From Ridges to Rivers: Watershed Explorations

Guide To An Independent Science Project

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Introduction

Does it matter to you?
* Clean drinking water?
* Fish in the lakes and streams?
* Clean lakes, rivers, or creeks to swim or boat in?
* Enough water to grow plants around your house?
* Enough water to take daily showers?

If you answered “Yes!” to any or all of these questions, then you might find Watershed Explorations is for you. You can use this book to help you find out what is going on with, and into, the water where you live.

- Investigate where you live and how it affects the water you drink and play in.
- Design a science project for school.
- Design a science project for a Science Fair.

The Meaning of Watershed

Even if you don’t know what we mean by “watershed”, you can figure it out just by thinking about the word. The word “shed” can refer to something that stores things, like a garden “shed;” or it can mean to allow something to run off, like an umbrella “sheds” waters. A watershed does both! Watersheds are really just another way of looking at the land we live on. A watershed is the land that captures water in any form, such as rain, snow, dew, sleet or hail. All the land whose water drains into a particular stream system or lake is the watershed for that body of water. All land is part of the watershed for some creek, stream, river, lake pond or puddle!

There is a limited amount of water on the earth, and **all** life forms depend on it. The land, or watersheds, form the collection basins for water that falls in the hydrologic cycle. Precipitation falling on the land can be absorbed by the soils or it can run off into the creek and river systems.

There are definite advantages to having as much water as possible soak into the soil. Think of a sponge for a moment. You can fill the sponge with water, let it sit and it will slowly release the water over time. That sponge represents a “soft” watershed. When the land around you allows the rain to soak in, the water can then slowly move down through the soil into the aquifers. This water will continue to replenish both the aquifers from which your wells pump water and the springs that release water into the creeks throughout the year, even during the dry season. The watershed that has so gently captured the water releases it slowly to you over the year in the form of clean, steady water flow in the creeks and through your taps to the drinking glass.

If, instead of acting as a sponge, your watershed acts like a piece of bare rock or cement, most of the precipitation runs straight off the land and into the creeks during the rains. Very little is stored in the soil to filter down and replenish the aquifer or the springs that feed the creeks. But there is a double whammy with a "hard" watershed. The water that runs quickly off the hard watershed all enters the creek system rapidly, causing the creeks and rivers to swell to flood stage. The watershed delivers unscheduled muddy water to your kitchen floor rather than clear water through the tap!

A watershed is a sort of hydraulic "commons"- we all live, work and play in watersheds, and what we do affects everything and everyone else in the watershed. From the forests in the headwaters of the watersheds, through the farmlands and towns in the valleys, and on to the marshes and estuaries at the river's mouth, both good news and bad news travels by water. Do the forests of the headwaters soak up rain and let it seep forth slowly from springs so the creek runs fresh and clear through town all year? Did paving the streets add so much new flood water to the river that it floods the downstream neighbors? Did the oil I spilled on my driveway wash downhill, into the creek and poison the fish that live in the creek below my house?

Water is a great solvent. It picks up and carries with it all sorts of chemicals and minerals. What you put on the land ends up in the water. We live beside and uphill of our creeks. We live on top of our aquifers. The decisions we make in planning where and how to build, farm, play, and dispose of waste all have real consequences to the water quality in our watershed. We all share those consequences!

My decision to build right on the creek bank and to cover that bank with cement has very real consequences for my neighbor: the water is now probably turned so that it flows right into his part of the creek bank. My neighbor's decision to dump the paint thinner from his business into a hole in his backyard has consequences for the whole community - we all share the water from the aquifer.

My neighbor, your neighbor, you, and I are all part of the "hydraulic commons" - we share the consequences of how the water flows and what it carries with it when it flows. Protecting the values of a properly functioning watershed is not just a question of protecting the watershed "environment" for its own sake. Water is our life blood. Protecting and caring for the watershed and all its parts means caring for our water supply.

This book attempts to help you begin to explore, study, and read the stories told by your hydraulic commons - your watershed.

User's Guide To Happiness and Understanding

Watershed science is fast becoming an extremely useful model for the study of natural environments as whole systems. A watershed includes many inter-related pieces that are all connected in what can be called the "big picture." If one part is affected the whole system is affected. Throughout your watershed investigations, always remember to keep looking at your questions in relation to the whole system. The greatest single challenge we may face in managing the earth's resources lies in looking at the parts of a system and then looking outwards to the whole system to which these parts belong. (Savory, 1988)

Watersheds have so much variety and complexity that in order to grasp an understanding of its parts it is necessary to break it into manageable pieces. Compare your watershed to a pizza. To really understand what makes a pizza, you need to look at its parts: the sauce, the cheese, the crust, the toppings. Just remember to keep thinking about what role that crust plays in forming the pizza as a whole, and what will happen to the pizza if the crust is altered in some way. The same goes for your watershed.

This guideline to investigating watersheds includes topics on land use, groundwater and surface water. Sup-topics on water quality and water quantity further simplify the break down. These topics are covered separately, though of course they all relate to one another. Never forget this connection to the whole! You will discover that we often refer you to other parts of the guide for further illumination of a problem you may be researching. Even if you don't actually do the investigations in those other parts, you might find it useful to read the background sections and think about the implications for your project.

Science, You and the Watershed

Water is the universal solvent. As it falls on the earth, it picks up in solution or suspension practically everything in its path and carries it on down hill. Water knows no political boundaries: rivers travel happily through different towns, cities, counties, states and countries, carrying with them the stories of how the land has been used, abused or cared for upstream.

It is these stories that we as concerned scientists are interested in reading.

The fascination and lure of science lies in its ability to help us understand the stories that are hinted at by casual observation. The earth has billions of stories, both big and small, to tell - about how the shapes of land on the earth were formed; how it is that I can drink this water but may not even swim in that water; how it is that this creek has no insects while that creek two miles away is teeming with great numbers and types of insects; why this creek that my grandmother says never used to flood now pours out over its bank almost every year.

The condition of the land around you has a great effect on both the quantity and quality of water in your area. The purpose of this book is to help you:

1. **Develop the eyes to see the relationships between the land, water and life on earth;**
2. **Explore in more detail some of those relationships in general;**
3. **Develop the tools to examine the condition, and the reasons for that condition, of your watershed in particular.**

Keen observation, careful experimental design, and thoughtful examination of the data can help us to unravel the threadline of these stories. Your curiosity in this phase of "Watershed Explorations" will lead you to begin to read new and fascinating stories that your world has to tell the discerning listener...

There are a number of steps to reading the stories of your watershed. We'll go through them here as a guide to how to begin your scientific investigations.

Step 1 Think Like A Water Drop

Before you do almost anything else, you probably need to know where in the world you really are. We're not talking about street addresses here; we're talking about your ecological address. It's odd how we get so serious about learning our street address and all about which state and country we live in, but we forget that we live on the earth itself and that the earth provides (in very different ways in different places) those thing we really can't live without - food, water, materials for making shelter, and air. If you doubt the true necessity of these thing, try swapping water - and this means in any form - soda, juice, milk, or plain old H2O - for a new TV for a week and see how you feel at the end of it!

Since this is an exploration of watersheds, think like a water drop.

* Look around at the lay of land around you:
  - Is it steep, flat, rolling hills?
  - How fast will water drain off the hills?
  - How much of the land is "hard" - bare rock, cement or covered with other impermeable surface? How much is relatively soft and absorbent?

* Examine the way rain falls in your area:
  - How much rain do you get every year?
  - Does the rain tend to fall gently or does it come down in sod-soaking-gully-washers?
  - Does it rain all year long, or are there distinct rainy and dry seasons?

* Determine which watershed you live in:
  - Where does the water go after it rolls off your roof, driveway, or sidewalk?
  - What larger watershed does your small watershed feed into?

* Think about the condition of the surface water in your area:
  - Do the creeks in your watershed have water in them all year long?
  - Are the creeks, rivers or lakes in your watershed pleasant places to be?

* Investigate the source of your drinking water:
  - Does it come from ground or surface water?
  - Does it come from your watershed or is it brought in from a different watershed?
  - Does it have to be treated before you can drink it? Why?

* Investigate what happens to your waste water once you're done with it:
  - Where does it go after it heads down the drain?

At this point, you need to find a way to pick a topic for more detailed study. There are two very different approaches you could take.

One Approach:
Find-An-Interesting-Spot-In-Which-You-Would-Like-To-Spend-Time

If you go for the interesting spot approach, we would suggest that you find a spot where you can look out over your watershed and pick some area for study. This could be a place:

* that you would like to spend some time and explore;
* where you spend lots of time anyway;
* a place you know you can get to;
* someplace that is special to you;
* someplace that has had a catastrophic event like a fire, flood or hurricane that you would like to examine in more detail;
* areas that are in the news concerning water.

Another Approach
Pick-A-Topic-That-You -Want-To-Investigate

If you go for the interesting topic approach, you might like to spend some time:

* Looking at the newspaper to find out what some water or watershed issues are in your community
* Talking with your local water quality regulatory control board or local ecologically concerned citizen's groups to find out if they are involved in research in which you might be able to become involved.
* Look through this book for ideas that capture your imagination.

Whichever approach you take, and it may be a combination of the two, you should next move onto the Messing Around Stage before pinpointing your subject.

Step 2 Messing Around

Yes, we're serious about this! Before you can really come up with any kind a good question to begin exploring, you probably need to go out and actually look around - **outside**! Don't try to be an armchair scientist at this stage. **Go outside.** There will be plenty of time later to sit in a chair and think over your discoveries. You won't make any discoveries in the chair itself - you have to go out and get the raw materials for your ruminations!

We've helped you in this by identifying some major watershed issues that might catch your interest. Within those general headings, you'll find some guidelines for directed exploration. We've discovered that, until you become a more experienced field scientist, you might need some help in focusing your observations. Try some of the general exploration suggestions and measurements to get you started.

Step 3 Identifying A Question

You may discover that, through the course of the general exploratory field work (the **Messing Around** stage), you have come up with some interesting and intriguing observations that lead you to begin to ask yourself questions.

This is the part where you get to start speculating like crazy. You get to ask yourself all sorts of fun questions like:

- Why did that happen?
- Why didn't this happen?
- Why did I find these creatures here but not over there?
- How would the (*fill in the blank*: temperature, pH, color, smell, turbidity etc...) change if I looked at the same things below (*fill in the blank*: town, sewer effluent outflow, feed lot, factory pipe outlet, clearcut, etc...)?
- How much soil will get into the creek from that one plowed field over there? How does soil in the creek affect what lives in the creek?
- What would happen if...?
- Why does the water in this pond look like pea soup?
- What would happen if we slowed the water down somehow?
- Why does my drinking water come from 400 miles away?
- Why can't we swim in that lake?
- How do different fertilizers affect the water quality in the streams, and how does that water quality affect the life in the stream?
- How do different farming approaches affect the groundwater or surface water quality?
- How does the population of creek insects change over the course of a year? Why?

This section is actually quite deceptively tricky, because now you have to figure out which question you really want to answer. The first step is to ask yourself: Can I answer this question using the tools of scientific investigation? Please be aware that science doesn't even pretend to deal with questions like: Is there a God? Why is there a God? Science approaches the world by asking **how** things work.

Narrowing your question to one that you think you can really deal with can be quite frustrating. It really helps to find someone to talk it over with. Be precise and clear in stating the questions that interest you. You may discover that you need to prune your question down to size as you contemplate the steps that you would need to take to answer the question. Be realistic in what you can actually undertake. Field work, and the subsequent lab work, can take a huge amount of time if you tackle too broad a question!

Step 4 Approaching The Question
Experimental Design And Data Collection

Here again, there are two different types of investigations you could undertake: Descriptive Natural History or the Controlled Experiment.

A Descriptive Natural History science project documents what is actually occurring in some place in your watershed. It often uses two different locations as a way of examining the effect of some factor on something else. You might compare physical and biological characteristics of a creek upstream and downstream of an urban area or farmed area. You might document the amount of soil eroding off plowed versus grazed land. You might examine the effectiveness of different erosion control techniques at two construction sites. You might like to compare the number and types of beneficial insects found on traditional farms and organic farms. These projects can describe trends and become the basis for more focused and controlled experiments.

The Controlled Experiment science project usually takes place in the lab or under very carefully controlled circumstances. You may be interested in investigating the effect of amounts of nitrates and phosphates on algae growth so you set up growth chambers in the lab with different, measured concentrations of the two fertilizers in each. You might set up highly controlled and artificial erosion experiments with side-by-side experiments with different land treatments.

Whether you choose a Descriptive Natural History Project or a Controlled Experiment, there are a few cardinal rules of scientific investigation that you need to keep in mind.

Controlling Variables: This is much easier in the controlled experimental approach where you actually have control of things than out in the real, and messy, world with the descriptive natural history project where you have lots of things going on and have very little control whatsoever! The concept is much the same in each, however. Keep your variables as consistent as possible.

In the controlled experiment, change only one thing at a time! If you keep changing several things, you'll never have a really good handle on what caused what.

In the descriptive natural history project, try to keep as much about the two sites similar as possible. At the very least, note the things that are similar and those that are different so you can begin to account for the effects of all the differences. This will help a lot when you get to the point of trying to make sense of your data. If you wish to examine how well filter strips, for example, keep soil out of the creeks, pick two sites that are similar in all respects except presence or absence of filter strips. It is not exactly a fair test to use one steep field and one relatively flat field.

Replication of experiment: Once is not enough! The more replications you have, the more confident you can be that your results actually are actually linked to your experimental manipulation instead of to some fluke. Ideally, scientists can never really get too much data. Practically, however, you have to draw the line somewhere. Scientists are constantly having to decide how much data is sufficient. This is a decision that you, as the scientist, will have to make too.

In the controlled experiment, do the same experimental treatment more that once! The more replications you have, the more confident you can be about the results. Of course, you will need to decide how many are sufficient.

In the descriptive natural history project, collect data several times. If you are looking at sediment in the creek above and below a construction site, for example, collect several bottles of water from each site.

Keep good notes. Keep notes on everything! It is one of Murphy's Laws that you always need those notes that you didn't bother to take. A simple spiral bound notebook or lab notebook is great. Field scientists often take their notes in pencil because it doesn't smear on the paper in wet weather.

Cameras are great ways to document and illustrate your project. Videos may even be quite useful for some of the investigations, especially the section on Flow.

Step 5 Analyze Your Data

Now you get to look at your data and see if you can make sense of it. This is the armchair part, by the way. This is where you begin to flesh out the story you began reading in the **Messing Around** and **Identifying A Question** stages.

Again, a few rules to remember:

Listen to the data!!! What does your data tell you? Can you see patterns in it? Does the data support your general hypothesis that led you to try this experiment? How do you account for "oddball" results? Remember, there may be more factors that you did not control for that will change your results.

Beware: it is very easy to fall in love with your hypothesis and try to twist the data around to support it. Remember, you need to change the equation to fit the universe. Don't try to change the universe to fit the equation!

There is no such thing as a failed experiment - unless you are sloppy in design or execution. There are "expected results" and "unexpected results". The major new discoveries in science usually fall into the "unexpected results" category, by the way. The key is to try to understand **why** things turned out the way they did. Be open-minded to unexpected results. Remember that you are listening to the story the land and water are telling you and you really don't know the ending unless you **listen** carefully!

Step 6 Identify The Next Step

One of the most interesting parts of science is that for every question that you answer, you usually find at least two more that beg to be examined. Mark Twain said that he always wrote the first line to the next chapter before he went to bed so he'd know where to start the next morning instead of floundering around trying to pick up his train of thought. Do the same!

Learn a Lot and Have Fun!

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Surface Waters

Dirt Made Our Lunch... and Dinner... and Even Dessert!

"He is the greatest patriot who stops the most gullies."

Patrick Henry

Step 1 Introduction

Let's say you are interested in the subject of erosion. Why on earth would you be interested in such a thing? Your stomach is the key to one answer. Dirt, or "soil" as the farmers call it, makes our lunches... and dinners and breakfasts and everything else we eat. Rich, fertile topsoil is one of the most valuable commodities in the world. The Natural Resources Conservation Service (NRCS) has partially traced the fall of great civilizations to the loss of their topsoil and ability to feed their people. (Lowdermilk, 1975) Erosion is the transport of soil, often top soil, off the land and into the creek systems where it is carried off to other places. When erosion strips our top soil, it is almost like we are mining the soil - and that means that at some point we will run out of it! The hills above Jerusalem were eroded to bedrock in historical time. The hills of Lebanon,once covered with cedar trees, have been stripped of trees and are now reduced to rocky hills that are bare of soil. It can happen here too.

But erosion is actually a two-fold tragedy. The top soil that is so fertile on the fields ends up in places where it is not wanted and in effect becomes the bad guy. Eroded soil ends up in the creek beds where it clogs fish gills and smothers their eggs. Creeks that used to be so full of trout that you could literally catch them with a pitchfork (go look at some of the old photos or ask old timers for their stories) may now be full of mud and tires. The soil may also end up in an estuary where it silts in the channels, covers the rich oyster beds, and shortens the life span of these critical fish breeding and nursery grounds.

Do we have to live without clean streams? Without abundant fish? Without the rich shellfish beds of the estuaries? NO! NO! And again NO! But this will all depend on us and how we treat the land around us.

So this brings us to some of the questions that you might like to explore in your own watershed on the subject of erosion.

Step 2 Messing Around

This is the time to go out and **Mess Around,** also known as General Exploration. The best time for general exploration is during a rain storm, so hopefully you don't mind getting wet.

What is happening in your area to top soil? Is it being lost or gained? What is the rate of loss or gain? How muddy are the creek bottoms?

You might like to start by calling your local Natural Resources Conservation Service (used to be the Soil Conservation Service: find it under US Government, Department of Agriculture in your phone book). You can ask them the general questions above and they also might be able to direct you to some good places to go out and explore.

Background

Water, soil, plants, gravity, and wind are all players in the erosion drama. Water and wind tend to move soil around if the soil is left bare and exposed. Plants help prevent erosion in numerous ways. They break the force of falling rain drops and thus keep the soil particles from literally bouncing around. The stems and fallen debris act as dams to slow the pace of the water flowing past. The slower the water moves, the less force it has and the less soil it can move. Organic plant material, such as leaf litter, helps soil to absorb water. The more water that is absorbed, the less water will be running around on the surface and therefore less soil will be lost due to erosion. The roots of plants also do an outstanding job of holding the soil particles in place.

Erosion patterns are divided into three different types: sheet erosion, rill erosion, and gully erosion. **Sheet erosion** occurs when soil erodes off slopes in thin, even layers. You won't really see any distinct water channels. The ground, however, is often bumpy and variable; therefore, sheet erosion eventually leads to the development of small rills. **Rill erosion** occurs when the sheet water flowing off a slope begins to collect into small channels and carve small gullies that are less than one foot deep. These small rills join together, concentrating the flow of water into fewer channels. This increased water flow can carve even deeper channels and form what is know as **gully erosion.** Gully erosion includes gullies that range in size from a small rut to a minor canyon.

Soil loss may look most dramatic in gullies where the water is concentrated, but even larger quantities of soil are lost from sheet and rill erosion due to the large surface area being affected.

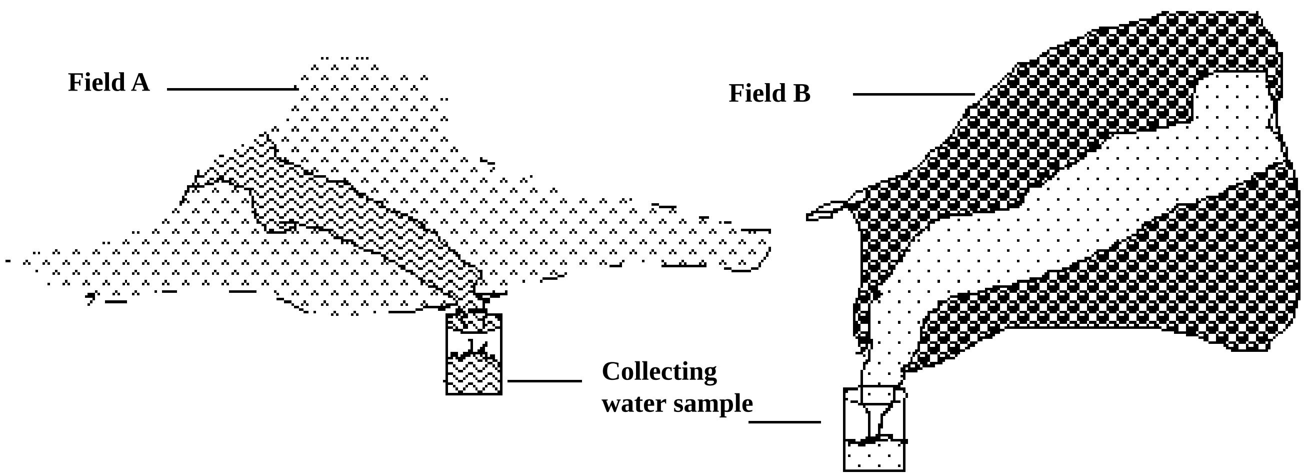
Think about places where you have seen erosion occurring. Does it appear to be sheet, rill or gully erosion? Can you determine at first glance what the cause is? Gully erosion often develops at the end of culverts, ditches, and roof drains or from runoff from improperly aligned roads.

Materials You Will Need

- Clear glass or plastic jars. They should all be the same size
- Loose leaf notebook and pen
- Messing Around Data Sheets: Erosion (pg **21**)
- Camera, if possible

Procedure

- During or immediately after a rain, go out and find a few farm fields (if you are rural) or yards and construction sites if you live in town. Find at least two drainages whose water looks pretty different. Look for:
    - Drainages that are flowing with clear water
    - Drainages that are flowing with muddy water



- Fill out a **Messing Around: Erosion Data Sheet** for each of the sites.

- Collect a water sample at each site.

- Take pictures at each site.

- Calculate the amount of soil coming off each site per liter of water.

STEP 3 Identifying a Question

During the general exploration stage, you examined several different sites. Comparing the data sheets should begin to give you a sense as to

- What contributes to erosion? (The “don’ts”)
- What contributes to stability of the soil - what keeps it in place? (The “do’s”)

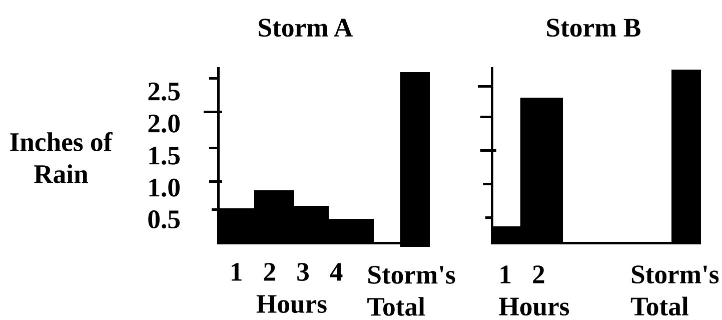
You might ask yourself how the following things affect erosion:

- Slope of the land
- Plant cover (are things growing in it or is it bare soil?)
- Amount and intensity of the rain storm
- Land uses
- Other?

Consider the following as you develop your investigation.

- Look at erosion during, and directly, after a storm event.

- The storm event has two critical factors that you will want to consider in your experi mental designs for erosion investigations: **rainfall volume** and **rainfall intensity**. The amount of rain falling on the watershed is important; how quickly it falls is even more significant. For example, a rain gauge may show that an area received 3 inches of rain during a 24 hour period. However, a rain gauge monitored every two hours during the same storm event might show that all of that rain fell during a 2 hour time period, or it might show that it rained an average of 1/4 inch every two hours. These are two **very** different intensities and will probably cause dramatically different rates of erosion.



Step 4 Approaching the Question Experimental Design and Data Collection

Re-read the Introduction. Pay close attention to the guidelines regarding controlling variables and replication of the experiment.

It will be important to keep good records as you conduct your experiments. Keep detailed notes on your field methods. (How you installed the erosion troughs and their locations; how often and what time of day you checked rain gauges, etc)

Be consistent in your data collection regarding time and location. Periodically evaluate your variables. Which variables stay constant? Which variable or variables change? If more than one variable changes, how does this affect your data?

Keep track of agencies and people contacted for expertise and guidance.

If you're having trouble arriving at your own investigation, we've provided several that might capture your interest.

Ideas for Investigations

Investigation # 1: Getting a Clear Picture: Erosion and Filter Strips
How Effective Are Filter Strips in Preventing Erosion?

Background

A filter strip is an area covered with plants that catches soil before it reaches a creek. A filter strip is usually downhill of, or adjacent to, a plowed field or bare soil. Sometimes a filter strip is an area that a farmer has left in its natural, vegetated condition. The idea is that any water coming off the bare soil will have to flow through the grass or other plants before entering the creek. The plants slow the water, and the mud - at least some of it - settles and thus never reaches the creek.

Materials You Will Need
- Rain gauge
- Tape Measure
- Erosion Troughs - government erosion troughs or plastic storage boxes -approximately 6 " depth x 6 " width x 12 " length
- Shovel
- Small shovel or scoop

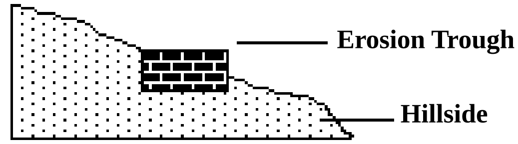
Procedure

- Locate a field that has a filter strip. The local Agricultural Commissioner's Office, Natural Resources Conservation Service (NRCS), or the US Forest Service can assist you in finding a site that uses filter strips to prevent erosion.

- These same agencies may be able to provide equipment such as erosion troughs. If not, plastic storage boxes 6 inches deep, 12 inches long and 6 inches wide will work.

- There are quite a few different questions that you could investigate. We have some ideas. How many can you realistically investigate? Decide on your objectives.
  - Effect of the width of the filter strip. Perhaps you can find a filter strip that varies in width along its length. Run tests at two or three different spots.
  - Effect of the slope of the field. Perhaps the slope of the field varies. Run tests on several different spots.
  - Vegetative characteristics of the filter strip. How effective are strips if they are primarily grass? Trees? Shrubs? Mixture? Perhaps you can find a filter strip that changes over its length. Run tests on these different spots.
  - Effect of the intensity of rainfall. Collect samples from the same erosion troughs after a number of different storms of different intensities.

- Install the erosion troughs. You need to install the troughs in pairs for each test you run: one in the field, and one below the filter strip. Place the erosion troughs in the ground so that the uphill top-edge of the box is even with the soil surface. Any soil eroding from above will be deposited in the trough. Try not to walk above the erosion troughs.



- Place a rain gauge at the site. The gauge must be checked every 24 hours if it has rained to obtain relatively accurate precipitation data. You will have to collect precipitation data more frequently during a storm if you want data on intensity of rainfall.

- Decide how many storms you would like to monitor. Of course the weather won't always cooperate, but if possible you want to look at a minimum of two or three storms.

