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Watershed Evaluation

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The Impact of Land Use on Water Quality – a Watershed Evaluation from Canoes

NCSR curriculum modules are designed as comprehensive instructions for students and supporting materials for faculty. The student instructions are structured in a "generic format" designed to facilitate adaptation in a variety of settings. Where appropriate, the generic version is augmented by a specific instructional module taught in the Pacific Northwest. The purpose of these specific versions is to provide those who are adapting modules greater insight into how the materials are used in a teaching/learning environment. In addition to the instructional materials for students, the modules contain separate supporting information in the "Notes to Instructors" section. The modules may also contain other sections which contain additional supporting information.

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The Impact of Land Use on Water Quality - Module Description

This module provides information on conducting a multiple session classroom, laboratory, and field-based experience to determine the impact of non-point sources of pollution on watersheds. The module is comprised of the following instructional sessions:

1. A preparatory classroom/laboratory activity in which students use remote sensing and Internet sources to gain a greater understanding of the watershed under study.
2. A field experience in which students evaluate the impact of land use on water quality through direct observation and measurement using canoes to access the sampling and observation points on the river.
3. An analysis laboratory in which students measure additional water quality parameters from field samples and evaluate the relationship between land use and water quality.

NOTE: Significant portions of this activity may be implemented without access to canoes. If canoes are not available, the preparatory classroom/laboratory activity (Session #1) and the analysis laboratory (Session #3) may be implemented without modification. The field activity (Session #2) will need to be modified as follows:

- Sampling points at various locations in the stream will need to be identified and accessed from shore
- Observation of land use in the watershed is most problematic and will need to be made by walking sections of the stream on shore. If an elevated vantage point is available some observations may be made from there.

SESSION 1: Laboratory Portion

Introduction

The availability of clean water is routinely among the top environmental concerns in public opinion polls. While great strides have been made in improving water quality in the United States in the last 40 years, most of this progress is due to reducing **point sources** of pollution such as outputs from factories or wastewater treatment plants. These sources are relatively easy to identify and have been curtailed through regulation and improved technology. By contrast, **non-point sources** of pollution – runoff from broad, usually poorly-defined areas such as agricultural fields or large urban areas - have proven more difficult to address (Fig. 1). Today, approximately two-thirds of pollution in rivers and streams originates from these non-point sources.

