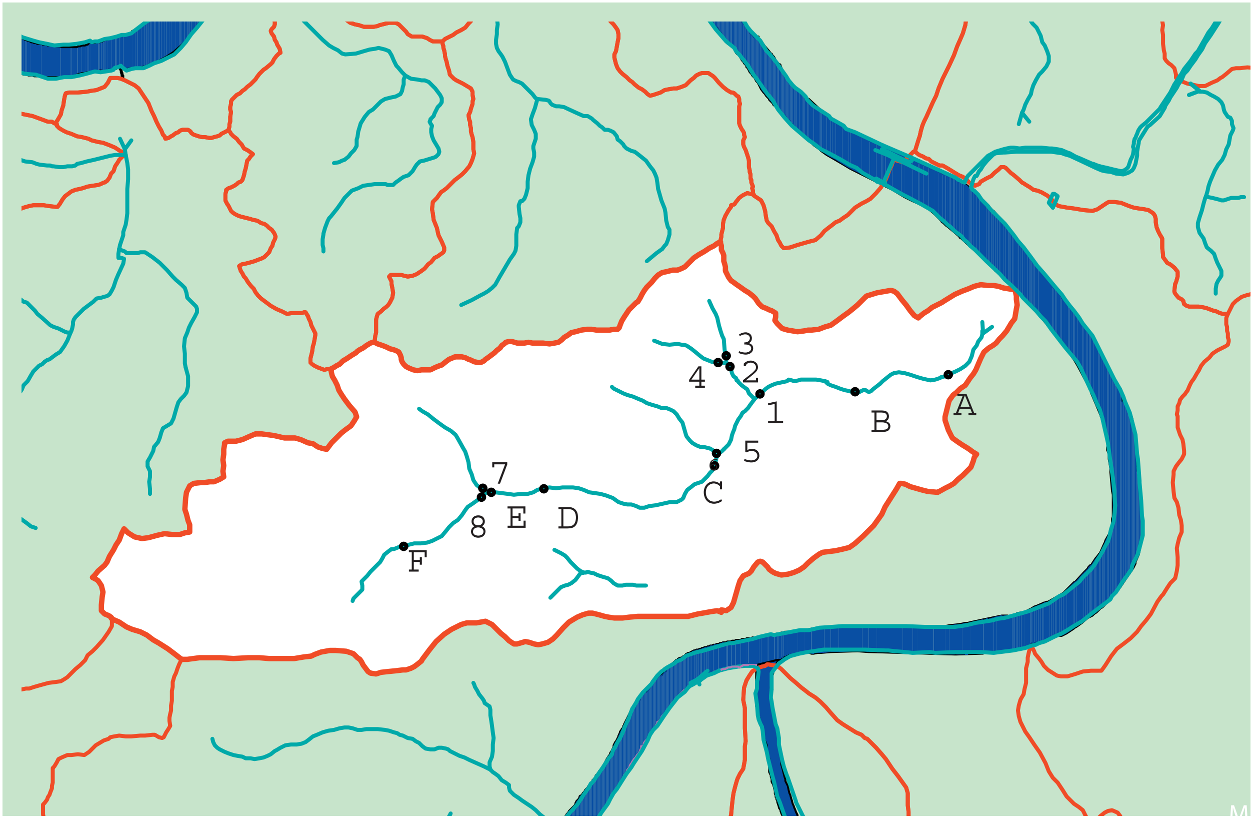


Figure VII-a: An Example of Testing Sites in the Thompson Creek Watershed

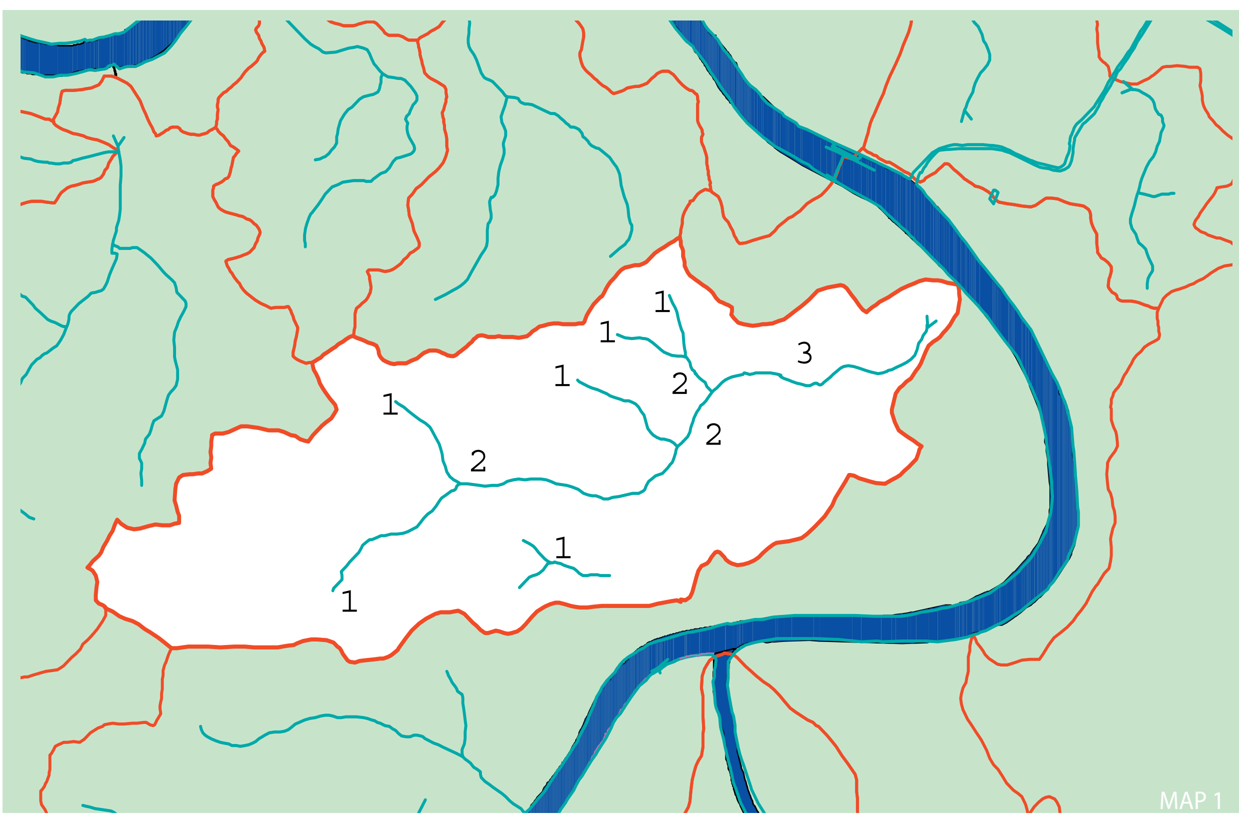
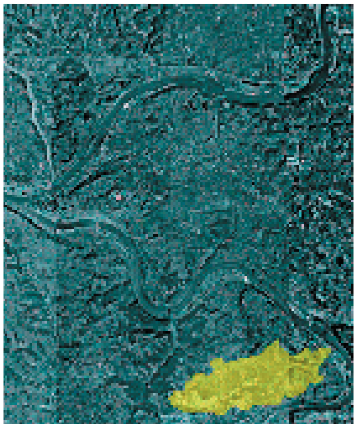


Figure VII-b: Stream Order


Thompson Creek Watershed

there, making observations close to, or just downstream from the addition of another contributing stream.

Test just above a joining of two legs of the stream on each leg and then again shortly before the contributing stream empties into the main stream. In some cases, test the downstream from the joining of two contributing legs. If one of the legs was the main stream, omit testing because of time restrictions.

Make most of the observations along the main channel because this would be where the observer would see the most drastic effects on the stream of upstream drainage problems or other physical issues. Any problems might warrant a closer look at a particular contributing stream. (Figure VII-a, VII-b)

Activity A: Site Selection and Watershed Mapping

Key Questions:

- *What is a watershed?*
- *What defines the boundaries of a watershed?*
- *How does a stream change as it moves from headwater to mouth?*

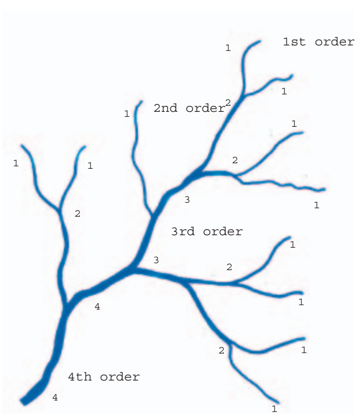
1. Discuss the definition of a watershed. Hand out topographic maps and review features such as contour lines. Explain that all points along a contour line are at the same elevation.