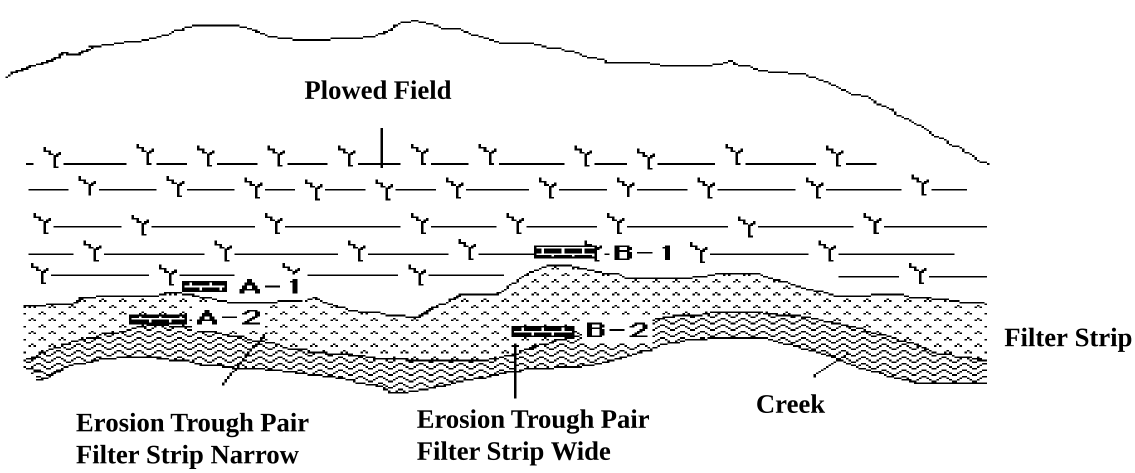
- Describe your study site:
  - length and width of the filter strip
  - amount of rainfall (measure after storm event)
  - rainfall intensity (may be obtained from weather service after storm event)
  - vegetation cover of field above the filter strip
  - slope length (length of the hill above the erosion troughs)
  - aspect (Which direction does the site face: N, S, E, W)
  - slope shape (convex, concave, linear)

- Within 24 hours after a rainstorm: (1) Check the amount of precipitation in your gauge; (2) Remove the water and soil from the erosion trough and weigh the contents (both water and soil).

- Evaporate the water and weigh the dry soil. An oven will speed the drying.

- Calculate the volume and weight of both the water and the soil. (One gallon of water weighs 7 pounds.)

- Examine
  - Amount of soil that washed into each of the erosion troughs.
  - Volume of water in each trough.
  - Grams of soil per liter of water in each trough.
  - Percentage of soil captured in the filter strip for each tested situation.
  - Effectiveness of each width or type of filter strip.



Investigation #2: In the Thick of It!
Erosion and Total Suspended Solids

Background

Topsoil is the richest, most fertile part of the soil's profile. Unfortunately, it is also usually the first to go when water flows over land stripped of its protective plant layer. Soil that has been moved around by erosion is called sediment. When sediment flows into streams and lakes, this soil that was so precious on the farm actually becomes a form of pollution. It is usually called a form of non-point pollution because it comes from a diffuse source like a hillside that you can "wave" at, rather than a pipe that you can "point" at. This sediment is basically soil out of place!

Soil erosion is, of course, a natural process. The rate of erosion is often accelerated by human activities, however, and this can cause some real problems. Water becomes unsuitable for valuable fish species like trout and salmon. The lakes behind dams fill in rapidly and the dam becomes useless for water storage, flood control and water sports. Estuaries fill quickly with mud and lose their ability to provide critical breeding and nursery habitat for a myriad of fish and shellfish species.

The following investigation looks at total suspended solids and turbidity. Total suspended solids refers to the amount of sediment a stream is carrying. Turbidity is a term used to describe the degree to which light is blocked. There is a direct relationship between total suspended solids and turbidity. If there is a lot of sediment in the water, light is blocked and the turbidity level is high. High turbidity means that sunlight is blocked and not able to reach aquatic plants for photosynthesis.

Materials You Will Need

- Plastic jars for collecting water samples
- Tape Measure (50 to 100 feet in length)
- 4 wooden dowels (1/2 inch diameter)

Procedure

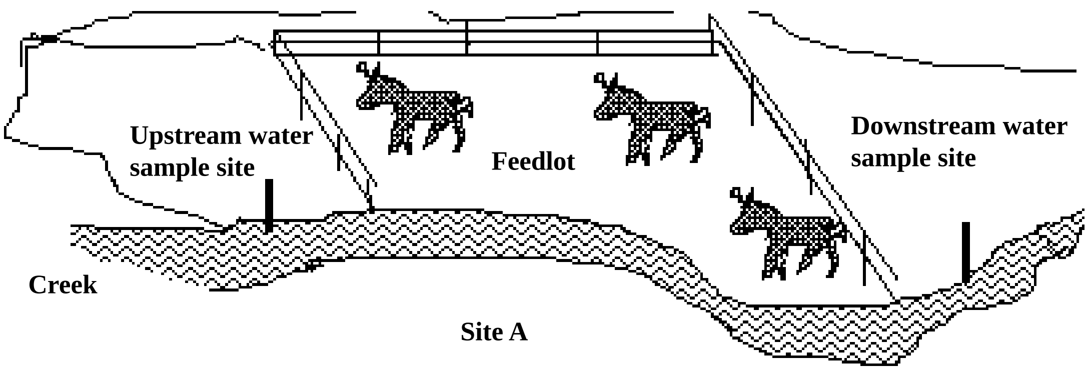
In this investigation you will examine the amount of sediment contributed by different sites along the creek.

- Pick two study sites that have similar slopes, soil type, slope length (how long the hill is), and aspect (N, S, E, W facing). The only major difference should be that one is well vegetated, while the other is disturbed (e.g., plowed field, construction site, feed lot, burned area). You may be able to find these sites on different locations on the same creek.

- Make observations about the land use practices at each site and note them in good detail.

- Sample the creek water for total suspended solids, both upstream and downstream of each site. Sample during or immediately after a rain storm, and again at intervals you decide appropriate (hourly? daily?) until you no longer see water running off the site. You might like to also collect direct samples of the site runoff before it reaches the creek.

- Pace the distance or use a tape measure to determine the distance from the site that the water sample is taken (upstream or downstream). Mark the sampling site by placing a wooden dowel in the ground. This way you can re-sample the same site during



another storm.

- Collect equal amounts of water from the creek at each sample location. Use jars of equal size. Determine the number of samples you want to take at each site. Is one enough? Two? Five?

- Allow the water to settle and observe the amount of soil that has settled in each jar. For a more accurate measurement, dry and weigh the soil that settles in each jar.

- Compare upstream and downstream sediment load for each of the sites. Did your site contribute measurably to the creek's sediment load?

BE CAREFUL: DO NOT wade into raging streams or rivers!!!! If the river is so high as to be dangerous, the amount of mud coming from your relatively small site will probably not be detectable anyway. Find a smaller rain storm to sample after.

When you collect water samples from creeks, you can tie a rope around, or tape a long pole to, a plastic wide mouth jar. Lower the jar into the water and pull it back. A bridge can be a great place to stand to lower a sample bottle.

Investigation # 3: Topsoil Where Art Thou?

Background

Topsoil is built by plants. Some farmers do not accept the idea that their job is to minimize the loss of topsoil. They want to create topsoil! More farmers and ranchers are beginning to take the concept of long-term sustainability seriously. They understand that cropping systems that allow continuous loss of topsoil are essentially mining operations and cannot last forever. They are working on developing crop and pasture rotations that build natural soil fertility and enhance water retention characteristics of the soil - activities that **build** topsoil. (See Malabar Farms by Louis Bromfield for an old, but eminently readable story about one farmer's experience in re-building his farm's topsoil. See also Bender, 1994; Fukuoka, 1978; and Mollison, 1988 for more modern accounts)

Procedure

Find a situation where top soil is actually being created! These places do exist, but may not be obvious to a casual on-looker. We found a place where the City Parks had cemented a little stream channel through the park and then planted grass along the cement channel. Now, some 12 years later, the grass rises a full 8 inches above the cement creek liner! This is top soil being created before our very eyes!

- Ask the NRCS for help in finding a farmer or rancher who is actively trying to build their top soil.
- Document the techniques they are using.
- Measure or document any success they have had.
- Calculate rate of top soil formation (you could do this with the case of the park we just mentioned).

Step 5 Analyzing the Data

Reflect back on some of your predictions. Does your data make sense? Do you need more information to fill in the story?

This is the time where you begin to look for patterns in your data and may be able to see interactions between the variables in your experiment. How do each of the variables interact with one another in your investigation?

Describe the criteria or methods used to make site selections. Do you think your decisions were good ones, based on your data? Would you do things differently next time?

Create a method for comparing your predictions to your results (e.g., a simple comparison chart).

Step 6 Identify the Next Step

Identify the new and exciting questions that came up during your investigations. Based on your initial investigation you may have discovered some questions for a more long term study.

Here are some ideas about how you may go about extending some of your investigations.

- You could extend your investigation on the use of filter strips by surveying local land owners to find out who is using erosion control methods. Find out how long they have been using these methods. Are there noticeable changes they could describe or show you? If they are not using some type of erosion control measures, are they interested in trying filter strips?

- The Natural Resources Conservation Service (NRCS) has some suggestions for preventing erosion, called Best Management Practices (BMPs) which includes filter strips. You could make observations or test the effectiveness of one or several of these.

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Messing Around Data Sheet
Erosion

Location: Date:

Time of Day:

Amount of rain fall in this storm:

Physical description of area from which run-off is coming:

Estimate amount of area (Given in acres - football fields):

Plant cover:

% shrub ______
% grass ______
% trees ______
% bare soil ______
% forbs ______

Slope (%):

General description in your own words:

General impressions of run-off:

Speed:

Color:

Is it cutting a channel in the soil? Yes No

Collected Run-off:

Amount of water collected:

Amount of soil in water (Allow soil to settle in sample.):

Other comments:

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Aquatic Ecology: Habitat Assessment and Bio-survey of Macro - Invertebrates

Step 1 Introduction and Background

When you decide to investigate aquatic ecology in the watershed what does this mean exactly? Well, it means that you are probably going to get wet. If you're lucky! Actually, "eco" means home, "ology" means to study, and aquatic refers to a fresh water environment. If you've decided to investigate the ecology of your creek or stream, you are going to be exploring the "home" of many different life forms that live in a fresh water environment and the things that affect them.

We share our watershed with many neighbors. In this Aquatic Ecology investigation, you will be exploring what kind of neighbor your community is to the creatures of the streams in the watershed. Let's think about sharing a creek with a fish. You might be surprised to find out that many of the same things **you** find attractive are the same things that make good **fish** habitat. For example, a cool, clear, shaded creek is an inviting place for people to spend time wading, picnicking and relaxing. Fish also need cool, clear, shaded waters. In addition, fish like good places to hide such as big rocks or logs, or under vegetation.

Think about a creek where you have spent time and what attracts you to it. Ask yourself:

- Is the creek a pretty place to spend time?
- Does it provide good places to swim and wade?
- Does the water look good?
- How does it smell?
- Does the creek have living things in it?
- In general, is the creek a positive or negative place?
  - What might cause negative conditions?
  - What positive indications can you find that this creek has good neighbors?
- Where would you begin to find out how healthy the creek is?

Answering these questions will give you a good idea about how inviting your creek is to both fish and people. The next step will help you to get started.

Step 2 Messing Around

Selecting a site to explore the creek

Think of a watershed as a big tree: the creeks and streams are branches of the tree; the trunk is the bay, ocean, or lake into which all the water eventually drains. If you live near a big river, such as the Mississippi, you may want to explore one of the smaller creeks that feed into it. Studying a small area of a very large watershed may provide a more manageable scale for your investigations.

Try to find a spot where you can look out over your watershed and pick some areas for study. They could be places:

- that you would like to spend some time and explore;
- where you spend lots of time anyway;
- areas that are in the news concerning water;
- a place you know you can get to;
- some place that is special to you;
- some place that has had a catastrophic event like a fire, flood or hurricane that you would like to examine in more detail.

Select an area of the creek, 100 feet in length, where you would like to start your exploration. There are two parts to this Aquatic Ecology messing around phase. The first is to look at the creek from a fish's viewpoint - does this provide a stable, safe and food-rich home? This is the General Habitat Assessment. The second part - the Biological Survey- will examine how clean the water is by looking at the macro-invertebrates (insects) that live in the water itself.

Respect for Landowners
Prior to going into your study area be sure to find out who owns the land and ask permission to study the creek on their property. Explain to them what you are doing and why. Most landowners will be cooperative, even enthusiastic about your studies.

Clothing
Wear old clothes and an old pair of comfortable shoes. Expect to get wet! This is a creek exploration. Bring a hat and sunscreen.

Safety
Wear shoes at all times. Metal and glass can be hazardous to bare feet.

Bring a simple first aid kit with you into the field. Make sure you know where the nearest phone is located.

It is always wise to work with a friend. If taking a measurement means putting anyone at risk, forget it! In some areas you might run into homeless camps. We recommend you find a different place to work.

Do not drink the water. Microbes are commonly found in even the clearest water; these microbes can make you very sick! If the water looks or smells weird to you, wear rubber or latex gloves when putting your hands in the water. At this point you know nothing about the quality of the water.

Learn how to identify poison oak and poison ivy. Keep clear of this plant. If you touch it, wash thoroughly with soap and cold water as soon as possible.

Field Notebook or Watershed Journal

Writing down observations can be a good way to remember things as well as helping you narrow down your investigation. We have provided a data sheet to help you chart some of your observations. You may want to change the data sheet as you develop your own method of charting observations. You may prefer to take photos or make a video - these are other ways of keeping track of observations. People absorb and sort information in different ways, so find a way that works for you. But get it down in some way — make a record of your observations!

Keep in mind that you are asking yourself questions to get a sense of:

- what creates a healthy or unhealthy aquatic habitat?
- how do people affect the aquatic ecology of an area?
- how do things going on in the upland areas of the watershed affect the creek environment?

There are some questions you can answer just by looking at the creek and the land around it. Note these answers in your watershed journal.

- Is there vegetation on the banks providing shade to the water?
- Can you see living creatures floating or swimming in the water?
- Are there any discharge pipes into the creek from a sewage plant or factory?
- Are there barriers to fish migrating upstream, such as log jams or dams?
- Is the creek muddy and filled with sediment?
- Is the creek choked with algae?

Background

You are going to look at the creek as a habitat for the animals that live in it: insects, fish, frogs, turtles. Since fish - and particularly the trout family - are often the top predators and most sensitive species, if they are present, it means everything else is probably present and healthy. The best way to determine if a creek is a good place for trout would be to imagine that you **are** a trout. So start looking at the world from a trout's point of view.

First, you need a place to lay your eggs. Clean gravel on the bottom of the stream is essential. Mud and silt (fine soil) on the bottom of the creek will smother your eggs. You avoid areas like this.

Second, predators such as raccoons, herons, bigger fish, and fishermen, are always a concern. You want to avoid being eaten at all costs. Your size will often determine who your predators are and where you can hide. Rocks, logs, aquatic vegetation, and over-hanging banks provide good cover from most predators. You look for over-hanging banks with lots of roots and vegetation that provide stable and secure cover. Banks with vertical slopes or little plant cover (and hence no roots to hold the soil together) can collapse easily and don't give you any place to hide. You may be a small fish now, but you will not always be small, so variety in habitat is important to you. As a little fish you can hide in the shade of an average rock or in shallow waters. As a bigger fish you will need deep pools for resting and hiding.

Third, you need oxygen. Fast moving riffles stir lots of oxygen into the water. And cold water holds more oxygen than warm water.

As a human, you are going to have an opportunity to look at each of these habitat characteristics. You will assign each habitat characteristic a score on your data sheet. Some of the characteristics may be more important to the fish than others, so those characteristics are given a higher score (are weighted) so that they will have the greatest affect on the overall habitat score. A high overall score indicates good habitat quality. <u>You will find definitions of the terms on the back of the data sheet.</u>

(Note: If you did a physical characterization of a creek site using the "Surface Water Quality " section, you might consider using the same site for your habitat assessment and bio-survey.)

Materials You Will Need

- Watershed Journal and pencil
- Rubber or latex gloves for each member of the group
- Rubber boots or old tennis shoes
- 50 or 100 ft. tape measure
- Yardstick
- Habitat Assessment Data Sheet (pgs 39-41)
- Camera (optional)

Field Time - Two hours

Procedure

- Always start downstream and move upstream.

- Select a starting point and measure an area 100 feet in length; 0 is the downstream point and 100 is the upstream point.

- Fill in your Habitat Assessment Data Sheet. **Note:** Remember, the more time you spend in the field, the easier it will become to make judgment calls about habitat conditions. Do the best you can to simply describe what you see. Use the notes on the back of the data sheet to help you understand the terms.
- Take time to assess the entire 100 ft. study length for each characteristic on the data sheet. You may find that the bottom sediment changes within the 100 foot study area. Take an average and don't worry too much - many of these "measurements" are really estimates. Just make sure you **remember these are estimates** when you analyze your findings and don't get stuck on thinking that there is a highly significant difference between a final score of 46 and 47, for example!

- Give a score to each parameter. Add the scores together for an overall habitat score.

Messing Around with Bio-survey of Macro invertebrates

Background

Once you have looked at the creek bed, banks, and water depth in the habitat assessment, you will now look at the quality of the water itself. A quick way of figuring out how clean the creek water is will be to look at the things that are living in it. "Macro-invertebrates" refer to animals that have no backbone and can be seen without a microscope. Some macro-invertebrates can live only in the cleanest, coolest water. Others don't seem to mind a little pollution or warmer water. Others can tolerate high levels of pollution. Keep in mind that these invertebrates are the food for the animals further up the food chain - like trout! If edible macro invertebrates are missing from the food chain, you can bet that the top predator fish like trout will be missing too.

You will be collecting and identifying the macro-invertebrates in your creek, then comparing your catch to a list of pollution-sensitive and pollution-tolerant macro-invertebrates to give you a rating of overall water quality.

Materials You Will Need

- Rubber boots or old tennis shoes
- Kick net
- Strainers - for catching larger creatures (.25 inch mesh-hole diameter)
- Field Guide to Macro-invertebrates (pg 38)
- Rubbing alcohol - 70 % (available at pharmacy)
- Glycerin (available at pharmacy)
- White or light-colored plastic tray or dishpan
- Plastic ice cube tray (preferably white) for sorting macro invertebrates
- Magnifying lens or box
- Turkey baster
- Small artists paintbrushes - get the cheap ones (to transfer invertebrates to sorting trays)
- Thermometer

Field Time: 1.5 to 2 hours

Preparation

- Make your kick net. Use a 2 foot by 3 foot section of plastic window screen. Sew or staple the ends to around two 1 inch wooden dowels.

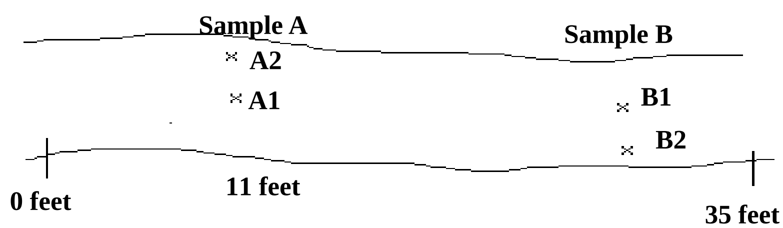
Procedure

- Take the temperature of the water by holding the thermometer about six inches under the water or on the bottom of the stream, whichever comes first. Hold it there for at least 60 seconds before reading it.

- If you did a habitat assessment and want to make comparisons between habitat quality and your bio-survey, do your bio-survey in the same 100 foot length of creek.

- Collect samples in a riffle area of the creek. A riffle is an area where water is swirling and bubbling over rocks that are between 2 to 10 inches in size. (See the Habitat Assessment Data Sheet for more information about riffles, pools, runs and glides.) A riffle provides shelter and lots of oxygen for aquatic creatures.

- Always use some type of random selection system for determining where along the riffle you will take samples. For example: If your riffle runs from 0 to 35 feet, throw a pebble at the random number table provided. Use the number the pebble lands on for your sample site if it is between 0 and 35. Keep throwing the pebble till you get a number you can use. If the number is 11, you'll sample at the 11 ft mark. This will be called Sample A. Repeat to find a second sample site, Sample B. (see the illustration)



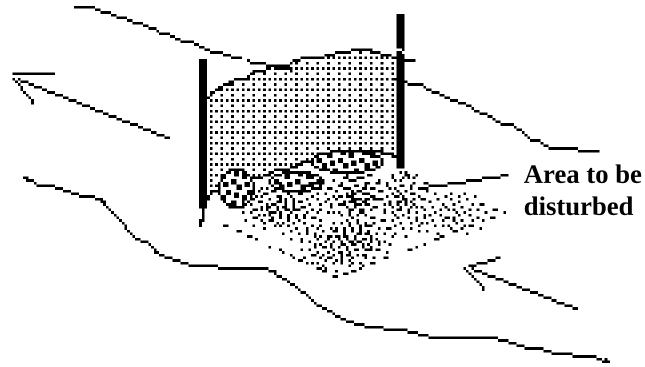
- You will set the net, disturb the gravel and swish the net at **two spots** on a cross section of the creek for each of your sample sites. One spot on each cross section should be fast flowing and the other should be slow flowing. These will be A1 and A2, and B1 and B2. (see the illustration)

- You want to thoroughly disturb the rocks and gravel in 1 ft x 1 ft x 6 inches deep area directly upstream of the net. All the invertebrates living in the gravel and on the rocks will float downstream and into the net.

    - Place dowels of the kick net six inches into the gravel of the creek bottom. There should be one person on each end of the kick net, holding it in place.

    - Place rocks along the bottom edge of the kick net to prevent critters from slipping under.

- Kick and shuffle upstream of the net.
- Gently rub the rocks - some creatures are attached to the rocks!
- Swish the net in the pan of water to free all the insects from the net.



- Repeat this for the second sample on the cross section. Your catch from Sample A-1 and Sample A-2 should be mixed together. Samples B-1 and B-2 should be mixed together. Do **not** mix A’s and B’s together!

- Gently sift your hands through the strained material, picking out the rocks, bark, trash, algae and twigs.

- **Decision:** (Describe why you make the decision you do.)

  a) Keep collected critters alive and put them back at the end of the day. This has the least impact on the creek.

  b) Kill and preserve your sample of critters. Preserving the sample makes it much easier to count and prevents the critters from moving out of the sample grids. You have a reference collection at the end of the investigation. You can take the samples home or to school and do counting and identification there. Dissecting scopes can be extremely useful since may of these creatures are rather tiny! If you decide to preserve them, place the macro-invertebrates in a solution of alcohol (50%) and (50%) glycerin.

- Fill in the Bio-Survey Data Sheet. Try to identify the critter to its Order (Kingdom, Phylum, Class, <u>Order</u>, Family, Genus, Species). That’s what our handy guide uses. Note whether the insect is a Class 1, 2, 3, or unknown regarding pollution tolerance. Estimate the numbers of each types: <10, 10-49, 50-99, and >100.

- If you cannot identify a macro invertebrate, draw it as accurately as possible and place it in a small jar. Put it in the “Unknown” category. Your County entomologist or someone at the local college may be of great assistance in helping to identify these and be truly interested in your work.

- Calculate the Bio Index Value: (See Data Sheet pg 37)
  - Count the number of types of Class I creatures you found. Multiply by 3.
  - Count the number of types of Class 2 creatures you found. Multiply by 2.
  - Count the number of types of Class 3 creatures you found. Multiply by 1
  - Add your numbers and compare them to the Water Quality Rating to see how healthy your stream is.

Step 3 Identifying a Question or Questions

This is your opportunity to wonder about what you found and to speculate like crazy about the reasons for it! In other words, you get to form a **hypothesis**.

Now that you have had an opportunity to poke around in the creek, what type of questions did you come up with? Don't think about whether your questions seem off-the-wall.

Habitat Assessment:

- What was the general result of your habitat assessment?
- Are there fish actually in your study site? What size? What kind?
- How does your result relate to surrounding or up-stream land uses?
- How do you think your results might compare to a site upstream or downstream? What might results be if you chose a site in town, by farmland, forest, clear cut, nature preserve or whatever?
- Are there other factors aside from land use in the immediately surrounding area that may be affecting habitat quality?
- Are there specific regulations or laws in place that protect this area? How could you find out more about these forms of protection?
- Is there any evidence that the area was once degraded and then restored? How could you find out more about this?
- Can you find any historical records- pictures, letters, descriptions etc. - concerning how this area used to look? Could you describe the creek's history over the past 200 years?

Macro-Invertebrate Study:

- What did your bio-survey tell you about water quality in that particular reach of the creek? Remember that these animals are sensitive to temperature, lack of oxygen, mud in the water, chemical toxins, too much fertilizer in the water, or lack of water in the creek during parts of the year.
- Were there significant differences between Sample A and Sample B? Why would this be?
- Is it possible to have many Class 3 organisms and still have good water quality? If so, why?
- Keeping in mind that water runs downhill, what is happening farther upstream that may be affecting the water quality at your study site? Remember to look at the big picture.

- How do you think your results might compare to a site upstream or downstream? What might results be if you chose a site in downstream of town, factories, farmland, forest, clear cut, nature preserve or whatever?

- Describe what you learned about biodiversity.

Ask for Help from Local Resources

You can be useful, invaluable, and get your science project done all at once! There are many people who specialize in watershed resources, and they often have all sorts of projects they would like to do but do not have the time to do themselves. They will be thrilled to steer you to a “real” project.

Call the local fish and game, water resources agency, or private land trusts. Tell them you want to do a science project in the watershed that investigates aquatic ecology. Ask to speak to someone who does scientific field work and could direct you to a field project or suggest an appropriate investigation. You may find there is an on-going monitoring project being done or a project that the agency needs to have done. We’ve had students who have investigated chromium levels in streams for the Water Quality Board and others who have monitored the streams flowing into a critical estuary.

STEP 4 Experimental Design and Data Collection

Your job is to create a framework for your question(s) based on some basic scientific rules. Start your questions out simple. There is plenty of opportunity to build upon questions and come up with more questions as you go along. In addition, come up with some predictions. These are hypotheses. What do you think is going to happen?

Re-read the introduction about controlling variables and replication of the experiment. Also, read the section on the relationship between collection of data and controlling variables.

Be consistent in your methods!!! You will be making judgment calls based on your observations and how they relate to a scoring system while doing habitat assessments. You will be identifying macro-invertebrates during the course of your bio-surveys. Take good notes and photos to help you keep track of your field methods. Each time you go out into the field refer back to these notes for consistency.

In any experiment or investigation it is important to control the variables. Variables in aquatic ecology could include any of the things we observed while out messing around, such as location of study area, sampling sites, time of day or year, weather. Change only one thing at a time. This allows you to associate any changes in your results with the variable that was changed. If you change several things you will never know what caused what!

Here are some examples of how to control your variables while doing an investigation in an aquatic environment.

1) Standardize variables as much as possible:
   - time of day
   - use same location
   - sample different locations as close to the same time as possible.

2) Keep good notes. Describe everything thoroughly. You can't have too much information.

3) It is also important to do the experiment more than once. The more replications you do the more confident you will be that the results are actually linked to the changes you made in variables. For example, monitoring a creek site only once would give you limited data and little assurance that your hypotheses was correct or incorrect. Sample at least several times. Note time of day, season and weather conditions. These are variables that can affect your results in the course of repeating an experiment.

4) If looking at a problem area, look upstream and downstream. Make sure no new creeks are entering the system in the meantime.

5) If you are looking at two different creeks, it is very important to describe any differences between conditions at each study site. For example, you may want to study two sites on the same creek that have different surrounding land uses or are located upstream and downstream of an effluent site or dam.

Ideas for Investigations

Investigation #1: Habitat Assessment and Bio-survey Investigation

Background

The results of your bio-survey will help you decide how you could further your investigation. For example, if your results indicated good to excellent water quality then don't bother with chemical, physical or nutrient testing.