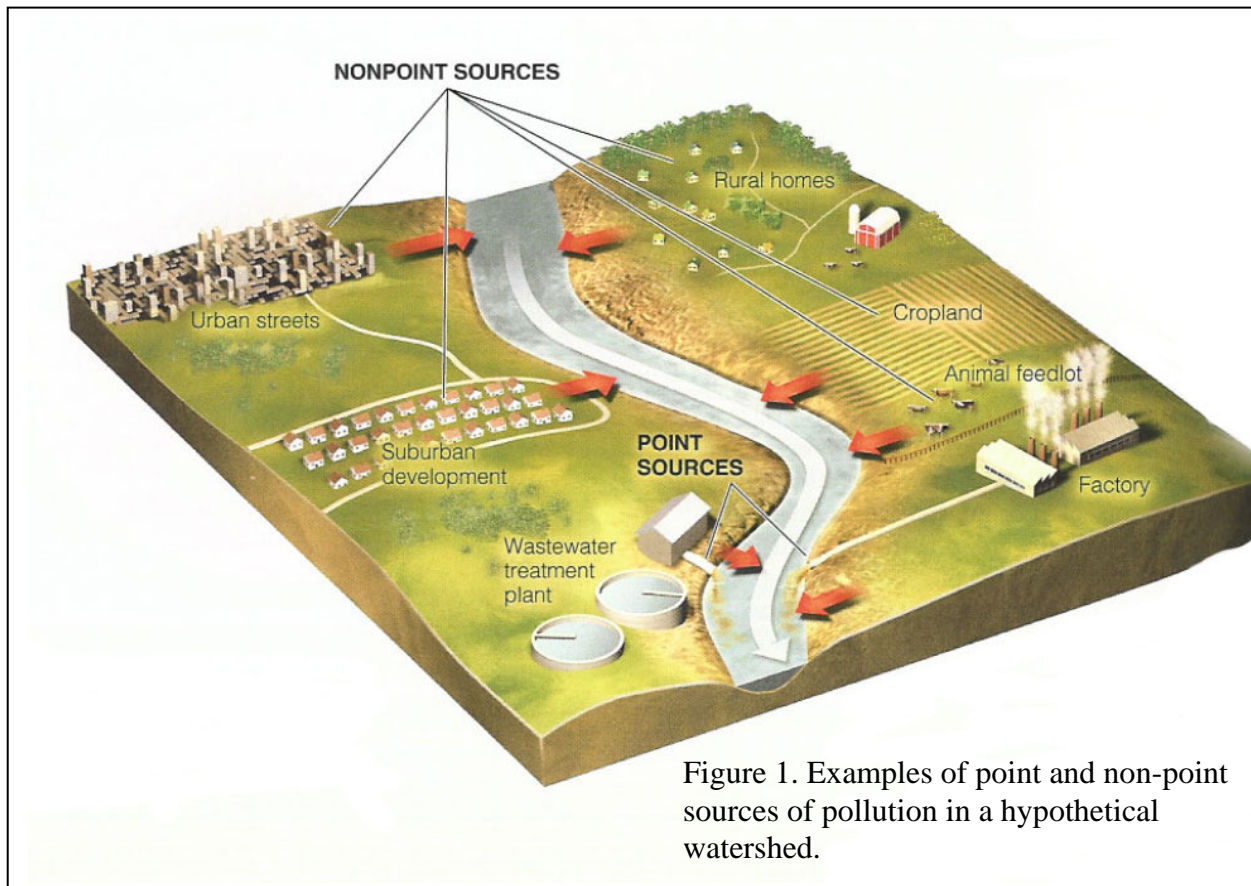


Figure 1. Examples of point and non-point sources of pollution in a hypothetical watershed.

Until recently, the conversion of natural landscapes to human-dominated lands, such as agricultural lands and urban areas, was considered a local phenomenon. It is now clear that land use practices have impacts that occur at regional and even global scales and that these practices have a significant impact on environmental quality. Air and water quality, wildlife habitat, and

forest health, for example, may all be impacted by changes in land use.

In this laboratory students begin an evaluation of the impacts of land use on the water quality of a local river. The concept of a river as part of a watershed and the influence of surrounding lands on river characteristics such as temperature, water quality, fish and wildlife is emphasized. The activity is conducted over three sessions. The first is a preparatory classroom/laboratory activity in which students use remote sensing and Internet sources to gain a greater understanding of the watershed under study. The second component is a field experience in which students observe and record land use characteristics in the watershed and measure water quality parameters. In contrast to most river-based curriculum which measures water quality values at a single location accessed from shore, this activity places students "on the river" where they are better able to appreciate its dynamic and interconnected nature. The third session is dedicated to the interpretation of water quality measurements and a synthesis of the results.

Objectives

Upon completion of this laboratory students should be able to:

1. Use various Internet sources of imagery (topographic maps and aerial and satellite images) to visualize a watershed
2. Determine land use and ownership in a watershed
3. Predict potential impacts of land use on water quality
4. Make recommendations for interventions that could be made to improve water quality

Procedure

The Use of *NASA World Wind* in Watershed Analysis

World Wind is open source software that provides access to high resolution aerial and satellite imagery. Imagery is available for the entire Earth's surface and layers may be applied for elevation, terrain, roads and a number of other features. *World Wind* can be downloaded for free at <http://worldwind.arc.nasa.gov>. The user interface features the ability to "search", "navigate", "zoom", "tilt" and "rotate" and to run some canned simulations. Vertical exaggeration can be manipulated to improve visualization of hilly terrain. Several "layers" of satellite and aerial imagery are available that allow you to image any place on Earth. Three-dimensional views of terrain are based on various sources of Landsat satellite data. Coverage for these images is excellent (worldwide) but resolution is significantly less (30 m/pixel) than other layers described below. Unlike *Google Earth*, *World Wind* features U.S. Geological Survey (USGS) topographical maps for the most areas in the United States.