2. Use the maps to locate the stream that you will be sampling. Use a colored pencil or highlighter to trace the stream from headwater to mouth. The mouth of a stream is generally at the lowest elevation in the watershed. Mark any tributaries that flow into the stream.

3. Determine the stream's watershed boundaries by using contour lines to locate the areas of highest elevation on either side of the stream.

4. Draw a simplified map of the stream and its tributaries. This map will be used later to record sampling data in a visual manner.

5. Label the stream order on the map. Using the information above (see Class Setting) select and mark sampling sites on the map.



Stream Order: Streams are classified by size and are identified by order.

1st Order: Year round water and not tributaries.

2nd Order: Two joining 1st Order streams.

3rd Order: Two joining 2nd Order streams.

Key Questions:

- *What affects the physical features of a stream?*
- *Do the physical features affect the chemical parameters?*

- *How do the physical features influence the stream and the type of organisms that can live there?*

1. In the classroom review the physical parameters data sheet and physical parameter information. Explain how to complete the data sheet for each parameter. Tell students to use the key questions as a guide to the information they should record.

2. Review safety. Take students to the sample sites and collect the data. Review results for each sample site.

See **APPENDIX VII-A:** Physical assessment field data sheet

Activity C: Chemical and Bacterial Assessment

(see the chapter "Water Quality Parameters)
Key Questions

- *How do you use the equipment to test for pH, temperature, dissolved oxygen, nitrates, and bacteria?*
- *What do the results indicate?*
- *Are any areas of the watershed more impacted than others?*
- *What might be affecting the water quality at the sampling sites? How does this affect other parts of the watershed?*
- *How does your data compare to 3R2N data? How does your data compare to the reference stream (Pine Creek) in the 3R2N study?*

1. The following parameters are recommended for sampling: temperature, dissolved oxygen, pH, nitrates, and bacteria. See appendix 6A for a listing of recommended test kits. Other parameters may be included to further evaluate specific impacts in the watershed you are assessing. *(Some bacteria tests are complicated and can be expensive. The 3R2N Project is currently trying to locate a resource that will offer access to bacterial testing equipment.)*

2. In the classroom, read the test instructions and practice using the test kits and meters. Wear gloves when conducting a test to avoid contaminating the sample and to protect your hands. Wear goggles to protect your eyes.

3. At the test site, rinse the testing containers a few times with the water you will sample.
4. Collect samples in the main current of the stream under the

surface of the water. Stand downstream from the water you are collecting.

5. Conduct each test according to directions on the kit or meter and record results on the data sheet. Repeat each test again and record results. If there is a significant difference between the results of the two tests, repeat the test a third time.

6. Pour all waste products in the waste container. Rinse testing equipment with distilled water before storing.

7. Back in the classroom, have students develop a color coded system to indicate results on the stream map they developed in Activity 1. A map should be developed for each parameter. See sample map. (Figure VII-c, VII-d)

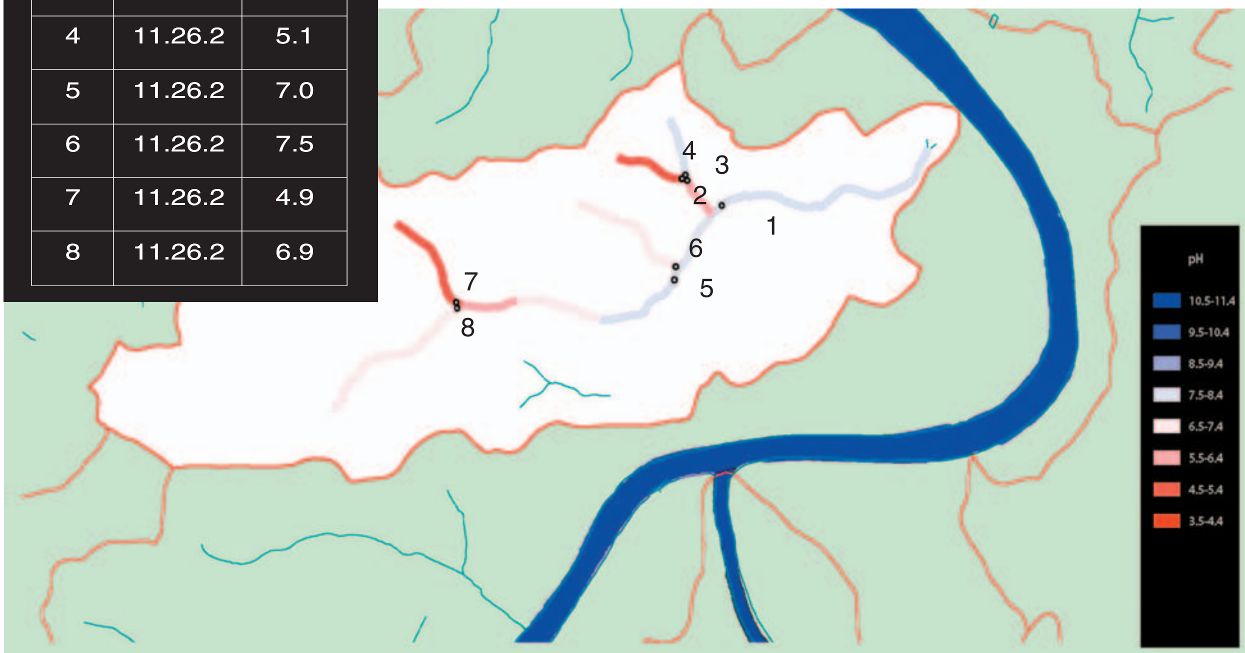
Activity D: Biological Assessment

(see the chapter “Water Quality Parameters: Biological Parameters)
Key Questions

- *Is there a diverse biological community in the stream?*
- *Does the biological community vary at different sample sites? Why?*
- *What do the results indicate about water quality?*
- *What factors might affect the biological assessment results?*
- *Discuss the connections between the physical, chemical/bacterial, and biological assessments.*
- *Compare the biological assessment to the 3R2N biological assessment. Discuss the idea of multiple metrics.*

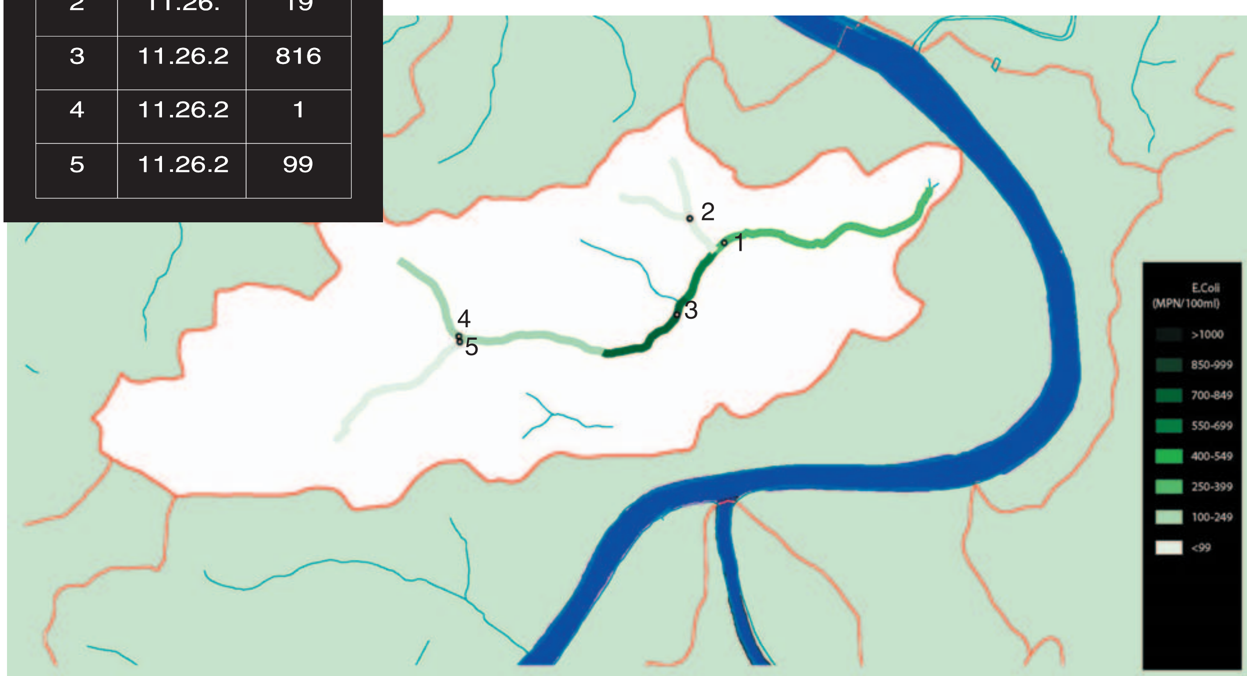
site	date	pH
1	11.26.2	8.0
2	11.26.2	5.5
3	11.26.2	7.5
4	11.26.2	5.1
5	11.26.2	7.0
6	11.26.2	7.5
7	11.26.2	4.9
8	11.26.2	6.9

Figure VII-c: pH testing data and geological interpretation



site	date	E.Coli
1	11.26.2	365
2	11.26.	19
3	11.26.2	816
4	11.26.2	1
5	11.26.2	99

Figure VII-d: E. Coli testing data and geological interpretation



Note to the Teacher:

Testing procedure
The testing procedure and test kits could be better used for more accuracy. Ideally, given enough time and resources, each variable would be measured at least three times from each site on each of at least three different days. Given this situation, the data would be much more precise to the actual condition of the stream.