However, if your bio-survey indicates that your creek water has problems, then you could try to predict the source of the problem. Look at surrounding land uses and effluent sources and begin to test parameters that will provide some answers.

Procedure

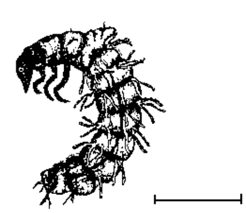
Here are some suggestions for different approaches you could take in doing a more focused bio-survey.

- **Effect of discharges into the Creek:** Conduct a bio-survey both upstream and downstream of a pipe that discharges water into the creek. This could be a sewage plant outlet, factory outlet pipe or whatever other type of pipe you find.

- **Effect of Land Use:** Conduct a bio-survey in two different areas of one creek. Each study area should be surrounded by a different land use. For example, one study site on the creek is located in an urban location, the other is located in an agricultural area. Or you could look at the stream above a town and below it.

- **Baseline: What is this area capable of sustaining in a natural state?:** It might be very interesting to find a watershed in a Natural Reserve to compare with a local urbanized or heavily farmed watershed. The Natural Reserve would give you baseline information about what your local streams should be capable of sustaining in the way of biodiversity. Compare the results.

- **Seasonal Fluctuations:** Conduct a habitat assessment and a bio-survey at the same location at different times of year. For the best results, conduct both the habitat assessment and bio-survey on the same day and then repeat the whole procedure at a different season of the year. Compare the results.



Caddisfly larvae Drawing by S.W. Downes, a 14 yr old student in water quality monitoring project

Investigation #2   Vegetation Survey and Bio-diversity

Introduction

Your research question: **How do riparian (creekside) vegetation, bank stability and insect populations differ between grazed (if you have a rural setting) or suburbanized (if you have an urban setting) and the natural state for this area?**

A simple way of mapping the vegetation along a creek is called n**on-floristic** mapping. For this type of mapping you do not need to know the exact species of plants. You do need to know whether the vegetation is a coniferous or deciduous tree, an understory plant, a fungus or woody debris. This type of mapping tells scientists how much is growing in an area, the general kinds of vegetation, and where they are found.

Conduct non-floristic mapping, aquatic bio-survey, and perhaps even a terrestrial insect population survey of two comparable reaches of creek: grazed (or backyard) and natural state. An excellent study could be done on two sides of a fence where your non-grazed (or backyard) area is directly upstream or downstream of the grazed area.

Procedure

- Use the random number table to determine starting points for your vegetation survey. Flip a coin to determine which side of the creek you will conduct each vegetation survey.

- Start the transect lines at the edge of the bank and continue them for about 10 meters. Adjust this length to your specific conditions.

- Follow the transect line from start to finish. Every time a tree, plant, fungus or woody debris **touches**, **grows under** or **hangs over** the transect line (a) estimate the height of the vegetation; (b) note the type of vegetation; and, (c) chart where on the transect line you found it. See the sample chart for help with the codes for each vegetation type and the set-up for the graph.

- Run at least three transect lines per site.

- Gather data on the other parameters you wish to examine:
  - Bank stability: a map may be useful, measuring the amount of exposed soil or areas that show signs of active erosion.
  - Insect diversity: Sample the aquatic and terrestrial insect populations with
    Bio-survey (aquatic)
    Net sweeps (terrestrial)
    "Shake the Bushes" method- lay a sheet under a bush, tree, etc and shake it hard to dislodge any insects. Estimate numbers of types and total numbers. You do not need to identify individual types. (terrestrial)

- Chart, graph, map and describe your results. Discuss relationships between your measurements and discuss other variables that might have influenced your results.

Definitions

Evergreen Tree: Trees that keep their leaves all year round. They never lose them all at once. These include the pines and other conifers, but also include the live oaks. These trees cast significant shade over the creek at all times of the year.

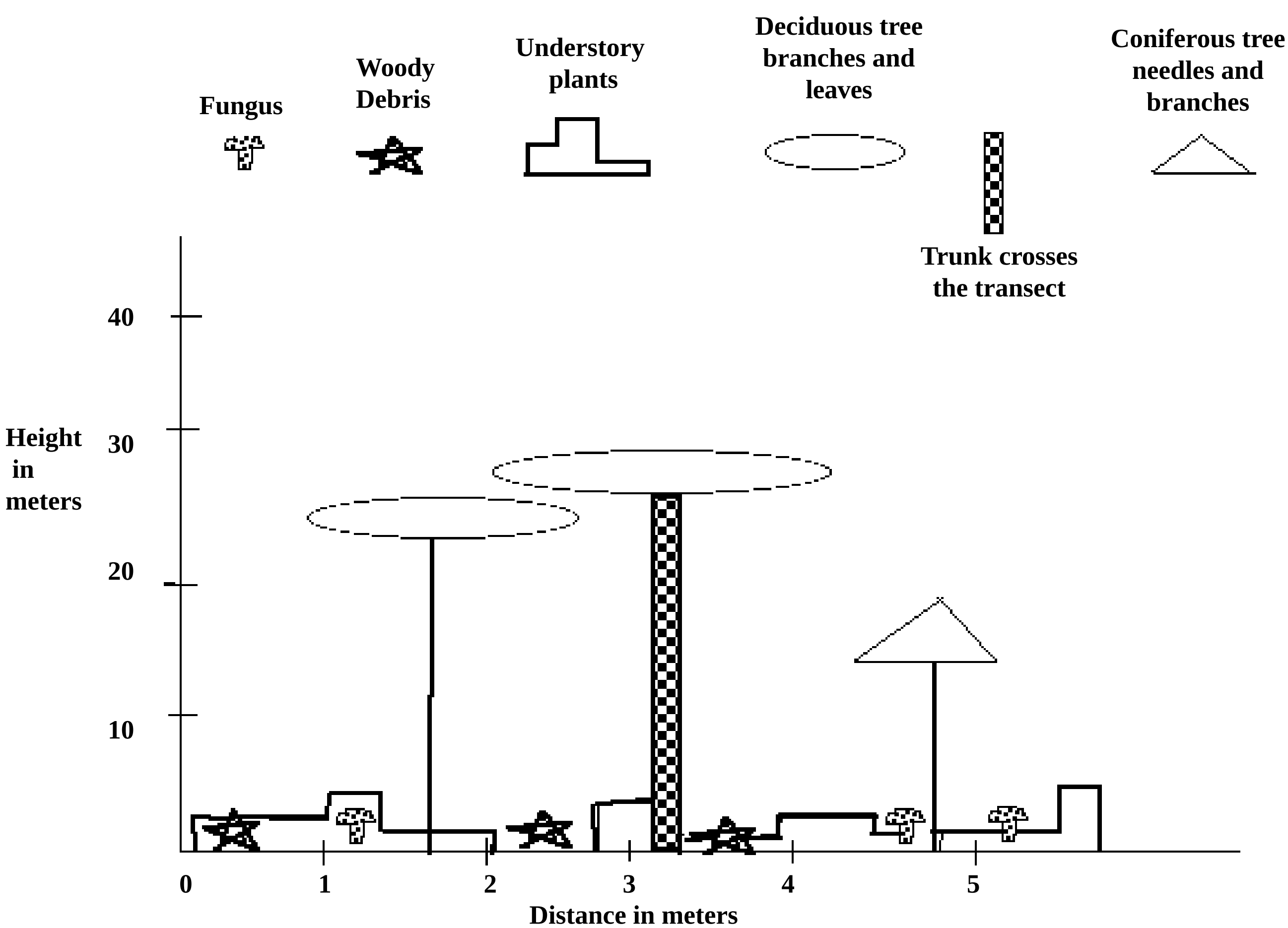
Deciduous Tree: A tree that sheds its leaves seasonally or at a particular stage in its life cycle. These cast shade only some of the year; at other times they allow lots of light into the creek.

Understory Plants: Vegetation that grows under the tree canopy. Understory plants are the low-lying vegetation such as shrubs, herbs, low vines, and grasses.

Fungi: Fungi - the mushrooms, mold, and mildew - are plants that lack chlorophyll and therefore are unable to produce their own food in the process of photosynthesis. Fungi are important in helping the dead leaves and wood decay and in helping the green plants absorb nutrients from the soil - they are important recyclers in the forest. **Note:** Lichen is algae and fungus living together in a symbiotic (mutually beneficial) relationship on a rock or tree. If you run across lichen you may want to note it on your graph with a different symbol.

Woody Debris: Woody debris includes fallen logs or branches that are bigger than 1 inch in diameter.

(Adapted from University of Washington Cooperative ExtensionWater Quality Program)



Step 5 Analyzing the Data

This is the time where you begin to look for patterns in your data and may be able to see interactions between the variables in your experiment. For example, what does your data tell you about the relationship between living (including people!) and non-living parts of the watershed?

Play with your data. Try looking at your data in all sorts of different ways such as figures, graphs, and tables. Sometimes looking at the patterns in the numbers can be helpful. Sometimes seeing the data in graphs makes differences and similarities pop out at you.

Analyze how your data "fits" into the scheme of the experiment, including your predictions. Account for oddball data. Accounting for this oddball data may lead you to your next questions.

Remember that there is no such thing as a "failed" experiment. There are experiments that had predictable results and experiments with unpredictable results. Sometimes the unpredictable results are far more interesting! You may discover something quite new to you (or even to science!) that leads you to call for further research.

Your first question could be considered the first line in your story. The data you collect begins to fill in the story. Maybe the results were not as straight forward as you thought they would be. Reflect back on some of your predictions. Does your data make sense? Do you need more information to fill in the story?

Step 6 Identify the Next Step

Identify the new and exciting questions that came up during your investigations. Based on your initial investigation you may have discovered some ideas for a more long term study.

If you found no correlation between the quality of your habitat and the bio-survey results (say you found good habitat and low biodiversity), investigate some other factors that might be affecting biodiversity in the creek. You might try some of the initial investigations outlined in the topic on "Chemistry in Creeks" in these guidelines.

References

California Department of Fish and Game. "California Stream Bioassessment Worksheet." December, 1993.

Stapp, William B. and Mark P. Mitchell. Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools. 1995. Thomas Shore, Inc., Dexter, Mich. For more information contact: Global Rivers Environmental Education Network (GREEN), 721 E. Huron Street, Ann Arbor, Michigan 48104. Phone 313-761-8142. FAX 313 -761-4951.

United States Environmental Protection Agency. Rapid Bioassessment Protocols For Use In Streams And Rivers: Benthic Macroinvertebrates and Fish. May 1989. E.P.A., Assessment and Watershed Protection Division, 401 M Street, S.W., Washington, D.C. 20460.

Washington State University Cooperative Extension and Seattle Water. Cedar River Watershed Field Trip: 4-H Challenge Water Quality Program. Contact: Gail Gohsman. Phone: 206-296-3900. Seattle Water Contacts: Ralph Naess and Celese Brune. Phone: 206-233-1510.

Bio-Survey Data Sheet

Date **Time** **Water temperature**
Weather

Sample A

#	Class 1	#	Class 2	#	Class 3	#	Other
______	caddisfly larvae	______	damselfly nymph	______	blackfly larvae		____________
______	hellgramite	______	dragonfly nymph	______	leeches		
______	mayfly nymph	______	scud	______	aquatic worms		____________
______	stonefly nymph	______	aquatic sowbug	______	midge larvae		
______	riffle beetle adult	______	clams	______	other snails		____________
______	water penny larvae						____________
______	gilled snail						____________

A. (# of types Class 1) x 3 = ________

B. (# of types Calss 2) x 2 = ________ **Add: A + B + C =** ____________

C. (#of types Class 1) x 1 = ________

Water Quality Rating ______________

Sample B

#	Class 1	#	Class 2	#	Class 3	#	Other
______	caddisfly larvae	______	damselfly nymph	______	blackfly larvae		____________
______	hellgramite	______	dragonfly nymph	______	leeches		
______	mayfly nymph	______	scud	______	aquatic worms		____________
______	stonefly nymph	______	aquatic sowbug	______	midge larvae		
______	riffle beetle adult	______	clams	______	other snails		____________
______	water penny larvae						____________
______	gilled snail						____________

A. (# of types Class 1) x 3 = ________

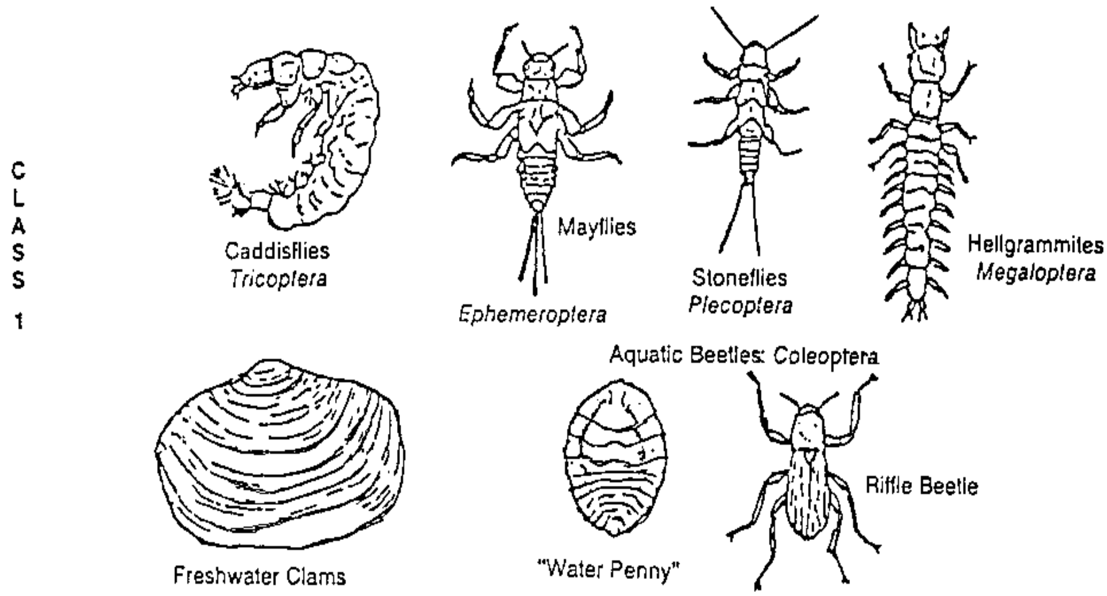
B. (# of types Calss 2) x 2 = ________ **Add: A + B + C =** ____________

C. (#of types Class 1) x 1 = ________

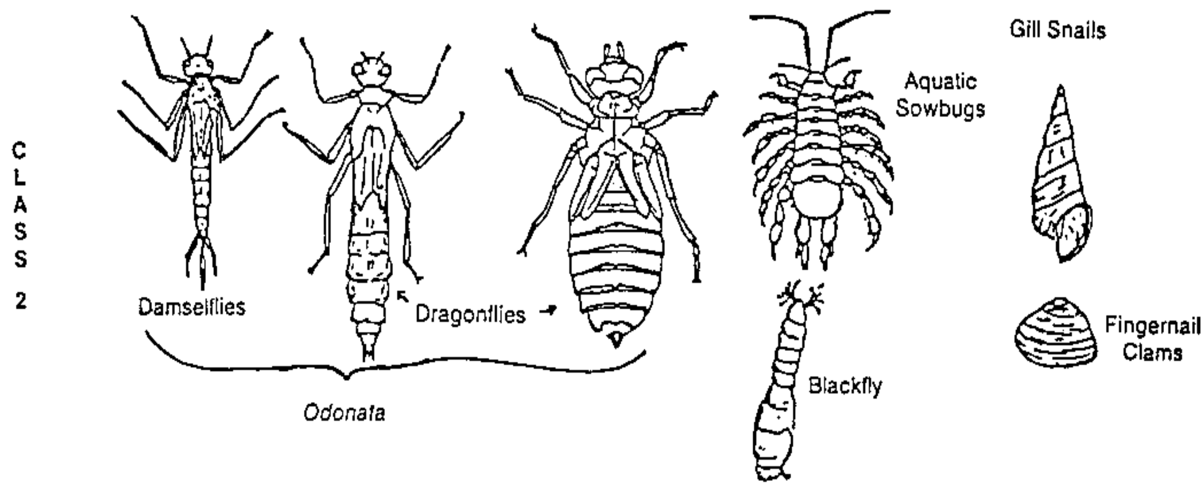
Water Quality Rating ______________

Excellent(> 22) **Good(17-22)** **Fair(11-16)** **Poor(<11)**

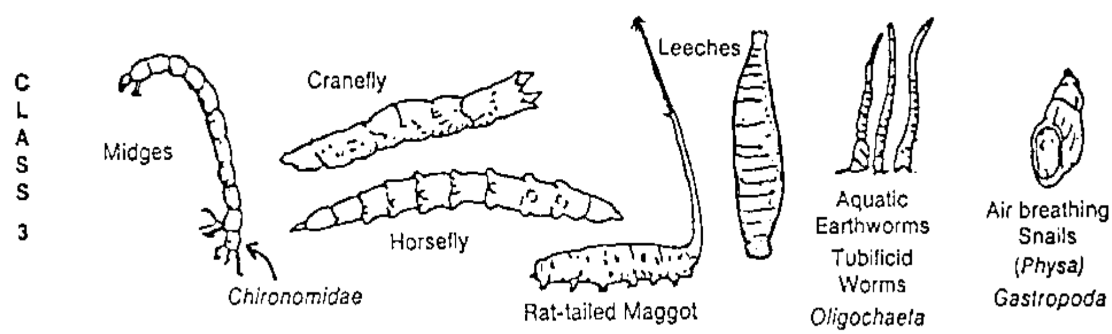
CLASS 1: Needs good water quality.*



CLASS 2: Can tolerate some pollution.**



CLASS 3: Found in polluted waterways.***



Habitat Assessment Data Sheet

(Based on California Stream Bioassessment Worksheet (Dec. 1993). Courtesy of California Department of Fish and Game)

Location: **Date:**

Time of Day: **Weather:**

Crew Members:

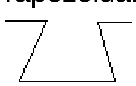
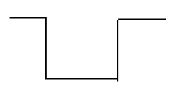
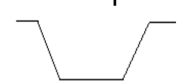
Bottom Sediment: (fines are sand or gravel less than 0.25 inches in diameter) **Score range: 0 - 20**

Excellent	Good	Average	Poor
less than 10% fines	between 10- 20% fines	between 20- 50% fines	Greater than 50 % fines
16 - 20 _______	11 - 15 _______	6 - 10 _______	0 - 5 _______

Available In-stream Cover for Fish: **Score range: 0 - 20**

Excellent	Good	Average	Poor
Greater than 50% mix of cobble, gravel, large and woody debris undercut banks, or other stable fish cover.	30 - 50% mix of cobble, gravel, or other stable fish cover. Adequate cover.	10 - 30% mix of cobble, gravel, or other stable fish cover. Cover availability is less than desirable.	Less than 10% cobble, gravel or other stable fish cover. Lack of cover is obvious.
16 - 20 _______	11 - 15 _______	6 - 10 _______	0 - 5 _______

Channel Shape: **Score range: 0 - 15**

Excellent	Good /Average	Poor
Trapezoidal	Rectangular	Inverse Trapezoidal
		
11 -15 _______	6 - 10 _______	0 - 5 _______

Habitat Assessment Data Sheet

(Based on California Stream Bioassessment Worksheet (Dec. 1993). Courtesy of California Department of Fish and Game)

Velocity/Depth (Score range: 0 - 20)

Excellent	Good	Average	Poor
All the following habitats are present: **pools** (slow/deep); **glides** (slow/shallow); **runs** (fast/deep); and, **riffles** (fast/shallow). Fairly even mix of all habitats gets a higher score.	Only 3 of the 4 habitats categories present. (missing riffles or runs score lower than missing pools and glides).	Only 2 of the 4 habitat categories present. (missing riffles or runs receive lower scores.)	Dominated by one velocity/ depth. (If the habitat is a pool or glide, give a lower score.)
16 - 20 _______	11 - 15 _______	6 - 10 _______	0 - 5 _______

Bank Vegetation Protection (Score range: 0 - 10)

Excellent	Good	Average	Poor
Over 90% of the stream bank surfaces are covered by vegetation.	70 - 89% of the stream bank surfaces covered by vegetation.	50 - 79% of the stream bank surfaces covered by vegetation.	Less than 50% of the stream bank surfaces covered by vegetation.
9 - 10 _______	6 - 8 _______	3 -5 _______	0 - 2 _______

Overall Score: (Add all the scores together.) ____ + ____ + ____ + ____ + ____ = ________

Excellent	Good	Average	Poor
85 - 69	68 - 47	46 - 25	24 - 0

DEFINITIONS

Bottom Substrate:
Bottom substrate is the material on the bottom of the creek or stream. The purpose of surveying bottom substrate is to determine desirable habitat for fish and invertebrates. Rock and gravel is considered the best since fish are best able to spawn in rock and gravel. Fine, silty sediment chokes fish eggs, since oxygen can't not flow freely. Fine sediment is material that has a diameter less than .25 inches in size. See the drawing of a small circle with a diameter of .25 inches; this will give you an idea about the size of material for comparison. You can use a strainer or screen mesh that filters out material smaller than .25 inches in diameter. Using the strainer, test a few spots on the creek to get an idea about the substrate size. (EPA Protocols, May 1989)

Available In-stream Cover for Fish:
Excellent in-stream cover indicates that at least 50% of the study area is covered with cobbles (larger than a pebble, smaller than a boulder), gravel, large woody debris, and undercut banks. To make this determination, briefly survey the entire study area (e.g., 100 foot reach of the creek). Decide what percentage (%) of the entire study area has some type of good cover. Logs, tree roots, submerged vegetation, and undercut banks provide excellent cover for a wide variety of aquatic organisms. Try to think of yourself as a small fish; where would be the best places to hide from predators? Consider hiding in the shade of a boulder or under some over-hanging plants. (EPA Protocols, May 1989)

Channel Shape:
The channel shape tells you a lot about bank stability. The trapezoid shape indicates an excellent channel shape; it provides good in-stream cover and indicates bank stability. Both of these characteristics are important for good fish habitat. Steep banks, such as those in the rectangular shaped or inverse trapezoid shaped creeks, are more subject to failure. A bank with an inverse trapezoid shape may result from intensive use by cattle or sheep; in this case, little root structure or vegetative cover would be available. (EPA Protocols, May 1989)

Velocity/Depth:
There are categories for stream depth and velocity, determined by scientists Oswood and Barber (1982), that are excellent for invertebrates and fish. Ideally, a creek habitat will include a combination of all four of these categories. These categories include: (1) **glide** (slow and shallow); (2) **pool** (slow and deep); (3) **run** (fast and deep); and (4) **riffle** (fast and shallow). You do not have to measure the stream flow to make this determination. Look at your study area and make general observations about depth and velocity. The creek is shallow if the depth is less than 1 foot. **Note:** Riffles and runs are particularly good invertebrate habitat, because invertebrates tend to live on and under rocks in fast, oxygenated water. Therefore, these habitats receive higher scores when present. (EPA Protocols, May 1989)

Bank Vegetation Protection:
The soil on the banks of a creek is generally held in place by plant root systems. Good vegetative cover usually indicates good bank stability. Look at the land extending 25' from the bank on both sides. This vegetation assessment includes ground cover only. Ground cover can include woody debris and leaf litter. **Note:** It will only enhance your investigation if you make observation notes about the presence of tree canopy or shrubs that provide shade or cover for the creek habitat. (EPA Protocols, May 1989) See “Investigation # 2: Vegetation Survey” for looking at both ground cover and canopy vegetation.

For Your Notes

Chemistry In Creeks

Step 1 Introduction and Background

Creeks, rivers, lakes, ponds - we are all drawn to places like these. We swim and boat, dabble our feet and play in water ... **if** it is clean and inviting! This can be a big if these days in some places. During a recent visit to the Idaho farmbelt, people were horrified by a suggestion that they swim in their farm ponds. It seems that they are on the end of a long line of flood irrigation canals. The agricultural chemicals that have washed into the water make it such a brew that people will not even dabble their feet in it. This water flows right back into the Snake River and then into the Colombia River at the end of its journey through the farmlands.

Lake Erie has had the opposite story. In the late 1960's it was considered a dead lake characterized by scum, dead fish and foul odor. Much has changed and the lake once more supports fish populations and in most places is clean enough for swimming.

Remember that creeks are the drainage system for the land. Whatever goes on the land or into the water upstream in the watershed, may end up sooner or later farther down the system. This includes silt, agricultural chemicals, household chemicals, and anything that is dumped onto the streets or sidewalks. Sewage treatment plants, factories, construction sites, and feed lots are often along creeks or lakes. Water washes off the sites or is emptied into the creeks from pipes. Face it, water is great to live by, and for thousands of years you could get rid of your wastes by dumping them in the water and watching them flow away. Away from you, that is! As the world became more crowded, **away** from you meant **toward** someone else. At some point, the downstream folks began to complain. And we pretty much all live downstream of something! How clean is the water running through your hometown or community?

Perhaps you have done a habitat and biological assessment of your creek (see Aquatic Ecology section) and the results have shown that the habitat is good but the biological diversity is poor. You are looking to explain the low biological diversity. Direct water quality testing, as outlined in this section, would be a good place to start.

The following investigations provide some ideas for examining surface water quality. You will have an opportunity to evaluate temperature, turbidity, pH, dissolved oxygen, nitrates, and ortho-phosphates.

It is important to do some research on the above mentioned parameters before you start your investigations. Gain an understanding of the following terms: photosynthesis, eutrophication, biological oxygen demand, pH and turbidity. Be aware that these parameters often affect one another. For example, temperature affects the amount of dissolved oxygen available in water because cool water can simply hold (or dissolve) more oxygen than warm water can. Fertilizers promote algae growth which can turn clear water into pea soup.

Step 2 Messing Around with Chemistry In Creeks

Field Time: 2 hours

Materials you will need

General Items

- Watershed Journal and pencil
- Rubber or latex gloves for each member of the group
- Camera (optional)
- Chemistry in Creeks Data Sheet (pg 60)

Watershed Journal: You need to get your observations down somehow. We have provided a data sheet. It may give you ideas about how to develop your own method of charting your observations. Fasten the data sheet to your notebook or it will crawl off and get lost! People absorb and sort information in different ways. Find a way that works for you - photos, drawings, whatever, but get it down in some way — make a record of your observations.

Chemical test kits are required for several of the water quality investigations. There is a list at the end of this section of chemical supply companies that can provide these test kits. Take advantage of the customer service phone numbers. The service representatives can be very helpful in determining a good kit to use to meet the goals of your project. The kits are expensive, though, which brings us to the next point.

Money: Try to obtain a small grant of $300 to $500 to cover costs for chemical test kits. Rotary Club, Lion's Club, Kiwanis Club and corporate sponsors are a good place to start making your requests. More complicated tests, such as for heavy metals or a specific chemical pollutant, are conducted at an analytical lab. If you choose to do these tests, try to obtain funding from an agency (e.g. Water Resources Agency, U.S. Fish and Wildlife, Science Museum) to pay for the costs of these tests.

General Water Collection Methods: It is recommended that you obtain a water sample that is representative of the creek: the middle of the creek is best. **Safety is the primary consideration. Do not wade out into fast moving creeks or rivers to obtain water samples!** You can devise a tool such as a bucket attached to a string or a water bottle attached to an extended rod. These tools can be used from bridges, overpasses or creek banks to obtain a water sample safely. Avoid sampling in stagnant water. If little or no current exists then push the sample bottle away from you, underwater, to create a current.

