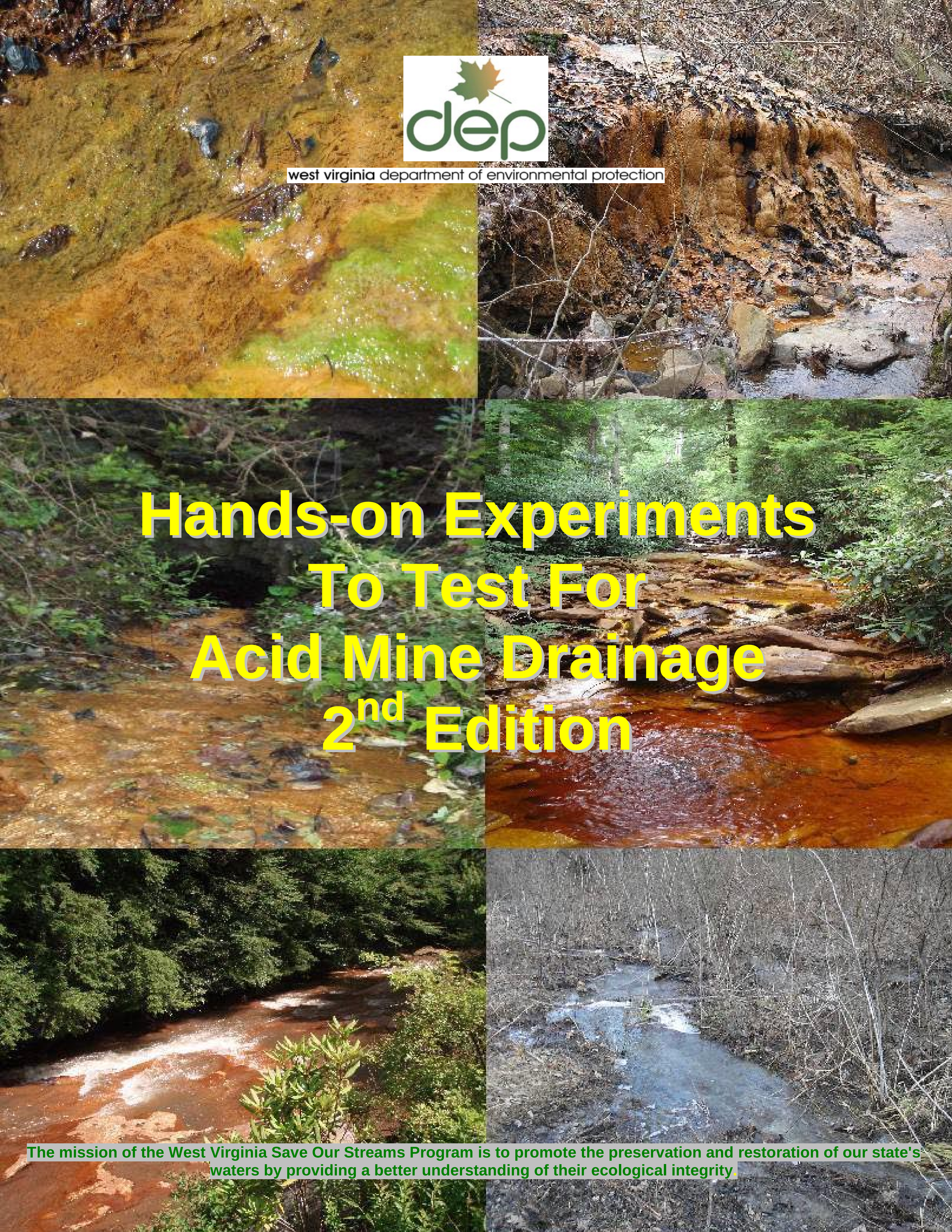

dep

west virginia department of environmental protection

Hands-on Experiments To Test For Acid Mine Drainage 2nd Edition

The mission of the West Virginia Save Our Streams Program is to promote the preservation and restoration of our state's waters by providing a better understanding of their ecological integrity.

Original version written in 2000 by:

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2nd edition revised by Timothy Craddock (Feb 2009)

Front Cover - Collage of acid mine drainage photos from Fayette, Monongalia, Preston, Putnam, and Tucker Counties in West Virginia

Photo and illustration credits - Jeff Bailey, WVDEP, Watershed Assessment Branch; Jennifer Dupree, WVDEP, Nonpoint Source Program, Jami Thompson, WVCA, Watershed Resource Center; Tim Craddock, WVDEP, Save Our Streams, Vivian Stockman, Ohio Valley Environmental Coalition, US Geological Survey, Environment Canada, Cacapon Institute, Izaak Walton League of America, Michelle Craddock, US Global Change Research Program, Environmental Microbiology and West Virginia University.

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The Experiments

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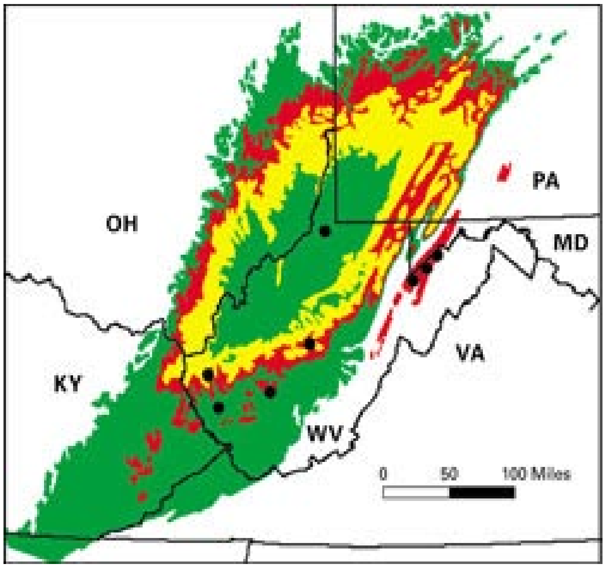
These experiments should always be done with the proper supervision from a teacher or parent. Always use caution and the proper protective equipment (Recommendations: rubber boots, gloves, safety glasses) when you are in or around a stream. Always make sure you have permission before entering private property. "Do not go stream collecting without an adult!"

Safety Tips: Always use the buddy system, have an adult check the stream flow and the stream bottom for sharp objects, and when wading in a stream, always wear shoes with rubber soles and good traction. Do not enter the stream if you cannot see the bottom, or do not enter after a hard rain. Wait for several days of dry weather before conducting any outside experiment in or around a stream. Do not go stream collecting without a responsible adult!

What is acid mine drainage?



Distribution of coal-bearing strata in the Appalachian region study area. Dots indicate core-hole locations. **Green** areas have a low potential for acid mine drainage from surface mining; **red** areas have high AMD potential; and **yellow** areas have intermediate AMD potential.

Acid mine drainage (AMD) is water contaminated when pyrite, an iron sulfide, is exposed and reacts with air and water to form sulfuric acid and dissolved iron. Some or all of this iron can precipitate to form the red, orange, or yellow sediments in the bottom of streams containing mine drainage. The acid runoff further dissolves heavy metals such as copper, lead, mercury into ground or surface water. The rate and degree by which acid mine drainage proceeds can be increased by the action of certain bacteria.

There are a number of environmental problems caused by AMD. It disrupts growth and reproduction of aquatic plants and animals, diminishes valued recreational fish species, degrades outdoor recreation and tourism, contaminates surface and groundwater drinking supplies, and causes acid corrosion of infrastructure like wastewater pipes.

Most of the acid problem is located in western Pennsylvania, much of West Virginia, eastern Kentucky, southwestern Ohio, western Maryland and a limited amount in southwestern Virginia.

The northern Appalachian coal fields (bituminous or soft coal) extend from northwestern Pennsylvania, south of the New York state line and west of the Susquehanna River, through western Pennsylvania and southeastern Ohio, and through most of West Virginia and into western Maryland and southwestern Virginia, eastern Kentucky, and northeastern Tennessee. Runoff water, polluted by acid, iron, sulfur and aluminum, has often drained away from the mines and into streams. Mine drainage is particularly heavy in the western and, to a lesser extent northeastern, Pennsylvania, and northern and south central West Virginia. Northeastern Pennsylvania is largely anthracite coal.

Alkaline Mine Drainage

The drainage from some mines is alkaline with high levels of metals. Generally, the rock that produces alkaline drainage has calcite and/or dolomite present.

Metal Mine Drainage

The mid-Atlantic region has a number of abandoned metal mines, some from the era of the Civil War. These mines produced lead, gold, and other metals. Drainage from these mines can contain high levels of these metals.

Dear Kids, Teachers, Parents, Guardians, and all Concerned Citizens

Photo courtesy of Vivian Stockman (Ohio Valley Environmental Coalition)

What questions do you have about acid mine drainage, the colors in the water, the critters in the water, or any other water quality questions? This document will help you answer some of those questions and more. It is full of simple experiments that will lead you to some of the answers, but more importantly it will help you understand how important it is to protect, preserve, and learn about our environment.

Dr. Robbins and her sister wrote a science activity book for kids in 1992. (It is now out of print by the federal government and only available from Colorado School of Mines.) It is called "What's Under Your Feet?" They talked to many scientists while writing the book. One fascinating finding was that most scientists find their vocation (what they would like to do when they grow up) by age 8 or 9. This means that, when they were children, they were making observations about their environment.

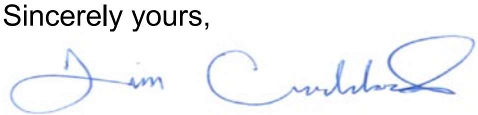
These observations were so powerful that they formed the basis for understanding how the world works.

Now, everyone is not going to become a scientist. But everyone is going to enter the job market. It is my opinion that working with our environmental is going to provide many jobs in the future. I think that if we get the kids out and looking and getting dirty now, they will have a body of observational knowledge needed to compete in that future job market.

The kinds of experiments that are laid out here are some of the very things that scientist do when they are trying to understand the natural environment and to help clean up problems left from past activities. The observations that kids will be making will also be helping present day scientists.

These are our thoughts on why we put these experiments together. We are outdoor people, so we have written this for other outdoor lovers. Some of the experiments are also indoor activities. In the next section is a general description of some goals and objectives we hope to accomplish with these experiments. As you try them and invent new ones at home and at school, please keep these goals and objectives in mind, but also keep fun in mind. Please feel free write or e-mail any of the authors with all of your comments or questions.

Sincerely yours,



Being "**scientific**" involves being curious, asking how things happen, and learning how to find the answers. Curiosity is natural to children, but they need help understanding how to make sense of what they see. All we need is a willingness to observe and learn with them, and, above all, to make an effort and take the time to nurture their natural curiosity.

What Is Science? - The Basics

Science is not just a collection of facts it is so much more. We all need a basic understanding of the scientific process or Scientific Method, to help us better understands our environment. The steps below are an example of the process:

- Observing what's happening.
- Predicting what might happen.
- Testing predictions under controlled conditions to see if they are correct.
- Trying to make sense of our observations.

Science fiction writer Isaac Asimov describes science as "a way of thinking, a way to look at the world." Science also involves trial and error - trying, failing, and trying again. Science does not provide all the answers. It requires us to be skeptical so that our scientific "conclusions" can be modified or changed altogether as we make new discoveries.