Weather
Weather and season can dramatically affect all variables considered within this study. This must be considered when generating the timeline and scope of the assessment. A complete watershed assessment would include data collected in different seasons in order to represent the condition of the stream throughout the course of the year.

Inclement weather conditions must be taken into consideration when planning field testing and reporting results at any time of the year. Extreme conditions affect variables across the board and can have a drastic affect on final results. Any given day on which testing is done should be representative of the season.

Potential Difficulties
Some other characteristics can provide useful information about the watershed in question. Should the resources be available, inclusion of these characteristics would create a more accurate depiction of the stream. For example, soils can have a profound effect on a watershed. They can affect the permeability, chemical makeup, flow rate, and ecosystem of the water. This topic though, would require knowledge and testing that might be well beyond the scope of a group carrying out a general watershed assessment.

short explanation for each.
APPENDIX VII-A1 & VII-A2: Physical Assessment Field Data Sheet
APPENDIX VII-B Field-ready checklist of observations with short explanation for each.

Water Test Kits and Meters

pH

pH meter
pH Pocket Pal Tester
HACH Company
Catalogue No. 44350-33

pH kit
Wide Range pH Kit
HACH Company
Catalogue No. 1470

Dissolved Oxygen

Dissolved Oxygen High Range Kit
HACH Company
Catalogue No. 1469

Nitrates

Nitrate Nitrogen
(Zinc Reduction Octa-Slide)
LaMotte Company
Catalogue No. 3354

Nitrogen-Nitrate Low Range Kit
(Cadmium Reduction)
HACH Company
Catalogue No. 14161

Bacteria (Coliform/E.Coli)

Collilert
IDEXX Laboratories

m-ColiBlue 24 MF Kit
HACH Company

Physical Assessment

1. Bank

Bank Stability

Measures the erosion potential and whether the stream banks are eroded. Steep banks are more likely to collapse and erode than gently sloping banks. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soils.

Key Questions:

- *How stable is the bank?*
- *If a meandering stream has created and outer bank, how high is it? How steep?*
  How many trees have mostly exposed roots?
- *Approximate # of tree falls in the area.*

◆ **Vegetative Bank Coverage**

Measures the amount of the stream bank that is covered by vegetation. The root systems of plants growing on stream banks help hold soil in place, reducing erosion. Vegetation on banks provides shade for fish and macroinvertebrates and serves as a food source by dropping leaves and other organic matter into the stream. Ideally, a variety of vegetation should be present, including trees, shrubs, and grasses.

Key Questions:

How much of the stream bank is covered by natural vegetation?

How much of the stream is shaded by overhanging trees (canopy cover)?

Is there evidence of vegetative disruption – mowing, grazing, tree or shrub removal?

2. In-Stream Channel

Channel Alterations

Measures changes in the shape of the stream channel. Many streams in urban and agricultural areas have been straightened, deepened, dredged or diverted into concrete channels. These streams have fewer natural habitats for aquatic organisms than naturally meandering streams. Channel alterations include: concrete channels, artificial embankments like gabion, significant artificial straightening or deepening, dams, or outflow pipes.

Substrate

Measures the composition of the stream bottom. The substrate indicates what type of organisms may live in the stream and natural and human forces that have impacted it. Substrate sizes range from fine sediments, like clay, silt or mud, to increasingly larger particles, like sand, gravel, cobble, or boulders. If rocks become embedded (surrounded or covered with silt, sand or mud), fewer living spaces are available to macroinvertebrates and fish.

Key Questions

Estimate the percent of the stream bottom that is silt or mud, sand, gravel, cobble, or boulder.
Estimate the percent of embeddedness or the extent that rocks are surrounded by fine sediment.

Velocity & Depth

Measures the amount of water and speed at which it is moving. Fast water increases the amount of dissolved oxygen, keeps pools from being filled with sediment, and moves food items through the system. Slow water provides spawning areas for fish and keeps macroinvertebrates from washing downstream. Shallow water tends to be more easily aerated, but deeper water stays cooler longer. The best stream habitat includes a variety of velocity/depth combinations that can maintain a wide variety of organisms.

Measure stream velocity by marking off a 10 meter section of stream run and measuring the time it takes a floating object (stick, orange, cork ball) to float the 10 meter distance. Repeat 5 times in the same 10 meter section and determine the average time. Divide the distance (10 meters) by the average time (seconds) to determine the velocity in meters per second.

Key questions

What is the depth of stream pools, runs and riffles?
What is the stream velocity? What is affecting it (slope, channel shape, debris, etc.)

Are there a variety of velocity/depth combinations in the stream?

Channel Flow

Measures the percentage of the existing channel that is filled with water. The flow status changes as the channel enlarges or as flow decreases. When water does not cover much of the streambed, the living area for aquatic organisms is limited.

Key Questions

Does water reach the base of both banks?
How much of the channel substrate is exposed?

Channel Sinuosity

Measures the sinuosity or meandering of the stream. Streams that meander provide a variety of habitats and stream velocities that reduce the energy from storm water. Straight stream segments are characterized by even stream depth and unvarying velocity.

Key Questions

How much longer would the stream be if it were straightened out?

Sediment Deposition

Measures the amount of sediment that has been deposited in the stream channel and the changes to the stream bottom that have occurred as a result of the deposition. High levels of sediment deposition create an unstable and continually changing environment that is unsuitable for many aquatic organisms. Sediment deposition can indicate the level of uncontrolled storm water runoff and presently occurring degradation of stream habitat.

Sediments are naturally deposited in areas where the stream flow is reduced, such as pools and bends, or where flow is obstructed. These deposits can lead to the formation of islands, shoals, or point bars (sediments that build up in stream, usually at the beginning of a meander) or can result in the complete filling of pools. To determine whether sediment deposits are new, look for vegetation growing on them.

Key Questions

Are there any fresh sediment deposits? How large?
Are there any point bars?
Do any sediment deposits support vegetation?

General Observations

A general measure of the visual appearance of the stream. This measure may indicate disruptions in the watershed from natural occurrences or human activities.

Key Questions

Is the water clear or cloudy?
Describe the color of the water.
Does the water have an odor? Describe it.

Appendix VII-A1: Physical Assessment Field Data Sheet

Date: ___________ Time: _________________ Site ID#: _______________

Weather Conditions:
Current conditions:______________________

Previous 24 hours: ______________________

Bank Stability **(Rate right and left banks)**	
Vegetative Bank Coverage	

Channel Alterations	
Substrate	
Velocity & Depth	
Channel Flow	
Channel Sinuosity	
Sediment Deposition	
General Observations	

Appendix VII-A2: Chemical and Bacterial Assessment Data Sheet

Date: ___________ Time: _________________ Site ID#: _______________

Weather Conditions:

Current conditions:______________________

Previous 24 hours: ______________________

Temperature	
pH	
DO	
Nitrate	
E. Coli	
Other Test	
Other Test	
Micro Invertebrates	
Micro Invertebrates	

Appendix VII-B:

This section is provided by the Senior Environment Crops
Pennsylvania Volunteer Water Quality Monitoring Field Manual
(Adapted from Volunteer Stream Monitoring: A Methods Manual, United States Environmental Protection Agency, Office of Water, Draft Document #EPA 841-B-97-003, Nomvember 1997.)

Contents:

The Biosurvey and Stream Habitat Assessment will be conducted twice a year in the spring and fall. The spring survey will take place from late March through May, and the fall survey will occur from late August through October. The location of the stream within Pennsylvania will determine when to conduct the survey. The northern areas of the state will want to conduct their surveys in May and again in late August or September, while the southern areas will want to conduct their surveys in late March or April and again in September or October.