Some high resolution images are also available. For example, USGS Ortho Imagery is particularly useful and available for most areas in the United States. This layer allows for high resolution (1 m/pixel) viewing of 3-D aerial photography. *World Wind* also features USGS

Urban Area imagery for selected cities which provides images of very high resolution (0.25 m/pixel). This allows the user to view urban landscapes in dramatic detail to the level of seeing individual buildings and cars.

The date of the images depends on the data source for each layer and varies from about 1990 to 2004. USGS topographical maps may be somewhat older. It is unlikely that you will be able to see the world in real-time using these tools anytime soon. Images are public domain, thus educational use of these images does not require copyright permission.

Minimum System Requirements

Windows 2000 or XP
700 MHz CPU
128M RAM
1GB disk space
3-D graphics card
Internet connection

NASA World Wind is an excellent place to start for analysis of a watershed primarily because it allows 3-D viewing of USGS topographic maps for most areas in the United States. On these maps differences in elevation are indicated by contour lines which can be visualized using the controls provided by the software.

Examination of USGS Topographic Maps

1. Open the *NASA World Wind* program and use the "Place Finder" icon to locate the watershed under study. Under "Look for place named:", enter the name of the river or a nearby town and click, "Go". Move your location by dragging the *left* mouse click. Zoom in for a closer look by rolling the scroll wheel on your mouse or, alternatively, holding both mouse buttons down and pushing *forward* to zoom in and pulling *back* to zoom out.
2. Click on the "USGS Topographic Maps" icon to activate that layer.
3. Become familiar with the entire watershed study site by following the river from its entry into a major river, bay or the ocean to its source in the uplands. Use the "zoom" function to view in greater detail. On most rivers, distance along the river is indicated with the symbol "X" every mile. These so-called "river miles" can be used as benchmarks to locate features in the watershed.
4. The three-dimensional aspects of a watershed can be viewed by "tilting" and "rotating" the image. Drag the *right* mouse click to control these features. "Travel" through the study watershed to familiarize yourself with these controls.
5. Turn your attention to the lands immediately adjacent to the entire river. Land

ownership plays a significant role in how that land is managed and broad categories of ownership can be determined from the USGS maps. Public lands and their boundaries such as national and state forests, county parks, wildlife refuges, etc. are clearly indicated on these maps. Lands without any designation can be assumed to be owned by private landowners.

6. Note the distribution of forests (green areas) and non-forested areas (white) on the maps. Pay particular attention to those lands immediately adjacent to the river.
7. Note any other features (e.g., towns, roads, levees, parks, dwellings, etc.) along the river that have the potential for impact on water quality or aquatic habitats.

Examination of USGS Digital Ortho Photos

USGS Digital Ortho Photos provide high resolution (1m/pixel) images that can be used to visualize the watershed in great detail in three dimensions. Images are in black and white and are particularly useful to obtain detail on land use in the watershed. Features such as agricultural land, clearcuts, and forests of different ages can be easily distinguished from one another based on tonal and textural differences.

1. Click on the “USGS Digital Ortho Photos” icon to activate that layer.
2. Re-examine the watershed as above using this imagery.

Examination of Landsat Imagery

(OPTIONAL ACTIVITY or DEMONSTRATION)

Since 1972, NASA has launched a series of earth observation Landsat satellites. Seven such satellites have been launched providing a 33-year old record of the Earth's continental and nearby ocean surfaces. The resulting imagery provides unprecedented access to data critical to land surface monitoring and global change research. Landsat 7, the latest in this series, was launched on April 15, 1999 and continues to provide high quality data.