Children have their own ideas

Children develop their own ideas about the physical world, ideas that reflect their special perspectives. Below are some perceptions from some sixth grade students:

- Fossils are bones that animals are through wearing.
- Gravity is stronger on the earth than on the moon because here on earth we have a bigger mess.
- A blizzard is when it snows sideways.

Children's experiences help them form their ideas, and these often don't match current scientific interpretations. We need to allow our children to ask questions and make mistakes without feeling "stupid." We can help our children look at things in new ways. For instance, in regard to the blizzard, we could ask; "Have you ever seen it snow sideways? What do you think causes it to move sideways sometimes?"

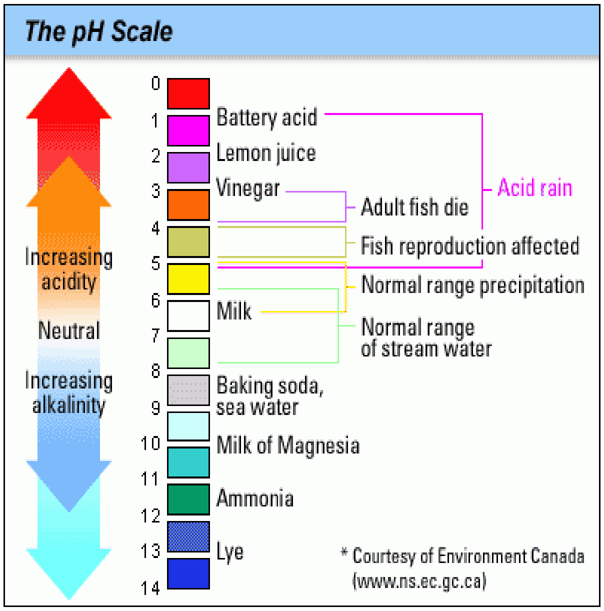
Hands-on works best

Children, especially younger ones, learn science best and understand scientific ideas better if they are able to investigate and experiment. Hands-on science can also help children think critically and gain confidence in their own ability to solve problems. Some science teachers have explained it this way:

- What engages very young children? Things they can see, touch, manipulate, modify; situations that allow them to figure out what happens - in short, events and puzzles that they can investigate, which is the very stuff of science.

The goals and objectives of "**Hands-on Experiments to test for Acid Mine Drainage**" are to help us all become more familiar with one of our environmental pollution problems, "Acid Mine Drainage." However, its ultimate goal is to encourage us to get outside, develop a better understanding about our environment through observation and experimentation, and help us become aware of how human activities can change the nature of our environment.

Making your own litmus paper



The pH of a substance is a measurement (color change or number change) of how much acid or base a substance may contain. Many acids and bases are important to the internal chemical reactions that take place in living things. Most living things attempt to keep themselves at equilibrium (neutral), but this is sometimes very difficult due to the pH of the surrounding environment.

The pH scale (the measure of acids and bases) ranges from 0 to 14, with 7 being the middle or neutral point. A substance with a pH of less than 7 is acidic and if it greater than 7 it is basic, also called alkaline. Each time there is a change in pH of one unit, it is the same as multiplying ten times (increase or decrease) the strength of the acid or base. Litmus paper is one way to measure the strength of an acid or base substance. Other ways include, electronic pH meters and test kits that will measure acids and bases by comparing color scales.

Tools and things you will need

Red cabbage	5 x 8 index card	Plastic sheet to contain the mess
Lemon juice	Vinegar	Blender
Strainer	Baking soda	Eye dropper

Hint: Lemon juice and vinegar are acids and should turn the paper pink (lower pH). Baking soda is a base and should turn the paper green (higher pH). If there are no color changes with your test liquids, this means they are neutral.

What to do?

1. Pull off the cabbage leaves.
2. Press them down hard on the white card until the card turns purple (6th grader Peter Cable discovered that the purple in the leaves works the best).
3. When you have turned the whole card purple, put a drop of each test substance on the card.

More things to do (You will need a blender and adult supervision)

1. Cut cabbage into chunks
2. Blend the cabbage chunks into a blender until liquid
3. Strain the contents of the blended cabbage with the strainer
4. Mix a drop of this liquid with the substance being tested.

What is acid and how do you know it?

Robert Angus Smith, a Scottish chemist, was the first to use the phrase "acid rain" in 1852. He noticed that the bricks in the buildings were falling apart, and through scientific experimentation, later found that there was a connection between London’s polluted skies and the pH of its rainfall.

Most scientists today agree that normal rainfall is slightly acidic with a pH of 5.6. The rain naturally reacts with carbon dioxide in the atmosphere to form a weak carbonic acid. Therefore, scientists define acid rain as any wet precipitation (rain, sleet, and snow) with a pH of less than 5.6. The rain becomes more acidic when it reacts with other gases in the atmosphere such as sulfur dioxide and nitrogen oxides. These other gases are naturally present in the atmosphere in small amounts; Industrial activities have increased their amounts.

Tools and things you will need

Glass or sturdy plastic bowl   Stirring rod   Measuring cup
Litmus paper

- Vinegar, lemon juice, baking soda, chalk, milk of magnesia, cola, or coffee - a few drops of each

What to do

1. Get a cup of water out of your local creek and pour it into a bowl.
2. Wash and dry the measuring cup.
3. Test the pH of the water with litmus paper (acids turn the paper pink).
4. Measure out one cup of baking soda.
5. If the water is acid (pH less than 7), slowly stir baking soda into the bowl.
6. Test with new litmus paper periodically until the paper turns blue. (This happens when the acid is neutralized.)
7. Repeat with a variety of acids (lemon juice, cola, and coffee) and a variety of bases (milk, milk of magnesia, and chalk).

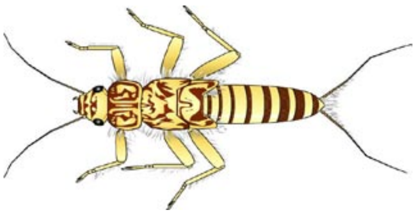
What did you see?

1. How much baking soda was needed to neutralize your creek water, coke, lemon juice etc.?
2. What happened when you combined two different acids?
3. What else did you see?

What do you conclude?

1. Which substance had the highest pH (was the most basic)?
2. What are your conclusions? "**Write down what think**."

If your creek water is clear, is it clean?



Studying aquatic organisms: Every creek has a different chemistry; some are polluted others are not. One good way to learn about your creeks chemistry is to study the aquatic life (benthic macroinvertebrate) in the creek. Biologist and other scientist have collected these organisms from many different places and many different types of creeks. By studying the macroinvertebrate in the creeks, you can learn something about the chemistry of the water and the physical environment, thereby determining the health of the creek.

Tools and things you will need

Gloves	Boots or waders	Nets (Rectangular, Kick or D-net)
Forceps/Tweezers	Collection containers	Litmus paper
Magnification (cubes/loupes)	Identification guides	Additional references

What to do?

1. Test the pH of the water with litmus paper. "Write it down."
2. Find a stretch of your creek that has a riffle. A riffle is a shallow rapid where water flows swiftly over small rocks (gravel and cobble size).
3. Place the net just downstream or in the riffle.
4. Kick and rub the rocks to get the aquatic organisms to fall off the rocks. Do this for two to three minutes (Make sure you rub the rocks upstream from the net.)
5. Collect the aquatic organisms caught in the net and place them in a tray filled partially with water.
6. Using different kinds of magnification observe the macroinvertebrates and compare them to the pictures found in this document or other sources.

For more information about conducting a complete stream survey, click-here.

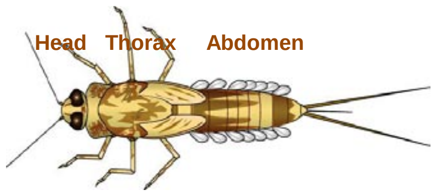
What did you see?

1. How many aquatic organisms came off the cobblestones?
2. What kind of aquatic organisms were there?
3. What other things were collected in the net?
4. What else did you see?

What do you conclude?

1. What information can you interpret from the types of aquatic organisms?
2. What are your conclusions? "**Write down what you think**."

On the next four pages are two kinds of visual identification keys that will help you become more familiar with the different kinds of benthic macroinvertebrates found in our streams, rivers and wetlands.

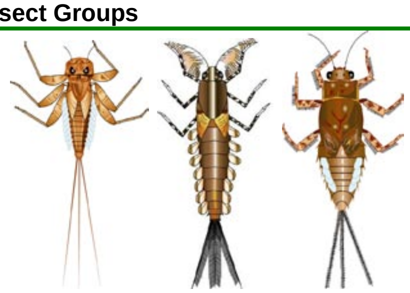


Small minnow mayfly

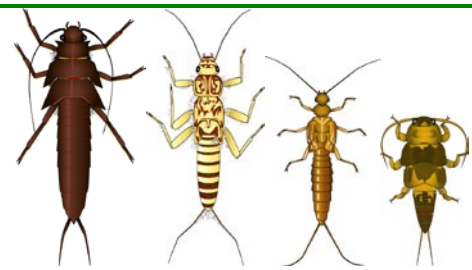
What is an insect? An insect is an invertebrate (an animal with no spine) that has three-pairs of legs (except Diptera) and three body divisions; the head is the location of the mouth, antenna and eyes; the thorax is the attachment site for the legs and wing pads; and the abdomen, which often has a variety of structures attached including filaments gills and tails. Gills are usually leaf-like, plate-like, or thin filaments. Tails can be long and thin, hairy, webbed or paddle-like. Most of the **benthic macroinvertebrates** you will encounter during stream surveys are aquatic larva or nymphs of insects. Most adult stages are not aquatic but the beetles are the exception. The majority of the insects are described on page one and the top of page two; non-insect group descriptions and Illustrations begin on page two.