The method you use to collect macroinvertebrates depends on the type of stream you are sampling - rocky bottom versus muddy bottom. Rocky bottom streams are defined as those with bottoms made up of gravel, cobbles, and boulders in any combination and usually have definite riffle areas. Muddy bottom streams have muddy, silty or sandy bottoms and lack riffles. Generally, these are slow moving, low-gradient streams. The goal is to sample habitats having the greatest abundance and diversity of benthic macroinvertebrates. Habitats that are unimpaired by pollution or alteration are the ones that contain a diverse population of pollution sensitive macroinvertebrates.

Rocky Bottom Streams

Use the following method of macroinvertebrate sampling in streams that have riffles and gravel/cobble substrates. You will collect three samples at each site using a 1m X 1m, 500 *u*m kick net and combine them to obtain one large sample.

1. Identify the Sampling Location

- The sample area will consist of a 30-meter stream reach. Mark off your 30-meter stream reach. If possible, it should begin at least 15 meters upstream of any human-made modification (i.e. bridge, dam, etc). Choose three spots within the 30-meter area. The three spots should be in riffles, or if no riffles are present, three run areas with gravel or cobble substrate. Try to sample riffles having different flow velocities and substrate types to maximize the diversity of habitats sampled.
- Sketch the 30-meter stream site using the data sheet indicating the location of the three sampling spots. Mark the downstream site as #1, the midstream site as #2, and the upstream site as #3.

2. Get Into Place

- Always approach your sampling locations from the downstream end. This keeps you from biasing your second and third collections with dislodged sediment or macroinvertebrates.

Sample the Downstream Site #1 First.

• Select a 1 meter by 1 meter riffle area for sampling at site #1. Have one team member position the net at the downstream end of the sampling area. This team member should have the net in front of him/her facing upstream. Hold the kick net handles at a 45 degree angle to the water's surface. Be sure that the bottom of the net fits tightly against the stream bed so no macroinvertebrates escape under the net. Use rocks from the sampling area to anchor the net against the stream bottom. Don't allow any water to flow over the net.

3. Dislodge the Macroinvertebrates

• The second team member should stand within the 1 meter by 1 meter area. Fill a bucket one third full with stream water. Pick up any large rocks (i.e. boulders >10 in.) within the area and look on the bottoms for any organisms, especially non-netspinning cadisfly larvae. Hold them over the bucket and rub the rocks thoroughly so any macroinvertebrates clinging to the rocks will be dislodged into the bucket. Then place the "cleaned" rocks outside of the sampling area. Continue "cleaning" the large rocks over the bucket until there are no large rocks within the sampling area. The large rocks will be returned to the sampling area once the sampling is completed.

• Thoroughly stir up the sampling area with your feet. Start at the upstream end of the sampling area and work your way towards the net. Stop once you reach the net and have thoroughly stirred up the first two or three inches of the streambed. This should take about 3 minutes. All dislodged organisms will be carried by the stream flow into the net. Before removing the net be sure to rub any large rocks you used to anchor the net.

4. Remove the Net

• Try to remove the net without allowing any of the organisms it contains to wash away. While the net holder grabs the top of the net handles, the kicker grabs the bottom of the net handles and the net's bottom edge. Remove the net from the stream with a forward scooping motion.

• Roll the kick net into a cylinder shape and place it vertically in the partially filled bucket. Pour or spray water down the net to flush its contents into the bucket. If necessary, pick debris and organisms from the net by hand. Release any fish, amphibians, or reptiles caught in the net. Return the large rocks to the sampling area.

• If the bucket becomes too full with water, pour some of the water out through the kick net screen. The screen will catch any organisms that are being carried by the water, and they should be returned to the bucket sample. You may also use a series of buckets with one of the buckets containing a screened bottom (600 *u*m mesh).

5. Collect the Second and Third Samples

• Repeat steps 2 through 5 for the other two sites. Combine the debris and organisms from all three sites into the same bucket. This is called compositing and will provide a better representation of the stream's macroinvertebrate community.

6. **Sorting Macroinvertebrates**

- Pour the contents of the bucket into a white dishpan (or other large shallow white pan). Add more stream water if needed. Sort through the debris looking for anything that swims, crawls, wriggles, moves or is hiding in a shell. Use tweezers, spoons or turkey basters to remove the insects to the sorting trays (ice cube trays work great - put like organisms in the same tray).

7. **Identifying Macroinvertebrates**

- Use a hand lens or magnifying glass along with the aquatic macroinvertebrate identification sheets to identify your organisms.
- Record the number of individuals of each type of organism you have identified on your field data sheet.
- Once you have identified all the organisms to the best of your ability, return the macroinvertebrates to the stream. Return the organisms to the downstream section of the stream (near site #1) to allow them to locate suitable attachment sites. Rinse the dishpan, bucket, and kick net making sure there are no organisms clinging to the sides.

8. **Calculating the Stream Water Quality Rating**

- Assign one of the following abundance codes to each type of organism. Record the code next to the actual count on the field data sheet.

R (rare) = 1 to 9 organisms found in the sample.
C (common) = 10 to 99 organisms found in the sample.
D (dominant) = 100 or more organisms found in the sample.

- The field data sheet divides the macroinvertebrates into three groups based on their ability to tolerate pollution. The three tolerance groups are as follows:

Group I - Organisms that are sensitive to pollution and are typically found in good-quality water.

Group II - Organisms that are somewhat sensitive to pollution and are typically found in fair-quality water.

Group III - Organisms that are tolerant of pollution and are typically found in poor-quality water.

- Follow the instructions on the data sheet to calculate the stream water quality rating.

Muddy Bottom Streams

Use the following method of macroinvertebrate sampling in streams that have muddy, silty or sandy bottoms or lack riffles (slow-moving streams-e.g.coastal plain streams). You will combine samples from 20 “jabs” with a 1 foot wide D-frame net to get a representative sample of macroinvertebrates.

1. **Determine Types of Habitats Present**

   • Muddy bottom streams usually have four habitat types - vegetated bank margins, snags and logs, aquatic vegetation beds and decaying organic matter, and silt/sand/gravel substrate. Not all streams will have all habitats present or present in significant amounts.

   Habitat Descriptions:

   Vegetated Bank Margin - This habitat consists of overhanging bank vegetation and submerged root mats attached to banks. The bank margins may also contain submerged, decomposing leaf packs trapped in root wads or lining the stream banks. This is generally a highly productive habitat and is often the most abundant type of habitat.

   Snags and Logs - This habitat consists of submerged wood, primarily dead trees, logs, branches, roots, and leaf packs lodged between rocks or logs. This is also a very productive habitat.

   Aquatic Vegetation Beds and Decaying Organic Matter - This habitat consists of beds of submerged, green/leafy plants that are attached to the stream bottom. This habitat can be as productive as vegetated bank margins, and snags and logs.

   Silt/sand/gravel Substrate - This habitat includes sandy, silty or muddy stream bottoms, rocks along the stream bottom, and/or wetted gravel bars. This habitat may also contain algae-covered rocks. This is the least productive of the four muddy bottom stream habitats.

   • The sample area will consist of a 30-meter stream reach. Mark off your 30-meter stream reach. If possible, it should begin at least 15 meters upstream of any human-made modification (i.e. bridge, dam, etc.).

   • Determine the types of habitats present and sketch the 30-meter stream site indicating the location of the habitat types.

2. **Determine How Many Jabs in Each Habitat**

   • The goal is to collect a total of 20 jabs and combine the jabs into one combined sample. The D-frame net used to collect samples is 1 foot wide, and a jab should be approximately 1 foot in length. Thus, 20 jabs equal approximately 20 square feet of combined habitat.

   • The following are some scenarios to help you determine how many jabs to take in each habitat. No matter what the make-up of your stream's habitats, note on your data sheet the types of habitats present and the number of jabs taken from each habitat. This data will help characterize your findings.

   Scenario 1: If all four habitats are present in plentiful amounts, jab the vegetated banks 10 times and divide the remaining 10 jabs among the remaining three habitats.

   Scenario 2: If three habitats are present in plentiful amounts and one is absent, jab the silt/sand/gravel substrate - the least productive habitat - 5 times and divide the remaining 15 jabs among the other two more productive habitats.

Scenario 3: If only two habitats are present in plentiful amounts, the silt/sand/gravel substrate will most likely be one of those habitats. Jab it 5 times and the more productive habitat 15 times.

Scenario 4: If some habitats are plentiful and others are sparse in frequency, sample the sparse habitats to the extent possible, even if you can only take one or two jabs. Take the remaining jabs from the plentiful habitat(s). This rule also applies if you cannot reach a habitat because of unsafe stream conditions. Jab a total of 20 times.