NASA World Wind provides various layers of Landsat 7 imagery that are useful in watershed evaluation. This imagery presents some advantages and disadvantages over the USGS imagery. The primary advantage is that the coverage is worldwide as opposed to only U.S. for USGS imagery. Also, since both 1990 and 2000 imagery is provided, comparisons can be made between them to view land use *change* over time. The primary disadvantage is that resolution is lower (30 m/pixel) and thus, less detail can be seen. Landsat layers available include Community Landsat 7 (pseudo-color), Landsat 7 Geocover (1990 and 2000) and NLT Landsat 7 (pseudo-color). This imagery is best suited to viewing broad-scale patterns such as landforms, forest harvest patterns, urban and rural development patterns and agricultural land use.

As an example of the capabilities of Landsat imagery, investigators have used Landsat images to

examine crop diversity in California's Imperial Valley. More than 25 separate crops were identified in nearly 9000 fields covering 458,000 acres. The entire study which used only Landsat imagery required only 45 person-hours to complete. Such inventories are a critical tool used in crop forecasting which in turn is used to plan for future labor, fuel and transportation needs over a wide region.

For more information on Landsat see <http://landsat.gsfc.nasa.gov>

The Use of *Google Earth* in Watershed Analysis

Google Earth is a source of high resolution aerial and satellite imagery that is available for free download (<http://earth.google.com>). Imagery is available for the entire earth's surface and layers may be applied for elevation, terrain, roads and a number of other features. Users can easily navigate from one location to another using a mouse, keyboard or navigation controls provided with the software. Although the resolution varies from site to site, at many locations users can zoom in to the level of individual trees and buildings. Users can search for rivers, towns, business addresses and latitude and longitudinal coordinates. The user interface is intuitive and can be easily learned by faculty and students.

Other features include the ability to mark separate study sites and "fly" to them for more detailed study. Elevation data are provided and can be manipulated to exaggerate the elevation effect. A "tilt" function allows users to change their perspective while viewing hilly terrain. Distance between features and the dimensions of features can be measured with a measuring tool. The user defines the endpoints for the line as well as units of measure.

For all of its strengths (cost, ease of use, availability, etc.), *Google Earth* does have some drawbacks. The resolution of images is uneven. In some areas individual trees can be resolved while in others, high elevation images can be seen clearly but zooming in results in images that are unclear. USGS topographic maps are not available with this software. Advanced features such as measuring distance along a user-defined path and determining area within polygons are available, but these come only with *Google Earth Plus* and *Google Earth Pro* versions which must be purchased.

Minimum System Requirements

Windows 2000 or XP
Pentium 3, 500 MHz
128M RAM
400MB disk space
3D-capable video card with 16Mbytes of VRAM
Internet connection

Procedure

1. Follow the coordinates provided by the instructor (or alternatively, enter a river or nearby town name location) to "fly" to the watershed under study.
2. To become familiar with the study site, follow the river from its source to its entry into a major river, bay or the ocean.
3. Use the "rotation" feature and the "tilt" feature to get various 3-dimensional views of the study watershed. Try changing the **elevation exaggeration** ("Tools", then "Options") from the default setting of "1" to "2" or "3". This feature will exaggerate the appearance of elevation changes and should assist you to visualize the watershed. Try navigating through the watershed moving upstream. With careful observation you should be able to determine its approximate boundaries. The boundaries will appear as ridge tops.
4. Identify the major land uses along the length of the river under study. Possible categories may include:
 - Forest
 - Agricultural
 - Urban
 - Residential
 - Industrial
 - Disturbed (e.g., clearcut, mine, new excavation)
5. Closely examine the entire course of the river under study and estimate the percentage of the river that is bordered by each of the land uses you have identified in #4. While land use throughout the watershed may have an impact on water quality, for this part of the activity, consider only those lands immediately adjacent to the river or stream.
6. For each land use you have identified in #4, predict the potential impacts of that land use on the water quality of the river or the quality of the adjacent riparian zone by completing the table entitled, "*Impacts of various land use on water and riparian area quality based on examination of remote sensing imagery*". These impacts will need to be inferred from the examination of satellite and aerial imagery you have just completed with *Google Earth* and *NASA World Wind*.

Impacts are divided into **point sources** (localized impacts such as those that originate from the end of a pipe or ditch) and **non-point sources** (diffused impacts such as those that originate from runoff of large land areas).