Insect Groups

Instructions provided at the bottom of page two



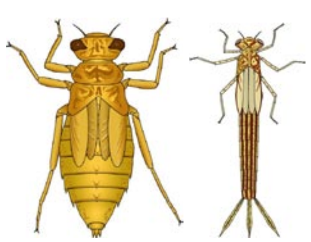
Mayflies (Order **Ephemeroptera**): Three-pairs of legs with a single hook at the end; three some-times two tail filaments; gills attached to the abdomen, which may sometimes be covered and difficult to see. Mayflies exhibit several types of move-ments (or habits); swimmers, clingers, crawlers and burrowers. (**VS-M**) (**M**)



Stoneflies (Order **Plecoptera**): Three-pairs of legs with two-hooks at the end; two tail filaments; no gills attached to the abdomen but some kinds may have gills near the top of the abdomen; gills if visible, mostly on the legs and thorax. (**S-VL**) (**M**)

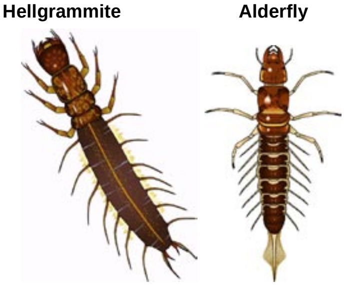
Case-building caddisflies (Order **Trichoptera**): Grub-like soft body and a hard head; Three-pairs of legs located on the upper third of the body; tail is small and usually forked, sometimes fringed with hairs; gills are scattered on the underside of the abdomen. The case is a relatively solid structure made of a variety of stream-bed materials held together by silk. (**VS-L**) (**M**)

Dragonfly Damselfly



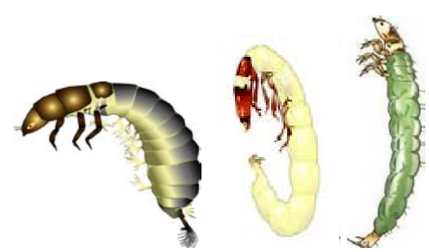
Dragonflies and **Damselflies** (Order **Odonata**): Three-pairs of legs; large eyes; long spoon-like jaws; no tails on the abdomen. Dragonflies have a broad shaped abdomen, while the Damselfly abdomen is much narrower. Damselfly gills are attached to the end of the abdomen, they look like tails. (**M-VL**) (**M**)

Hellgrammite Alderfly



Fishflies and **Alderflies** (Order **Megaloptera**): Three-pairs of legs; large pinching jaws; eight-pairs of filaments attached to the sides of the abdomen. Fishflies also called **hellgrammites** have a two-hooked tail, whereas Alderflies have a single tapered tail and are usually much smaller and lighter in color. (**M-VL**)

Common netspinner Finger-net caddisfly



Net-spinning caddisflies (Order **Trichoptera**): Similar characteristics as above but the abdomen usually has more abundant gills, especially the **common netspinner** (family **Hydropsychidae**). The net-spinner's structure is also made of a variety of streambed materials, which are held together more loosely by fine strands of silk. The **free-living caddisfly** (right) does not build a case or net. (**S-L**) (**M**)

Water penny Riffle beetles

Beetles (Order **Coleoptera**): Three-pairs of legs; body usually covered by a hard exoskeleton. The Most common kinds collected are the **water penny** and **riffle beetles** (left-right), but others kinds are also found. (**VS-L**) (**M**)

True flies (Order **Diptera**): Usually the body is segmented with some type of visible features either along the body, or at the head or tail regions (i.e. head, tails, prolegs, whelps etc.). This order is the only aquatic insect without fully developed legs in the larval stages. True flies are very diverse, with many kinds of aquatic varieties. Several common kinds are described here. (**M**)

Non-biting midge (Order **Diptera**; family **Chironomidae**): Segmented body with a visible head; two leg-like projections at the front and rear. Sometimes they are bright **red** in color. (**VS-M**)

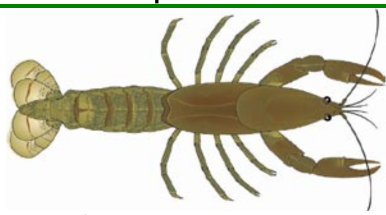
Illustrations courtesy of the Cacapon Institute (http://www.cacaponinstitute.org/) and artist Jennifer Gillies; used with permission

Crane fly (Order **Diptera**; family **Tipulidae**): No legs, no visible head; plump body with lobes along the segments; may have structures that look like tentacles, lobes or one bulb at the end of the body. (**S**-**VL**)

Black fly (Order **Diptera**; family **Simuliidae**): Body has a bowling-pen shape (lower is wider than the upper); there are multiple brushes/fans on the head and a ring of hooks on the abdomen. (**VS**-**M**)

Watersnipe fly (Order **Diptera**; family **Athericidae**): Plump body, looks very much like a caterpillar; on the underside there are structures that look similar to legs but are not segmented; the tail is forked and fringed with hairs. (**S**-**L**)

Non-Insect Groups



Crayfish (Order **Decapoda**): Five pairs of legs, the first two usually have large claws; large flipper-like structure at the end of the abdomen. (**M**-**VL**)

Scud/Sideswimmer (Order **Amphipoda**): Seven pairs of legs, the first two may be claw-like; body is somewhat higher than it is wide. Usually swims with a sideways motion. (**S**-**M**)

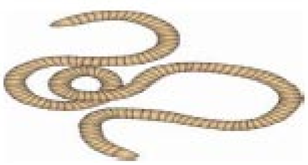
Aquatic sowbug (Order **Isopoda**): Seven pairs of legs, the first two may be claw-like; very long antenna; body is wider than it is high, giving the animal a fairly flattened appearance. (**S**-**M**)

Mussels **Clams**

Clams and **Mussels** (Class **Bivalvia**): Fleshy body enclosed between two-hinged shells; the shape and ridge spacing of the shells can determine different kinds. **Mussels** are usually larger than clams and have dark colored oblong shells. (**VS**-**VL**) (**M**)

Operculate snails (Class **Gastropoda**; sub-class Prosobranchia): Fleshy body enclosed by a single shell, which is usually coiled in an upward spiral. The opening of the shell is covered by an operculum (door). (**VS**-**L**) (**M**)

Non-operculate snails (Class **Gastropoda**; sub-class Pulmonata): Fleshy body enclosed by a single shell, which is sometimes coiled upward but also may lie flat or have a conical shape. The opening of the shell is not covered by an operculum. (**VS**-**L**) (**M**)



Aquatic worms (Class **Oligochaeta**): Body is long with numerous segments along its entire length; has no visible head or tail. (**VS**-**VL**)

Leeches (Class **Hirudinea**): Body is long and thin or slightly widened; 34–segments along its length, but there appears to be many more. (**S**-**VL**)

Flatworms (Class **Turbellaria**): Soft elongate body without segment; head triangular shaped with eyes on top, which give the animal a cross-eyed appearance. (**VS**-**L**)

http://www.dep.wv.gov/sos

Sizes illustrated not proportional

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601 57th Street, SE
Charleston, WV 25304

Instructions: Identification is easier when the organism is viewed in the same orientation as its illustration. Illustrations are drawn mostly in top and side views; the water penny is shown in underside view. The (**M**) symbol indicates that multiple kinds may be collected from the group (Order or Class). Use **morphological** features as your basis for identification; the invertebrate's size and color are often variable and influenced by environmental factors. Only a few of the many kinds possible are illustrated. (**Size range in mm**)

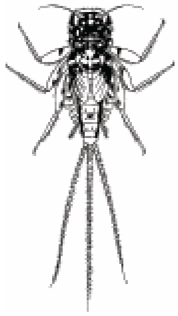
Size categories: > 50 Very large (**VL**); 50 - 30 Large (**L**); 29 -10 Medium (**M**); 10 - 5 Small (**S**); < 5 Very small (**VS**)

Note: This field guide will help you identify common aquatic invertebrate classes and orders, and a few families. You should always refer to a more complete guide for verification of family level identification. Eventually, you will be able to identify a wide variety of families in the field.

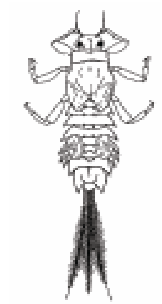
Illustrations courtesy of the Cacapon Institute (http://www.cacaponinstitute.org/) and artist Jennifer Gillies; used with permission

Visual Guide to Common Macroinvertebrates

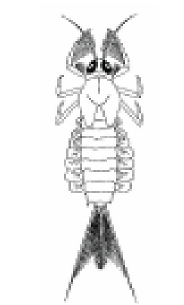
Flathead mayfly (L)



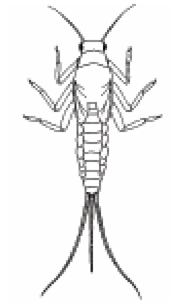
Spiny-crawler mayfly (L)



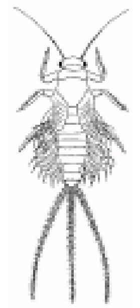
Brush-legged mayfly (L)



Minnow mayfly (M)

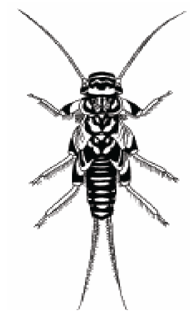


Prong-gilled mayfly (L)

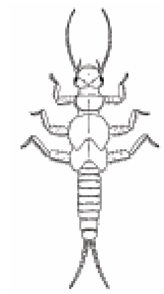


Burrowing mayfly (L)

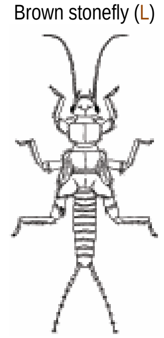
Common stonefly (L)



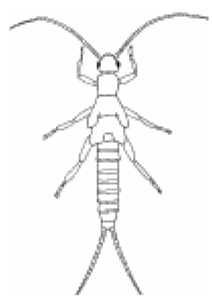
Green stonefly (L)



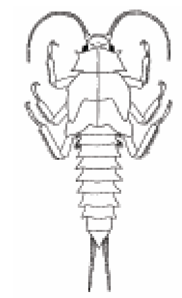
Brown stonefly (L)



Small winter stonefly (L)



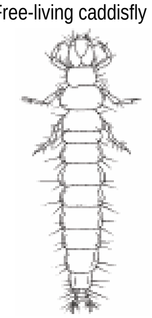
Giant stonefly (L)



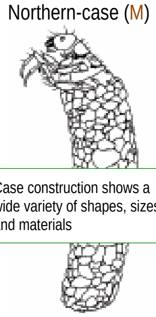
Common netspinner (M)

Finger-net caddisfly (L)

Free-living caddisfly (L)

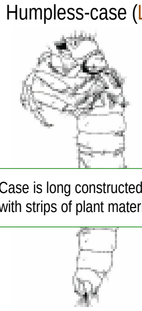


Northern-case (M)



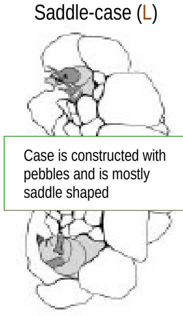
Case construction shows a wide variety of shapes, sizes and materials

Humpless-case (L)



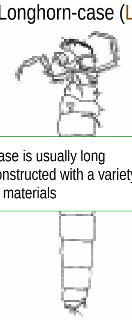
Case is long constructed with strips of plant materials

Saddle-case (L)



Case is constructed with pebbles and is mostly saddle shaped

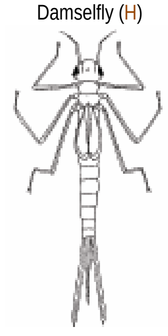
Longhorn-case (L)



Case is usually long constructed with a variety of materials

Dragonfly (M)

Damselfly (H)



Low (L)			Moderate (M)				High (H)		
1	2	3	4	5	6	7	8	9	10

The tolerance ratings are based upon the organisms' ability to withstand changes in the environment (i.e. pollution) mostly from human influences.

The purpose of this guide is to provide images and common names of benthic macro-invertebrates that volunteers may collect from our streams and rivers. This is not a complete list and is only meant to distinguish between the most common orders and a few representative families (kinds).

Insect Groups

Mayflies (order Ephemeroptera)

Three pairs (6 total) of legs; one hooked claw at the end of each leg; gills on the abdomen (may be covered by plates); 2 or 3 tail filaments and 2 short antennae. (M – L)

Stoneflies (Order Plecoptera)

Three pairs of legs (6 total); 2 hooked claws at the end of each leg; no gills on most of the abdomen but may have gills on the legs, thorax and upper abdomen; 2 tail filaments and 2 long antennae. (M – VL)

Caddisflies (Order Trichoptera)

.