- Mark on your sketch the habitats that you will sample in and how many jabs you will do in each habitat. Number the habitats starting with the habitat that is in the most downstream location and number progressively as you move upstream.

3. **Get Into Place**

- This type of sampling requires only one person to disturb the stream habitats. Sampling partners can stand outside of the sampling area holding the bucket and spray bottle and assist in rinsing the net contents into the bucket after every few jabs.
- Fill the bucket and spray bottle with clean stream water.
- Check the net to be sure it is clean from the last use.
- Enter the stream outside and downstream of your first sampling location.

4. **Dislodge the Macroinvertebrates**

- Approach the first sample site from downstream and sample as you walk upstream. Here is how to sample in the four habitat types:

Vegetated Bank Margins - Jab the vegetated bank margins vigorously, with an upward motion, brushing the net against vegetation and roots along the bank. The entire jab motion should occur underwater.

Snags and Logs - Hold the net with one hand under the section of submerged wood you are sampling. With the other hand (which should be gloved), rub about 1 square foot of area on the snag or log. Scoop organisms, bark, twigs, or other organic matter you dislodge into your net. Each combination of log rubbing and net scooping equals one jab.

Aquatic Vegetation Beds - Jab vigorously, with an upward motion, against or through the plant bed. The entire jab motion should occur underwater.

Silt/sand/gravel Substrate - Place the net with one edge against the stream bottom and push it forward about a foot (in an upstream direction) to dislodge the first few inches of silt, sand, gravel or rocks. To avoid gathering a netful of mud, periodically sweep the net back and forth in the water, making sure that water does not run over the top of the net. This will allow fine silt to rinse out through the net.

- When you have completed all 20 jabs dump the contents of the net in the bucket and rinse the reversed net thoroughly into the bucket to catch remaining bugs. If necessary, pick any clinging organisms from the net by hand and put them in the bucket.

5. **Sorting Macroinvertebrates**

• Pour the contents of the bucket into a white dishpan (or other large shallow white pan). Add more stream water if needed. Sort through the debris looking for anything that swims, crawls, wriggles, moves or is hiding in a shell. Use tweezers, spoons or turkey basters to remove the insects to the sorting trays (ice cube trays work great - put like organisms in the same tray).

6. **Identifying Macroinvertebrates**

• Use a hand lens or magnifying glass along with the aquatic macroinvertebrate identification sheets to identify your organisms.

• Record the number of individuals of each type of organism you have identified on your field data sheet.

• Once you have identified all the organisms to the best of your ability, return the macroinvertebrates to the stream. Return the organisms to the downstream section of the stream (near site #1) to allow them to locate suitable attachment sites. Rinse the dishpan, bucket, and D-frame net making sure there are no organisms clinging to the sides.

7. **Calculating the Stream Water Quality Rating**

• Assign one of the following abundance codes to each type of organism. Record the code next to the actual count on the field data sheet.

R (rare) = 1 to 9 organisms found in the sample.
C (common) = 10 to 99 organisms found in the sample.
D (dominant) = 100 or more organisms found in the sample.

• The field data sheet divides the macroinvertebrates into three groups based on their ability to tolerate pollution. The three tolerance groups are as follows:

Group I - Organisms that are sensitive to pollution and are typically found in good-quality water.

Group II - Organisms that are somewhat sensitive to pollution and are typically found in fair-quality water.

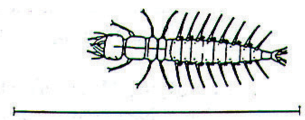
Group III - Organisms that are tolerant of pollution and are typically found in poor-quality water.

• Follow the instructions on the data sheet to calculate the stream water quality rating.

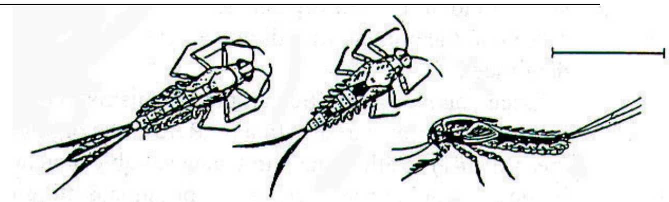
Group I - sensitive

Water Penny Larvae - Order Coleoptera:
4-6 mm flattened disclike forms, found clinging to rocks, a dorsal plate conceals the head and 6 legs.

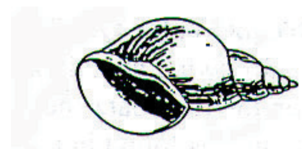
Dobsonfly Larvae (Hellgrammite) - Order Megaloptera:
25 - 90 mm, dark colored, 6 legs, well developed chewing mouthparts, 2 short antennae, 8 abdominal segments each with a filament, 2 anal prolegs with hooks.



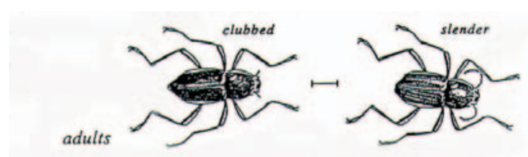
Mayfly Nymph - Order Ephemeroptera: 3 - 20 mm (not including tails), elongate, cylindrical to flattened form, head with slender antennae, 6 legs with one claw or no claw, wing pads present, platelike or feathery gills along abdomen, 3 long tails (sometimes 2).



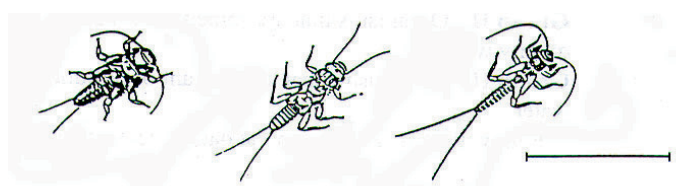
Gilled Snail - Class Gastropoda:
vary in size, a thin, horny plate, the operculum, seals the opening to the shell when the foot is retracted.



Riffle Beetle - Order Coleoptera:
1 - 8 mm, oval elongate body, 6 legs, slender antennae, crawl underwater.



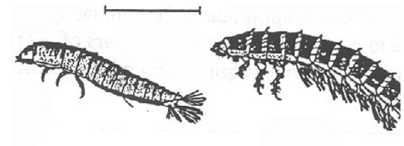
Stonefly Nymph - Order Plecoptera:
5 - 35 mm (not including tails), 6 legs with clawed tips, long slender antennae, 2 tails, gills may be present on mouthparts, thorax, and/or legs, rarely present on abdomen, hardened thoracic segments.



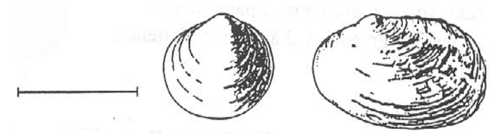
Non-Net-Spinning Caddisfly Larvae - Order Trichoptera: 2 - 40 mm, usually found within a case attached to the bottom of rocks, case made of plant material or rock particles, long and caterpillar-like, distinct head, chewing mouthparts, antennae reduced or inconspicuous, 3 pairs of legs, no wing pads or tails, end of abdomen has prolegs each with a claw.

Group II - somewhat sensitive

Beetle Larvae - Order Coleoptera: 2 - 60 mm, distinct head, 2 antennae, 6 legs, 8 to 10 segmented abdomen, may or may not have abdominal gills or lateral filaments.

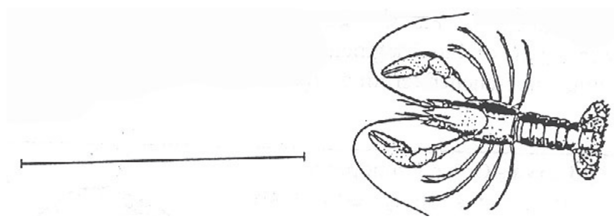


Clams - Class Pelecypoda: 2 - 250 mm, two-piece (bivalve) shell, commonly oval with concentric growth lines.

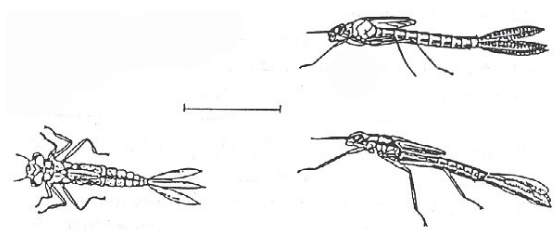


Crane Fly Larva - Order Diptera - Family Tipulidae: 10 - 100 mm (sometimes larger), white, green or brown caterpillar-like body, segmented, disc at end with 3 to 6 "fingerlike" appendages on end.