Enter one of the following into each cell on the table:

0 = no negative impact

1 = minor impact

2 = moderate impact

3 = major impact

X = unable to determine

During the field portion of this exercise you will observe and measure more directly some of these impacts.

Additional Watershed Information

Although *Google Earth* and *NASA World Wind* provide access to a variety of remote sensing imagery, some watershed information is best obtained using other sources. Some examples include the following:

- Fish and wildlife surveys
- Ecological restoration efforts
- Ongoing or planned development
- More specific land use maps
- More detailed information on land ownership
- Water quality monitoring data
- Accounts of historical conditions

Your instructor will direct you to web resources that will provide you with some of this additional information. Visit these web sites and record any information relevant to the connection between land use and water quality for the watershed under study. This information should be incorporated into your lab product.

Impacts of Various Land Use on Water and Riparian Area Quality (Based on examination of remote sensing imagery)

Point Source					Non-point Source								
	Heated Effluent	Volume Extraction	Solid Waste Dumping	Indust. Effluent	Grazing	Inc. Temp.	Stream Channelization	Habitat Loss	Fertilizer runoff	Sediment runoff	Pesticide runoff	Livestock manure runoff	Introd. of invasive species
Forest													
Agricultural													
Urban													
Residential													
Industrial													
Disturbed													

Enter one of the following into each cell on the table:

- 0 = no negative impact
- 1 = minor impact
- 2 = moderate impact
- 3 = major impact
- X = unable to determine

NOTE: Brief descriptions of each of these impacts appear on the following page.

Brief descriptions:

Heated Effluent - waste water released from a pipe or ditch at a temperature higher than ambient water temperature

Volume Extraction - removal of water from river for irrigation or industrial use

Solid Waste Dumping - deposits of usually non-toxic materials (e.g., tires, old appliances)

Industrial Effluent - discharge from any industrial facility (e.g., sewage treatment, chemical plant)

Grazing - livestock access to river or riparian zone

Increased Temperature - resulting from removal of shading

Stream Channelization - straightening of streams by excavation or levees

Habitat Loss - removal or disturbance of any aquatic habitat or vegetation in riparian zone

Fertilizer runoff - observed/inferred runoff from agricultural or residential lands

Sediment runoff - observed/inferred runoff from disturbed lands resulting in increased turbidity

Pesticide runoff - observed/inferred runoff from agricultural or residential lands

Livestock manure runoff - observed/inferred runoff from agricultural lands used for grazing livestock (or livestock access to river)

Introduction of invasive species - observed establishment of non-native, invasive species in river or in riparian zone

Assessment

There are at least two options for assessment. In the first option, students respond to the following questions individually or in small groups and submit a lab product. The second option is a comprehensive final report (suggested content described below) that is submitted individually. Each of these can be customized according to personal preferences and course goals.

OPTION I - Answers to Questions

A. Examination of *NASA World Wind* and *Google Earth* Imagery

1. Land ownership has a strong influence on how a parcel of land is used. Private lands may be owned by small individual landowners who live on-site or large corporations such as timber companies who own large parcels. Public lands may be owned and managed at the county level (e.g., county parks), state level (e.g., state parks, state forests, state roadways) or federal level (e.g., national forests, national wildlife refuges). What types of land ownership are represented on those lands that are immediately adjacent to the river under study? Be specific where possible.
2. What is the relationship between land ownership and water quality? Give specific examples.
3. How would you describe the distribution of forests (green areas) and non-forested areas (white) in those lands immediately adjacent to the river along the course of the river?
4. Why is this important?
5. What other features (e.g., towns, roads, levees, parks, dwellings, etc.) along the river have the potential for impact on water quality or aquatic habitats?
6. Describe these potential impacts.

7. List the major land uses that occur along the length of the river under study and then estimate the percentage of the river that is bordered by each of these land uses. Complete the table below.