Three pairs of legs (6 total); segmented grub-like body; some kinds may have gills along lower and upper portions of the abdomen; small hair-like tails or hooks. Case builders may be enclosed in a case (retreat) that they construct using stream bottom materials such as pebbles, sand grains, woody debris, pieces of plant material or some combination; others construct a net, which consists of materials held together by a silk-like thread. Note: The free-living caddisfly does not build a retreat. The case builders often construct a specific case that can sometimes be used in their identification. The common netspinner caddisfly is more tolerant than most of the group. The abundant gills on the underside of their body, their filamentous tails and their particular motion can distinguish them. (S – L)

Damselflies and Dragonflies (Order Odonata)

Damselflies: Three pairs of legs (6 total); long, thin abdomen; large eyes; extended lower lip; 3 fan like structures, which are actually their gills, at the end of the abdomen. (M – L)

Dragonflies: Three pairs of legs (6 total); extended lower lip; large eyes; rounded or extended abdomen; no gills on the abdomen; no tails but may have knobs or points on the abdomen that resemble tails. (M – VL)

Fishflies and Alderflies (Order Megaloptera)

Three pairs of legs (6 total); filaments along the body starting just below the legs; variable tails at the end of the abdomen. Alderflies have a long tapered tail; hellgrammites have hooked-tails. They also have gill-tufts under each of their filaments, fishflies and alderflies do not. All members of the group have large pinching jaws on the head, (M – VL)

Beetles (Order Coleoptera)

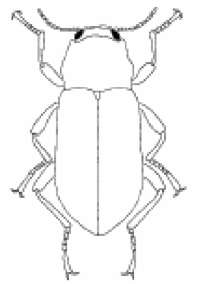
Three pairs of legs (6 total); mainly rounded or oval shape as adults; a few kinds have tails hooks or filaments, hard bodies and visible wing-pads. The most commonly encountered beetles are the riffle beetle, which is a small dark beetle and water penny, which looks like a penny. The whirligig beetle larva may have many filaments along their bodies similar to fishflies. (VS – L)

< 5	5 - 15	15 - 30	30 - 50	> 50
(VS)	(S)	(M)	(L)	(VL)

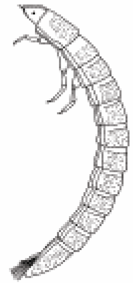
Size ranges (mm)

Visual Guide to Common Macroinvertebrates

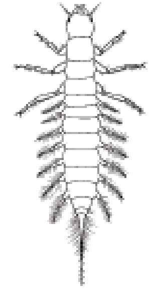
Riffle beetle adult (M)



Riffle beetle larva (M)

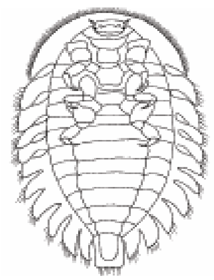


Alderfly (M)

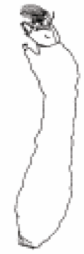


Hellgrammite (L)

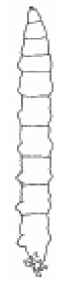
Water penny (L)



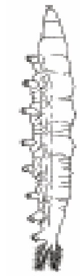
Black fly (M)



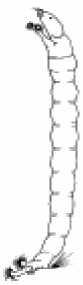
Crane fly (M)



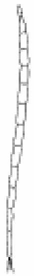
Watersnipe fly (L)



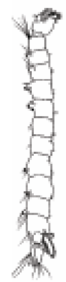
Non-biting midge (H)



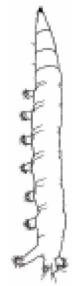
Biting midge (H)



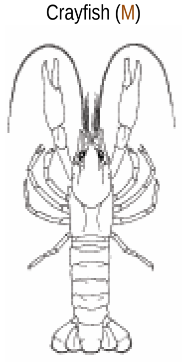
Dixid midge (H)



Dance fly (H)

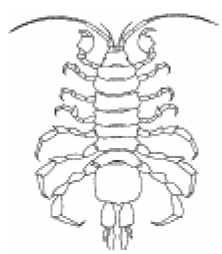


Crayfish (M)

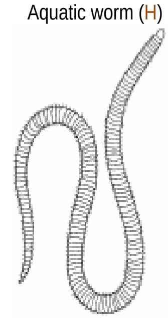


Scud/Sideswimmer (M)

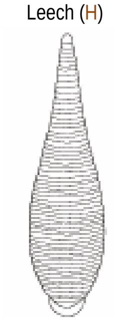
Aquatic sowbug (H)



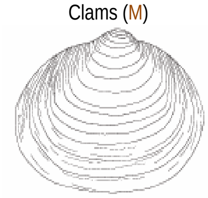
Aquatic worm (H)



Leech (H)



Clams (M)



Mussels (L)

Snails (M)

True Flies (Order Diptera)

No legs or may have structures that resemble legs (false-legs); mainly segmented grub-like or worm-like bodies; tiny hair-like tails, lobes, tentacles or other structures at the end of their abdomen (or no tails); often a distinct head can be seen, but on other kinds no head is visible. Many different kinds of flies are encountered, the more common kinds include the crane flies, most have no legs, a plump segmented body and numerous tentacles or bulbous structures; watersnipe flies has false legs and a forked hooked tail, looks similar to a caterpillar; black flies have a bowling pin or vase shape and fan-like structure on their head; non-biting midges are usually very small with a thread-like or worm-like body (some are red in color) with a very erratic wriggling motion. There are many more Diptera that are sometimes collected, but the only the images of the biting midge, dixid midge and dance fly are shown here. (VS – L)

Non-Insects

Crayfish, Scuds and Sowbugs (Sub-phylum Crustacea)

More than three pairs (more than 6 total) of legs; claws on the first several pairs of legs, which may be enlarged; long antenna. This group includes the crayfish, which looks like a small lobster, scuds also called sideswimmers resemble a shrimp and are flattened from side to side, and the aquatic sowbugs, which resemble a pill bug and are flattened from top to bottom. (M – VL)

Leeches and Worms (Phylum Annelida)

Worm-like appearance; no legs and many segments along the entire length of the body. This group includes the aquatic worms and leeches. The suckers on both ends of their body distinguish the leeches from other annelids. Flatworms are also sometimes collected, but they are not truly Annelids, they belong to the phylum Platyhelminthes. An image of the flatworm is not provided. (M – VL)

Clams and Mussels (Class Bivalvia)

Two cup-shaped shells connected by a hinged structure; the shell is made of calcium carbonate and is usually very strong and hard to open. Mussels have an oblong rough, often dark color shell. Most clams are smaller and have a rounded shell. The Asian clam can be distinguished from the native pea clam by the raised ridges; pea clams are often smaller and its shell feels smooth to the touch. (S – L)

Snails (Class Gastropoda)

Single coiled shell that mostly opens to the right when the point is held facing towards you. Operculate snails have an operculum "a door that shuts the shell" and are commonly known as gilled snails. Some have shells that open to the left when the point is held facing towards you; shells also may be rounded flat or coiled. Many of these are non-operculate snails that do not have an operculum and are commonly known as pouch or pond snails. (S – L)

Images courtesy of the University of Minnesota's Water Research Center; used with permission

Note: The image sizes are not proportional nor do they represent actual sizes; in some cases colors can be variable. Color and size should not be used as distinguishing characteristics when attempting to identify benthic macroinvertebrates. Not all families that may be collected are shown here. Most of the images are drawn in lateral of top views.

Learn more at: http://dep.wv.gov/sos

Why does acid mine drainage form?

The weathering process: In many areas, acid drainage forms naturally when certain minerals come into contact with water, air and bacteria. This contact and the chemical reactions that take place are part of the weathering process.

The weathering of the rocks and minerals in the creek slowly releases the acids, salts, metals and sulfates into creeks, rivers, lakes and wetlands. Weathering is a natural process, but many times human activities interfere and can increase the amounts. When too much of these acids and minerals enter creeks, they become polluted and can no longer support animals.

Tools and things you will need

Rocks or solid materials	Limestone	Coal chunks
Pieces of ore	Litmus paper	Tap water
Bottles	Gloves	Rubber boots

- Use small pieces; iron, aluminum, or magnesium ores are available at local science and nature supply stores such as, the World of Science.

What to do?

1. Collect solid materials that are found where you live.
2. Add tap water to bottles. Measure the pH with litmus paper.
3. Add one type of solid material to each of the water bottles. You may want to crush the solid materials into small pieces to get better results.
4. Put water but no solids in one bottle. (This is called your control.)
5. Measure the pH over time and write down what you see.

What did you see?

1. What materials lowered the pH of the water?
2. What materials raised the pH of the water?
3. How long did it take for acid to form?
4. What else did you see?

What do you conclude?

1. What materials in your area do you think can cause acid mine drainage?
2. How could you prevent acid mine drainage from forming?
3. What are your conclusions? "**Write down what you think**."

What types of plants like acid water?

There are very few plants that prefer acid conditions in creeks. However, some plants such as cattails can help to change the chemistry of the water by the uptake of pollutants and trapping of materials with their root systems. These wetland plants work in cooperation with bacteria in the soil to help improve the condition of the water.

Today scientists are testing many of these plants to see how they are able to do this. By learning more, scientists are able to create new environments, such as wetlands, to help improve conditions in acid streams and rivers.

Tools and things you will need

Small shovel	Rubber boots	Litmus paper
Magnifying lenses	Gloves	

- **Use caution:** some plants have spines or sticky substances to annoy animals.

What to do?

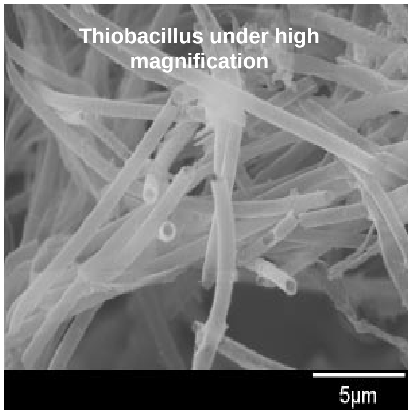
1. Test the pH of the water with litmus paper. (Is your creek acidic?)
2. Collect, draw, or take photos of some of the plants growing along side your creek. If you collect plants, only take one. If you find only one plant by your creek, do not collect it. We would prefer that you draw or take pictures of the plants instead.
3. Take any plants that you collect and press them in a phone book between sheets of newspaper.
4. Identify and make a list of these plants.
5. Dig out one or two of the plants to the root, or find their seeds to see if you can get them to grow somewhere else (do not take any plants without permission).
6. Take a field trip to a wetland area.

What did you see?

1. What types of plants grow along the creek?
2. What kind and color of soil did they grow in (hard, soft, squishy, wet, orange, black, or gray)?
3. What equipment did you need to keep the plants alive?
4. What else did you see?

What do you conclude?

1. What information did the plants give you?
2. What are your conclusions? "**Write down what you think**."



Who is very small and living in your creek?

Looking at bacteria and algae: Acidic environments are difficult places to live for many plants and animals; however, certain types of bacteria and algae can survive and flourish. These small one-celled life forms collectively known as microorganisms can be very colorful. The colors are a result of the many different types of chemical processes, of which these life forms are capable. For example, iron-oxidizing bacteria are able to "remove" dissolved iron in the water and form minerals that look like rust.