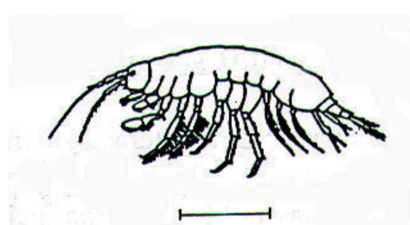
Crayfish - Order Decapoda: 10 - 150 mm, 2 large claws, 8 legs, 2 long antennae, resembles a tiny lobster.



Damselfly Nymph - Order Odonata - Suborder Zygoptera: 10 - 30 mm, elongate and slender forms, 2 antennae, 6 legs, 2 pairs of wing pads, no gills along body, 3 leaflike "tails" on end of abdomen.

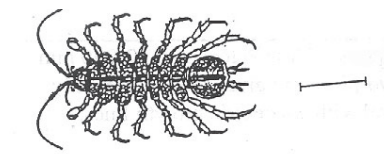


Scud - Order Amphipoda: 5 - 20 mm, laterally flattened, white to grey, swims sideways, 7 pairs of legs (first two pairs modified for grasping), resembles a shrimp.

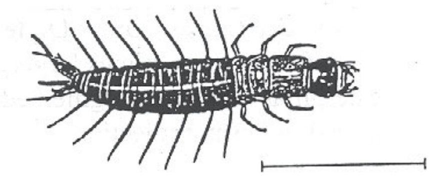


Group II - somewhat sensitive *(continued)*

Sowbug - Order Isopoda:
5 - 20 mm, 7 pairs of legs
(first pair modified for grasping),
2 antennae, flattened body, top to bottom.



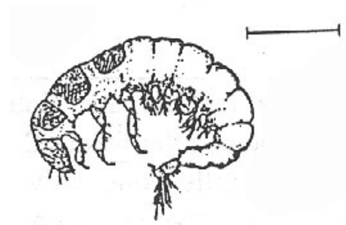
Fishfly Larva - Order Megaloptera -
Family Corydalidae:
10 - 25 mm, reddish-tan often with
yellowish streaks, no gill tufts underneath
abdomen, resembles a small hellgrammite.



Alderfly Larva - Order Megaloptera -
Family Sialidae: 10 - 25 mm, abdomen
with 7 pairs of 4 to 5 segmented lateral filaments
and a single unbranched terminal filament.

Net-Spinning Caddisfly Larva - Order Trichoptera

Family Hydropsychidae: 10 - 16 mm, strongly curved body, 3 thoracic segments that are sclerotized (hardened), branched gills on ventral side of abdominal segments, abdomen usually covered with small hairs, anal proleg with tuft of long hair and a hook, no case (free-living).

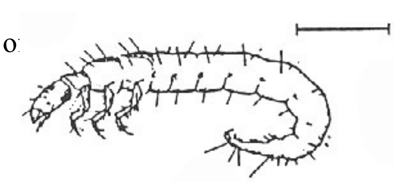


Family
Hydropsychidae

Family Philopotamidae: 10 - 12 mm, only first thoracic segment (pronotum) sclerotized (hardened), sometimes yellow or orange, head and pronotum brownish orange, pronotum bounded posteriorly by pronounced black line, 3 pairs legs, no prolegs or abdominal gills, abdomen strongly curved, no case (free-living).

Family
Philopotamidae

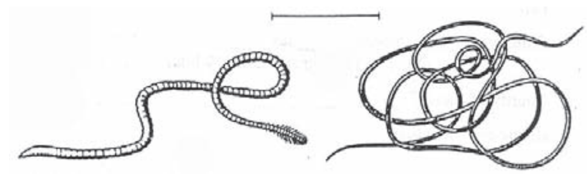
Family Polycentropodidae: 10 - 25 mm, whitish color tinged with purple, abdomen usually has a lateral finge o short hairs but never possesses gills, lower end of abdomen strongly curved.



amily
olycentropodidae

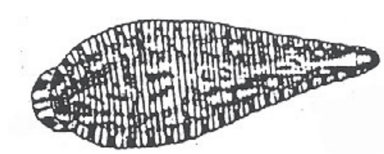
Group III - tolerant

Aquatic Worm - Class Oligochaeta:
1 - 30 mm (sometimes over 100 mm), elongate, cylindrical worms, segmented body (may be difficult to see segments), color variable.

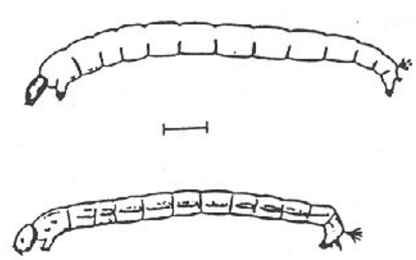


Blackfly Larva - Order Diptera - Family Simulidae:
3 - 12 mm, cylindrical body with one end wider, black head with fanlike mouth brushes.

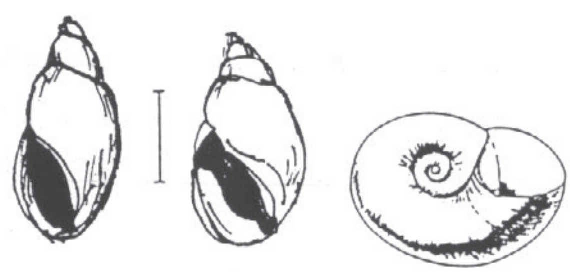
Leech - Order Hirudinea:
5 - 100 mm,
flattened segmented body,
both anterior and posterior suckers.



Midge Fly Larva - Order Diptera - Family Chironomidae: 2 - 20 mm, slender and cylindrical curved body, dark head with 2 legs on each side.



Other Snails - Class Gastropoda:
non-gill breathing snails, do not have an operculum to close the shell opening.



Macroinvertebrate Survey

Type of Stream

l Rocky-bottom l Muddy-bottom

Muddy-bottom Sampling Only: Record the number of jabs taken in each habitat type.

_____ Vegetated Bank Margin

_____ Snags and Logs

_____ Aquatic Vegetation Beds

_____ Silt/sand/gravel Substrate

Macroinvertebrate Count

Identify the macroinvertebrates (to order) in your sample using the identification card. We are only concerned with organisms that appear on the identification card. Record the number of organisms below and then assign them letter codes based on their abundance:

R (rare) = 1-9 organisms; **C** (common) = 10-99 organisms; or **D** (dominant) = 100 plus organisms.

example: _20___ (_C_) Water penny larvae

Group I - Sensitive

__________ (____) Water penny larvae

__________ (____) Hellgrammites

__________ (____) Mayfly nymphs

__________ (____) Gilled snails

__________ (____) Riffle beetle adults

__________ (____) Stonefly nymphs

__________ (____) Non net-spinning caddisfly larvae

Group II - Somewhat Sensitive

__________ (____) Beetle larvae

__________ (____) Clams

__________ (____) Cranefly larvae

__________ (____) Crayfish

__________ (____) Damselfly nymphs

__________ (____) Scuds

__________ (____) Sowbugs

__________ (____) Fishfly larvae

__________ (____) Alderfly larvae

__________ (____) Net-spinning caddisfly larvae

Group III - Tolerant

__________ (____) Aquatic worms

__________ (____) Blackfly larvae

__________ (____) Leeches

__________ (____) Midge larvae

__________ (____) Snails

Water Quality Rating

To calculate the index value, add the number of letters found in the three groups above and multiply by the indicated weighing factor.

Group I - Sensitive

(# of R's) x 5.0 =___________

(# of C's) x 5.6 =___________

(# of D's) x 5.3 =___________

Sum of the Index Value for Group I =___________

Group II - Somewhat Sensitive

(# of R's) x 3.2 =___________

(# of C's) x 3.4 =___________

(# of D's) x 3.0 =___________

Sum of the Index Value for Group II =___________

Group III - Tolerant

(# of R's) x 1.2 =___________

(# of C's) x 1.1 =___________

(# of D's) x 1.0 =___________

Sum of the Index Value for Group III =___________

To calculate the water quality score for the stream site, add together the index values for each group. The sum of these values equals the water quality score.

Water Quality Score =___________

Compare this score to the following number ranges to determine the quality of your stream site

l Good >40 l Fair 20 - 40 l Poor <20

Note: The tolerance groupings (Group I, II, III) and the water quality rating categories were developed for streams in the Mid-Atlantic states.

Macroinvertebrate Survey

Type of Stream

l Rocky-bottom l Muddy-bottom

Muddy-bottom Sampling Only: Record the number of jabs taken in each habitat type.