Land Use	Estimated percent

8. Is the land use relatively constant along its length or does land use change depending where you are on the river? If land use changes, describe which river segment (e.g., lower segment, upper segment, etc.) each land use dominates and explain why you think this occurs.
- B. Complete the table entitled “*Impacts of various land use on water and riparian area quality based on examination of remote sensing imagery*” as indicated. Submit this completed table with your lab product.
- C. Using Internet sources provided by the instructor, record any relevant additional information in the following categories:
- Fish and wildlife surveys
 - Ecological restoration efforts
 - Ongoing or planned development
 - More specific land use maps
 - More detailed information on land ownership
 - Water quality monitoring data
 - Accounts of historical conditions
- D. Interpretations/Conclusions
1. Based on this analysis, what water quality issues would you expect this river to have? List those specific water quality parameters that you would expect to be compromised and explain why.
 2. What fish and wildlife species would be impacted by the parameters you have listed in #1? Explain why.

3. What benefits are provided by an intact riparian zone that includes a forested zone over 100 m wide?
4. What interventions by public and private land owners would you recommend that would improve water quality in this river?
5. Next week you will be measuring various water quality parameters at three locations in the study watershed (upper, middle and lower portions of the river). Based on what you have observed here, what predictions can you make about the following water quality parameters? Use the following key to indicate relative measurements and complete the table below:

L = Low
M = Moderate
H = High

	Upper reach	Middle reach	Lower reach
pH			
Temperature			
Dissolved Oxygen			
Nitrate			
Turbidity			
Phosphate			

6. Describe any efforts currently underway to address water quality and riparian habitat issues in this watershed.

OPTION II - Final Report

Students prepare a formal report that synthesizes the information students are able to obtain from all sources. The information from this portion of the exercise will ultimately be synthesized with data and observations from the field portion of the exercise. Each student will produce a comprehensive report that summarizes findings of the field trip and synthesizes with other documentation (maps, photographs, etc.).

The report should include the following sections:

A. INTRODUCTION- 5 POINTS (1 or 2 paragraphs)

Use this section to briefly set the stage for what the report will cover. Briefly describe the land use-water quality relationship in a watershed and why it might be important. State your specific hypotheses for each water quality parameter that was measured.

B. DESCRIPTION OF WATERSHED - 5 POINTS (1 or 2 paragraphs)

Use this section to briefly describe the watershed under study. The following characteristics should be included:

- Location
- Fish and wildlife present
- Overview of land use and ownership
- Restoration efforts (if any)

Photographs and/or maps of the watershed may be included here.

C. METHODS AND MATERIALS - 5 POINTS (2 or 3 paragraphs)

In this section describe the experimental design of the study and procedures you have followed to obtain the data you have collected and analyzed. Include sufficient detail such that another researcher could duplicate your efforts. Be sure to include information such as dates, location, and equipment used.

D. RESULTS - 15 POINTS (3 or 4 paragraphs plus graphs, charts, etc.)

This section should include only information that was collected during this study (i.e., observations and data taken during field sampling). Where possible, summarize your data in tables, charts and graphs that help to visualize the data. Identify the major findings of the study. Extract the most relevant information from your tables, charts and graphs.

E. CONCLUSIONS and DISCUSSION - 20 POINTS

In this section you will summarize your conclusions (logically drawn from the RESULTS section) and attempt to place your findings into a broader context. It should be the longest section of your report.

First, return to your original hypotheses and compare your predictions to the results you obtained. Which hypotheses were supported by the data? Which hypotheses were not supported by the data? What findings were unexpected? What changes would you make in the experimental design if you were to duplicate the study?

Also in this section you should state your major conclusions and discuss them in the broader context of the land use – water quality relationship. What observations or measurements did you make that confirm (or refute) a relationship? What threats to water quality (observed or inferred) can be traced to land use practices? What applications might your findings have to forest management, fisheries management, land use planning or agricultural practices? What recommendations would you make concerning land use in this watershed? What benefits would you expect to result from these recommendations?