Many types of algae and bacteria use energy from sunlight to produce food, similar to larger plants, in a process called photosynthesis. These processes also create changes in the chemistry of the water. The many different types of bacteria and algae produce brilliant colors such as yellow, red, green, brown and even purple.

Tools and things you will need

Baby food jars	Eye dropper	Magnifying lenses
Gloves	Rubber boots	Litmus paper
Microscope (if possible)		

What to do?

1. With an eyedropper, collect in baby food jars the different red, yellow, orange, or brown flocculates (flakes found in the water, on the rocks or on the bottom sediments) in the water. Try filling some jars all the way to the top, and leave an air space in others.
2. Test each jar with litmus paper to check its pH and write down the results.
3. Put the jars on a windowsill. (Put some jars on a south-facing windowsill to get direct sunlight. Put other jars on a north-facing windowsill so they do not get sunlight). Certain algae will probably develop in the jars receiving the sunlight, and certain bacteria will develop in the jars that do not receive sunlight.
4. Observe over two or more weeks and take the pH of the water regularly. Take notes of what you see, including the date and time of your observations.

What did you see?

1. Observe a water sample every other day with a microscope (if possible). Did swimming protozoan hatch out?
2. Did any of the iron bacteria colonize (coat) the jar?
3. Did any of the iron bacteria form a reddish, oily looking film at the surface between the air and the water?
4. Did any of the iron bacteria form a brown ring at the top of the water?
5. What else did you see?

What do you conclude?

1. Did you collect acid loving iron oxidizing bacteria or neutral iron bacteria?
2. How can you tell the differences?
3. What are your conclusions? "**Write down what you think**."

What is in your creek water?

A creek can carry an amazing amount of chemicals. (One reason is that any activity on the land that surrounds the creek can usually affect the creek.) Some of these chemicals are so abundant that they mask "or hide" what is actually going on in the creek. For example, an abundant amount of minerals, metals, and sulfates may increase the pH of the creek, but when these substances drop out of the water, such as when the water flows over rocks or through wetlands, the chemistry of the creek changes and the pH may actually decrease.

Tools and things you will need

Gloves	Rubber boots	Litmus paper
Access to a Stove	Access to a Refrigerator	Hydrogen peroxide
Small jars (baby food jars, pill jars, etc.)		

What to do (Write down your results each time you check the pH)

1. Fill a small jar or pill bottle to the top with water from your creek.
2. Test the waters pH with litmus paper.
3. Pour in one capful of peroxide.
4. Let the red flocculates settle.
5. Test the water again for its pH.
6. Repeat the experiment with water placed in a refrigerator for one hour.
7. Repeat the experiment with water left in a warm stove for one hour.
8. Repeat the experiment with baking soda.

What did you see?

1. What happened when you put hydrogen peroxide in the water? What about baking soda?
2. What happened to the pH?
3. Which reaction (refrigerator or warm stove) occurred faster?
4. What else did you see?

What do you conclude?

1. What kind of chemical reaction did you perform?
2. Does heat or cold speed up a reaction?
3. What are your conclusions? "**Write down what you think**."

How many colors does iron have?

The oxidation-reduction process: Iron is common element of many creeks, especially in the Appalachian region. Iron (Fe) has many different forms and many different colors. Each color tells a different story about the chemistry of the creek.

Iron that is naturally found in the creek normally does not cause problems (it is part of the soil and the sediments), but metals can be increased by human activities to a point where they may become harmful to life in a creek. With iron, red is oxidized and black is reduced.

Tools and things you will need

Gloves	Magic marker	Rubber boots
Litmus paper	Shovel	Eye-dropper
Jars with lids		

What to do?

1. Fill jars with red, yellow, or orange flocculates (flakes that occur in the water, on rocks or on the bottom sediments) and water from a creek. These can be found in many creek, but are especially common in creeks affected by acid mine drainage.
2. Dig with a shovel in different places in and along the creek bed, until you find the color change from red to black.
3. Add some black sediment to some of the jars (and make sure water is to the top to keep out oxygen).
4. Label the jars with the dates of collection.
5. Put covered jars on a north-facing windowsill and observe them over several weeks.

What did you see?

1. Make observations as to what happened to the colors over several weeks.
2. At the end of the experiment, uncover the jars and smell them. "Write down what you smell."
3. What else did you see?

What do you conclude?

1. Which of these colors are from iron?
2. Which iron was oxidized and which was reduced?
3. What are your conclusions? "**Write down what you think**."

What is the black stuff on the rocks?

The manganese cycle: Finding the minerals that coat the rocks in a creek is a very old profession. The prospectors of years ago used to scrape off the coatings from the rocks in a creek and send them to a laboratory for analysis. These prospectors were usually looking for gold and silver, but many times they found a wide variety of minerals and metals.

The coatings and colors on the rocks can usually tell you about the most abundant minerals in a creek. Many times, the darkest mineral in a creek will cause the color. Manganese is almost always the darkest color mineral in the creek.

Tools and things you will need

Rubber boots	Gloves	Magic marker
Magnifying lenses	Litmus paper	String or small rope
Jars with lids	Microscope (if possible)	Glass slides

- **Other materials**: These materials can be such things as cans, bottles, tile, Styrofoam, paper, plastic bag etc.

What to do?

1. This experiment requires that your creek have black-coated cobblestones.
2. Tie a string or small rope across your creek. Attach some of the materials listed above along the string, making sure they are dangling in the water. (You can also attach them to tree roots or wooden stakes.)
3. Fill a large jar with creek water; Drop a microscope slide into the jar. Examine the slide at least once a week (should examine it more often). Write down what you see and any changes that occur over time.
4. Write down what day you started the experiment.
5. Examine the items dangling in the creek at least once a week. Write down what you see and any changes that occur.
6. After about six weeks end the experiment; write down the ending date, along with any final observations.

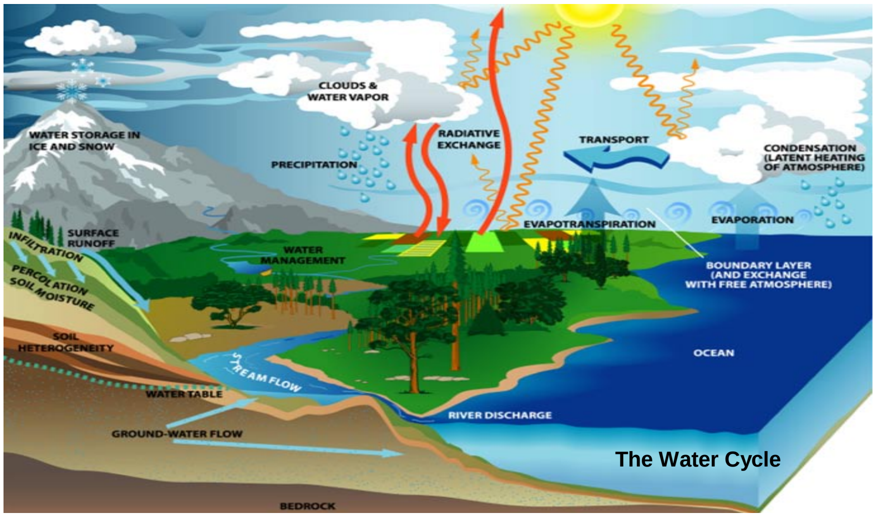
What did you see?

1. What materials became coated with manganese?
2. What did you see on the microscope slides?
3. Why do you think manganese sticks too many things?
4. What else did you see?

What do you conclude?

1. Which materials do you think manganese-oxidizing bacteria like best?
2. What are your conclusions? "**Write down what you think**."

Is the groundwater acid also?



The Water Cycle

The surface water, mainly from rain, runs off over the ground and fills creeks, rivers, lakes and wetlands. A small amount of the surface water does not run off, but instead seeps underground. This underground water is called ground water. Groundwater fills the spaces that are found in the soil and rocks and eventually flows downhill, just like creeks. The place that the groundwater is first observed as you dig down from the surface into the rocks and soil below is known as the water table. If you live in an area where your creek is acid, most likely the groundwater will also be acid.

Tools and things you will need

Shovel Gloves Rubber boots
Short length of PVC, steel, or aluminum pipe

What to do?

1. Test your creek pH with litmus paper.
2. Move away from the stream in a line (transect) and push a pipe down into the sediment, or dig a hole with a shovel.
3. Collect the water and test the pH with litmus paper.
4. Test another distance away from your creek.

What did you see?

1. How far down did you have to dig to find groundwater as you moved away from the creek?
2. Was the underground water the same chemistry as the creek?
3. What else did you see?

What do you conclude?

1. Would acids leak into the groundwater from the creek, or from other underground sources?
2. What are your conclusions? "**Write down what you think**."

What is the white stuff in the creek?

Both natural processes and pollution can cause foam (white soapy looking stuff) on a creek. It is usually caused by a combination of several different pathways. A simple definition of foam is "A gas (usually oxygen) mixed in a liquid containing some type of impurity." The foam is produced when air bubbles created by water flowing over rocks and over objects, combine or mix with the impurity.

Sometimes foams are natural. White colors can tell you when the element aluminum is present, or when sulfur-producing bacteria are present. The foam may also be the result of human activities in or around the creek.

Tools and things you will need

Gloves	Rubber boots	Litmus paper
Eyedropper	Shovel or stick	Jars with lids
Microscope (if possible)		

What to do?

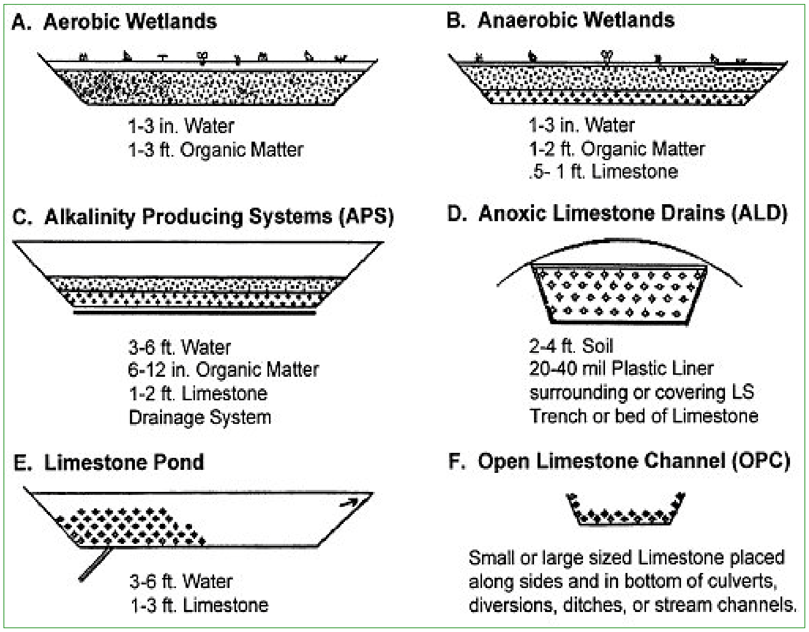
1. How can you tell if an impurity is present in the environment?
2. See if your creek has white foam.
3. Collect the white flocculates (flakes that occur in the water, on rocks or on the bottom sediments) in a baby food jar with an eyedropper.
4. Smell the mud under the white flocculate. What do you smell? A sulfur smell can indicate the presence of sulfur reducing bacteria.