_____ Vegetated Bank Margin

_____ Snags and Logs

_____ Aquatic Vegetation Beds

_____ Silt/sand/gravel Substrate

Macroinvertebrate Count

Identify the macroinvertebrates (to order) in your sample using the identification card. We are only concerned with organisms that appear on the identification card. Record the number of organisms below and then assign them letter codes based on their abundance:

R (rare) = 1-9 organisms; **C** (common) = 10-99 organisms; or **D** (dominant) = 100 plus organisms.

example: _20___ (_C_) Water penny larvae

Group I - Sensitive

__________ (____) Water penny larvae

__________ (____) Hellgrammites

__________ (____) Mayfly nymphs

__________ (____) Gilled snails

__________ (____) Riffle beetle adults

__________ (____) Stonefly nymphs

__________ (____) Non net-spinning caddisfly larvae

Group II - Somewhat Sensitive

__________ (____) Beetle larvae

__________ (____) Clams

__________ (____) Cranefly larvae

__________ (____) Crayfish

__________ (____) Damselfly nymphs

__________ (____) Scuds

__________ (____) Sowbugs

__________ (____) Fishfly larvae

__________ (____) Alderfly larvae

__________ (____) Net-spinning caddisfly larvae

Group III - Tolerant

__________ (____) Aquatic worms

__________ (____) Blackfly larvae

__________ (____) Leeches

__________ (____) Midge larvae

__________ (____) Snails

Watershed

Grade 7

Explain the role of the water cycle within a watershed.
- Explain the water cycle.
- Explain the water cycle as it relates to a watershed.

Understand the role of the watershed.
- Identify and explain what determines the boundaries of a watershed.
- Explain how water enters a watershed.
- Explain factors that affect water quality and flow through a watershed.

Explain the effects of water on the life of organisms in a watershed.
- Explain how water is necessary for all life.
- Explain how the physical components of aquatic systems influence the organisms that live there in terms of size, shape and physical adaptations.
- Describe the life cycle of organisms that depend on water.
- Identify organisms that have aquatic stages of life and describe those stages.

Describe the impact of watersheds and wetlands on people.
- Explain the impact of watersheds and wetlands in flood control, wildlife habitats and pollution abatement.

Grade 10

Describe changes that occur from a stream's origin to its final outflow.
- Identify Pennsylvania's major watersheds and their related river systems.

Explain the relationship among landforms, vegetation and the amount and speed of water.
- Analyze a stream's physical characteristics. (terrestrial)
- Describe how topography influences stream. (terrestrial)
- Explain how vegetation affects storm water runoff. (terrestrial)
- Delineate the boundaries of a watershed.

Describe the physical characteristic of a stream and determine the types of organisms found in aquatic environments.
- Describe and explain the physical factors that affect a stream and the organisms living there.
- Identify terrestrial and aquatic organisms living there.
- Identify the types of organisms that would live in a stream based on the stream's physical characteristics.
- Explain the habitat needs of specific aquatic organisms.

Identify and describe natural and human events on watersheds and wetlands.
- Describe how natural events affect a watershed (e.g., drought, flood).
- Identify the effects of humans and human events on watersheds.

Grade 12

Categorize stream order in a watershed.
- Explain the concept of stream order.

- Identify the order of watercourses within a major river's watershed.
- Compare and contrast the physical differences found in the stream continuum from headwater to mouth.

Analyze the parameters of a watershed.
- Interpret physical, chemical and biological data as a means of assessing the
- environmental quality of a watershed.
- Apply appropriate techniques in the analysis of a watershed (e.g., <u>water quality, biological diversity</u>, erosion, sedimentation).

Evaluate the trade-offs, costs and benefits of conserving watersheds and wetlands.
- Evaluate the effects of human activities on watersheds and wetlands.

Environmental Health

<u>Grade 7</u>

Identify environmental health issues.
- Identify various examples of long term pollution and explain their effects on environmental health.
- Identify diseases that have been associated with poor environmental quality.
- Identify alternative products that can be used in life to reduce pollution.

Describe how human actions affect the health of the environment.
- Identify residential and industrial sources of pollution and their effects on environmental health.
- Explain the difference between point and nonpoint source pollution.
- Explain how nonpoint source pollution can affect the water supply and air quality.
- Explain how acid deposition can affect water, soil and air quality.

Explain biological diversity.
- Explain how diversity affects ecological integrity of the natural resources.

<u>Grade 10</u>

Describe environmental health issues.
- Identify the effects on human health of air, water and soil pollution and the possible economic costs to society.

Explain how multiple variables determine the effects of pollution on environmental health, natural processes and human practices.
- Explain how human practices affect the quality of the water and soil.

Explain biological diversity as and indicator of a healthy environment.
- Explain species diversity.

<u>Grade 12</u>

Analyze the need for a healthy environment.
- Explain how man-made systems may affect the environment.

Ecosystem and their Interactions

<u>Grade 7</u>

Explain the flows of energy and matter from organism to organisms within an ecosystem.

Identify and explain the characteristics of biotic and abiotic. (terrestrial)
Describe and explain the adaptations of plants and animals to their environment. (terrestrial)
Explain energy flow through a food web.
Identify the major characteristics of a biome. (terrestrial)

Compare and contrast different biomes and their characteristics. (terrestrial)
Identify the relationship of abiotic and biotic components and explain their interaction in an ecosystem. (terrestrial)
Explain how different soil types determine the characteristics of ecosystems. (terrestrial)

Explain how ecosystems change over time.
Explain how ecosystems change. (terrestrial)
Identify the succession stages of a given ecosystem. (terrestrial)
Explain how specific organisms may change an ecosystem. (terrestrial)
Explain a change in an ecosystem that relates to humans. (terrestrial)

<u>Grade 10</u>
Explain the biotic and abiotic components of an ecosystem and their interaction.

- Identify the major biomes and explain their similarities and differences. (terrestrial)
- Compare and contrast the interactions of biotic and abiotic. (terrestrial)
- Analyze the effects of abiotic factors on specific ecosystems. (terrestrial)
- Describe how the availability of resources affects organisms in an ecosystem. (terrestrial)
- Evaluate the efficiency of energy flow in a food chain.
- Examine and explain how organisms modify their environments to sustain their needs. (terrestrial)

Analyze how ecosystems change overtime.

- Identify and explain the succession stages in an ecosystem. (terrestrial)
- Identify causes of succession. (terrestrial)
- Analyze consequences of interrupting natural cycles. (terrestrial)

<u>Grade 12</u>
Analyze the interdependence of an ecosystem.

- Analyze the relationships among components of an ecosystem. (terrestrial)
- Explain limiting factors and their impact on carrying capacity. (terrestrial)
- Analyze the positive or negative impacts of outside influences on an ecosystem. (terrestrial)
- Analyze how different land use practices can affect the quality of soils. (terrestrial)

Analyze how human action and natural changes affect the balance within an ecosystem.

- Analyze the effects of substances that move through natural cycles. (terrestrial)
- Analyze effects of human action on an ecosystem. (terrestrial)
- Compare the stages of succession and how they influence the cycles existing in an ecosystem. (terrestrial)

Humans and the Environment

<u>Grade 7</u>
Describe how the development of civilization relates to the environment.

- Explain how people use natural resources in their environment.

Explain how people use natural resources.

- Describe how natural resources are used for survival.
- Explain how natural resources and technological changes have affected the development of civilizations.
- Explain how climates and extreme weather events (e.g. drought, flood) influence people’s lives.

Explain how human activities may affect local, regional and national environments.

- Describe what effect consumption and related generation of wastes have on the environment.
- Explain how a particular human activity has changed the local area over the years.

Explain the importance of maintaining the natural resources at the local, state, and national levels.

- Explain how human activities and natural events have affected ecosystems.

Grade 10

Analyze how society's needs relate to the sustainability of natural resources.

- Explain why some societies have been unable to meet their natural resources need.

Analyze the relationship between the use of natural resources and sustaining our society.

- Explain the role of natural resources in sustaining society.
- Analyze the effects of a natural resource's availability on an community or region.

Analyze how human activities may cause changes in an ecosystem.

- Analyze and evaluate changes in the environment that are the result of human activities.
- Compare and contrast the environmental effects if different industrial strategies (e.g. , energy generation, transportation logging, mining agriculture).

Grade 12

Explain how technology has influenced the sustainability of natural resources over time.

- Describe how technology has changed the use of natural resources by business and industry.

Analyze technology's roles on natural resources sustainability.

- Analyze the role of technology in the reduction of pollution.

Analyze how pollution has changed in quality, variety and toxicity as the United States developed its industrial base.

- Analyze historical pollution trends and project them for future.
- Compare and contrast historical and current pollution levels at a given location.