Notes to Instructors

A number of sources of satellite and aerial imagery have become available in recent years. Many of these have been made available to the public by federal agencies such as Natural Resource Conservation Service (NRCS), National Aeronautics and Space Administration (NASA) and United States Geological Survey (USGS) and, thus, are easily accessible. The availability of these images in formats that can be easily manipulated provides educators with a wide variety of opportunities to introduce students to natural resources at several scales. Among the various educational applications of these images are their assessments of land use, fire behavior, water resources, agricultural impacts, watershed analysis and forest management to name just a few.

Two sources of this imagery - *Google Earth* and *NASA World Wind* - are described in this exercise. Both are sophisticated programs with many shared features and both are available for free. Student access is best obtained by downloading the software to a computer laboratory outfitted with computers that meet the minimum specifications and then teaching the laboratory at that location. Alternatively, computers may be brought into the science laboratory or students could work on the activity outside the classroom on their own computers. These programs could also be used as a presentation tool in either lecture or laboratory settings.

There are a number of ways to conduct this laboratory. The primary objective is to familiarize students with the watershed under study using a variety of resources. Students will need access to the Internet to complete the activity. *Google Earth* and *NASA World Wind* are used to visualize the study site and the software will need to be downloaded to a bank of computers in the laboratory. Descriptions, applications and access to these resources are introduced on pp. 8 to 13. *NASA World Wind* will require downloading a number of files to the hard drive of laboratory computers and will direct you to some *Microsoft* web sites for additional software. The user interface for *NASA World Wind* is less intuitive than *Google Earth* and instructors will benefit from the quick tutorial offered under the HELP menu. Select “Walkthrough” and then, “Launch Flash Walkthrough of World Wind’s Basic Functions”. Instructors may also want to direct students to this tutorial prior to completing the exercise. Further information on the various types of imagery available with *NASA World Wind* may be obtained by selecting, “Launch Flash Walkthrough of World Wind’s Default Image Layers”.

Prior to the first laboratory, instructors should seek resources that will be made available to students as they become familiar with the watershed under study. These resources will need to be customized to your particular study site. I have included below some suggestions and specific resources for the Little Nestucca River, a field site in western Oregon that I have used for this activity. These provide a good starting point and you may be aware of other types of resources as well.

The Little Nestucca River is a small, salmon-bearing coastal river in western Oregon. The river originates in the forests of Oregon’s Coast Range and ultimately empties into Nestucca Bay, south of Pacific City. The watershed drained by the Little Nestucca is comprised of a variety of

land uses and ownerships including both private and public land. Potential impacts on water quality and riparian habitat vary with location in the watershed as follows:

- Upper reaches - logging (siltation, loss of riparian vegetation, temperature effects), runoff from roads, illegal dumping
- Middle reaches - agriculture, residential runoff (e.g., septic, lawn/garden chemicals)
- Lower reaches - agriculture, dairies, residential
- Estuary - agriculture

Resources

The following resources can be used to obtain information that cannot be gleaned from the *Google Earth* or *NASA World Wind* analyses. Use these resources to determine watershed boundaries, ownership, adjacent land use, planned or completed restoration efforts (if any), wildlife using the river system (wildlife surveys), fish using the river system (fish surveys), and for the results of previous water quality studies conducted.

Butler, D. 2006. The web-wide world. *Nature* 439(7078):776-778.

This review article describes the development of Google Earth and discusses applications of this new technology.

Environmental Protection Agency – Surf Your Watershed

www.epa.gov/surf

This EPA web site provides access to watershed information from across the United States. Watershed maps, environmental data, water quality monitoring programs and restoration efforts can all be accessed.

Foley, J.A., et al. 2005. Global consequences of land use. *Science* 309:570-574.

This article provides an excellent overview of the impacts of land use change on a global scale.

Huertos, M.L., L. Gentry and C. Shennan. 2003. Land use and water quality on California's Central coast: Nutrient levels in coastal waterways. Center for Agroecology and Sustainable Food Systems. Center Research Brief #2 (Winter 2003). 4 pp.