What did you see?

1. Look at the flocculates under a microscope.
2. Observe the changes over time.
3. What else did you see?

What do you conclude?

1. What types of substances are in your creek? How can you find out what is in your creek?
2. What are your conclusions? "**Write down what you think**."



How can acid mine drainage can be fixed?

Passive treatment methods: Acid mine drainage sometimes forms when certain minerals in the soil and rocks around mines are exposed to weathering processes during mining. These exposed minerals release their contents into creeks causing them to become acidic. This kind of pollution damages aquatic life and makes the water useless or harmful for others who depend on it for recreation or drinking water.

Today, coalmining and other industries use very expensive chemicals (active treatments) to treat these contaminated waters. However, there are also less expensive methods known as (passive treatments) that can help improve our rivers and streams. Passive treatment methods are used most often for treating pollution from abandoned mines (prior to SMRA-1977) but the methods are used in other situations as well.

Tools and things you will need

Bottles with caps	Compost	Litmus paper
Limestone	Leaves	Pine needles
Gloves & boots	Cobbles or other natural objects	Acid water from creek

- You will need enough bottles, and large enough, for each object you plan to test.

What to do?

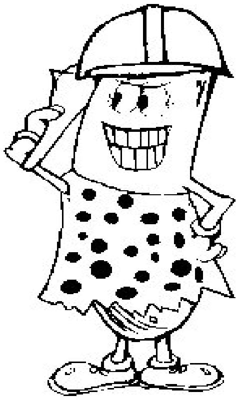
1. Find an acid stream by using litmus paper to measure the pH.
2. Collect the water in bottles.
3. Add one natural material to each bottle. Measure the initial pH.
4. Label each bottle and write down its pH.
5. Every few days for about two weeks, measure the pH to see what happens in each bottle. Write down the results.

What did you see?

1. What materials decreased the pH of the water?
2. What materials increased the pH of the water?
3. What materials caused solids to form at the bottom of the bottles?
4. What colors were the solids?
5. Did one of your experiments change acidic water to neutral?

What do you conclude?

1. What natural materials do you think can be used to treat acid mine drainage?
2. Can you create a treatment system using these natural materials?
3. What are your conclusions? "**Write down what you think**."



Using stinky bacteria to correct acid mine drainage

The sulfate reduction process: As mentioned in the previous experiment, there are many expensive ways to treat acid mine drainage, but there are also less expensive more passive treatment methods. These passive treatments may involve the use of constructed or natural wetlands. In a wetland the combination of the plants, the holding capacity (how long the water will stay in the wetland), the soils, and the bacteria are responsible for the treatment of acid mine drainage.

Many times these areas have a "rotten egg smell" which is caused when hydrogen sulfide gas is released through biological reactions that take place in the wetland. This is one way to tell if the wetland is doing the job of helping to treat the acid mine drainage.

Tools and things you will need

Acid water from creek	Wetland mud	Litmus paper
Collection boxes	Nine bottles with lids	Shovel
Gloves & rubber boots	Yeast	

- The plastic collection boxes should be large enough for one small shovel full of mud.
- The Bottles should be large enough for at least a tablespoon full of mud and a half of a tablespoon of yeast.

What to do?

1. Collect acid mine drainage in 9 bottles.
2. Collect mud that smells like rotten eggs from a wetland.
3. Add mud to 6 of the bottles and yeast to 3 of the bottles.
4. Measure the pH in the bottles over time; label each bottle and write down its pH. Watch for different colors to form.
5. Smell each bottle and write down what you smell (rotten eggs, a yeast smell, or something else).

What did you see?

1. What happened in the bottles having no yeast?
2. What happened in the bottles having yeast?
3. Which bottles really smelled like rotten eggs?
4. Which bottles had bacterial activity?
5. How did the bacteria affect the smell of the water?
6. What color was associated with the strong smell?
7. What else did you smell?

What do you conclude?

1. What might affect the ability of the bacteria to treat the water?
2. Why would people use compost in constructed wetlands?
3. What are your conclusions? "**Write down what you think**."

Tips for designing your own experiments

To use the "Scientific Method" you should design an experiment to test your "hypothesis." A hypothesis is a question, which has been reworded into a form that can be tested by an experiment. Your hypothesis should be based on the background information you gathered. Make a numbered, step-by-step list of what you will do to answer your question. This list is called an "experimental procedure". Your procedure should be detailed enough that someone else could do your experiment without needing to talk to you about it. This procedure should include:

1. Any important amounts or measures you will be using
2. Your one variable (what it is you plan to change) and how you will change it
3. Your control (constant measurements during the experiment)
4. How you are going to measure the change you observe
5. Diagrams or drawings so your ideas are clear

Your experiments must be done many times to guarantee that what you observe is accurate, or to obtain an average result. This process of repeating the same experiment many times is called "repeated trials". Experiments can be more or less complex depending on how they are set up.

Conduct experiments, gather data and record observations

As you do experiments, record all numerical measurements made. Data can be amounts of chemicals used, how long something is, the time something took, etc. Measurements are an important part of any experimental science project. Observations can be written descriptions of what you noticed during an experiment or problems encountered. You should be looking for differences between your control group and your experimental group(s). Two things to be aware of while doing your experiment and making observations:

1. If you did not observe any differences between the control and experimental groups then the variable you changed may not affect your experiment.
2. If you did not observe a consistent, reproducible trend in your experimental runs, there may be experimental errors affecting your results, or something affecting the results you may not have thought about.

If you suspect experimental errors, the first thing to check is how you are making your measurements. Is the measurement method questionable or unreliable? Maybe you are reading a scale incorrectly, or maybe the measuring instrument is not working. If measurements do not seem to be a problem, check to make sure you are following the rest of your procedure carefully from one run to the next. If you determine that experimental errors are influencing your results, carefully rethink the design of your experiments. Review each step of the procedure to find sources of potential errors. If possible, have a teacher review the procedure with you. Sometimes the designer of an experiment can miss something obvious. Keep careful notes of everything you do and everything that happens. Observations are valuable when drawing conclusions and useful for locating experimental errors.

References and Internet Resources

1 AIMS Foundation, 1988. Water, precious water: A collection of elementary water activities for grades 2 through 6. PO Box 8120, Fresno, CA
2 Costen, J. and Hornberger M., 1995. Water Wizardry: A teacher's guide to classroom activities and demonstrations about water pollution and remediation. US Geological Survey, Menlo Park, CA (To order contact: Michelle I. Hornberger, 345 Middlefield Rd., MS 465, Menlo Park, CA 94025)
3 Gartrell, J.E. et al. 1992. Earth – The Water Planet: National Science Teachers Association. (To order: US Geological Survey, MS 950, Reston, VA 20192)
4 McGee, E. 1995. Acid rain and our Nations Capitol: A guide to effects on buildings and monuments: US Geological Survey, Reston, VA (To order: US Geological Survey, MS 950, Reston, VA 20192)
5 Robbins, E.I. and Hayes, M. 1997. What's red in the water? What's black on the rocks? What's the oil on the surface - http://pubs.usgs.gov/gip/microbes/
6 Schrock, J.R. 1993. Surface mining of coal: The Kansas School Naturalist, Vol. 4, No. 1, Emporia State University, 1200 Commercial St., Emporia, KS 66801-5087
7 Sly, C. 1990. Water wisdom: A curriculum for grades 4 – 8: Publication of the Alameda County Office of Education. (To order: US Geological Survey Library, MS 950, Reston, VA 20192)
8 US EPA (Nonpoint Sources of Pollution) - http://www.epa.gov/owow/nps/
9 US EPA's Teaching Center: Order on-line or download a variety of publications on important environmental education topics - http://www.epa.gov/teachers/order-publications.htm
10 Zielinski E.J. 1995. Acid Mine Drainage in Pennsylvania, K-12 Awareness Activities: Pennsylvania Department of Environmental Resources, Bureau of Land and Water Conservation

To learn more about acid mine drainage, visit the Internet sites below, conduct research using your favorite web browser, or visit your local library.

1 AMD and Art
2 AMRC Learning House (What is AMD?)
3 Appalachian Center for the Economy and the Environment
4 Appalachian Coal Country Watershed Team
5 Eastern Coal Regional Roundtable
6 Exploring the Environment and Water Quality (Acid Mine Drainage)
7 Groundwater Pollution Primer (Acid Mine Drainage)
8 Marshall University's (Interactive Acid Mine Drainage Activity)
9 Passive Treatment Methods for Acid Water in Pennsylvania
10 US Army Corps of Engineers (Nationwide Permit Information)
11 US Dept. of Interior (Office of Surface Mining)
12 US Energy Information Administration (Coal Basics)
13 US Geological Survey: Introduction to Acid Mine Drainage
14 Valdosta State University (Acid Mine Drainage, the Unseen Enemy)
15 Wetland used to treat acid mine drainage in Putnam County, WV
16 WV Dept. of Environmental Protection (Abandoned Mine Lands and Reclamation and the Division of Mining and Reclamation)
17 WV University (Overview of AMD Treatment with Chemicals)
18 WV University (You Can't Judge a Stream by its Color)
19 WV University Extension Service (Land Reclamation and Acid Mine Drainage)
20 YouTube Video (Acid Mine Drainage in Dry Fork)

West Virginia Department of Environmental Protection/Division of Mining & Reclamation

Enviro FACTSHEET

ACID MINE DRAINAGE

Correcting coal's biggest environmental problem

When coal was formed, various metals in the coal forming plants were concentrated and immobilized. As coal seams are mined or opened during road construction, these metals are released and exposed to oxygen. If present in substantial concentrations, they produce acid mine drainage (AMD) that may contain dissolved iron, manganese, and aluminum as well as sulfates.