Wear rubber gloves if you have any concerns about the water quality where you are working. Some water just looks or smells so bad you really don't want to even touch it.

If you have the opportunity, try looking through the Internet or World Wide Web for information on what others have been doing on water chemistry. You may wish to use that information to focus on a hot topic.

Procedures for Messiing Around Stage

Turbidity and Water Color

Materials Needed
- 1 quart sized jar
- Wear light-colored, old tennis shoes that you don't mind getting wet

Background

Most flowing waters, with the exception of very large rivers such as the Amazon or the Mississippi, run clear in their natural state. All streams have some naturally occurring suspended sediment from decayed organic matter, minerals and sediment carried downstream, but large amounts of suspended solids block sunlight, clog fish gills, and bury fish spawning grounds. When you measure **turbidity** you are measuring the clarity of, and thus amount of suspended matter in, the water.

Oils or substances from vegetation that enter the creek, such as tannin from oak trees, can cause the color of water to change. Tannin causes the water to be tea-colored. Algae can also affect water color. Creeks or ponds thick with algae can be the color of split pea soup.

Procedure

A simple way to look at the amount of sediment in a creek is to collect some water in a jar from your creek and allow the sediment in the jar to settle for 5 minutes.

- Describe the turbidity, or cloudiness, of the water. How far down can you see? Wearing a light-colored shoe, put your foot beneath the surface. Is it visible at all depths? Describe.

- How much sediment is in your jar compared to the amount of water in the jar? What percentage is water? What percentage is sediment? Sediment can be measured by volume or by weight.

- What type of material did you find on the creek bottom? Is mud stirred up when you shuffle through the bottom material?

- What color is your creek?

- If the water has a color, what do you think the water color is caused by? Sediment, algae (green, brown, orange), tannins, chemicals, or something else?

Water Smell

Materials Needed
- Your nose

Background

Water's odor can give us information about what may be in the creek. Creeks can give off lots of scents - some pleasant, others offensive. You may smell woods' smell (decomposing organic matter), plants, chemicals, or even the mud flowing in the creek during a rain.

Procedure

- Describe how the water smells in your study area. Write down all observations about scent in your watershed journal. Some may not seem important or identifiable at the time, but may be meaningful later.

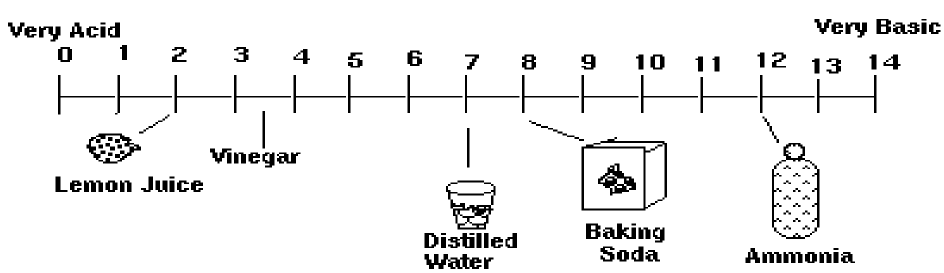
- Is the odor good or bad, in your opinion? Where do you think it is coming from?

pH

Materials Needed
- Wide Range pH paper: Hach Chemical Company or Ward's Chemical Supply
- Small jars or cups

Background

When you take a pH reading of the water you are looking at how acidic the water is. Water contains both H+ (hydrogen) ions and OH - (hydroxyl) ions. Pure de-ionized water (H_2O) has a pH value of 7; it has equal numbers of hydrogen and hydroxyl ions. A liquid that has more hydrogen ions than hydroxyl ions has a pH of less than 7 and is considered acidic. A pH greater than 7 indicates more hydroxyl ions and the substance is considered **basic**. The pH scale below shows some common substances and their pH value on the scale of 0 to 14. (Mitchell and Stapp, Field Monitoring Manual, 1995)



All this information is great, but why is it important for us to collect data about pH? Let's talk about what's normal and what isn't. Natural water tends to have a pH range between 6.5 and 8.5. Plants and animals are adapted to a certain pH. If the pH changes, even slightly, organisms may die. Animals in the beginning of their life cycle are particularly vulnerable to pH changes. A pH lower than 5 or higher than 9.0, is intolerable for most organisms. Heavy metals, such as copper and aluminum, dissolve and thus move into living systems in very acidic water.

Procedure

- Collect the sample toward the middle of the creek and below the surface.

- Measure the pH immediately after gathering the sample or place the sample in a cooler with ice and measure as soon as possible.

- Follow the directions on the pH paper or kit. For replications' sake, you might want to take several samples and run the pH test several times.

Temperature

Materials Needed
- Any type of submersible thermometer. We suggest thermometers made of plastic or metal because they tend to be most durable in the field.

Background

There is a direct relationship between water temperature and the amount of oxygen in water. The warmer water is, the less oxygen is available. Plants and animals need oxygen to live. Therefore temperature, and its counterpart oxygen, helps to determine the number and types of living species found in an environment.

Procedure

- Temperature is usually taken at 1 foot below the surface or on the bottom (whichever is closer).

- You might like to look at the temperature gradient by taking the water temperature at the surface and at the bottom.

- Be sure to document depths at which you take your temperature readings.

Dissolved Oxygen

Materials Needed
- Dissolved Oxygen Kit: Hach Chemical Company (1995): Catalog # 1469-00; Model OX-2P; # of tests - 100; Cost - $44.00; Range - 0.2 to 4 mg./L, 1 -20.
- Sampling jar
- Barometer

Background

Animals and plants, including those organisms that live in the water, need oxygen to survive. Fish and some aquatic insects have gills to extract oxygen from the water. Different organisms need varying levels of oxygen to survive. Trout need lots of oxygen whereas carp and catfish can survive in waters with low dissolved oxygen levels. Low levels or absence of oxygen in an aquatic environment mean the system is going to lose or has lost those creatures that depend on high levels of oxygen.

A certain amount of oxygen diffuses into the water from the air. Fast moving water and waves mix oxygen into the water. Aquatic plants and algae also add oxygen to the water through the process of photosynthesis.

Oxygen is removed from the water by warm water temperatures and the decay of excessive amounts of organic matter. Plants produce oxygen during the day, but use oxygen during the night as they respire, so dissolved oxygen levels can fluctuate quite dramatically throughout a 24 hour cycle. This can be hard on the fish since they can't "hold their breath" during the night, waiting for the return of more oxygen during the day!

Do some research on how physical and human-caused factors affect dissolved oxygen. Also read about "percent saturation" and its relationship to dissolved oxygen. Your high school science teacher may be helpful in explaining this concept. (see "Calculating Percent Saturation," page 29 -31 in Mitchell and Stapp, 1995)

Procedure

- Record the barometric pressure.

- Obtain the sample close to the center of the creek. Submerge the sampling bottle.

- Let the water flow into the bottle for several minutes. Make sure there are no air bubbles in the sample jar when you remove it from the creek.

- Follow the directions on the dissolved oxygen kit. Remember to be consistent with each sample you take and test. Counting the number of drops of PAO titrant is the key to this investigation. The number of drops added indicate how much dissolved oxygen is in the water. Note: The amount of sample water used in the experiment affects the relationship between titrant and dissolved oxygen.

Nitrates

Materials Needed

- Nitrate test kit - aquarium supply stores carry these. Use the range 0 -100 ppm. Cost: $11.00
- Sampling jars

Background

All living things need nitrogen to survive. Nitrogen is most commonly found in its molecular form (N_2). Blue-green algae have an amazing ability to use N_2 and convert it to nitrogen that other plants can use in the form of ammonia and nitrate. Humans also add nitrates to the environment through poorly functioning sewage and septic systems, fertilizers, and feed lot run-off.

Since nitrogen is a plant nutrient, it encourages excessive aquatic plant growth that leads to **eutrophication**. Eutrophication is basically too much of a good thing. Water with high levels of fertilizers such as nitrates and phosphates will support huge amounts of aquatic plant and algae growth. When these plants die, the organisms that decompose them use uptremendous amounts of oxygen in the water. The decomposition process can actually totally rob the water of its oxygen, suffocating aquatic animal life - fish, insect larvae, amphibian eggs - in the process.

High levels of nitrates in water can be harmful to humans too, particularly infants, leading to a condition called infant methemoglobinemia or “blue baby” condition.

Procedure

- Collect a water sample, again, from the center of the creek.

- Follow the directions on the test kit.

- The presence of nitrates is indicated in the sample by a pink to red color. The more intense the color, the greater the concentration of nitrates.

- NOTE: Cadmium metal is used as a reagent in this test. Cadmium is a toxic material and should be disposed of properly with a toxic material handler. Contact your local college or high school for information about disposal.

Ortho-phosphates

Materials Needed

- Ortho-phosphate Test: Hach Chemical Company, 1995 Catalog # 2248-01; Model PO-19A; # of tests -100; Cost - $62.25. This test can be used in clear or turbid waters.
- Sampling jars

Background

Phosphorus occurs in natural waters and in waste waters. Phosphorus, in natural conditions, can often be a limiting factor in plant growth because it occurs in such small quantities, is not always readily accessible, and is vital for a plant’s DNA. Humans, however, can contribute large amounts of phosphorus to the environment through agricultural run-off, industrial waste, and sewage outfalls. Excessive phosphorus leads to a process called “eutrophication”, particularly when high levels of nitrates are also present.

A test for ortho-phosphates is usually used to determine the amount of phosphorus in the water. This method can easily be used in the field. Be aware, though, that heavy metals (e.g., zinc, copper, lead) can interfere with the accuracy of an ortho-phosphate test. If you suspect heavy metals are present in the water, conduct a total phosphate test in the laboratory. This experiment requires heating the sample solution in a process called “digestion.” (Mitchell and Stapp, 1995)

Procedure

- Collect water sample.

- Follow the directions on the ortho-phosphate test kit.

Step 3 Identifying a Question or Questions

This is your opportunity to speculate like crazy! What about your explorations piqued your curiousity? Why did you find what you did?
How can you focus an investigation?

The following are some questions that may guide you to a particular investigation. Of course the best questions are your own! Remember that there are two major approaches to developing your science project:

- An outdoor field investigation. It might be interesting to find a protected watershed such as a nature preserve and compare the water quality with a more urbanized or farmed watershed of comparable size and locale. The results might be of genuine interest to people in your community.
- A laboratory project that looks at the basic science of water chemistry and it's biological effects.

Turbidity and Color

- What does a cloudy creek tell you about the land upstream of you? How could you investigate this?

- How do you think the sediment is affecting the creek and the things that live in it? How could you test your hypothesis?

- Can you think of ways you could measure the amount of sediment flowing into a small area? (See the section Dirt Made Our Lunch on erosion)

Water Smell

- Is there anything about the appearance of the water (e.g., oily sheen) that might indicate the source of a bad odor? You may suspect certain chemicals, depending on what is upstream of you. Can you find funding to help test the water for those specific chemicals?

pH

- What could cause high or low pH values in a creek or lake? Consider the various land uses, soils, and rainfall in the area. What is the pH of the rain in your area?

Temperature

- Begin to think about what might cause temperatures in a water ecosystem to change?
- Compare temperatures in small areas of the creek: sun versus shade, surface versus one or two feet in depth, moving water versus still water. Are there differences and why?
- What things do people do that change water temperatures in the creeks or lakes - power plants, clearing away creek vegetation, water treatment plants?
- Temperature affects the amount of oxygen available to animals in the water. How? Why is this important? How could you test this?

Dissolved Oxygen

- What exactly is the relationship between temperature and dissolved oxygen? How will a change of one or five or ten degrees affect dissolved oxygen levels?
- How do dissolved oxygen levels affect fish behavior? How could you test that?
- How do growing aquatic plants affect dissolved oxygen levels? How do decaying plants affect dissolved oxygen levels? How could you test this in an aquarium?

Nitrates

- Did you notice evidence of eutrophication (e.g, excessive algae in the water)?
- Are there septic sytems or a sewage treatment plant nearby? How can you find out whether they may be affecting the surface water?
- What types of agricultural land uses may add nitrates to the water? How would this happen? Can you document it happening?

Ortho-phosphates

- Describe some of the land uses in the area - farm fields, large expanses of fertilized grass, sewage outfalls etc.- and how they might influence the level of ortho-phosphates in the creek
- What household products could contribute to phosphate pollution? How would they make it to the creeks - down the storm drains as runoff from washing cars or fertilizers for the lawn, from soaps to the drain to the sewage plant?
- How much phosphorus does it take to make an algae population explosion in a jar?

STEP 4 Approaching the Question
Experimental Design and Data Collection

Before you actually design your experiment, re-read the section in the introduction that deals with controlling variables and replication of the experiment.

In any experiment it is important to control the variables. This allows you to associate any changes in your results with the variable that was changed. If you change several things you will never know what caused what!

Here are some examples of how to control your variables while doing an investigation in an aquatic environment.

- Take samples at the same time each day.
- Use same location.
- Use the same method each time you sample.

Determine ahead of time how long you will sample. Will you sample through two seasons and compare results, e.g., spring and summer? How often will you sample: once per week, twice per month, etc.? You may alter your plan as time goes on and you feel the need for more data.

Keep good notes. Describe everything thoroughly. You can't have too much information. Note changes in weather conditions. Weather can have a dramatic affect on water chemistry.

Replications are important! The more replications you do the more confident you will be that the results are actually linked to the changes you made in variables. Monitoring a creek site only once would give you limited data and little assurance that your conclusions are correct. Sample at least several times. Note time of day, season and weather conditions.

It is much easier to control your variables in a laboratory experiment. In some cases it may be best to create your own experimental site. For example, assume you want to look effect of sedimentation on the percentage of egg hatch success. You could place a set number of fertilized frog or fish eggs in a controlled environment, such as an aquarium. You have control over all the variables such as temperature, oxygen levels, lighting, predators, chemical parameters and suspended sediment. Then you vary the sediment load and plot the egg hatch success in relation to the how much sediment was in the tank. Make sure you have a control in which sediment is absent or minimal.

Working in the field gives you much less control over the variables, but allows you to work ina real system where the complexity is much higher. And, face it, the world is complex, that's what makes it so fascinating and endlessly interesting! Just remember to try to find places that are similar in as many respects as possible and note all the differences you can. Become intense and wide-ranging observers. If you are comparing two different creeks, describe in detail any differences between conditions at each study site. If looking at a problem area, sample both immediately upstream and downstream of the site. Field work is immensely satisfying!

Ideas for Investgations

Investigation # 1: From Pipe to Creek

Background

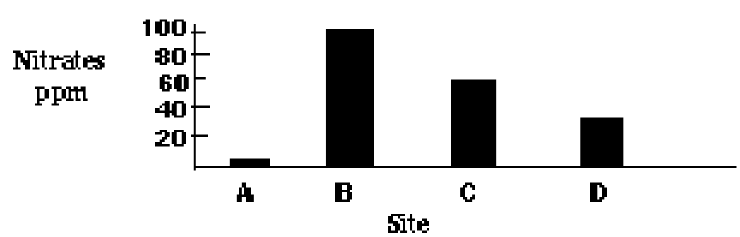
Sometimes you will find effluent, water coming out of a pipe or culvert, pouring directly into a creek or lake. The pipe could come from places like a factory, sewage treatment plant, or feed lot. You can design a field experiment that allows you to evaluate the effects of the effluent on the aquatic environment downstream. Looking at the water quality upstream from the site in comparison to several downstream sites can indicate if and where the effluent is having an effect on the downstream water quality.

Procedure

- Run your water quality tests on water from the effluent and both upstream and downstream of the effluent. For example, if you want to study the effect of sewage treament plant water coming into the creek, test water samples from: 1) the effluent itself; 2) immediately upstream; 3) immediately downstream; and 4) 1/4 mile downstream.
- Make sure there are no other creeks or pipes entering the system between your sample sites.
- Be sure to take the measurements at the same time and location each day for each study site.
- Make a map to show where the samples were taken or note the sample locations on an existing map. Photo essays can really jazz up the final report.
- If you are unable to conduct the water quality tests in the field, place the water sample in a container with a tight lid. Label the sample with date, time, location, and water temperature and store it in a cooler with ice. Conduct the water quality tests as soon as possible. The dissolved oxygen test should be conducted in the field whenever possible.
- Some of the variables that may be interesting to compare are pH, nutrient levels (nitrates and phosphates), descriptions of algal blooms, and temperature.
- Compare the results of upstream and downstream tests. An even stronger science project would combine the results of these chemical tests with an upstream/downstream survey of the macro-invertebrates. (see the Aquatic Ecology Bio-survey section)

Sites:

A. Upstream of pipe
B. Effluent from pipe
C. 0 miles downstream of pipe
D. 0.25 miles downstream of pipe



Investgation # 2: Diurnal Chemical Study

This experiment seeks to explore several questions regarding dissolved oxygen levels. Do readings for dissolved oxygen and carbon dioxide change depending on the time of day? If so, how? Is there a pattern to the change? What is the relationship between dissolved oxygen and carbon dioxide?

Background

Investigating dissolved oxygen and carbon dioxide in an aquatic environment will involve researching how these chemicals get into the water in the first place. To get you started, look at the process of photosynthesis. What do plants need to make their own food and what are the by-products of the process? How do the concentrations of these gases vary over time?

You will be studying carbon dioxide and dissolved oxygen in an aquatic environment. Keep in mind that these gases are dissolved in water, interact with one another, and are affected by both biotic (living) and abiotic factors (non-living). Do some preliminary library research on these relationships and you will have a good start on developing an experiment.

Procedure

- Portable, easy to use test kits can be obtained through CHEMetrics, Hach Chemical Co., or LaMotte Chemical Co.

- There are a number of ways you could conduct an experiment to measure changes in dissolved oxygen and carbon dioxide. You could take samples from the same location and test them for both dissolved oxygen and carbon dioxide every six hours for a 24-hour period. This would require that you camp out at your selected site. You could use a team of investigators to assist you so you could repeat the test for three 24-hour periods.

- It is important to chart air and water temperature at the same time the readings for dissolved oxygen and carbon dioxide are taken.

- The more times you can repeat the experiment the better. You will be more likely to see the development of any patterns if they exist.

- This experiment could be extended to compare changes that occur on a seasonal basis. The experiment could be repeated in spring, summer, fall and winter. Taking the measurements from the same location and at the same time of day is important to assure consistency in your data collection.

Investgation #3: Is There Such A Thing As Too Much Of A Good Thing?

Investigate the effects of large amounts of fertilizer on water. Investigation A is a field investigation. Investigation B is a laboratory experiment.

Background

We mentioned eutrophication in the Messing Around stage. This is your chance to see what happens when there is literally too much crap in the system! And, yes, we think the metaphor can carry over to all sorts of social situations too.

So what's the problem? Too much of a good thing can kill you, or in this case, kill the life in streams, rivers, lakes and ponds. Read up on the problems associated with excessive eutrophication of rivers and lakes.

Nutrient enrichment often leads to simplification of the food web, due to elimination of sensitive species from adverse conditions. A healthy ecosystem has a diverse and complex food web.

Investigation A:
Nitrates, Ortho-Phosphates and Dissolved Oxygen Levels

A field investigation. You will examine a certain site for signs of nutrient run-off and any subsequent effects on algal growth and dissolved oxygen levels.

Procedure

- Design a sampling strategy in relation to a site (feed lot; extensive, fertilized grassy areas like golf courses; sewage plants) that you suspect may be contributing lots of nutrients to a creek, river, or stream.

- Conduct nitrate and ortho-phophate tests at several pre-determined locations. Design a way to measure amounts of algae growing in the water

- Measure dissolved oxygen levels and chart them in relation to nutrient and/or algae levels.

This is just a sample: your graph may not look anything like this!

Investigation B
How much is too much?

A lab investigation. You will investigate the effect of adding increasing levels of nitrates and/or phosphates to pond or creek water.

Procedure

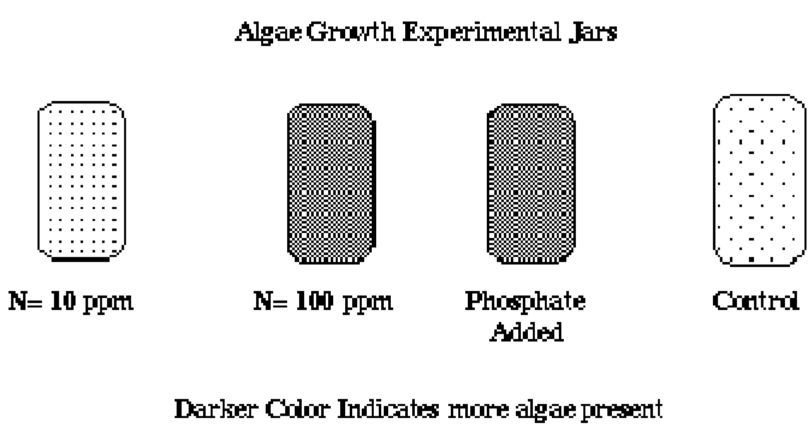
- The idea is to set up sample jars of creek water and to add increasing amounts of nutrients to look at the results of algae growth.

Think about

- How many replications of each treatment do you want?
- What treatments do you want to do: nitrate, phosphate, combinations of phsophate and nitrate or all three?
- How long will it take to see results?
- What will you look for in the line of results?
    - You could look at algae growth rates. How will you do that? Visual comparison of cloudiness might work. Or you could get fancy and measure the cloudiness with a spectrometer or do algae counts through a microscope.
    - Are you interested in knowing if the dissolved oxygen levels are different for the different treatments?

You could try to get reagent grade nitrate and phosphorus for your experiment. Ask your science teacher for help. Or you could experiment directly with common fertilizers.

You might try some quick and dirty pre-experiment experimental jars to get an idea of the quantity of fertilizer that is appropriate to add: one once? one gram? Document everything you do. These initial pre-experiemental jars will give you an important part of your story!



Step 5 Analyzing the Data

Your research questions and library research could be considered the first lines in your "story". The data you collect begins to fill in the story. Hopefully, the results of your field work brings up more questions. This makes for a more interesting science story. Perhaps the results were not as straight forward as you thought they would be. Reflect back on some of your predictions. Does your data make sense? Do you need more information to fill in the story?

This is the time where you begin to look for patterns in your data and may be able to see interactions between the variables in your experiment.

Figure out ways to organize data. Play with your data! Try different types of graphs and tables.

Analyze how data "fits" your predictions. Account for oddball data. Accounting for this oddball data will lead you to your next questions.

Step 6 Identifying the Next Step

What if your results turn up something very unexpected? How do you determine what the next step will be? Remember, if more questions have come up as a result of your investigation this is success! Here lies the potential to do further investigation or to develop more hypotheses. If you have been working in the creek or lake itself and have found some real problems, one next step might involve some type of community activity where you take the opportunity to share and apply what you have learned.

- Present a slide show to community leaders, land owners and the general public on your water quality testing and the results. Don't hesitate to share recommendations or ideas for improvement of water quality based on your studies.

- Go talk to younger students about your investigation and give them ideas for their own water quality projects.

- If you want to do a more extended study on your original topic or another topic, talk to resource agencies, teachers and community action groups to assist you in finding the funding and the volunteers to help you accomplish your goal.

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Investigating Streams and Rivers. Global Rivers Education Network, 216 South State Street, #4, Ann Arbor, Michigan 48104. Phone: 313-761-8142

Regional Water Quality Control Board, Central Coast Region No. 5. Nutrient Objectives and Best Management Practices for San Luis Obispo Creek. March 1994. Prepared by: Brent Hallock, Leslie S. Bowker, Walter D. Bremer, and Diane N. Long. This group is collectively part of the Coastal Resources Institute, California Polytechnic State University, San Luis Obispo, California 93407.

Slattery, Britt Eckhardt. WOW: The Wonders of Wetlands: An Educator's Guide. 1991. Environmental Concern, Inc., P. O. Box P, St. Michaels, Maryland 21663.

Stapp, William B. and Mark P. Mitchell . Field Manual for Water Quality Monitoring: An Environmental Education Program for Schools. 1995. Thomas Shore, Inc., Dexter, Mich. For more information contact: Global Rivers Environmental Education Network (GREEN), 721 E. Huron Street, Ann Arbor, Michigan 48104. Phone 313-761-8142. FAX 313 -761-4951.

Chemical Supply Companies:

Note: All recommended catalog numbers are from the 1995 Catalog.

Hach Chemical Company
P.O. Box 389
Loveland, Colorado 80537
Telephone: 1-800-227-4224
FAX: 1-303-669-2932

Ward's Chemical Company
East Coast Headquarters
5100 Henrietta Road
P.O. Box 92912
Rochester, New York 14692-9012
Telephone: 1-800-962-2660
FAX: 1-716-334-6174

LaMotte Chemical Products Company
P.O. Box 329
Chestertown, Maryland 21620
Telephone: 1-800-344-3100
FAX: 1-301-778-6394
References:
(Hach Chemical Company, pg. 795, Water Analysis Handbook, 1992)

CHEMetrics
Telephone: 1-800-356-3072

Chemistry In Creeks
Messing Around Data Sheet

Site Name ________________________ Date ___________ Time____________

Wind Speed ____________ Cloud Cover _____________ Air temp. ___________

Turbidity and color of water ____

Water odor ____

pH ___________

Water temp: Surface ___________ 1 ft down __________ Bottom ________

Orthophosphates ______________

Nitrates ______________

Dissolved Oxygen________

General observations. Include a site description and take photos.

For Your Notes

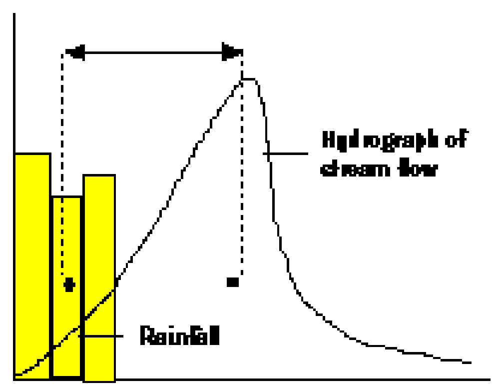
Water Moving Through the Watershed: Flow

Step 1 Introduction: Is Your Watershed Hard or Soft?

It is fun and rather illuminating to get an idea of how much water is actually flowing along in a creek at any given time. What is particularly amazing to those of us who live in the semi-arid West is that, even though it does not rain for over 6 months of the year, we still have water that flows continuously down some of our streams and rivers. Where in the world is all this water coming from?!

Simple calculations of the volume of water falling on your watershed are apt yield numbers that are staggering. One inch of rain over one square mile yields 2.23 **million** cubic feet of water! If your watershed is 20 square miles in area and you get 10 inches of rain a year on average, multiply 2.23 million x 20 x 10 and you get 446 million cubic feet of water dumped each year into your watershed. Watersheds that are relatively “soft” can absorb tremendous quantities of water. If your watershed is functioning well and the rains are gentle and even, much of that will soak into the ground. Some will be stored as ground water, some pumped out for use, and some will be released slowly over the year into the creeks. It is this stored and slowly released ground water that keeps the creeks flowing even during extended dry spells.

A watershed that has been “hardened”, on the other hand, acts like a giant funnel. Water that has little opportunity to be absorbed into the soil will run off quickly and be gone. If you hear people refer to “flashy” conditions in the watershed, this is what they are referring to. The two-fold tragedy of this is that not only does the watershed experience devastating floods, but the springs and creeks dry up quickly since there is no longer ground water feeding them. This process has been thoroughly documented for the watershed above Florence, Italy. (See Klein, 1969).