Glossary

Abiotic: A nonliving factor or element (e.g., light, water, heat, rock, energy, mineral.)

Biological diversity: Precipitation with a pH less than 5.6 that forms in the atmosphere when certain pollutants mix with water vapor.

Biotic: An environmental factor related to or produced by living organisms.

Closing the loop: A link in the chain of recycling events that promotes the use of products made with recycled materials.

Commodities: Economic goods or products before they are processes and/or given a brand name, such as a product of agriculture.

Composition: The process of mixing decaying leaves, manure and other nutritive matter to improve and fertilize soil.

Consumer: 1) Those organisms that obtain energy by feeling on other organisms and their remains. 2) A person buying goods or services for personal needs or to use in the production of other goods for resale.

Decomposer: An organism, often microscopic in size, that obtains nutrients by consuming dead organic matter, thereby making nutrients accessible to other organisms; examples of decomposers include fungi, scavengers, rodents and other animals.

Delineate: To trace the outline; to draw; to sketch; to depict or picture.

Ecosystem: A community of living organisms and their interrelated physical and chemical environment.

Endangered species: The total of the surroundings (air, water, soil, vegetation, people, wildlife) influencing each living being's existence, including physical, biological and all other factors; the surroundings of a plant or animal, including other plants or animals, climate and location.

Equilibrium: The ability of an ecosystem to maintain stability among its biological resources (e.g., forest, fisheries, crops) so that there is a steady optimum yield.

Extinction: The complete elimination of a species from the Earth.

Groundwater: Water that infiltrates the soil and is located in underground reservoirs called aquifers.

Hazardous waste: A soil that, because of its quantity or concentration or its physical, chemical or infectious characteristics, may cause or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of, or otherwise managed.

Homeostasis: The tendency for a system by resisting change to remain in a state of equilibrium.

Incinerating: Burning to ashes; reducing to ashes.

Integrated pest management: A variety of pest control methods that include repairs, traps, bait, poison, etc. to eliminate pests.

Lentic: Relating to or living in still water.

Lotic: Relating to or living in actively moving water.
Mitigation: The policy of constructing or creating man-made habitat, such as wetlands, to replace those lost to development.

Niche (ecological): The role played by an organisms in an ecosystem: its food preferences, requirements for shelter, special behaviors and the timing of its activities (e.g., nocturnal, diurnal), interaction with other organisms and its habitat.

Nonpoint source pollution: Contamination that originates from many locations that all discharge into a location (e.g., a lake, steam, land area).

Nonrenewable resources: Substance (e.g., oil. Gas, coal, copper, gold) that, once used, cannot be replaced in this geological age.

Point source pollution: Pollutants discharged from a single identifiable location (e.g., pipes, ditches, channels, sewers, tunnels, containers of various types).

Pest: A label applied to an organism when it is in competition with humans for some resource.

Recycling: Collecting and reprocessing a resource or product to make into new products.

Regulation: A rule or order issued by an executive authority or regulatory agency of a government and having the force of law.

Renewable: A naturally occurring raw material or form of energy that will be replenished through natural ecological cycles nor identifying, evaluating, selecting and implementing actions to reduce risk to human health and to ecosystems.

Shredder: Through chewing and/or grinding, microorganisms feed on non-woody coarse particulate matter, primarily leaves.

Stream order: Energy and nutrient flow that increases as water moves toward the oceans (e.g., the smallest stream (primary) that ends when rivers flow into oceans).

Succession: The series of changes that occur in an ecosystem with the passing of time.

Sustainability: The series of changes that occur in an ecosystem with the passing time.

Trophic levels: The role of an organism in nutrient and energy flow within an ecosystem (e.g., herbivore, carnivore, decomposer).

Waste stream: The flow of (waste) materials from generation, collection and separation to disposal.

Watershed: The land area from which surface runoff drains into a stream, channel, lake, reservoir or other body of water; also called a drainage basin.

Wetlands: Land where water saturation is the dominant factor determining the nature of the soil development and the plant and animal communities (e.g., sloughs, estuaries, mashes).

Bibliography

Water Quality

- 3 Rivers 2nd Nature, 2001, *Phase II Draft Report*.
- 3 Rivers 2nd Nature, 200l, *Stream Daylighting Opportunities in the Pittsburgh Region*, Carnegie Mellon University, Pittsburgh, Pennsylvania.
- Campbell, Gayla and Wildberger, Steve, 1992, *The Monitors Handbook*, LaMotte Company.
- DCNR, Pennsylvania Bureau of State Parks, 1998, *Watershed Education.*
- Ferguson, Bruce, Pinkham, Richard, and Collins, Timothy, 1999, *Re-Evaluating Stormwater*, Rocky Mountain Institute, Snowmass, Colorado, STUDIO for Creative Inquiry, Carnegie Mellon University, Pittsburgh, Pennsylvania.
- Galloway, Ed and Meislik, Miriam, 1999, *An Overview of Pittsburgh History: From the "Forks of the Ohio" to the "Steel City" and Beyond,* Pittsburgh, Pennsylvania.
- HACH Company, 2002, *Important Water Quality Factors*, Loveland, Colorado, www.hach.com.
- Koryak, Michael, 1990, *Rivers Reborn*, U.S. Army Corps of Engineers, Pittsburgh District, Pennsylvania.
- Lake Access, http://lakeaccess.org
- Mitchell, Mark K. and Stapp, William B., 1996, *Field Manual for Water Quality Monitoring, 11th Edition,* Dubuque, Iowa.
- Murdoch, Tom and Cheo, Martha with O'Laughlin, Kate, 2001, *Streamkeeper's Field Guide,* Adopt-A-Stream Foundation, Everett, Washington.
- Tarr, Joel A. and Yosie, Terry F., *Critical Decisions in Pittsburgh Water and Wastewater Treatment,* Pittsburgh, Pennsylvania.
- Taylor, Will, Dunn, Margaret, and Busler, Shaun, 2001, *Accepting the Challenge,* Slippery Rock Watershed Coalition.
- The Watercourse and Western Regional Environmental Council, 1995, *Project WET,* Bozeman, Montana.
- U.S. Environmental Protection Agency, Office of Wastewater Management, http://epa.gov, 2002.
- U.S. Environmental Protection Agency, Office of Water, *Volunteer Stream Monitoring: A Methods Manual*, 1997.
- U.S. Geologic Survey, Water Science for Schools, http://usgs.gov
- Water Environment Federation, 1997, *Water Sourcebook, Grades 9-12,* Alexandria, VA.
- WQED Pittsburgh, 2002, *Pittsburgh History Series,* Teachers' Guide.

3 Rivers 2nd Nature Bioassessment

The following metrics were used to develop biological condition scores:

- Modified Hilsenoff Family Biotic Index as a percent of the reference station
  - Reflects the tolerance of different macroinvertebrate families to organic pollution (excess nutrients from sewage or fertilizers). The higher the biotic index, the more impacted the stream.
- Taxa richness as a percent of the reference station
  - Represents the total number of taxa (orders, families, genera, and species) present in a sample. Generally the higher the taxa richness, the higher the diversity of the population. Streams with a higher diversity are considered healthier.
- Percent EPT organisms
  - Represents the percent of organisms in the orders Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly). These orders include

many species that are sensitive to pollution. Generally, the more EPT taxa, the better the water quality.

- Percent non-AC organisms
  - Annelida (sludge worms, leeches) and Chironomidae (midges) are macroinvertebrate groups that are highly tolerant of pollution. Organic pollution usually results in low diversity, but high numbers of AC organisms.

(New metrics designed for the study)

- Percent non-crustacean organisms
  - The crustacean *Gammerus* (scud) is not normally considered to be highly pollution tolerant. However, they can dominate the community in streams with very alkaline urban drainage. In urban streams a low percentage of *Gammerus* and a high percentage of non-crustacean organisms can be used to assess stream health.
- Percent EPT organisms exclusive of Baetidae mayflies
  - Mayflies are generally considered good indicators of healthy water because they are sensitive to pollution. Relative to other mayflies, Baetidae mayflies are somewhat tolerant of organic pollution, but this does not normally affect the metric. However, a number of highly alkaline streams in the study are dominated by Baetidae mayflies, indicating that they are also tolerant of these conditions. A metric that removes Baetidae mayflies from the percent EPT organisms can account for these conditions.
- Total number of organisms as a percent of the reference station
  - Organic pollution can result in large numbers of a few species of 23pollution tolerant organisms. In this situation, a large total number of organisms can indicate degradation. However, in this study low numbers of all organisms were found in highly impacted streams. Under these conditions, the study used this metric to place a positive value on a higher total number of organisms.