Less than five percent of active West Virginia mines have any water quality problems. Coal seams in some areas produce poor quality drainage with varying concentrations of acidity and metals. Most AMD is from abandoned mines, where no one has the responsibility to correct the problem. As a result, hundreds of miles of streams and rivers in West Virginia are affected. Acid mine drainage sources are classified under one of these three categories:

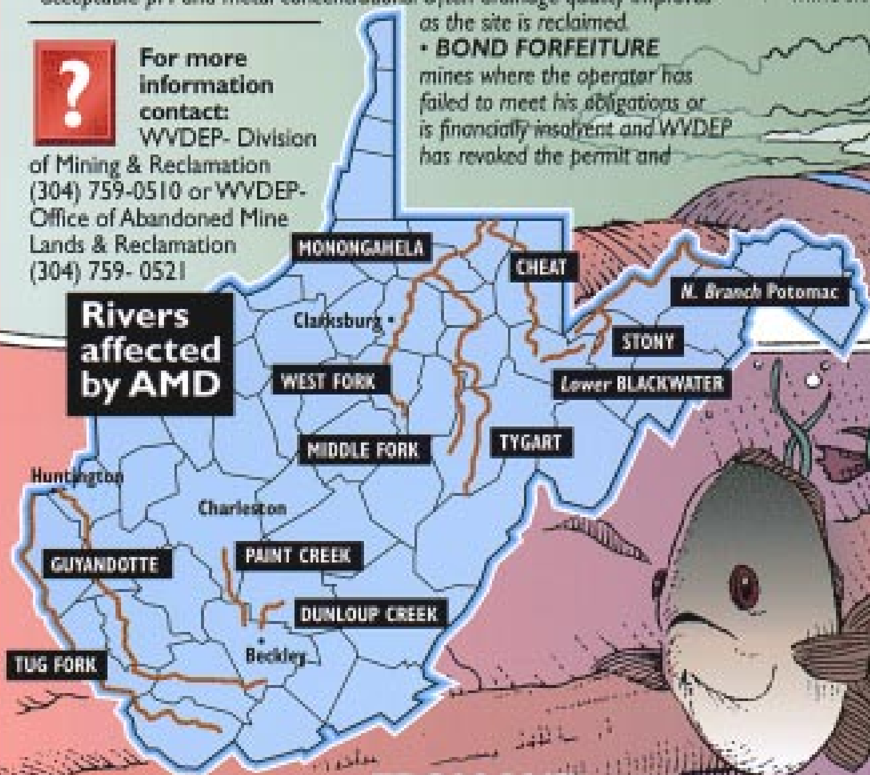
- ***ACTIVE** mine sites where the operator is required to treat discharges to acceptable pH and metal concentrations. Often drainage quality improves as the site is reclaimed.*
- ***BOND FORFEITURE** mines where the operator has failed to meet his obligations or is financially insolvent and WVDEP has revoked the permit and may use securities to mitigate the drainage. About 10 percent of bond forfeitures have water quality problems. WVDEP chemically treats at several sites to protect water uses, and has integrated passive amelioration at other sites as it reclaims them.*
- ***ABANDONED MINE LANDS** where mining ceased prior to new laws in 1977. WVDEP initiates water quality improvement efforts as it reclaims dangerous and unsightly remnants of past mining.*

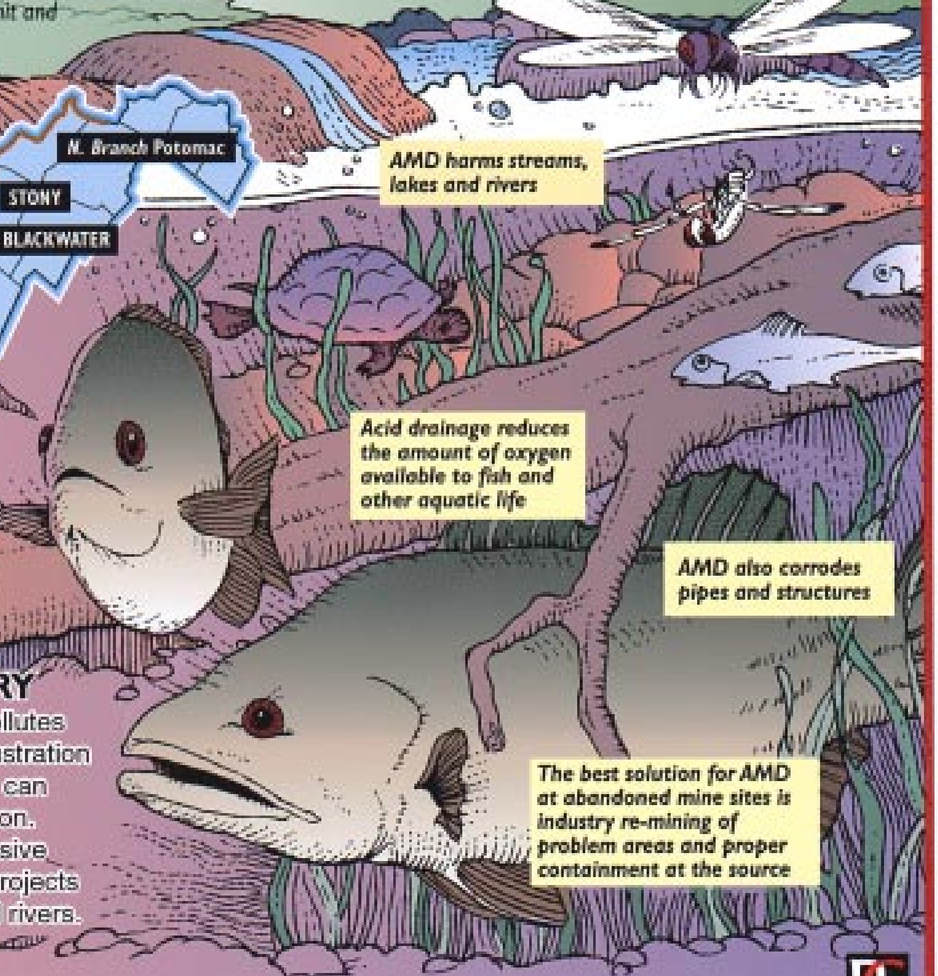
Water and mine soil testing and extensive planning, combined with rigorous enforcement in potentially acidic areas prevents future AMD problems at current mine sites.

"ACTIVE" AMD TREATMENT
Utilizes strong alkaline chemicals such as lime, caustic soda, ammonia and calcium oxide.

"PASSIVE" AMD TREATMENT
Includes reclamation, limestone sand in streams, and directing the drainage through limestone ditches, buried channels, or constructed wetlands.

For more information contact:
WVDEP- Division of Mining & Reclamation (304) 759-0510 or WVDEP- Office of Abandoned Mine Lands & Reclamation (304) 759- 0521





FROM AMD TO RECOVERY

Some ways AMD pollutes are shown in this illustration of the transition that can occur with reclamation. WVDEP has aggressive stream restoration projects on several impacted rivers.

West Virginia Department of Environmental Protection • 1356 Hansford St. • Charleston, WV 25301 • 304-558-4253

Section 319

NONPOINT SOURCE PROGRAM SUCCESS STORY

West Virginia

Passive Treatment Systems Restore Water Quality

Waterbody Improved Acid mine drainage from abandoned coal mines impaired West Virginia's Morris Creek, prompting the state to add the creek to its 1996 Clean Water Act section 303(d) list of impaired waters for metals and pH. To restore the stream, project partners installed various passive treatment systems [e.g., anaerobic and aerobic wetlands, open limestone channels (OLCs), polishing ponds] at four sites in the watershed. As a result, metal concentrations in Morris Creek have dropped significantly. West Virginia proposes to remove this waterbody from the section 303(d) list in 2010.

Problem

Morris Creek flows through Kanawha County, approximately 25 miles southeast of Charleston, West Virginia, and joins the Kanawha River in the town of Montgomery. West Virginia first placed Morris Creek on the section 303(d) list in 1996 for metals and then again in 1998, 2000, 2002 and 2004 for pH and metals. Stretches of the stream were devoid of aquatic life, and deposits of iron and aluminum existed at several points along the streambed, preventing the creek from supporting its warm-water fishery, drinking water and contact recreation designated uses (Figure 1).

West Virginia developed a total maximum daily load (TMDL) study in 2005 for the Upper Kanawha River system, which includes Morris Creek. The TMDL analysis suggested that for Morris Creek to achieve water quality standards, metal loads would need to be reduced—aluminum by 5,900 pounds per year (lbs/yr), iron by 8,007 lbs/yr and manganese by 4,444 lbs/yr.

Project Highlights

In 2002 the newly formed Morris Creek Watershed Association (MCWA) contacted the West Virginia Department of Environmental Protection's (DEP's) Abandoned Mine Lands (AML) program and the U.S. Office of Surface Mining to request assistance in treating the acid mine drainage polluting Morris Creek. In response, AML and MCWA conducted a watershed-wide monitoring sweep and identified four primary project sites.

By 2003 AML began planning for passive treatment systems at the four sites—Possum Hollow, Blacksnake Hollow, Lower Mainstem and Upper Mainstem Morris Creek. The Possum Hollow site treatment system consists of an aerobic wetland,

Figure 1. Acid mine drainage flows into Possum Hollow, a Morris Creek tributary.

40 by 350 feet, with 3 to 18 inches of limestone in a 60-mil liner, and a polishing pond with an area of 25 by 60 feet. The second site, Blacksnake Hollow, is in a small, very steep area with several acid mine drainage sources seeping out of the hillside from old mine voids. Although a low volume of water typically flows from Blacksnake Hollow (10.5 gallons per minute), the flow contributed highly acidic water (246 milligrams per liter) before the project. The steep terrain and lack of space required partners to select OLCs as the treatment system. Check dams in the OLC slow water flow and lengthen the treatment time. Although project partners expected the Blacksnake Hollow project to accomplish the least amount of water quality treatment of any of the projects, they believed that, when combined with the treatment success of upstream systems, it would help to fully restore Morris Creek.

The third and fourth sites are upstream from a residential section of Morris Creek, where the old Eureka #2 mine discharges highly acidic water from several seeps and collapsed portals adjacent to the stream for several hundred feet. Two projects were designed to treat these sources: the Lower Mainstem and the Upper Mainstem sites. The Lower Mainstem passive treatment system consists of an anaerobic wetland with five 30 by 250-foot cells lined with 6 to 9 inches of limestone in a 60-mil liner, a 30 by 100-foot-wide polishing pond, and wetland plantings consisting of cattails, bull rushes and common rushes. The Upper Mainstem treatment system is the largest of the four projects. To treat the discharges adjacent to the creek, partners installed a 15 by 450-foot-wide drainage channel with five check dams lined with a 12-inch layer of limestone (Figure 2). The creek itself is routed through a 450-foot OLC to add alkalinity.

Figure 2. The Upper Mainstem Morris Creek treatment system includes a drainage channel lined with limestone.

Results

Partners finished installing treatment systems in September 2006. Water quality improved immediately. Initial monitoring results showed that Morris Creek and its tributaries (Possum and Blacksnake hollows) met water quality standards for pH, aluminum, iron and manganese below the treatment sites. In fact, the treatment systems reduced metal loads far beyond that required by the TMDL (Table 1). In response, aquatic life is returning to the creek, including a surviving population of brown trout fingerlings (stocked by Trout Unlimited). DEP expects to remove Morris Creek from the 303(d) list of impaired waters in 2010 if conditions remain improved.

Some challenges remain. Flooding and sediment accumulation have caused some problems with the systems in the two years since construction. The efficiency of the Lower Mainstem treatment system has declined, allowing the iron levels to rise again in the creek below this site. However, pH and aluminum continue to meet water quality standards. The partners plan to secure an engineering review of the system to isolate the problem and fix it.

Table 1. Initial environmental results after installing acid mine drainage treatment systems in the Morris Creek watershed.

Project site	pH level: pre/post treatment	Metal reductions achieved		
		Aluminum (lbs/yr)	Iron (lbs/yr)	Manganese (lbs/yr)
Possum Hollow	3.5/6.7	390.55	47.45	102.2
Blacksnake Hollow	4.4/5.0	84.45	76.65	36.86
Lower Mainstem	4.0/6.3	1,759.3	9,249.1	1,098.65
Upper Mainstem	4.2/5.4	31,006.75	276,483.85	31,119.9
Total Reductions	--	**33,248**	**285,857**	**32,320**
TMDL Allocations	--	5,900	8,007	4,444

Although the creek is not officially considered impaired for sediment, partners recognize that excess sediment is entering the creek. As part of the comprehensive effort to restore Morris Creek, the DEP Nonpoint Source Program applied to the U.S. Environmental Protection Agency for two grants to reduce sediment loads. The Phase I project, completed in September 2007, restored 1,500 feet of abandoned road, armored culvert outfalls and improved road drainage. The project should reduce sediment entering Morris Creek above the Upper Mainstem site by 213 tons/year. Another part of this project reduced erosion pressure from a large slip area known as the Jones Hollow Slip. This section of the project should reduce sediment by 370 tons/year. Phase II, which began in 2008, includes stabilizing stream banks along the residential section of Morris Creek.