Example of a Hydrograph

Watersheds can be hardened in numerous ways. Paving is an obvious one. Excessive logging and over grazing can also effectively harden up a watershed. Any time the soil is compacted and the protective plant cover and decaying organic matter is removed, the watershed cannot do its job well. The water speeds up, it doesn’t absorb as rapidly, it runs off quickly with all the soil it can carry, and is gone.

Hydrologists in the 20th century have often concentrated on draining wetlands, straightening creeks, and speeding the flow of water through the watershed. The saying “Today's problems are yesterday's solution” comes to mind, because hydrologists today are busy reconstructing wetlands, putting the meanders back into creek channels, and slowing the entry of water into the creek systems!

You will have the opportunity to examine the way water flows though your watershed and examine how your watershed’s flow characteristics may have changed throughout the past several decades.

Step 2   Messing Around

Background

Measuring flow, or **discharge** as it is called, coming down a creek is rather easy and can be done in many ways. The least expensive and easiest is to measure how fast the water is flowing by floating an orange or orange peel in the water and timing how long it takes to float a known distance. You then measure the creek's cross sectional area, and from these two measurements you can calculate the discharge, or flow.

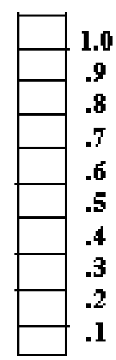
Hydrologists measure flow as a way of understanding what is happening to the water in the watershed. The creeks are the drainage system for the watershed. Any water that can't be held by the watershed flows down into the creeks and on through the system.

Sometimes the hydrologists are interested in what happens during high flows because really high flows are floods where creeks change shape and form and things tend to get damaged if they are anywhere close to the floodplain.

Sometimes hydrologists are particularly interested in the low flows because these flows are dependent on the reservoir of groundwater. In semi-arid climates, everyone seems to want that little bit of water - the farmers, the recreationists, and the fish. A group of students checked flow gages the whole way down a small watershed all through one summer to get a handle on when and perhaps why the flows in the creek disappeared.

Materials you will need

- An orange
- Measuring tape - one marked in tenths of feet are easiest to use, but if all you have are the inches kind, you can deal with it
- Yardstick - again, in tenths of feet if possible
- Watershed Journal and pencil
- Messing Around Data Sheet: Stream Discharge
- Bright flagging
- Staff gage (optional - see illustration)
- Watch with second hand



Procedure

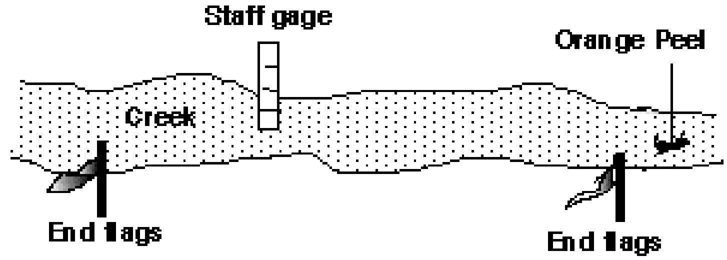
There are two parts to this. One will be to actually measure the discharge of a creek. The other will be to examine local historical records of over-the-bank flood events for a creek.

Part 1: Creek Discharge (Flow) Measurements

- Discharge, or flow, is the volume of water coming down the creek at a given moment. In order to measure discharge, you must get a cross sectional area of the water by measuring the depth and width of the water. You then need to measure how fast the water is moving. Discharge is most often measured in cubic feet per second. For this

activity it really helps to have a couple of people.
Find a relatively straight section of creek. The distance should be equal to two to three widths of the creek channel. Mark the beginning and the end with bright flagging. Measure the distance.

- Peel and eat your orange, but save at least five good pieces of skin for floats. Orange peel are perfect as floats since they are bright and easy to see. They are of more or less equal density to the water and so accurately measure the water's speed.



- Throw your orange peel float into the water upstream of the beginning flag. Begin your timing as it floats past the marker flag. Stop the timing when it floats past the end flag.

- You need to do this five times. Throw the float into different parts of the channel, since water may flow at different rates near the center of the stream and close to the banks. You need to get an average rate of flow.

- Calculate **mean surface velocity.** Average your times for the five trials. Divide by the distance the peel floated.
  Distance / average float time = mean surface velocity in feet per second.

- To get the mean velocity of the water in the cross section, you need to use a fudge factor since the water flows fastest at the surface where all it has to rub past is air. The water on the bed of the creek has to scrape past rocks and gravel, so it moves more slowly. You will multiply the mean surface velocity by 0.8 to get the mean velocity of the water. (Leopold, 1994, pg 39)
  Mean velocity of surface water x 0.8 = mean velocity

- Take at least 10 depth readings of the creek across its width. Average these to get an average depth. Measure the width of the surface of the water. Calculate the cross sectional area of the water: **Average depth x width = area in sq ft**

- Calculate the discharge:
  area in sq ft x mean velocity = discharge in cfs (cubic ft per second)

- If you are working on a creek where your equipment will not be disturbed by others, place a staff gage along the edge of the creek. A staff gage is any old piece of wood marked off with a scale of tenths of feet or centimeters.

- Note the level of the water on the staff gage and record it along with your discharge measurement. If you come back to this place again to measure stream discharge and staff gage level, you will begin to collect data that can eventually be used to draw a hydrograph of the stream's flow. (See Investigation # 1)

Part 2: Historical Records of Over-The-Bank Flood Events

- Call the County or City Public Works hydrologist for the location of local gage stations and a list of over-the-bank events and flows for a given creek. You want records of the numbers of these flood events for as far back as they have records. Or you may want information on when the creek dries up.

- If they can't help you, check in the Government Documents section of the local college library for *Surface Water Records or Streamflow Characteristics for (*your state name*).* Find the records for your gaging station.

- Count the number of over-the-bank flood events, or length of time the creek bed is dry, for a given time period and calculate the frequency per year: for example, 1935-1954, 1955-1974, 1975-1994. Has the frequency of over-the-bank floods changed? Why might this be? Has the period of time the creek bed is dry each year changed? Why might this be?

Step 3 Identifying a Question

What are the hot topics in your community relating to the way water moves through the watershed:

- Are they flooding issues?
- Are they conflicts over scarce summer water?

See if there is a local watershed or creek group near you. These organizations are popping up all over. Check the phone book yellow pages under "Conservation Organizations" if you don't already know about any. These groups may put you to work on a real project for which they need information.

Or look at our suggested investigations.

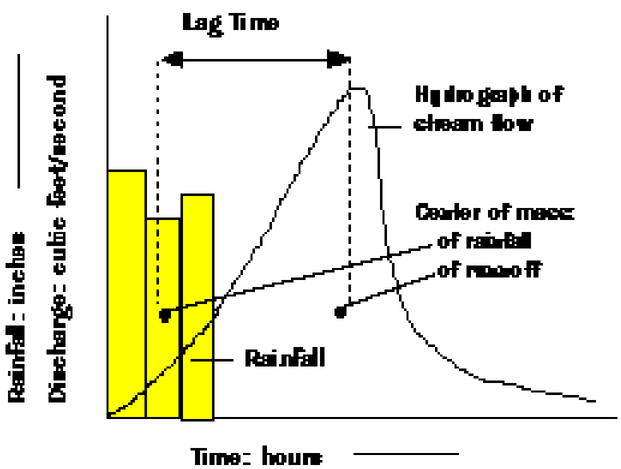
Ideas for Investigations
Investigation #1: Backyard Hydrology

Background

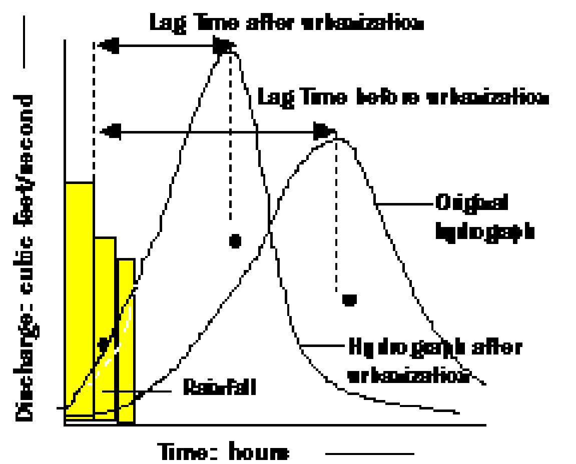
Hydrologists are extremely interested in how water moves through the watershed. One of the tools they use to characterize that movement is the hyetograph/hydrograph pair. A hyetograph charts how much and for how long rain fell. The accompanying hydrograph examines how much of and when the water comes down the creek. (See illustration). This pair allows one to examine how fast the water is flowing off the watershed and into the creek system.

The critical relationship to examine is the lag time. Lag time is defined as the time between the center of mass of the rainfall and the center of the mass of the discharge. In general, the longer the lag time, the lower the peak flow, though elevated flows will continue for longer than with a short lag time. The same amount of water will move through the creek system, but it will come at a lower and steadier rate rather than flashing through in one large slug of water.

When an area is urbanized and paved or hardened in other ways, not only does more volume of water run off, but the lag time is often shortened if no steps are taken to slow its progress off the hillsides and into the creek system. More water hitting the creek channels at the same time than ever before will produce record high peak flows.



Example of a Hydrograph



Sample Hydrograph before and after urbanization. Note the higher peak flow and shorter lag time after urbanization.Mmore water enters the streams at a faster rate.

Hydrologists are now beginning to realize that increasing lag time is to their great advantage. Flows may remain higher than normal but below flood stage for longer, but over-the-banks flood events are not as frequent as when the lag time was shorter.

Your research in this investigation will center around how hydrographs for the same creek will differ in different intensities of rainstorms; and how saturation of the soil affects the hydrograph for a given creek in rainstorms of roughly equal intensity and duration.

Materials you will need

- Materials from the Messing Around stream discharge measurement activity
- Double log paper (log-log)
- Umbrella
- Rain gage

Procedure

- This works best if you have a small permanent or ephemeral creek in your backyard or close by. You could even try this on a gutter in front of your house, though it may be more difficult to get accurate discharge readings since the channel is broad and shallow.

- You need to establish a discharge rating curve for your creek. Follow the instructions in messing around to get your readings. You will need to do this a number of times at different levels of water and chart the readings on double log paper to begin to establish your creeks discharge rating curve. Of course the more samples you do, the more accurate your rating curve will be. Leopold states, however, that most charts on double log paper will have a slope of about 0.34. (Leopold, 1994)

- You can make your job easier if you read the staff gage levels and take velocity readings when the creek is high, but wait for the cross sectional readings till the weather dries and the creek level falls.

- To do this, wait till the water has fallen and then stretch a **completely level** line across the creek at given staff gage levels for which you are missing the cross sectional area calculations. Your line will mimic the water. Take the measurements as though the line were the water level. Do this for all the events for which you read the staff gage and took velocity measurements, but did not do cross sectional area readings.

- You can now chart a discharge rating curve for your creek. Use double log paper (log-log) and plot your staff gage height as the ordinate and your discharge calculations as the abscissa. Draw a straight line by eyeball through the readings to get your discharge rating curve. This will allow you to estimate discharge for those staff gage readings for which you do not have actual measurements.

- Then the real fun begins. When it starts to rain, you sit outside under your umbrella.
    - Read the rain gage every 10 minutes.
    - When the water level in the creek begins to rise, read the staff gage every 2 minutes.
    - Note the clock time for every reading.

- This is the real interesting stuff. You can chart how fast the rain is coming down. You can chart how fast the and how far the water rises in the creek or swale. You can plot these two events out on the same graph to get a rainfall hyetograph and resulting hydrograph. You can chart the lag time, which is defined as the time between the center of mass of the rainfall and the center of mass of the discharge. **Illustration pg 65**

- You now have a pretty nice picture of how water moves through your little portion of the watershed. You can do this for several different storms and see how your watershed reacts to:
    - different types of storms - slow gentle rains versus hard quick downpours

- rain on soil that is saturated vs rain on soil that is unsaturated.

Investigation #2: Slow That Water Down!
aka Blanket Box Hydrology

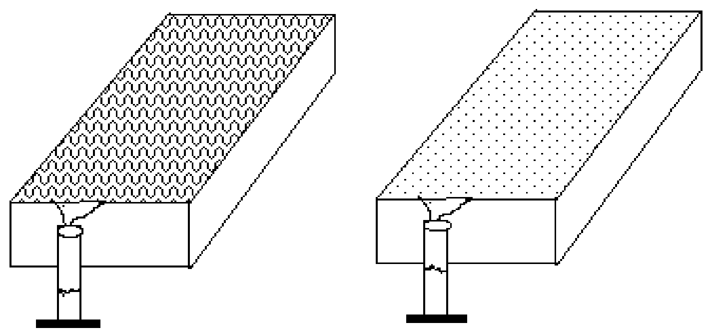
Background

You will be doing basically the same thing as in **Investigation #1: Backyard Hydrology**, only this time in a blanket box. It is probably much simpler and drier, but requires very precise timing and measurements. You can also investigate what types of things lengthen or shorten lag time and increase or decrease total discharge.

Read the background and procedure for **Investigation #1: Backyard Hydrology** as background for this experiment.

Materials

- Plastic blanket boxes with aluminum foil spouts
- “Rain “machine - your design
- Graduated cylinder
- Watch with second hand
- Another person to help you with timing



Procedure

- Set up the blanket boxes with soil and various coverings: sod, aluminum foil, indoor/outdoor carpet, others.

- Design a “rain” machine. It needs to meet these specifications:
  - It needs to deliver a known amount of water to your trays at a steady rate.
  - It needs to adjustable so you can increase the steady rate of “rainfall.”

- Note the time and begin your rain.

- Capture the rain coming off the tray in a graduated cylinder. Write down the level of water in the graduated cylinder at regular intervals. Your decision as to frequency of readings will depend on how fast your rain falls and how much of it there is. You need enough readings to make a hyetograph/hydrograph pair.

- Repeat this for different soil saturations, soil coverings, rainfall intensity, slopes, or whatever other variables you find interesting.

- Plot your hyetograph/hydrograph pairs on double log paper as outlined in **Investigation #1: Backyard Hydrology**. You don’t need to do discharge rating curves because you will capture all the discharge in the graduated cylinder and measure it directly.

- Compare your graph pairs, paying special attention to total discharge and lag times.

Investigation # 3: How Has My Watershed Changed?

Background

Hydrologists speak of “soft” and “hard” watersheds. A “soft” watershed easily absorbs water into the soil. Much of the rain falling on pastures, cropland and forests has a chance to sink into the ground. In a “soft” watershed, vegetative cover is usually good; plants are spaced closely together and dead plant litter stays in place.

As our population grows, so does the amount of hard, impermeable surface on our watersheds. Compacted soil, streets, driveways, parking lots, buildings, asphalt playgrounds all are impermeable. Forest lands that have been clearcut do not absorb water as well as the forest did. When the surface of the watershed does not easily absorb water, there is a lot of run-off.

This investigation guides you to an examination of the changes in land covering that have taken place in your community and watershed over the past few decades.

Materials you will need

- Two Low Altitude Aerial Photographs of your study area: one recent, one in the past. Possible sources: County Agricultural Commissioners office, Cooperative Extension, University Geography Department, Land Trust organizations. If all else fails call “How to Obtain Aerial Photographs from U.S. Geological Survey”, User Services Section, EROS Data Center, Sioux Falls, South Dakota 57198, phone: 605-594-6151; “Landsat Products and Services” is also available from the same address. Or you can order over the internet at www.usgs.gov.
- Acetate overlays
- A copy of NRCS Technical Release No. 55 (they may order one for you or let you use their copy)
- Soils Maps - Library, above named offices, University Soils Department

Procedure

Find two aerial photographs of your community, one taken as recently as you can find and another that is at least 10 years old. It will really help to have the two photos taken at the same scale. You are going to look at how the change in land use has affected the amount of runoff.

Check your soil types using the Soils Maps that are available at the local County Extension office, Natural Resources Conservation Service (NRCS) office, or possibly local library. Chart on an acetate overlay for your photo the Soil Group(s) - A through D - of your study area.

Check the general topography of the study area, looking at slope. You will need this information when you look at rainfall curve numbers.

Refer to Technical Release 55 “Urban Hydrology for Small Watersheds” from the Natural Resources Conservation Service. Look up the section on runoff curves for urban areas. there are all sorts of categories for the major Soils Groups A-D such as open space, impervious, fallow field, pasture, woodlands, crops etc. Decide which ones are pertinent to your pictures. Note the rainfall curve numbers for each land use and slope. Make the best decision you can because you will need to justify or explain it when you write up your report.

Develop a way to calculate the amount of land surface in each of the major categories you see in both pictures. The impervious surfaces will include streets, sidewalks, parking lots, driveways, patios, structures, asphalt playgrounds etc.

- Make a transparent overhead photo copy, project on the wall and develop a way to directly measure paved over areas.
- National Institute of Health (NIH) has a new free computer program called Image. You would scan in your photo images onto a computer disc and then use your mouse to draw around the edges of the paved areas on the computer screen. The program will automatically calculate the area inside your drawings. (See Reference section for how to order this over the World Wide Web)

Go back to TR 55 and look at Table T-1, the Runoff Depth for Selected Curve Numbers and Rainfall. You can read directly the amount of runoff predicted for that land use. For example, if your curve number is 98, one inch of rainfall will yield approximately 0.79 inches of runoff.

Calculate the difference in expected runoff for the two photos.

What does this mean in terms of flooding potential? Has the community done anything to address this issue? If the community keeps records of over-the-bank flood events, can you find any correlation between increased amounts of impermeable surface and greater numbers of floods?

Step 4   Approaching the Question
Experimental Design and Data Collection

The really interesting questions in hydrology require long-term study. Creek and watershed hydraulic dynamics are not on a semester schedule. You may discover that if you decide to work on water flow in the watershed that you become involved in some long-term studies. Some of the investigations we suggest are really quite simple and can be carried out over a life time, producing some very important and quite useful data.

Be accurate in your measurements. Sloppy measurements gives you sloppy results that are hard to interpret. Results are hard enough to interpret when the data collection is tight. If you do the actual stream discharge investigations, take the time to get the hang of timing, measuring, and writing notes all basically at the same time!

If you choose to do seasonal flow data on a creek, decide how often you want to take flow measurements. If you measure every week or every two weeks (e.g., fall through spring on the West Coast or spring through summer or fall in the Midwest or East Coast), you will have baseline data to compare to storm event data.

> **WARNING! Be very cautious when taking stream measurements during storm events. DO NOT ENTER RIVER WASHES DURING STORM EVENTS. DO NOT WADE INTO FLOODING CREEKS.** Sample from a bridge. Note the height of the water on the bank. You can calculate volume when creek subsides by measuring the creek channel cross-section.

Step 5: Analyzing Data

Re-read the Introduction on Analyzing Data.

You may not have a highly experimental investigation, but rather more of a descriptive project. If you chose to compare contemporary conditions with historical conditions, you will be looking for trends. Remember the value of charts, graphs, and photographs.

Step 6: Identify the Next Step

Creek hydraulics and creek channel reconstruction and restoration are a hot topic these days. Take a look at the last section in this book on Sustainable Land Use. You might take some of the concepts you have explored and apply them to projects that are proposed in your area.

References

Izaak Walton League of America. Save Our Streams: A Citizen Action Program. 1992. Izak Walton League of America, 707 Conservation Lane, Gaithersburg, Maryland 20878-2983. Phone 301-548-0150.

Klein, Richard M. "The Florence Floods" (1969) in Ants, Indians, and Little Dinosaurs. Ed. Alan Ternes. Charles Scribner's Sons: New York. 1975.

Leopold, Luna. A View of A River. 1994

Leopold, Luna. Water: A Primer. W. H. Freeman and Company, San Francisco. 1974.

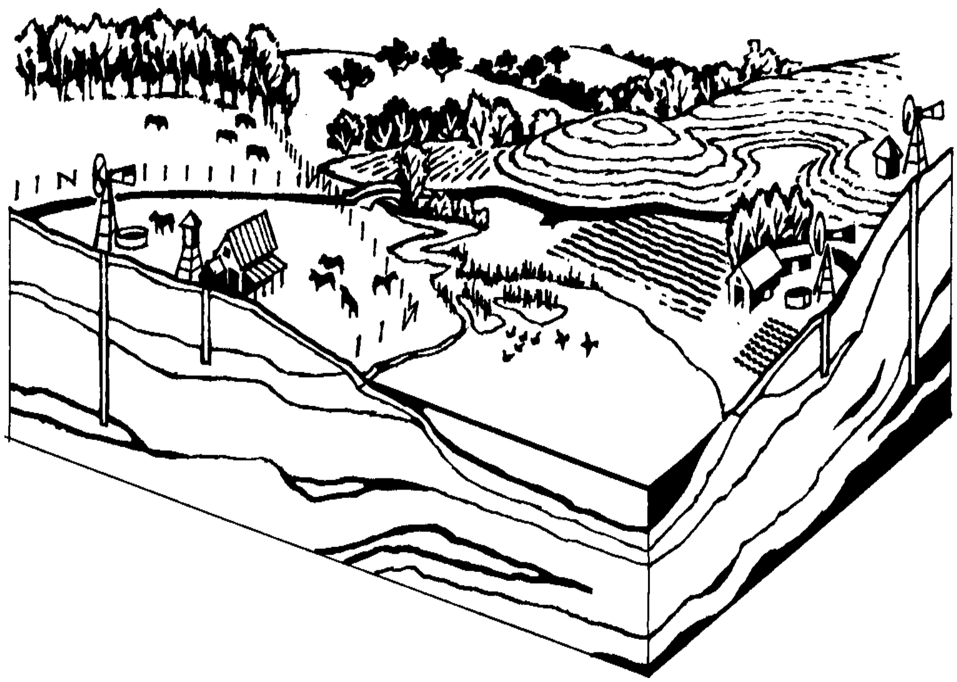
Savory, Alan. Holistic Resource Management.

NIH free computer software program: Image is available over the Internet from zippy.nimh.nih.gov.

Investigation # 1: Backyard Hydrologyis adapted from Luna Leopold's book "A View of the River".

For Your Notes:

Ground Water

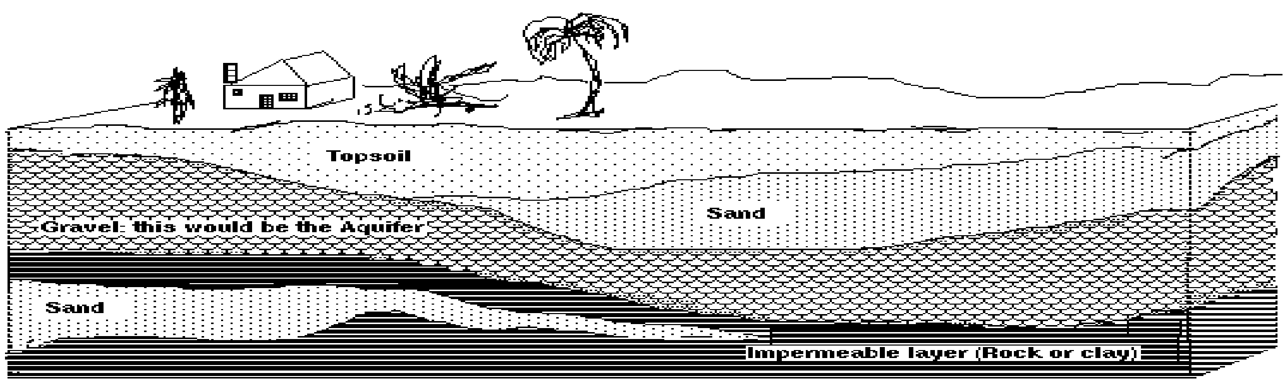


Life Blood of the Earth: Ground Water

Step 1 Introduction

How much of the earth's water is available for our use? To answer this question let's imagine a one gallon jug that represents all the water on the planet. Only one tablespoon, less than one percent of the total, is available fresh water. Sea water makes up 97 percent of the earth's water and 2 percent is locked up in icecaps and glaciers. There are large amounts of water underground but much of it is too deep for us to access with the technology available at this time. (National Geographic, Water , 1994)

Let's start with how water gets into the ground and how it moves. During the course of the hydrologic cycle, water gets into the ground by infiltrating through the soil surface and percolating down through the pore spaces in the soil. At some point, the water collects in a sand, gravel, or rock formation (e.g., sandstone or limestone) that carries and stores water. This formation is called an "aquifer." An aquifer can be a few feet thick or hundreds of feet thick; it can be small (a few acres) or very large (thousands of square miles); it can lie close to the surface or be thousands of feet below ground. Aquifers can even occur on top of one another, separated by impermeable layers of rock or clay.



Gravity and capillary action are the two forces that draw water below the surface. Gravity is the primary force that acts to pull water rapidly downward through large soil particle spaces. Capillary action is when a liquid clings to the surface of a solid object and is pulled to the next particle by surface tension. For example, put one end of a wash cloth in a bowl of water. Hang the other end over the edge of the bowl and observe the results.You end up with a puddle of water on the floor! Water is drawn towards the dry end of the cloth, up and out of the bowl. Water in soil can be drawn both upward and downward by capillary action in situations where the soil pore spaces are small. Gravity works with capillary action to pull water down to dry areas from wet areas above. Evaporation of water from the surface of the soil works with capillary action to draw water upward from the damp soil under the surface. (Leopold, 1974, pg. 13 -14)

Step 2   Messing Around

Messing Around with the Water Table

Materials you will need
- Watershed Journal and pencil
- Sand (enough to fill 4 pie pans 1/2 full)
- 2 clear pans (Casserole dishes are great)
- Water (approx. 1 gallon)
- Measuring cup

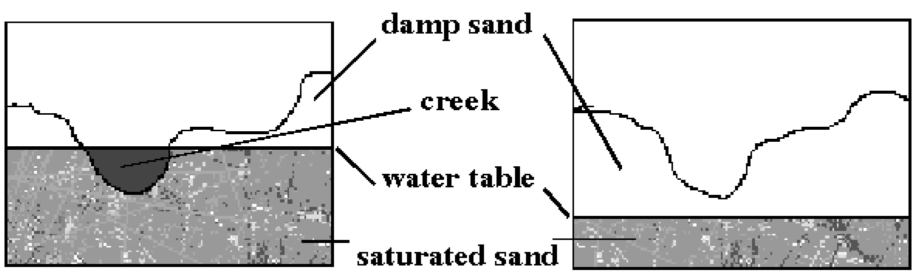
Background

Under the porous surface of the earth are impermeable layers like bedrock and clay layers that the water cannot penetrate. When it rains, water percolates down and collects above an impermeable layer. The top of the ground water surface is called the **water table**. A good way to understand a water table is to do the following activity.

Procedure

- Half fill two clear pans with sand.
- Dig a hole in the sand in the middle of one pan.
- Pour water into the first pan. Notice what happens to the sand. Describe how the water moves through the sand. When does water begin to collect on the bottom of the pan? Is the remaining sand in the pan wet or dry? Why?
- Carve a v-notch in the sand of the second pan. This notch will mimic a stream in the watershed. Pour the same amount of water into the pan with the V-shaped notch. Where is the water level in the notch? Where is the water level in the rest of the pan?
- Explain why water may flow in a stream long after a rainstorm, even in a dry, desert environment?
- Experiment with pouring water into a pan that has saturated sand. Pour the water along one edge of the pan. Describe what happens to the water table initially, then over a 15 minute period.

Water Tables
(Cross section)



Messing Around with Infiltration/Percolation and Ground Water Recharge

Materials you will need

- Watershed Journal and pencil
- Measuring cup or beaker
- Empty metal can - soup or vegetable can

  Before removing the bottom of the can, measure the amount of water need to fill the can to a level of two inches. This is the amount of water that you will use in the experiment below. Now remove the bottom of the can.
- Hammer
- One gallon of water
- Area that has several different soil types
- Watch with second hand

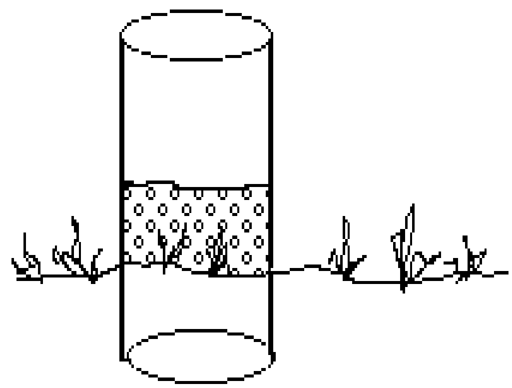
Background

Infiltration is the process by which water sinks into the soil surface. Percolation is the process by which water moves through the soil once it has made it through the surface. Infiltration and percolation are very important in determining how well the ground water aquifers are recharged. If the earth's surface were covered in plastic, water wouldn't be able to get into the soil, and therefore would not able to percolate down to the aquifers. People create such barriers to ground water recharge whenever they pave over the soil for streets, buildings, and parking lots. Water that does not sink into the soil becomes surface run-off.

Infiltration/percolation rate is the speed with which water penetrates the soil surface and passes into the ground. It is often measured in inches per hour. The infiltration/percolation rate depends on two things: the characteristics of the soil material and the type and density of vegetation growing on the surface. The larger the pore spaces between soil particles, the more quickly water will infiltrate and percolate. For example, take a cup of clay and a cup of gravel. Pour a 1/2 cup of water into each. Through which material will the water move most quickly? If you predicted the gravel, you're probably right. The gravel has large spaces between the particles that allows the water to move easily. The clay, on the other hand, is made up of very fine particles with little pore space. Clay tends to expand when it gets wet, making these pore spaces even smaller. (Leopold, 1974, pg. 10-11)

Procedure

- Find several areas where you would like to test the infiltration rate. These can be bare or vegetated.



- Describe the soil and vegetation for each test area. You can take a measured amount of soil and place it in a jar of water. Shake well to make a mudshake. Allow to sit undisturbed and record the layers that appear. This will help you gauge the particle sizes in the soil.

- Use your hammer to tap the can into the ground about one inch. **Note:** If you live in an area where the soil is hard or compacted, you may need to consider using a steel pipe and a sledge hammer. Steel pipe is available at a plumbing supply or hardware store.

- Be ready to begin timing the infiltration/percolation rate of the water.

- Measure out the amount of water you determined necessary to fill the can to a level of two inches.

- Pour the water into the can and time how long it takes to disappear entirely into the soil. (No pools of water will be visible.)

(Activity adapted from University of Washington Cooperative Extension Watershed Curriculum, 1995.)

Step 3 Identifying a Question

Before going on to the investigations, take some time to think about some of the following questions.

- How is ground water used in your community? Describe situations where water is either added to ground water or pumped out of the ground. What effect might septic systems have on ground water levels?

- How do changes in weather affect ground water levels (e.g. flood years versus drought years)? What effect does evaporation have on ground water recharge?

Now get a bit more specific. What particular questions interest you?

* You may want to examine the whats and whys of changes in the water table in your area over time.
* How does the aquifer level fluctuate over the seasons?
* How do different farming techniques affect infiltration/percolation rates and hence ground water recharge?
* You might be interested in exploring the relationship between ground water pumping and land subsidence in your area.
* What questions are brought to mind by local news concerning ground water?

Step 4 Approaching the Question
Experimental Design and Data Collection

Whatever you decide upon - a question of your own or one of the investigations outlined - re-read the the section in the **Introduction to Scientific Investigation** on controlling variables and replication of the experiment.

Some things to keep in mind:

* If you are looking at ground water levels over time, make sure you are using data from the same time of year. In many areas, especially the arid west, these levels may fluctuate quite dramatically from season to seaon.
* Consider how trustworthy the data is you get from different sources.
* How was ground water level determined? Were the same techniques used in each case? Are the techniques comparable?

Ideas for Experiments

Investigation #1: Charting Ground Water Wells

Background

Water table levels are influenced by the rate of water moving into them and the amount of water pumped out of them. Generally, it takes water a long time to move around underground. In very dry places, current rainfall does not add much to currently available ground water. Some ground water that is being pumped out of the ground in these arid places fell as rain over 10,000 years ago. It is often referred to as "fossil water."

Consider the result of pumping more out of the aquifer than is replaced or recharged each year. What will happen to the aquifer and production of the wells that tap into these aquifers? To answer this question, fill your sink half way and let the faucet continue to drip into the sink Take a cup and remove water continuously. This exercise could be compared to an unbalanced ground water pumping and recharge situation. What happens over time to the amount of water in the sink?

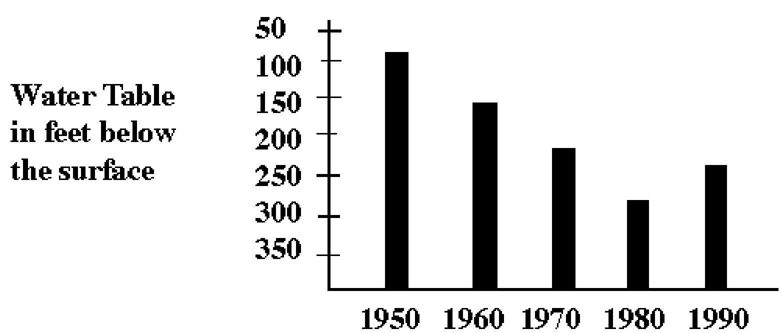
Procedure

- Contact county or city engineering departments, local water company, farmers, ranchers or any other well owners and request information about ground water levels over time. Get records as far back as possible.

- If possible, get information about springs in the area. Older members of the community can be a gold mine of information!

- After gathering your data, decide how you can best show this information graphically.

- Find additional historical information about weather, ground water use, flooding, land use changes, or population increases that may have affected ground water levels over time. Find a way to graphically display this information. Can you find any correlation with your ground water level data?



Ideas for Experiments

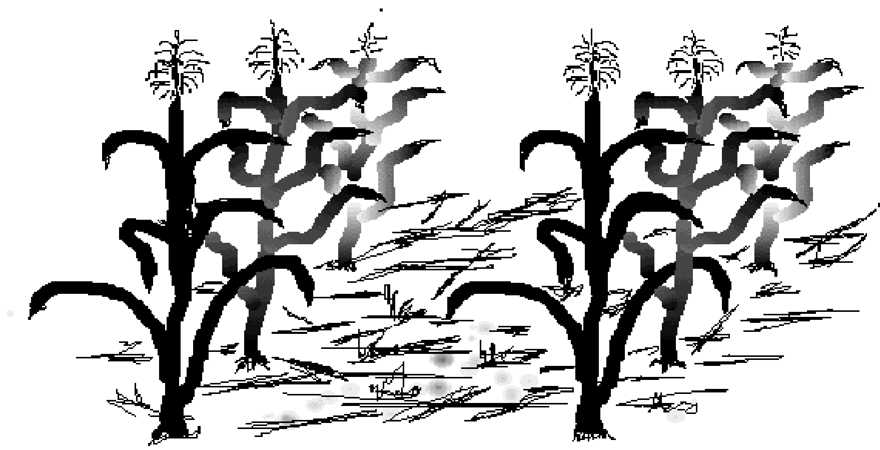
Investigation #2: Let's Talk About Land Use and Infiltration

Background

Traditionally, farmers have plowed the land to increase infiltration. However, plowing can lead to increased erosion. What are some of the trade-offs that farmers or ranchers might make in order to achieve a priority objective such as better water infiltration? Are there any methods you are aware of that may lead to increased infiltration without causing erosion problems?

Some farmers are using a techniques called no-till. By not plowing the land, they reduce erosion significantly. There is some evidence that by not disturbing the soil structure - the worm burrows and old root channels - the infiltration and percolation rate can also be enhanced.

Crop residue, between rows of corn, for example, can hold soil in place during rain.



Procedure

- Talk to the Natural Resources Conservation Service and the Resource Conservation District about various local land use practices and ranchers or farmers that may be willing to talk with you. Tell them you want to investigate local ranching and farming practices that are used to increase water infiltration.
- Ask about ranching and farming priorities regarding land use. What is most important to these individuals: maximizing crop production, controlling erosion, good water infiltration? What methods are used to balance these priorities?
- Find a farmer who is practicing no-till. Examine infiltration/percolation rates on those soils. Compare to infiltration/percolation rates on a farm with similar soil types that is farmed using traditional plowing techniques. You might simultaneously examine erosion rates at these two sites using some of the techniques described in the Erosion section of this manual.

Step 5 Analyzing the Data

- If data comes in the form of numbers on a spreadsheet, is there a way that you can display this information graphically?

- Think about ways that you can graphically display two sets of data on one table or chart. For example, compare percolation rates on two different properties where the land management methods differ, such as till versus “no-till” agriculture. You could map ground water well location and water table depth.

Step 6 Identify the Next Step

Identify any new questions that came up during your investigations. Based on your initial investigation you may have discovered some ideas for a more long term study.

Do some research through the local newspapers on historical or current events that relate to water use. For example, in our community there was a controversy about ground water pumping and its effects on buildings near the wells; some of the nearby buildings were sinking.

Another community that used septic tanks was pumping from both an upper and lower aquifer. Following the closure of the wells pumping the upper aquifer, water table levels began to rise and seasonal ponds began to form around houses in the low-lying areas. Think about the kind of data you would need to analyze and graph this situation. How would you explain it?

These are real examples. Your own community probably has its own stories. We encourage you to look locally!

References

Leopold, Luna. Water: A Primer. 1974. W. H. Freeman and Company, San Francisco.

Reisner, Mark. Cadilac Desert.

Reisner and Bates. Over Tapped Oasis.

Washington State University Cooperative Extension and Seattle Water. Cedar River Watershed Field Trip: 4-H Challenge Water Quality Program. Contact: Gail Gohsman. Phone: 206-296-3900. Seattle Water Contacts: Ralph Naess and Celese Brune. Phone: 206-233-1510.

Water Law. David H. Getches, West Publishing Company, P.O. Box 64526, St. Paul, Minnesota 55164-0526. Copyright, 1984.

Ground Water Quantity
Messing Around Data Sheet

Water Table Models

Draw both of your water table models. Show the water table line, wet sand and dry sand.

Water Table Model # 1

Water Table Model # 2

Infiltration and Ground Water Recharge Messing Around Data Sheet

Site # 1

Appearance of the Soil:

Composition ______________________________

General appearance (e.g. plowed, crusted over, plant cover etc.)

____

____

What did you use to conduct the test? ______________________________

(e. g., metal can and hammer or steel pipe and sledge hammer)

Amount of Water ______________________________

Time for Infiltration ______________________________

Site # 2

Appearance of the Soil:

Composition ______________________________

General appearance (e.g. plowed, crusted over, plant cover etc.)

____

____

What did you use to conduct the test? ______________________________

(e. g., metal can and hammer or steel pipe and sledge hammer)

Amount of Water ______________________________

Time for Infiltration ______________________________

Site # 3

Appearance of the Soil:

Composition ______________________________

General appearance (e.g. plowed, crusted over, plant cover etc.)

____

____

What did you use to conduct the test? ______________________________

(e. g., metal can and hammer or steel pipe and sledge hammer)

Amount of Water ______________________________

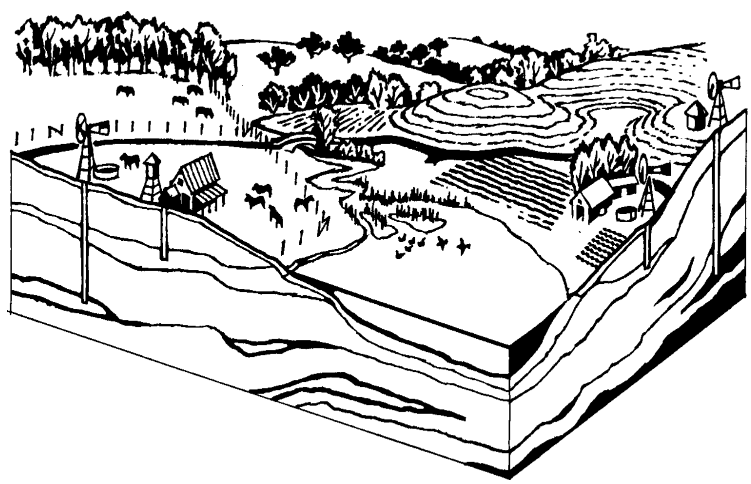
Time for Infiltration ______________________________

Life On Top Of The Aquifer

Step 1 Introduction and Background

When you think about ground water what do you envision? A big lake or river running under the ground? It is possible for water to occupy underground caverns and caves, but most ground water moves and is stored in the small spaces (called pore spaces) between soil particles. Areas underground where the soil has become saturated with water are called “aquifers”. Aquifers can be composed of sand, gravel or fractured rock. These materials can hold large quantities of water and water is easily pumped from them. The larger the pore spaces the easier it is for water to move. For example, sand and clay may hold the same amount of water, but which one do you think would be easier to pump water from?

A lot of communities get their household water from wells, and thus from ground water. What we need to remember is that we are living and working, manufacturing and playing **on top of our water supply**. What goes onto the soil has a very good chance of going down with the water soaking into the ground and, most importantly, **coming back up with the water** when it seeps or is pumped out again!



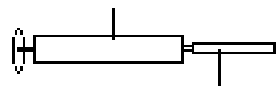
For a long time people knew very little about how ground water aquifers were recharged or how the water moved under the earth’s surface. Almost no thought was given to the effect of dumping, spraying or otherwise distributing chemicals on the ground. Today our understanding is better, but in all honesty we are still “flying in the dark”. It’s hard to know what it’s like underground and to predict how and where the water or pollutants will travel. The problem with ground water pollution is that it is out of sight and sometimes out of reach.

One of the things we do know, however, is that not only are ground water levels sinking in many urban areas of the arid west (indicating that more water is being pumped out than is soaking back into the aquifers), but many agricultural, household and manufacturing chemicals are coming back out of the ground in our drinking water supplies. What has also become obvious is that quite often the chemicals that we are seeing appear in the ground water have taken 30 or more years to move through the soils to the aquifers. The pollution problems we are seeing today may very well be the result of long-past actions.

Step 2 Messing Around with Ground Water Pollution

Materials you will need

- Clear plastic shoe box
- 10or 12 cc Plastic syringes (available at vet supply or feed stores)- attach 1.5 inches of 1/4 inch drip tubing to the end to make a pump that can reach down into the straw "well casing".
- Several plastic drinking straws
- Food Coloring
- Water
- Sand, gravel, and clay powder (or clay soil)
- Spray bottle filled with water



Background

Rain water soaks through the soil layers and becomes ground water. At this point the water disappears from our view. How do we go about studying something that disappears? The following investigation uses a model that enables us to view ground water movement on a small scale. The clear plastic box allows you to have a window underground. This model will also allow you to witness the spread of pollution in the underground environment. As you work with this model, start to make some general predictions about how water and pollutants will move underground and the factors that affect this movement.

Procedure

- Put layers of sand, gravel and clay in the clear plastic shoe box. Leave some clearance at the top of the box.

- Use a spray bottle or a measuring cup and slowly add water to the surface of the model. Watch and record how the water moves into and through the different soils. Add water to the model until it pools on at least part of the surface. Where is the ground water table? Mark the ground water table on the side of the model.

- Place the end of your plastic syringe (ground water pump) into the surface soil and pump water out. Observe the ground water movement as you use the pump.

- Create a "well casing" by placing a 2 inch piece of straw in the soil and placing the pump into the top end of the straw. Again, pump water out.

- Place a few drops of food coloring on the surface of the model. This dye simulates a water soluble pollutant. What happens to this pollutant when you pump water from the well? How fast does the pollutant move? Does it move at different speeds through the different soil types?

- Keep playing with the model. How does the addition of more water affect the pollution movement? What happens if you re-arrange the soil types?

Step 3 Identifying a Question

This is your opportunity to speculate like crazy! Why do you think things happened as they did? How could you test that?

- Which type of soil particle will allow ground water to move most easily?
- What are your predictions about the effects of changes in the arrangement of soil layers in your ground water model? How do these changes influence pollution movement in ground water?
- Have a friend hide some pollutants in your model. Baking soda is a great one since you can easily detect it's presence with pH paper or vinegar. You are a scientist who must come up with a design to find and define the extent of the problem. How would you go about doing this?
- Can you mimic your own community's soil structure and examine how water and pollutants might move through them?
- Do some library research on groundwater decntamination.

Step 4 Approaching the Question Experimental Design and Data Collection

Determine whether your investigation will be qualitative or quantitative. A qualitative experiment is an opportunity to observe and describe change over time - it is descriptive in nature. A quantitative experiment is an experiment where you can measure the results.

Reread the introduction with regard to controlling variables and replication of the experiment. Also, read the section on the relationship between collection of data and controlling variables.

Approaching the question has to do with experimental design. Your job is to create a framework for your questions based on some basic scientific rules. Start your questions out simple. There is plenty of opportunity to build upon questions and come up with more questions as you go along. Based on your results of your messing around with the model, you should be able to make some predictions.

Keep good notes! Describe everything thoroughly. You can't have too much information.

Ideas for Experiments

Investigation #1:
Create Your Own Ground Water Model

Background

This investigation will provide you with a more sophisticated opportunity to witness ground water and pollutant movement. This investigation is great if you like to build things. Half of the experiment involves designing, building and refining your own equipment.

Materials you will need

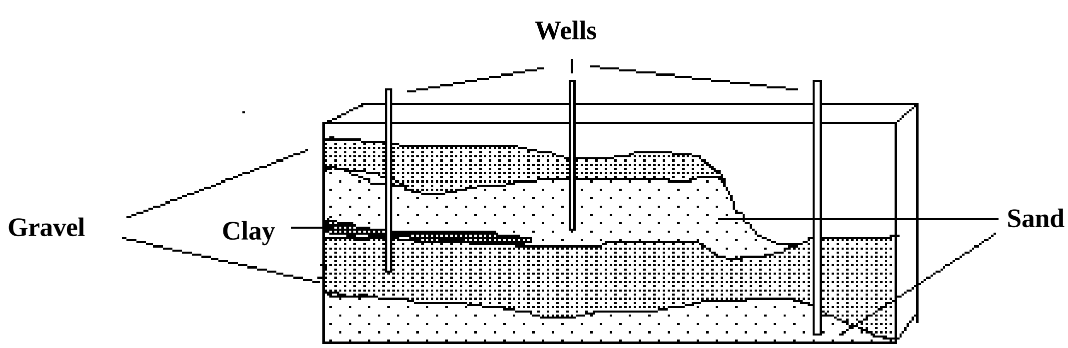
- Hard to say - it all depends on your design.

Procedure

You are going to create a “window underground” by building a Plexiglas box shaped like an oversized ant farm. Keep the following design considerations in mind.

- The idea is to make a transparent box that is narrow enough to be able to accurately track water and pollutant movement. We recommend 18 inches long by 12 inches deep by no more than one inch wide.
- Your model will contain gravel, sand, clay and water. These things are heavy so make sure your box can take it.
- You will be adding water and possibly other liquids to your ground water model. It should be water tight, but you might like to design in a method for draining water out (e.g., holes at the bottom).
- You will want to sink wells into the different layers: how will you “case” (or line) the well holes? How will you get your pumps to work in the deep wells?
- Think about ways that you could simulate the introduction of pollutants into the ground water. You will want to be able to see the pollution and “track” its movement. You could use a gelatin capsule with food dye buried under the surface to simulate an underground tank or barrel, spilling it directly on the ground, or injecting it into a disposal well.

Here is an illustration of our model. We encourage you to improve on its design and to try different layering patterns for the soils.



Investigation #2:
Natural Solutions to Ground Water Contamination:
Oil Degradation by Microbes

Background

Welcome to Microbiology! This experiment gives you an experience with a pollution control method called bioremediation. **Bioremediation is a process in which bacteria or fungi are used to degrade pollutants.** The bacteria actually feed on the pollutant, turning it into something that is not harmful to the environment. Since the bacteria are actually eating the pollutant, it is important to match bacteria with pollutants they will eat. Bioremediation is commonly used to degrade pollutants such as gasoline, diesel fuel, and oil. This experiment uses bacteria to digest motor oil.

Before you begin this experiment you might want to learn more about the process of bioremediation and how it is used by environmental professionals. Some methods you may want to find out more about include: bio-venting, fixed film bioreactors, aerobic bioreactors and anaerobic bioreactors.

Materials You Will Need

The materials are all available through Carolina Biological Supply Co. (ph:1-800-334-5551). Juli Hauser (Microbiology Department) of Carolina Biological Supply Co. developed the following experiment using the bacteria *Pseudomonas aerouginosa*. Your science department may be of help in obtaining some of the following materials.

Minimal Broth

1 liter distilled water
7 grams of dipotassium phosphate
2 grams of monopotassium phosphate
0.5 grams of sodium citrate
o.1 grams magnesium sulfate
1 grams ammonium sulfate

Oil Suspension

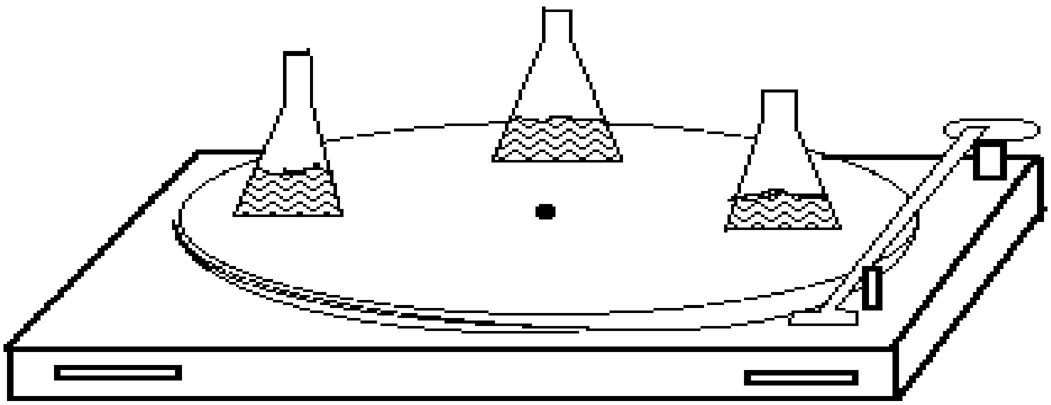
1 milliliter of motor oil without detergents or additives
4 milliliters distilled water
1 drop of dish detergent

Additional

1 milliliter dextrose
Erlenmeyer laboratory flasks - the number of replications dictates how many you need
Metal inoculation ring
Bacteria - *Pseudomonas aerouginosa* (Carolina Biological Supply Company: request bacteria tube on agar slant, Catalog # 155250)
Tin foil
Record turntable (for slow agitation of the flasks) Look at garage sales, thrift stores, and your family's collection of old stuff.

Advance Preparation

- Develop a method for agitating the final solutions on a continuous basis. You need something that will continually rotate or agitate the solution slowly. A record turntable turned on at 33 rpm is perfect!



Flasks on a Turntable

- You want the cheapest motor oil available, without detergents or additives. The more expensive brands put more additives in the oil. Once you have the technique mastered for the oil with no additives, it might be interesting to compare results with those using oil that **does** have the additives.

- Decide on the number of replications you want: how many experiments, controls, oil with additives, etc. Adjust the amount of supplies to accommodate your needs.

Procedure

- Assemble the Minimal Broth and sterilize it in an autoclave for 15 minutes at 121 degrees Celsius at 15 psi. (Your high school lab should have one. Ask your science instructor for assistance if you have never used one before.)

- Blend oil suspension in a blender until thoroughly mixed.

- Prepare a 10% solution of dextrose and put it in the autoclave for 20 minutes at 115 degrees Celsius at 15 psi. This ensures a sterile filtered solution.

- Make a solution that consists of
  - 100 milliliters of the prepared Minimal Broth
  - 1 milliliter of sterile filtered dextrose solution
  - 1 milliliter of the oil suspension

- Add equal portions to two flasks.

- Inoculate one flask with the bacteria *Pseudomonas aerouginosa*. “Inoculate” means to add the bacteria to the prepared solution. There are detailed instructions that come with the bacteria that describe how to inoculate a solution. You should have enough bacteria in one tube for several inoculations. Try to add equal amounts to each sample flask. **IMPORTANT:** Flame or sterilize the inoculation ring before and after each inoculation to prevent contamination. Note: The bacteria will arrive on an agar slant. The agar is food for the bacteria. The bacteria will need some food initially in the oil solution. It is fine balance between including, in your inoculation, so much agar with the bacteria that they do not digest the oil or not enough agar to get the bacterial colony started and the bacteria dies.

- Cover the flasks with tin foil; the foil should not be so tight that it doesn’t allow air exchange.

- Place the flasks on the agitator where they will be agitated for 8 weeks on a continuous basis.

- Develop a schedule for monitoring the results. Describe what you observe on a daily or weekly basis. After 8 weeks, check the flasks for the appearance of oil.

Step 5 Gathering and Analyzing the Data

- How did you keep track of your procedures and results in this experiment?
- How did your predictions match up to your results?
- How will you display your data: e.g., graph, pie chart, photographs?
- What types of comparisons did you make between the flask inoculated with the *Pseudomonas aerouginosa* and the flask without the bacteria? If you tried oil with additives, how did it compare to the pure oil?
- How do you account for unexpected results? How are your results affected by your laboratory procedures?
- This was a qualitative experiment; can you think of a way to do a quantitative experiment on the topic of bioremediation?

Step 6 Identify the Next Step

Identify any new and exciting questions that came up during your investigations. Based on your initial investigation you may have discovered some ideas for a more long term study.

- Find out how bioremediation is used by engineers and environmental scientists dealing with water purification. Environmental consulting and engineering firms are a good place to start.
- Investigate other methods for solving ground water pollution and soil contamination problems. Remember, if the ground water is polluted the soil is also affected.
- Develop a list, with the help of your local water resources agency or county environmental health department, that indicates some of the types of businesses that commonly contribute to ground water pollution problems. Document some methods of preventing these pollution problems. For example, for many years dry cleaning businesses dumped their chemical wastes like solvents into the sewer system or into ground storage sumps. This led to extensive ground water pollution in many communities. What alternative treatment or disposal methods are used in your community?

Messing Around Data Sheet
Ground Water Pollution

Draw a picture of the soil profile in your “messing around” ground water model (e.g., gravel, clay layers, sand and organic humus):

Describe what happened when you pumped water from the soil surface and from the different ground water wells? Describe any differences in results.

Describe what happened when you added pollution to the model. What happened when you pumped nearby ground water? What happened when you added more water to the model?

Estimate by observation or testing what percentage of the soil in the model was affected by the pollution after you pumped from the wells and added water. Did the pollution spread? How much? How fast?