Partners and Funding

The projects received a nonfederal match of $971,810: $312,683 from the Watershed Cooperative Agreement Program (state matching funds) and $659,127 from AML. The DEP Nonpoint Source Program contributed $690,167 in section 319 funds. Project costs totaled $1,661,977. The MCWA provided project assistance and initiated valuable partnerships, such as that with the DEP Nonpoint Source Program. The success of these projects is due in large part to the MCWA.

U.S. Environmental Protection Agency
Office of Water
Washington, DC

EPA 841-F-08-001FF
November 2008

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West Virginia Geological and Economic Survey

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GEOLOGIC MAP OF WEST VIRGINIA

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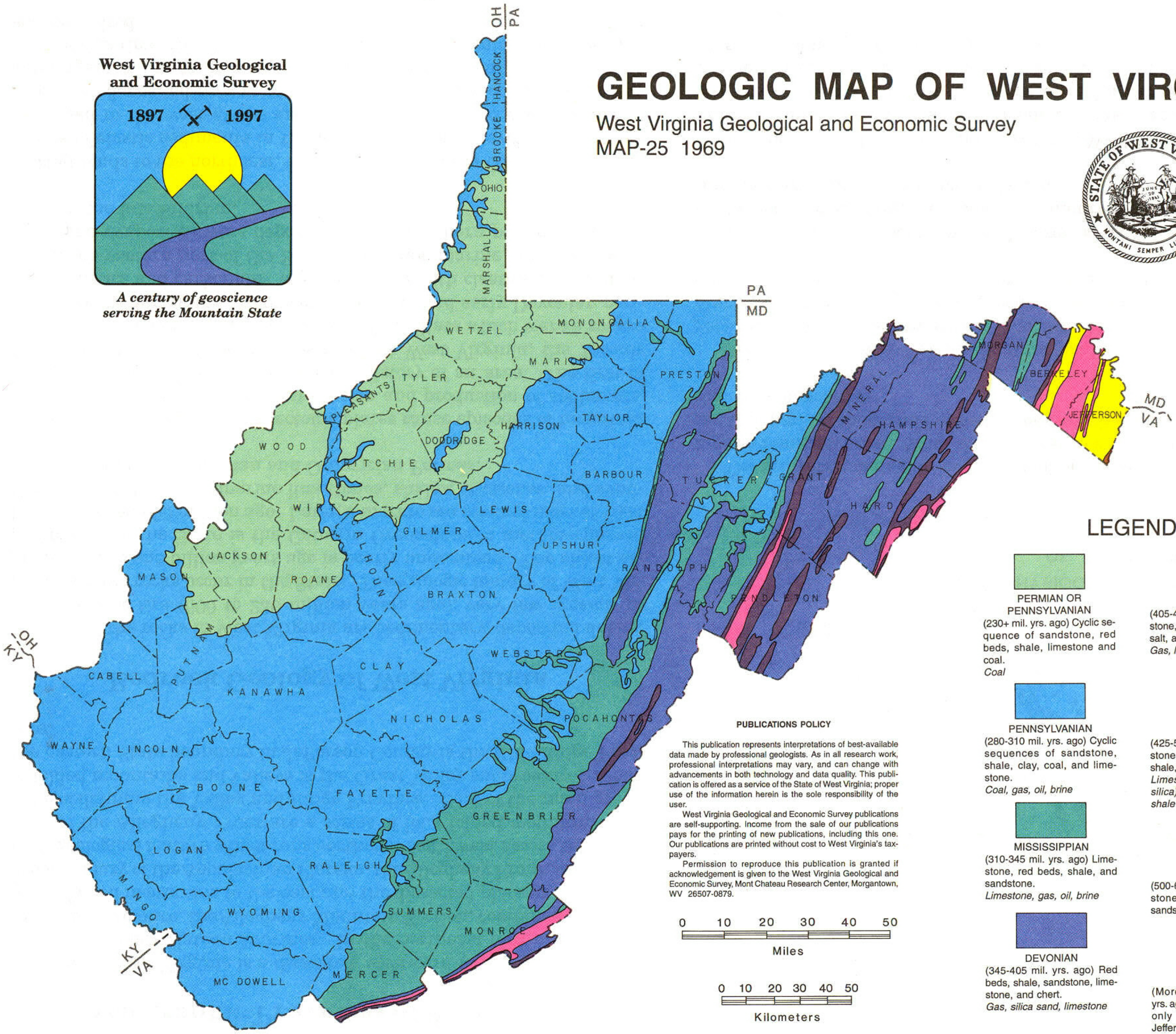

LEGEND

PERMIAN OR PENNSYLVANIAN
(230+ mil. yrs. ago) Cyclic sequence of sandstone, red beds, shale, limestone and coal.
Coal

PENNSYLVANIAN
(280-310 mil. yrs. ago) Cyclic sequences of sandstone, shale, clay, coal, and limestone.
Coal, gas, oil, brine

MISSISSIPPIAN
(310-345 mil. yrs. ago) Limestone, red beds, shale, and sandstone.
Limestone, gas, oil, brine

DEVONIAN
(345-405 mil. yrs. ago) Red beds, shale, sandstone, limestone, and chert.
Gas, silica sand, limestone

SILURIAN
(405-425 mil. yrs. ago) Sandstone, shale, limestone, rock salt, and ferruginous beds.
Gas, limestone, artificial brine

ORDOVICIAN
(425-500 mil. yrs. ago) Limestone, dolomite, sandstone, shale, and metabentonite.
Limestone (particularly low silica), building stone, clay-shale

CAMBRIAN
(500-600 mil. yrs. ago) Limestone and dolomite, some sandstone and shale.

PRECAMBRIAN
(More than 600 mil. yrs. ago) Greenstone. Present only in extreme eastern Jefferson County.

PUBLICATIONS POLICY

This publication represents interpretations of best-available data made by professional geologists. As in all research work, professional interpretations may vary, and can change with advancements in both technology and data quality. This publication is offered as a service of the State of West Virginia; proper use of the information herein is the sole responsibility of the user.

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Miles

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Physiographic Provinces of West Virginia

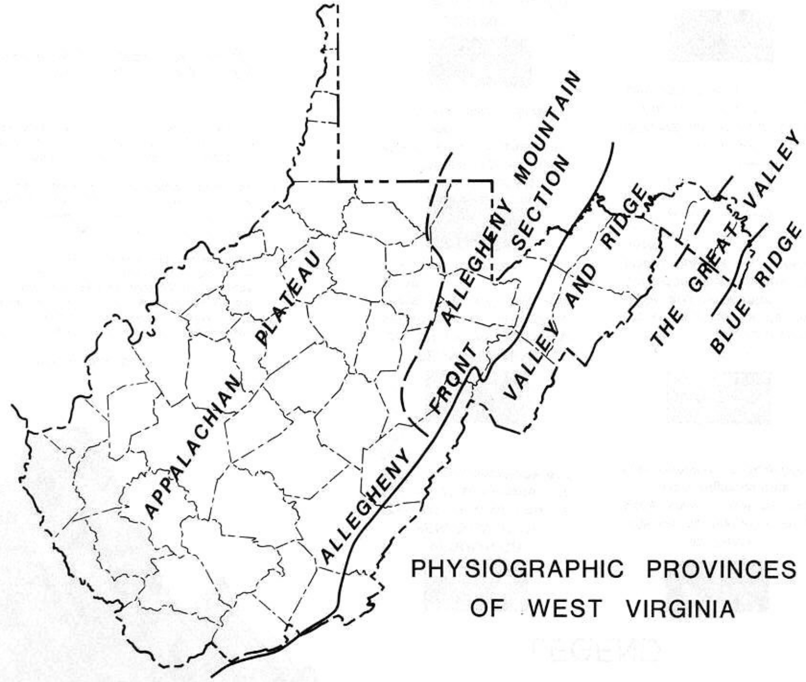
Most of West Virginia is a dissected, westward-tilting plateau called the Appalachian Plateau Province. In the northeast part of this province, a subprovince, the Allegheny Mountain Section, combines elements of the folded mountains to the east and the dissected plateau. The eastern boundary of the Appalachian Plateau, the Allegheny Front, is a prominent geological feature which runs northeast-southwest across the State. East of the Allegheny Front are a series of long folded mountains and valleys defining the Valley and Ridge Province. East of the main group of folded mountains and valleys is the Great Valley subprovince. Along the eastern State boundary in Jefferson County is the Blue Ridge Province.

Bedrock Geology of West Virginia

Most of the rocks in West Virginia are sedimentary, deposited during the Paleozoic Era (600 to 230 million years ago); very few igneous or metamorphic rocks occur in the State. The geologic history of West Virginia prior to one billion years ago is poorly understood. The oldest exposed rock in the State is the Catoctin Greenstone, a metamorphosed lava deposited 800 million ago. Later, a marine sea covered most of West Virginia and deposited marine limestones, shales, siltstones, and sandstones during the Cambrian and Ordovician Periods.

Movements of the earth's tectonic plates cause episodes of mountain building which, with subsequent erosion and production of sediments, can have major effects on the geologic history of an area. The first of these mountain-building episodes to effect West Virginia, the Taconic Orogeny, formed mountains to the east of the State which were a source of sediments during the Ordovician, Silurian, and early Devonian periods. Clastics and carbonates were deposited with clastics predominating in the eastern part of the State. Also, non-marine deposition took place and evaporites were deposited in the northern part of West Virginia in the late Silurian.

Highlands to the northeast, formed in the Acadian Orogeny, were the source of clastic sediments in the Middle and Late Devonian. The sea regressed to the west at the end of the Devonian and continental red beds were deposited over most of the State. The sea covered West Virginia again in the Middle Mississippian (about 330 million years ago). During this time, the Greenbrier Group, composed mainly of limestone, was deposited.



PHYSIOGRAPHIC PROVINCES OF WEST VIRGINIA

The sea retreated again near the end of the Mississippian, and during the Pennsylvanian, West Virginia was low-lying and swampy. During this period, thousands of feet of non-marine sandstone, shale, and coal were deposited.

During the Permian Period, the Appalachian Orogeny, the dominant geologic event in the formation of the Appalachian Mountains, began. Much folding and thrust-faulting occurred, especially in the eastern part of the State. Erosion became the predominant geological process.

No sedimentary rocks from the Mesozoic Era (230 to 70 million years ago) exist in West Virginia. However, hundreds of igneous dikes from this time are found in Pendleton County.

The glaciers of the ice ages never reached West Virginia. A large lake caused by an ice dam to the north resulted in lake deposits in the northern part of the State and drainage changes and alluvial deposits in the southern part. These are the only Cenozoic Era (younger than 70 million years ago) deposits in West Virginia.

Save Our Streams

A citizens volunteer stream monitoring program

West Virginia Department of Environmental Protection
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