References

Cobourn, John. Protecting Our Water Resources: A Guide for Washoe County Residents. October, 1993. University of Nevada Cooperative Extension, Box 8208, Reno, Nevada 89452. Phone 702-784-4848.

Leopold, Luna. Water: A Primer. 1974. W. H. Freeman and Company, San Francisco.

National Geographic Special Edition - Water: The Power, Promise, and Turmoil of North America's Fresh Water.. 1993, Vol. 184, No. 5A.

Carolina Biological Supply. Microbiology Department. 800-334-5551.

Sustainable Choices

Who's Bugging You?
Pest Control and Water Quality

Step 1 Introduction

Have you ever heard the expression “Today’s problems are yesterdays solutions”? It is actually a great phrase and should be considered whenever you come up with what you think is a great solution to a problem, because what it asks you to do is think about both **intended** and **unintended** effects of a course of action.

Reports are coming in from around the country of contamination of water supplies by chemicals such as soil fumigants, dry cleaning fluid, weed killers, and pesticides. Chemical pesticides and fertilizers have been solutions for decades to the problems of pest control and boosting plant growth for many of us on the home, on the range, and on the farm.

Use of pesticides, including herbicides (weed killers), has had some rather nasty unintended effects. Face it, chemicals get spilled accidentally. Trains occasionally derail and dump whole tanker loads into a river. Or someone misreads the label and applies too high a concentration. Or farmworkers are accidentally exposed to high concentrations of the chemicals. Or no one realized that certain pesticides or herbicides would remain active for so long and no one thought they would actually migrate into the aquifers to come back to haunt us at the drinking fountain. And this is the kicker: the chemicals lose their effectiveness as the insects develop resistance to these chemicals.

You may want to do some initial investigation or research on chemicals used in agriculture and the resulting effects on the environment and workers who apply these chemicals. What happens to a pesticide after it is applied to crops? How long do different chemicals remain active or “persist” in the environment? Does the pesticide kill just one pest or does it affect everything it comes in contact with? Think in terms of food webs in an ecosystem. This will help you understand how chemicals can travel through the living parts of an ecosystem.

An increasing number of farmers and gardeners are becoming interested in alternative and, hopefully less environmentally dirsuptive, types of pest control. We are going to introduce you in this section to the tools of biological and cultural control of pests.

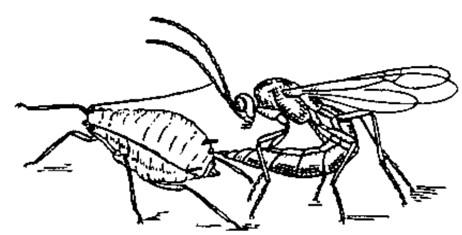
These are tools used by farmers who practice either integrated pest management (IPM) or organic farming. Both organic and IPM farmers use a lot of different methods to manage unwanted insect visitors. It’s like having a tool box. The lighter weight tools, such as biological control and cultural control are used first. These are often quite effective against certain pests. The heavy weight tools, like chemical control, are used as a last resort. Both organic and IPM farmers use biological controls and cultural controls. They also both use chemical controls - organic farmers use naturally occurring chemicals and IPM farmers use the more potent (and toxic) synthetic chemicals. Organic and IPM farmers who are successful consider the whole ecosystem, not just the pest.

Step 2 Messing Around

Biological Control

It's a bug eat bug world out there! And we can make use of that fact! Biological control involves using natural enemies to reduce animal and plant pest populations to acceptable levels. There are two primary methods of biological control: classical control and augmentative control.

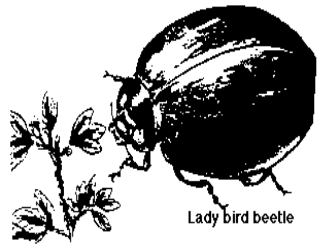
Classical biological control involves the intentional introduction and establishment of a pest's natural enemies. Many insect and weed pests are not native to the areas where they are causing the most damage. One of the reasons they may be so successful at damaging everything in sight is that they may not have any natural enemies in their new home. The pests may have moved around the world, but their enemies stayed at home. Scientists will often return to a pest's native home to search for those organisms that prey on the pest. These enemies are often very host-specific, that is, they will only attack a certain species of insect or plant. The enemies are brought back to the problem area, reared in mass quantities, and released. Once an effective enemy population is established, usually the land manager need not intervene further. Classical control has proved successful with both plants and animals. The story of the ash whitefly in California is a great example. The insect appeared in California in the late 1980's. Large populations quickly built up, causing premature leaf drop on both ornamental shade trees and certain fruit trees. The honeydew produced by the whitefly dropped onto sidewalks, cars, and patios making it unpleasant to be outdoors. Biologists returned to the pest's native countries of Israel and Italy. Ash Whitefly exists in small numbers in those countries, but is not a pest. Why would this be? It turns out that a tiny non-stinging wasp whose larvae ate the whitefly's larvae was the answer. This little wasp was brought to California, raised in large numbers, released, and the problems with the ash whitefly quickly vanished. The whitefly itself has not vanished, but it's population is kept low enough by the wasps to prevent the whitefly from causing any noticeable damage.



Small braconid wasp stinging aphid
Order Hymenoptera
length, 1/12 in.

Augmentative biological control involves the mass release of a natural beneficial insect, usually a predator to control a native pest. For example, lacewings may be released to boost the natural predator population and bring a pest population of mites or aphids down to a reasonable level. This method is different from classical biological control because it generally requires releases of the beneficial on a continual basis. Since many of the crops these predators are used on are annuals, the lacewings' habitat is constantly disrupted and plowed under, so the population needs to be re-established after each new planting. Farmers are now beginning address this issue by establishing border plantings of plants that can feed and sustain the predator population between crops.

One tool of biological control makes use of natural **predator-prey** relationships. Lady bugs and lacewings eat aphids and mealy bugs which can be very destructive to the garden. Therefore, lady bugs are a beneficial predator insect. Then there are the **parasites**, **parasitoids** and **pathogens**. Parasites often don't kill their host outright, but they weaken it enough that it has a hard time reproducing. Few babies means few problems! The term **parasitoid** sounds like something you might find on a science fiction movie set, but these organisms are actually active in our own backyards. Parasitoids have a highly specialized relationship with their host organism. Some species of tiny wasps are common parasitoids in the garden. Adult parasitoid wasps do not eat caterpillars, but will sting the caterpillar to paralyze it and lay their eggs inside the caterpillar's body. When the eggs hatch, the larvae (worm-like stage) eat the caterpillar alive from the inside out.



Did you know you can actually give insects diseases? **Pathogens** are diseases and certain ones can act as pest controls. Bacteria called *Bacillus thuringiensis* (or BT for short) will kill most caterpillars. The bacteria is sprinkled or sprayed on the leaves of plants that are being eaten by caterpillars. The caterpillar eats the leaves, the toxins produced by the bacteria poison the caterpillar, and it dies. Biologists have found a virus that attacks the grape leaf skeletonizer. The virus is now well established and has kept the grape leaf pest under control. Again, the virus doesn't kill off all the skeletonizers, but it manages to keep the population so low that no real damage is done to the grapes.

If you'd like more information on biological control, you can find some outstanding resources on the Internet. Both Cornell University and Colorado State University, for instance, have homepages on biological control that are replete with close-up photos and the newest information. Cruise the Web and see what you find!

Messing Around with Predators and Prey

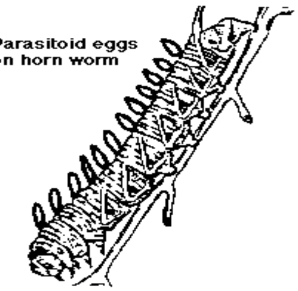
- Survey a garden, lawn, grassland, greenhouse or even house plants for both pest and beneficial insects. This will probably mean finding a garden that is not heavily sprayed with pesticides. Refer to the Resources list at the end of this section for books and posters that can help you identify the insects you find. Look for predators in action!

- Capture invertebrates with a net or tray. Put a white sheet or tray under the plants and shake the plants vigorously. Get out your **good quality** hand lens or dissecting microscope and ID chart and figure out what you caught in your sheet or tray. The diversity may be staggering to you. Read up on their life cycles and roles in the ecosystem. The books in the Resources section have great information on both pest and beneficials life cycles.

- Set up a terrarium(s) with pests and predators. Observe the interactions. You could wild-harvest them from your garden or you can order the beneficials from a supplier - call your county Farm Advisor for local information.

Messing Around with Parasites, Parasitoids and Pathogens

Procedure



- Go out into the garden with a hand lens and look for evidence of insects that have become the victim of a parasitoid. If you have problems with tomato hornworms, look for the hornworm caterpillars that have little white eggs protruding from their backs. These are definitely parasitized. You could place the affected hornworm in a terrarium covered by a nylon stocking mesh and watch the progression of the cycle.

- Do you have white butterflies flitting around your garden? Chances are they are members of the cabbage butterflies. Plant a garden of young cabbage or broccoli. Watch for small yellow eggs to be laid on the surface of the leaves. These eggs will hatch into minute caterpillars. Spray half of the plants with BT (you can find this at the garden store). Examine the caterpillars on the two sets of plants daily. Look for insects that have been killed by the BT. They will appear dark, limp, soft and very dead. Compare the damage between the control and treated plants.

Cultural Control

Cultural control refers to the suite of actions that people can take to manipulate or control a pest. Some examples are picking horn worms off your tomato plants, placing a baffle (looks like a hat) underneath your bird feeder to keep squirrels out, placing netting over your blackberry plants to prevent birds from eating the fruit, pulling weeds in your garden, and trapping pest insects. Cultural control practices also include timing of watering, planting or discing to maximize disruption of pests life cycles, judicious use of fertilizers to help plants maintain resistance to pests and pathogens, and use of genetically disease resistant varieties of plants. These are all ways to keep pests under control without using chemicals.

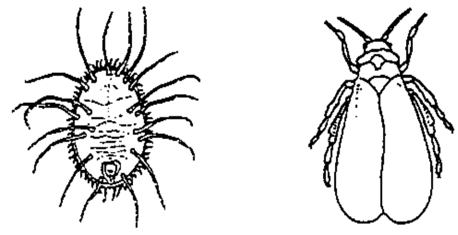
Messing Around with Cultural Practices

Flour Moths

• Have you ever opened a box of cereal and discovered that the cereal is clinging to the sides of the box by this mass of fine threads? That means you have flour moths! You can investigate the effectiveness of “traps” for these insects. The traps use the insect’s sex hormones to attract the moths which then become stuck on the sticky paper inside. They are available from the *Gardens Alive!* catalog in the Reference section.

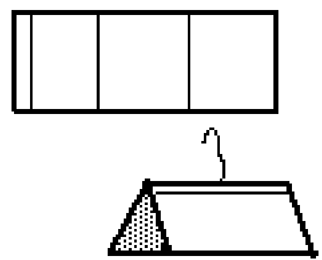
Trapping plant pests.

- Certain insects are drawn to different colors, and you can use this fact to trap them. Thrips and white flies make good subjects. They do a lot of damage and your gardening friends will love you if you can help them get rid of their infestations. First you need to learn to identify white flies and thrips. Check out the books in our reference section.



Greenhouse whitefly
Trialeurodes vaporariorum

- Next, make some experimental traps of different colors. Cut strips of thin cardboard (manila folders, cereal boxes or whatever you have) into sections seven inches long by 3 inches wide. Paint them or cover them with colored paper. You want one strip each of red, blue, yellow, green, black, and white. Fold them as shown in the drawing. Smear all three sections of each with a sticky substance - Tanglefoot and Pest Barrier are two brands you can find at the garden supply store. Tape the traps together as shown.



- Place the traps around the infected plant. Check your traps after several days, count the insects you trapped, and determine which color attracted the most pests.

Messing Around with Thresholds

How many bugs can you live with? You may tend to be perfection oriented - you want the produce you buy to look perfect and you want to completely eradicate bothersome insects in your gardens. Are these realistic goals? Are they even desirable goals? People practicing biological control methods do not seek to eradicate pest species from the face of the earth, or even from their gardens. They seek to reduce pest population to a level where the damage they do is tolerable.

Keep in mind that not everyone has the same priorities! For example, thrips cause scarring on oranges. In South America, the indigenous women often will not buy the oranges unless they are scarred. The scarring indicates that the oranges will be sweeter, because the sugars concentrate around the scars. In this country, many people buy only those fruits and vegetables that look perfect. For others, the fact that something is grown with a minimum of toxic chemicals is of greatest importance, and small blemishes do not bother them.

Procedure

- Try some surveys and blind taste tests that investigate aesthetics versus taste. Find out what people consider important. How do they decide what fruits or vegetables will taste best?

- Include questions in the survey that investigate interest in or attitudes toward how fruits and vegetables are grown - organic or IPM versus traditional farming methods.

Step 3 Identifying a Question

You had the opportunity to play around with several different aspects of biological and cultural control of pests. You may have already come up with some ideas for more in-depth investigations. In case you have not, you may find this next section helpful in zeroing in on a specific question.

Biological Control

- What type of predator to prey ratio do you need to control specific pests in your garden or in a terrarium setting? How could you investigate this in a lab situation? Think back to your predator - prey observations in the terrarium.

- What are the habitat requirements of your natural enemy populations? How do you keep your predator or parasitoid insect populations going throughout the year? Organic growers often will cultivate plants whose flowers provide nectar to the beneficial insects throughout the year. You'll find lists of these in Appendix A.

- What type of pest problems do you encounter that might be addressed by biological control measures? Internet cruising may give you some innovative ideas.

- How do plants compete with or antagonize one another? Are there any plants you can think of that prevent other plants from growing nearby? How could you check out your theories?

Cultural Control

- What types of plants could we place in the garden to attract beneficial organisms - predators, parasites, and pathogens?

- What types of plants are particularly vulnerable to pests? How can we protect them?

- How do various surfaces, shapes and colors attract or repel certain pests and beneficials? Think about your use of color strips in the garden. Observe flower shapes. How do birds and insects interact with different flowers?

Thresholds

- What seemed to be most important to people in your threshold surveys? Taste or appearance?

- If the taste was superior were people willing to sacrifice in the area of appearance? Why or Why not? What did imperfect appearance represent to taste testers?

- Were testers interested in how fruit or vegetables were grown (e.g., organic versus IPM versus traditional farming)?

- What level of control of the pest is needed in order to maintain a quality that appeals to the buyer? Describe based on your survey.

Step 4 Approaching the Question
Experimental Design and Data Collection

Re-read the Introduction and pay close attention to the section on data collection, controlling variables, and replication of the experiment.

If you are working in the field, you will have more difficulty in completely controlling the variables than if you were doing lab experiments. Try to keep as many variables as consistent as possible and keep good notes about inconsistencies:

- Collect or observe at the same time of day.
- Visit the same sites each time.
- Try to sample in similar weather conditions, or at least note any weather differences.

Make sure you have enough replications to feel comfortable with your results:

- Is one sample per location per visit sufficient? How many can you realistically do?
- How long through a season will you sample? And how often - once a day, week, month?

In lab experiments, make sure you treat all observation jars the same except for the one variable you are testing. You should always have a control. If you place 50 aphids in a jar with five lacewings; also, keep a jar with 50 aphids and 0 lacewings in a jar under the same conditions. This helps you to know what effect the lacewings had on the aphids.

It is important to understand the concept of “tolerance” prior to deciding on a method of biological or cultural pest management.

- How much pest damage can be tolerated?
- How does the tolerance level change from person to person? Does a commercial farmer have less tolerance for pests or disease than you do in your garden?

When you design a biological control experiment, **timing is everything**. If your plants have gone through their life cycle before your control organism hatches, or your beneficials all hatch out before you have your pests introduced into your experimental jars ... well, you’ll have to start all over again. Remember that pests are easiest to control at their most vulnerable life cycle stage: the early larval stage. Get some expert advice on timing from an IPM or organic grower, Extension agent, biological control expert, or the companies listed under Resources in this section.

Here are some suggestions for finding both beneficials and pests:

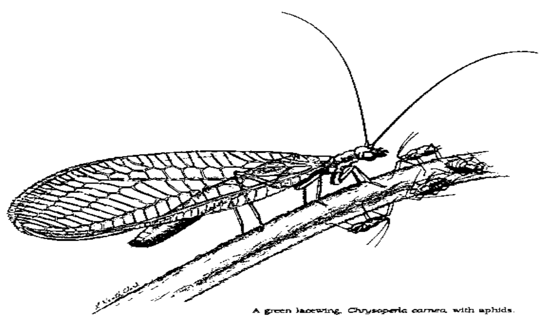
- Hunting tools: sweep net (A piece of fine meshed fabric will work); trowel; a white cloth; hand lens; tray; sticky boards (Petroleum jelly on cardboard works well.)
- Places to look: undersides of leaves; under logs, rocks and flower pots; mulch and plant debris; around flowers, especially small flowers like anise, Queen Anne’s lace, and buckwheat.
- Beneficials you might find: ground beetles, lady bugs, minute pirate bugs, big-eyed bugs, damselflies, lacewings, tiny parasitoid wasps, and dragon flies. Frogs, toads, spiders and birds can also be beneficials that eat or discourage pests.
- Clues that pests may be around: ants; sooty mold; curled leaves. Ants are attracted to the honeydew produced by sap sucking insects such as aphids, scale and whiteflies. Sooty mold grows on the honeydew.

Ideas for Investigations

Biological Control Investigation #1
Aphids versus the Lacewings

Background

Green lacewings are beneficial predators. They feed on small insects such as aphids, thrips, pear psylla, insect eggs and mites. Lacewings are commonly used in greenhouses to control pests. Larval lacewings act as predators. The larval stage lasts for ten to fourteen days. The adult lacewings, however, do not eat other insects but feed instead on nectar. If you order lacewings from a supplier they will arrive as eggs and hatch approximately two days later. Lacewing eggs can easily be identified because they are oval, pale green, and are attached to a hair-like stem. When they hatch, the larvae will look - and eat!- like little alligators.



A green lacewing, *Chrysoperla carnea*, with aphids.

Lady bird beetles are also used as a beneficial predator in the garden; however, lady bird beetles that are introduced to the garden tend to disperse very quickly to other areas. Naturally occurring lady bird beetles tend to be the most effective aphid control.

Bio-control is effective when the activity of one species reduces the negative effects of another species. You will have the opportunity in this experiment to make observations on the behavior of both predator and prey. You may want graph or chart daily observations.

Materials Your Will Need

- 5 one-gallon jars (glass or plastic), with a very fine mesh across the top. The jars should be half full of potting soil.
- Leaves or stems infested with aphids
- Lacewings (one for every 25 aphids) These can be ordered through Rincon - Vitova. See “Resources” section.
- Hand lens

Procedure

- Prepare 5 one-gallon jars with potting soil.

- Order lacewings from a supplier. ***Remember:*** *The insects usually come in large quantities; you may want to share the order with a friend.*
  - Describe your experiment to the supplier.
  - Find out what life stage the insects will arrive in; and,
  - Is a food supply included in the order?

  Note: You may or may not want to supplement the lacewing's diet during the investigation - they are supposed to eat the aphids! Feeding them may alter the results, so if you do feed, keep track of how much.

- When the lacewings arrive, place them in the jars along with the aphid infested plant material. Count the aphids in each jar. (Are you going to be glad if you have a **good** hand lens!) Make sure the leaves are free from apparent disease and other insects.

- Be sure to note the ratio of lacewings to aphids in each jar. Note any differences between conditions in each jar.

- One or two jars remain a control: jars with aphids, and no lacewings.

- Make observations during the life stages of the lacewings. Suggestions:
  - Proportion of lacewing eggs that hatched.
  - What were the life stages of the aphids during the experiment?
  - How many aphids in each jar were eaten by lacewings during the larval stage (10 to 14 days) of the lacewing?
  - What were population trends of the lacewings during the experiment?

Biological Control Investigation #2
What Makes a Caterpillar Sick?

Background

Once you have an infestation of caterpillars, your plants can quickly begin to look like lace. If you want to catch the caterpillars before they become a problem, you will have to start looking for eggs. Tomato horn worms, cabbage loopers, and corn earworms all have eggs that are large enough to see. Army worms lay eggs in a cluster that are easy to spot. Turn over leaves and look in the crown of seedlings for eggs and small caterpillars. A good garden pest book will help you identify the eggs of different types of caterpillars. (See Flint))

This experiment examines the use of a pathogen - the bacteria *Bacillus thuringiensis* (BT)- for control of caterpillars.The wonderful thing about using BT as an insecticide is that it attacks only the caterpillars that actually are eating your plants and leaves most of the pests' natural enemies unharmed. (Flint, pg. 48) This investigation will give you the opportunity to see BT in action.

Materials You Will Need

- A garden where caterpillars make their home. Plants in the cabbage family are favorite targets of caterpillars.
- Watershed Journal
- Magnifying lens (A quality hand lens can be ordered through a biological supply company or purchased at retail education stores.)
- *Bacillus thuringiensis* (BT can be obtained at garden stores)

Procedure

- Find at least 10 healthy looking cabbage loopers, tomato horn worms or another type of caterpillar. Cabbage or broccoli plants are a good place to start. Check your own and friends' gardens for likely subjects.

- Place or plant <u>two sets</u> of seedling plants in an area where each set will receive the same amount of sunlight. Note: Watering and fertilizing should be the same for both sets of plants.

- Put an equal number of caterpillars on each set of seedlings.

- Cover each set of seedlings with a mesh or netting that will prevent the caterpillars from escaping.

- Sprinkle the bacteria *Bacillus thuringiensis* on one set of seedling plants. Follow the directions carefully on the label. Variables such as weather and water pH can alter the effectiveness of the BT. In fact, you could test the effect of different pHs on the effectiveness of BT.

- Monitor plants and caterpillars for two weeks. Document changes in caterpillars' appearances.

- Note any differences between the treated and control plants.

Biological Control Investigation # 3
Attack of the Parasitic Wasps!

Background

The *Trichogramma* species of wasps are some of the parasitoids we've been talking about that attack the larvae of many moths and butterflies. There are several varieties of *Trichogramma* available from insectaries.

Commercial growers would probably release 100,000 to 300,000 wasps per acre of cultivated crops, twice weekly over a period of 10 weeks in the summer. "Augmentative" biological control is different from classical biological control because it generally requires releases of the beneficial on a continual basis. Wasps are not generally used to control pests in small gardens because the expense usually outweighs the benefit. This small scale investigation may provide some insight on the use of augmentative biological control. This investigation involves observation of the parasitoid/prey relationship.

Materials Your Will Need

- 1 or 2 Goniosis wasps
- 1 or 2 Naval orange worm larvae
- Large gelatin capsules
- A hand lens
- Watershed Journal

Note: The Goniosis wasps, naval orange worm larvae and gelatin caps can be obtained for a minimal cost by ordering them from insect supplier Dan Bigham, phone # (209) 564-2620.

Procedure

- Contact an insect supplier and order:
  - *Goniosis* wasps
  - naval orange worm larvae
  - large gelatin capsules

- Place the wasp in the gelatin cap with the naval orange worm larvae and observe the results. Document interactions several times a day.

Cultural Control Investigation # 4
Attracting Good Insects As A Bio-Control

Background

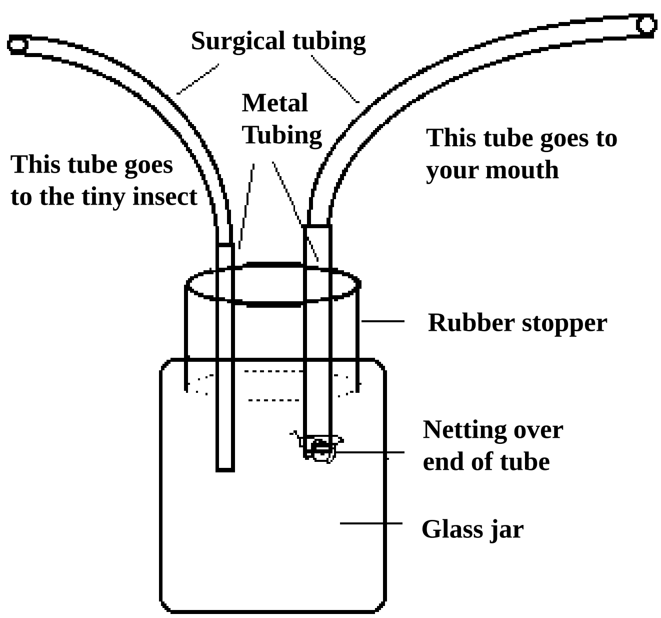
One of the primary ways that you can attract beneficial insects to a garden is to cultivate plants that attract them. Beneficial insect plants not only attract good predatory insects to the garden, they also attract other desirable wildlife like hummingbirds, help control weeds, and add more variety and beauty to your garden. Plants that attract beneficial insects include various types of trees, shrubs, ground covers and grasses. Many beneficial plants are hardy and thrive in a variety of areas.

Materials You Will Need

- Plants that attract beneficial insects (See Appendix A for suggestions and how to get these plants.)
- Insect collecting equipment
- Hand lens

Procedure

- Locate insectary plants in bloom. Survey the insect visitors at various times of the day. Try to collect every type of insect that you see visiting the plant. You might try an aspirator for the tiny insects. (See the diagram)
- Identify the beneficial insects. Find a way to estimate the numbers of each species of beneficial visiting the plant at a given moment.
- Repeat this for another type of plant in bloom in the area.
- Compare the flower structures of the two different types of plants.
- Compare the results for the two different types of plants.



Insect Aspirator - this allows you to suck tiny insects into the jar without inhaling them. Put one tube into your mouth and aim the other at a tiny insect. Inahle.

Step 5 Analyzing Data

Many of these investigations are descriptive in nature rather than highly quantitative. Document in detail your observations. This documentation can take many different forms. The world of insects is truly lurid and fantastic. These investigations would be outstanding places to hone your micro-photography skills. Many of the predator/prey and parasitoid/host interactions could be photographed with a high-powered macro lens. Perhaps you have access to equipment for time-lapse photography. These, in combination with written observations and interpretations could yield an impressive project.

You could create a chart or a database to keep track of the following information, as it applies to your investigation:

- Insect type (Order or Species)
- Arrival or collection date of insects
- Beneficial or pest?
- Life stage of insects (e.g., egg, larvae, adult)
- Time spent in each life stage.
- Is an additional food supplement needed? If so, what?
- Ratio of beneficials to pests in controlled experiments
- Number of pests consumed per beneficial per day
- Number of pests or beneficials that died from causes other than interaction.
- Conditions of controlled environments (e.g., temperature, sunlight, watering, etc.).
- General observations and observations of insect interactions and behavior.

Step 6 Identify the Next Step

We would hope that this section has opened a whole new world for you. We have touched only superficially on the intricacies of biological control. We hope you are led to more in-depth investigations!

RESOURCES

Brown, Vinson. How To Follow The Adventures Of Insects. Little, Brown, and Co.,Boston. 1968.

Daar, Sheila and Helga Olkowski. Common Sense Pest Control. Taunton Press: Newtown, CT. 1991.

Flint, Mary Louise. Pests of the Garden and Small Farm: A Grower's Guide to Using Less Pesticide . Division of Agriculture and Natural Resources, University of California: Oakland. 1990

Jordan, William. Windowsill Ecology: Controlling Indoor Plant Pests with Beneficial Insects.

Price, P. W. 1984. Pp 19-50 in C.B. Huffaker and R.L. Rabb (Eds.), Ecological Entomology. Wiley, New York.

Starcher, Allison. Good Bugs for Your Garden**.** Algonquin Press. 1995

World Wide Web: Cornell University's Biological Control Home Page: URL: http://www.nysaes.cornell.edu:80/ent/biocontrol/

Beyond Pesticides: Biological Approaches to Pest management**.** Division of Agriculture and Natural Resources, University of California. ANR Publication Number 3354. 1992. (Check your local Cooperative Extension Office or order from ANR Publications, University of California, 6701 San Pablo Ave., Oakland, CA 94608-1239

Attracting and Keeping Good Predators as a Bio Control.
Cornflower Farms — P.O. Box 896, Elk Grove, CA, 95759
Ph. 916-689-1015, fax 916-689-1968 contact: Jeff Chandler
This company provides a beautiful catalog on plants and the beneficial insects they attract and feed throughout the year.

Gardens Alive! catalog
5100 Schenley Place
Lawrenceburg, IN 47025
ph: (812) 537-8650
FAX: (812) 537-5108

Native Sons (Dave Fross) Nursery in Arroyo Grande has all the plants listed in the Cornflower Catalog.

Video — Bio Control by Natural Enemies by USDA 20 minutes in length. Could be used to set the stage for bio control investigations on pests and predators.

UC - Integrated Pest Management (IPM), poster of beneficials, $5.00. UC Farm and Garden Publication.

INSECT SUPPLIERS

Rincon - Vitova Insectaries, Inc.
P.O. Box 1555
Ventura, CA 93002
805-643-5407 or 643-3169
P.O. Box 95, Oak View, CA 93022, 805-643-5407. They are involved in education and will work with you to decide what to order for your experiment. Consider sharing the cost of an order with a friend.

Dan Bigham supplier of parasitoid wasps 209-564-2620
ecto-parasitism -Goniosis

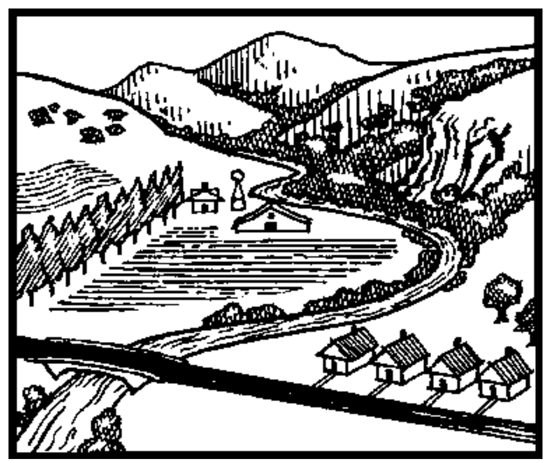
Sustainable Land Use

"The closer that you can have it to like nature would have it
the better off you are in the long run. It's more economically sound."
Rancher, Horse Heaven Creek, Oregon

Step 1 Introduction

The burning question is how to develop systems to farm, graze, log, and generally live on the land in our watersheds that are sustainable over the long haul. Wes Jackson, a leading thinker in the sustainable agriculture movement, speaks of our country's tradition of "going west to find freedom, abandoning worn-out land to cultivate virginal pasture... If we look at the land as a nurturing mother ... we might see that true agricultural freedom is not the freedom to *go*, but the freedom to *stay*." This is our only planet, and this is our only water.

Sustainable design, whether of farming, grazing, pest control, or urban landscapes, looks to understand and work with systems, the "big picture." John Wesley Powell, statesman and explorer in the late 1800s, concluded that watersheds were the only logical geographical land use planning tools. Now, over 100 years later, we begin to heed his wisdom.



This section is going to help you examine how we design our communities, with an eye to working **with** the natural systems of the watershed rather than **against** them.

Plants, animals, and water can all work together in a well-functioning watershed to maintain a certain amount of stability to the way water flows through the watershed and to protect the quality of that water. Whether it is an urban or industrial development; logging, ranching or farming operation; or just Jessie Normal going about his/her daily life, whatever is done in the watershed should be done with a few cardinal rules in mind.

- **Slow** the movement of the water over the upland areas of the watershed and **soften** the watershed, giving water both the **time and opportunity to soak in** rather than run off.

- **Protect and stabilize the creek banks.** Even in highly urbanized areas, long term experiments in bio-engineering - the integration of plants into creek bank engineering design - have shown that the plant component provides much higher long-term stability than traditional engineering techniques alone.

- **Give the creek adequate space** to adjust its meanders as conditions change upstream in the watershed. This may involve re-establishing the meanders that are hydraulically appropriate for that particular creek if the creek has been altered.
- **Be aware** that what goes on the land may end up in the water. Consider the unintended environmental effects of toxics, and design ways to clean the water that comes off the streets and farms.

Thus far we have been fairly successful in cleaning up the pollution that enters our waters via pipes. The source of this type of pollution is obvious, and one needs to work with the owner of the pipe to get it cleaned up. Our biggest water pollution problems now come from diffuse sources, sources you can wave at rather than point to.

It's that old, nagging problem of cumulative effects. Whatever chemical, soil or water runoff comes off my tiny little lot may be insignificant, but what comes off 10,000 little lots begins to add up!

We are often told that people need to balance economic needs with the needs of the environment. If you think long-term like the rancher quoted above, you may find that the two needs are one and the same!

Step 2 Messing Around

You are going to take a field trip to look at ways that people act as "good neighbors" in your watershed. This is actually a wonderful exercise since you get a chance to see all the creative, outstanding solutions to problems that people have developed. We have suggestions here, but there may be opportunities in your watershed that we haven't even thought of. Explore any of them, using the general guidelines below.

Materials you will need

- Watershed journal
- Aerial photographs or satellite imagery of the watershed. Often available through City or County Planning or Agriculture departments, Colleges, Cooperative Extension, State Water Resources, and the Natural Resources Conservation Service.
- Camera (optional, but would be a great asset)
- Transportation (bicycle, car, or your own two feet)
- USGS Topographic map of the watershed (Found at sporting goods stores)
- Compass

Procedure

- If you are interested in studying grazing or farming issues, contact the local Cooperative Extension office or the Natural Resources Conservation Service. Tell them you are interested in watershed issues, discuss the keys points of the **Introduction** to this section, and ask to examine their prize demonstration projects.

- If you are interested in looking at urban issues, contact the local City or County Planning Department. Tell them you are interested in watershed issues, discuss the keys points of the **Introduction** to this section, and ask to examine their prize demonstration projects.

- Cruise the Internet looking for creative projects that people around the world are involved in. G.R.E.E.N., Global Rivers Environmental Education Network, has an Internet address: <green@green.org>.o or WWW at <gopher:// gopher.igc.apc.org/00/orgs/green>

- Locate aerial photos or satellite imagery of the place you want to visit. Make photo copies if possible.

- Contact the landowner if necessary, and then visit the site.

- Take your maps, photos and Watershed Journal with you and make notes of ways the site has dealt with the issues of interest.

  * **For cattle ranchers**: ask about innovative grazing techniques that attempt to deal with water quality. Have springs drying up been an issues for them? What practices do they use to keep springs and creeks running during the dry season? Holistic Resource Management by Allan Savory is an excellent resource on understanding and working with systems, especially grazing management, and planning around multiple goals.

  * **For farmers:** What types of practices were used to increase percolation? Minimize runoff? Protect streams from excessive sediment? Minimize chemical use? etc.

  * **For urban developments:** What types of solutions are land use planners using to deal with problems associated with their projects?
    - How are they contending with potential flooding? Are they using detention basins to slow down the peak flows during a storm event?
    - What opportunities are there for groundwater recharge: natural or constructed wetlands; detention ponds; retention dams; lots of permeable surfaces, depressions, or gravel basins for house downspouts; rocked drains etc.? How do soils on the site affect the selection of a ground water percolation design?
    - How are they dealing with pollution associated with runoff? Are they constructing wetlands that filter pollutants?
    - What alternatives are there to dealing with some of the solid waste generated by the project? Is community composting an option?

If you don't like what you saw in your community and want to research some state-of-the-art approaches, try one of these books: Sustainable Communities by Van Der Ryn and Calthorpe; Design for Human Ecosystems by John Lyle; and Design With Nature by Ian McHarg. Landscape Architecture put out an issue specifically on sustainable design (January, 1994). Find it in university libraries or by writing to Landscape Architecture, 4401 Connecticut Ave., NW, 5th floor, Washington D.C., 20008-2302. Ph: (202) 686-2752.

Step 3 Identifying a Question

Grazing and Land Management

- What information did you find on plants or grazing techniques that maximized water infiltration into the soil and minimized erosion? You test could for these in similar pastures under different grazing management with erosion troughs (see **Dirt Made Our Lunch**) and infiltration experiments (see **Life Blood of the Earth**).

- Are some grasses seen as more valuable than others from a standpoint of both productivity and land stability? How are ranchers working to increase the percentage and diversity of valuable plants on their range? Do these techniques work?

Land Use Development

- Consider doing a site analysis and developing a design, focusing on watershed issues, for a site slated for development. (This is **Investigation #3**) You should consider at least:
  - topography: slope and aspect
  - water drainage patterns and channels: this includes creeks, swales, and sheet flow over the hillside
  - vegetation and wildlife analysis

  In the course of developing your design, keep in mind the “big picture”. Be careful to look at how your designs affect the whole system, both upstream and downstream neighbors. Geographic Information Systems (G.I.S.) computer software may be a useful tool for looking at or creating a model of the “big picture”.

- Try building a scale model of your design. You could do some testing of your design with respect to water flow. For guidance in constructing models to scale refer to Environmental Awareness Education Program: Built Environmental Education Program (B.E.E.P.) by the Central Coast Chapter of the California Council of the American Institute of Architects (CCAIA), Education Committee, by Dan Conwell (editor). The San Luis Obispo County Superintendent of Schools or School of Architecture and Design at California Polytechnic State University, San Luis Obispo can be contacted regarding copies of this document.

Wetlands

- Analyze the design and performance of innovative designs you found for dealing with wetlands and creeks. Document this. What is really great about this is that someone else did all the work building your experimental hardware! You could check how much water the detention basins held during a given rainstorm, how slowly they released water, how high the downstream channel was filled, what other functions the detention basin serves.

- Constructing your own wetland may provide insight into how wetlands function as wildlife habitats, natural drainages, and natural filter systems. Books such as Water Gardens by Peter Stadelmann and The Family Water Naturalist by Heather Angel and Pat Wolseley may provide useful information on these subjects.

- Learn more about how wetlands function as natural filters and how specific wetland plants that act as filters for toxic materials. Set up a wetland to test the effectiveness of these. Fragile Ecosystems by Barbara Matilsky discusses projects using plants to absorb heavy metals.

Step 4 Approaching the Question
Experimental Design and Collecting Data

You may choose to do an tightly controlled experiment or comparison of the effects of different land treatments. If so, it will be worth your while to re-read the **Science, The Watershed And You** section on experimental design and data collection.

You may choose to do a site design based on your findings from library research. This does not involve the rigors of actual testing of a hypothesis, but you must

- outline your design criteria
- justify your decisions for choosing those criteria
- choose your design
- justify your design choices

Ideas For Investigation
Investigation #1 What's Up in the Wetland?

Background

In this investigation you will have an opportunity to conduct an experiment using a small constructed wetland with aquatic plants. Wetlands and the plants that grow in them can act as an excellent filter for pollutants. Water moving through a wetland is slowed and particles such as suspended sediment are dropped. The aquatic plants can also change the water chemistry by using up the excess nitrates and phosphates, and perhaps even buffering the pH.

Decide on a precise research question.
- What is the effect of a certain type of aquatic plant on pH and nitrate and phosphate levels in a constructed wetlands?
- Which type of plant, or combination of plants has the greatest beneficial effect on pH and nitrate and phosphate levels?
- How fast do pH and nitrate and phosphate levels change in wetlands with specific aquatic plants?
- Other?

Materials You Will Need
- Watershed journal
- 2 or more plastic tubs (Holds 5 to 50 gallons of water)
- Water to fill the tubs
- Rocks and mud for the bottom of the tubs
- Various aquatic plants (See list in Appendix C) Note: Many nurseries are beginning to carry aquatic plants. If a local nursery doesn't carry aquatic plants, maybe they can tell you where you can order them.
- "Runoff water" - Mix several tablespoons of laundry detergent with the water in each tub. Add a few tablespoons of high nitrogen and phosphate fertilizer. This will simulate wash water and fertilizer runoff from your yard.
- Thermometer
- Nitrate test kit - aquarium supply store
- Phosphate test kit (optional)
- Wide spectrum pH paper
- 2 small aquarium pumps (optional)

Procedure

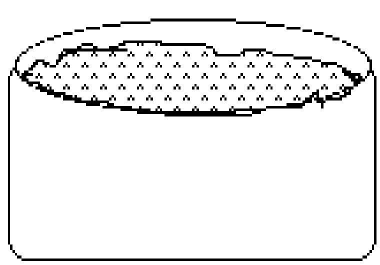
- Mix your runoff water brew. Keep careful track of the amounts of fertilizer and detergent added. Test the water for pH, nitrates, and phosphates.

- Prepare two tubs with rocks and soil. They should be as similar as possible. Refer to “Recommended Reading” for books on how to construct a small wetland garden. Books on water gardens are also available at the library.

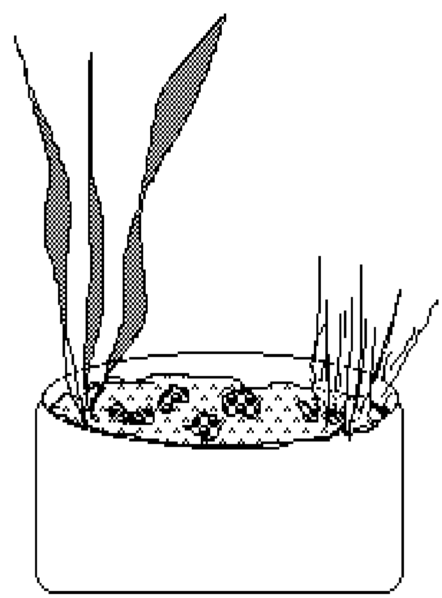
- Determine a method for oxygenating the water in the tubs. You can use small aquarium pumps or scoop and dump the water out and back into the tubs every so often to oxygenate the model wetlands.

- Add aquatic plants to one or more of the tubs according to your specific research design.

- Track the changes in pH, nitrates and phosphates over time. Compare the water quality in your aquatic systems.



Control Tub



Experimental Tub

Investigation # 2 Grazing and Land Management

Background

Well grazed pasture lands support good above ground plant cover to slow the water as it flows over the surface, allowing more of it to absorb into the soils. The thick mat of roots also work to hold the soil in place. Perennial grasses are particularly valuable since the roots of these grasses may reach depths of more than 10 feet. Deep roots provide channels for deep water infiltration. These same roots can bring deep minerals to the surface and make dry season use of the deeper moisture. Pastures rich in these perennial grasses both function well hydrologically and often support better livestock growth since they provide high quality feed for longer in the season.

Along creek banks, the incredible root mat of wetland plants such as sedges hold the soil of the creek bank and help the creek stabilize into a deep, cool, narrow channel capable of supporting valuable cool water fish such as trout.

Ranchers usually have a number of objectives for their grazing lands.

- Increase plant diversity. An increase in plant diversity leads to higher nutrient values in the forage and higher cattle productivity
- Increase the density of perennial grasses since perennial grasses have a longer growing season than annual grasses.
- Increase cover. Increased cover prevents erosion.
- Decrease the less palatable species such as thistles, rip gut brome and mustard

Pastures can show many different conditions. And you can find all these conditions in a single given pasture if it is not managed properly. Cows tend to camp out in the shade near the water where the plants are greenest - and this means along the creeks and other wetlands. A single large pasture that gives cattle unrestricted access to the creeks may have some areas that are ungrazed and show signs of over-rest; areas that show signs of proper grazing; and other areas, particularly along creeks, that show signs of severe over-grazing. One goal of a good rancher is to manage his cattle in such a way as to have the forage in the pastures used evenly.

- **Signs of a properly grazed pasture:** Perennial grasses do best when last year's dead growth is mowed or grazed off. This allows sunlight to reach the crown of the plant to stimulate new growth. Animals' hooves also work to break up the capping of the soil surface and provide little dips and depressions- suitable microclimates for the germination of new seedlings. Diversity of desired species is high. Enough residue is left to slow water movement over the soil, allow for infiltration, and prevent erosion.

- **Signs of an overgrazed pasture:** Most of the palatable plants like perennial grasses are eaten to the ground and the undesirable plants like star thistle remain. Frequent heavy grazing of a plant like a perennial grass prevents the plant from ever building up strength. The root system weakens, the plant loses productivity and may even eventually die. Overgrazed pastures have little residue left on the surface, so water runs off rapidly, preventing groundwater recharge and increasing erosion in the creek channels. ("Tips on Land and Water Management for Small Farms and Ranches in Montana", USDA Natural Resources Conservation Service)

- **Signs of an over-rested pasture:** Over-rested pastures do not have the previous year's growth removed by the cattle and they lack the hoof action needed to break up the soil capping and create microclimates for new seedlings. Often the perennial grasses are large, but show little actual new growth. Cover is high in these pastures, at least for the first few decades. Studies indicate that eventually, over many years, the spacing between individual perennials grows larger, few new seedlings emerge, and cover actually declines.

Materials Needed
- Watershed Journal
- Measuring Tape
- Throwing Dart
- 2 Yardsticks
- Ruler
- Roll of string or flagging tape
- Stakes
- Ziplock style bags for collecting plants
- Camera

Procedure

- Talk to local ranchers, universities, or Cooperative Extension to locate various grazing conditions. Find one site each for the following condition (it's OK if you can only find two sites for comparison).
    - over-grazed
    - over-rested
    - properly grazed.

  Remember that you may find all three conditions in the same pasture since livestock may use different parts of the pasture differently!

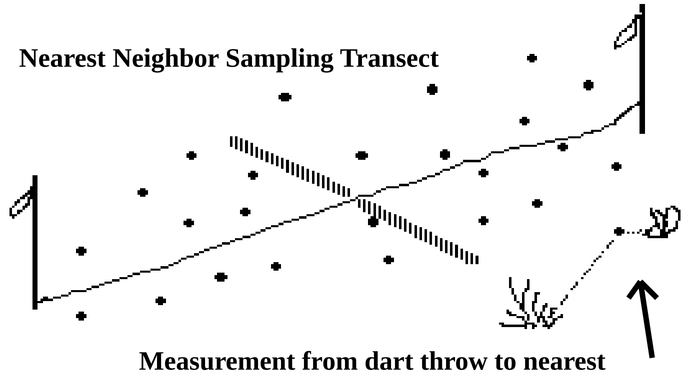
- Get permission from the landowners to conduct your study on their property.

- Learn about the differences between annual and perennial grasses. Try to identify the dominant perennial and annual grasses and undesirable weeds that grow in your area. Ask the ranchers or local plant specialists for help.

- Begin a data sheet in your journal for each site indicating:
    - location
    - range condition: over-grazed, over-rested or properly grazed
    - soil type (Soils Maps are available through Natural Resources Conservation Service)

- You will be sampling along one or more transect lines for each site using a sampling technique called Nearest Neighbor. Transect data is best taken in the spring when the plants are big enough and green enough to be identified!

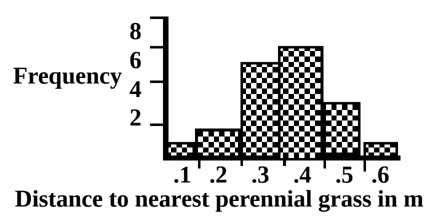
- Randomly select a starting point for the transect line. You can throw something over your shoulder to randomly select a starting point.



- Measure a transect line 50 feet in length. Mark the ends of the transect line with a stick. Stretch bright flagging between the sticks and place a yardstick on each side of the transect line, crosswise. These markings will help you to keep your dart throws within one yard of the line.

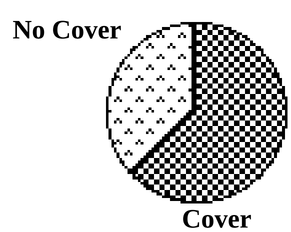
- Take a photo of the transect area. It is best to have a landmark such as a utility pole, tree or hill top in the photo for reference.

- Begin at one end of the transect line and randomly throw the dart somewhere near the transect line. You will be gradually moving along the transect line, randomly throwing the dart until you have 25 data points. Beginning with your first dart throw you will collect the following data:
  - Record what is directly beneath the dart point
    - bare soil
    - plant (Identify or collect a sample plant to be identified later. Collect the whole plant if it's smaller than a shrub. It's really hard to identify a plant from one measly leaf! Label the bags with the site name and point number!)
    - Duff or decomposing matter
    - gravel or rocks
  - Measure and record the identify of, and distance to, the nearest plant.
  - Measure and record the distance to the nearest perennial grass. Use ruler or measuring tape.



- Record the information for each of the twenty- five data points along the transect line in your watershed journal.

- For each site:
  - tally the number of different plant species,
  - Graph the distances to nearest perennial grass. Calculate the average distance between the dart and the nearest perennial.
  - Indicate "cover" (plant or duff material) or "no cover" for the each dart point. Illustrate the "cover" data on a pie chart by showing: % of data points with "cover", % of data points "no cover". You can obtain 100 % by multiplying the data points by 4. For example, 10 points with cover = 40%.



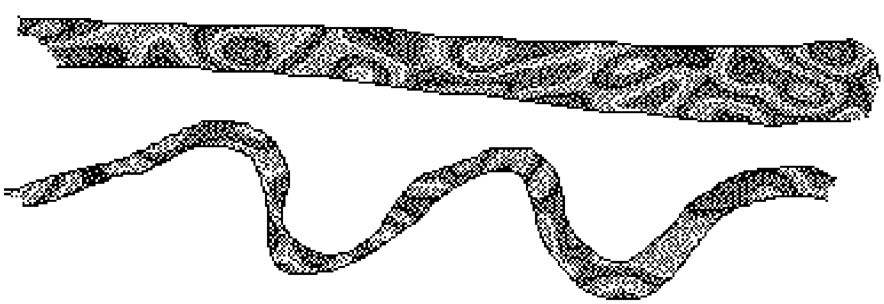
- Compare the results between the various sites. How widely spaced are the perennial grasses at each of the sites? Which site had the greatest diversity of desirable plants. Which had the greatest number of undesirable plants?

Investigation # 3   Land Use Development

Background

Most large development sites will have at least one reach of creek to deal with. The hard engineering approach of the past decades has been to straighten, widen, and berm the creek channels and to drain the wetlands so there would be more safe places to build and grow crops. The reality has been that as water is directed more rapidly into the creek system from harder, less absorptive watersheds, there are **more** events in which the creek channel capacity is exceeded and floods occur. Buildings that were placed in the supposedly "protected" flood plain now flood with increasing frequency. Over the decades that we built flood control projects, the cost of flood damage has actually escalated! (Leopold, 1994)

Many creek channels were widened and straightened to speed up the water. Banks were often stripped of vegetation by improper grazing or an attempt to "neaten things up." Over the ensuing years the water in these channels has sought to re-establish the curving meanders that are found in all undisturbed creeks. The meanders serve to slow the water and dissipate its energy. When you look at natural systems, especially those that are affected by water, you can see one pattern that stands out from all others. **Nothing comes in a straight line.** There are reasons this is true. Streams, by nature of the bipolar molecular structure of water working in concert with the soils and rocks the water flows through and past, will make meanders and curves that are actually quite mathematically regular. (See Luna Leopold & article from Water Journal.)



Which shape best describes your creek channel: a snake or a rod?

Design for a community should consider dealing with the diffuse, or non-point source, pollution coming off the lawns and streets. Wetlands may be one component of such a design. Wetlands can filter sediment, trap nutrients, and allow for groundwater recharge.

For this investigation we ask you to find a development site and conduct a site analysis of the design. You will evaluate how the developer has proposed to deal with watershed issues. You will be asked to develop your own set of design criteria and considerations for this development site. How can you increase opportunities for ground water recharge? Can a wetland be incorporated into the design to offset the effects of non-point pollution and increased runoff from newly paved surfaces? Is composting encouraged in the design of the project? Are the plants appropriate in terms of water usage and their microclimate? This will be an opportunity to creatively use everything you know about watersheds and land use management.

Materials Needed
- Watershed journal
- For a development site obtain the following:
  - Site development plan
  - Drainage plan
  - Soils Map
  - Vegetation map
  - Topographic Map
  - Wildlife Survey
  - Aerial photos (optional, but helpful)
- Camera
- Large sketch pad
- Construction paper
- G.I.S. software (optional)

Procedure

- Research the topic of sustainable communities: you'll find a list of some of the classics in the **Reference** section.

- Develop a set of watershed related criteria and a list of potential solutions that you consider critical to any design.

- Find a development site for investigation. You may know of one through the newspaper or talk to city and county planners and ask them to recommend a site. You could even work on a very small scale: redesign your own home and yard!

- You will need access to topo maps, soils information, drainage plans and the site development plan. Get as much information about a site as possible.

- Get familiar with the site development plan using all the maps and information available to you. Ask for help if there are aspects of the plan that you do not understand. It may take some practice.

- Go out to the site and look at it. Take the site development plan, your sketch pad, and your criteria/solution list with you.

- Examine the existing conditions. Get a sense of where buildings, drainage basins and roads from the plan will actually go. Sketch your own ideas of what should go where.

- Go home and play with your ideas. You may want to draw out a design or even build a model to scale using old file folders or cardboard. A model like this will give you an opportunity to move things around and devise many alternative designs.

Make buildings, drainage ways, detention/retention ponds, wetlands, roads, parks, greenbelts and wildlife corridors. Do you want to orient the houses to be able to take advantage of solar heating? Can the creeks be made into linear parks, thus providing for recreation and preventing flood damage simultaneously? Feel free to completely redesign the whole thing!

- Explain your site design decisions.
- Most important, if this site is still under consideration, it has to go through a series of public hearings. Present your design at the public hearings along with a concise statement of the key issues you think need consideration.

Step 5 Analyzing the Data

Your project here may not have been highly experimental, especially if you chose project design. Your analysis will center on your rationale for your particular design in terms why you selected your specific goals and how you think your design will perform to meet those goals. It will certainly be a stronger project if you do the mathematical calculations necessary to back up your statements. (See **Investigation # 3 How Has My Watershed Changed?** in the Flow section)

Step 6 Identify the Next Step

Your next step may be to do further research on a particular subject. It might also be to become more involved in your community's efforts to understand and protect its watershed. There are some wonderful projects going on all over the country. Cruise the Internet and World Wide Web for contacts and inspiration. Cruise your own community for projects. We'll include a few samples to whet your appetite.

- "No Dumping to Drains" program: Community groups have been stenciling pictures of fish on the sidewalk above the storm drains to remind people that whatever you dump in the gutter ends up directly in the creek. One community even stenciled a trail of fish and amphibians over the sidewalks and across roads to mark the trail of a creek that has been put underground and through culverts when the are was developed. See Appendix B for a "How to Guide" about doing a program like this in your community.

- Estuaries are places of critical concern - there aren't many left that are anywhere near their natural state. There may be some great research or education programs you could tie into.

- There are groups all over the country doing things like digging up creeks that had been put underground years ago to create new community parks, re-planting disturbed creek banks, playing squirrel and planting hundreds of acorns or other tree seeds in barren lots and in parks in need of trees; attending workshops and conferences with names like "Friends of Trashed Rivers." Get connected! Get Involved!

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