U.S. Environmental Protection Agency. Office of Water – Watersheds.

www.epa.gov/owow/watershed/

This EPA site provides a good introduction to the watershed concept and links to a number of useful watershed sites including:

- *The Watershed Information Network (access to information about your watershed)*
- *A presentation on the Mississippi River Basin and the Gulf of Mexico “dead zone”*
- *Watershed Academy (watershed training modules)*
- *Surf Your Watershed (access to information about your watershed)*

U.S. Environmental Protection Agency. 2004. Protecting water resources with Smart Growth. Washington, D.C.

www.epa.gov/smartgrowth/pdf/waterresources_with_sg.pdf

This EPA document discusses the connection between land development and water quality and describes strategies at the regional and local levels that protect water resources.

U.S. Environmental Protection Agency. Watershed Academy

www.epa.gov/watertrain/smartgrowth/

This EPA site includes an on-line training module (slide presentation) that describes the links between land use and water quality. This module illustrates how historical trends in population growth and land use have become the most significant challenge for preserving water quality.

U.S. Geological Survey topographic maps

These maps are widely used in natural resources and provide a wealth of information that can be applied to watershed studies such as topography, land ownership, bodies of water and place names. Maps can be ordered from the USGS, purchased locally, purchased on CD's or downloaded from the Internet (see NASA World Wind).

Waterkeeper Programs

www.waterkeeper.org/mainwaterkeepers.aspx

Waterkeeper programs are citizen-based groups that monitor the quality of rivers across the United States. This web site provides a listing of local groups that have focused on one or more rivers. The groups go by several names such as "watershed councils" or "riverkeepers groups". Although the information they can provide varies tremendously from one group to another, it is a good place to start to learn some of the water quality issues for the watershed you wish to study with your students. Some groups have quite sophisticated water quality monitoring programs.

Oregon-specific Resources

The following resources are specific to the Nestucca watershed in western Oregon. They are included here to serve as examples of the types of site-specific resources that should be made available to students. Instructors should identify similar sites for their location prior to implementing this activity.

Coastal Landscape Analysis and Modeling Study (CLAMS)

www.fsl.orst.edu/clams/

See “tour” for a historical overview of coastal landscapes.

Keller, R. 1998. Paddling Oregon. A Falcon Guide by the Globe Pequot Press. Guilford, CT. 470 pp.

Selection of field sites is a critical decision for the field portion of this activity. Local or state-wide guides are widely available for most regions of the country. This is an example of one of these guides. Most will include maps, levels of difficulty, skill levels required, recommended craft, suggested conditions and points of interest.

Nestucca Bay National Wildlife Refuge

www.fws.gov/oregoncoast/nestuccabay/

The Little Nestucca River trip takes students through one of Oregon's coastal national wildlife refuges. As a result, information on that portion of the watershed can be gleaned from the efforts of the U.S. Fish and Wildlife Service. The emphasis is on wildlife and wildlife habitat including restoration efforts. Maps of the refuge are also provided. Education programs include exotic species removal and planting of native riparian species.

Nestucca/Neskowin Watersheds Council

www.tcwrc.org/councils/nestucca/nnwc2.html
www.oregoncoast.com/nnwc/

The Nestucca/Neskowin Watersheds Council provides maps, a water quality monitoring program and a restoration program that includes a riparian planting and an education component. The group has also completed a Rapid Bioassessment Study and the report is available on their website.

Oregon Department of Environmental Quality

www.deq.state.or.us

Follow “water quality” links to state-wide information on water quality monitoring and non-point source control programs. Every state has a similar agency with primary responsibility for water quality monitoring.

The information gleaned from these sites will prepare students for the following field experience. Ultimately, the information will be synthesized with student measurements and observations into their final report or used to answer questions.

SESSION 2: Field Activity

Introduction

This portion of the exercise is conducted at an appropriate field site. Students investigate a study watershed using canoes and compare their observations and measurements with predictions made in the previous laboratory-based exercise.

At this point you should be quite familiar with many aspects of the watershed under study. *Google Earth* and other resources provide us with an unprecedented look at a watershed without ever getting our feet wet. Although much can be determined using some of these resources, there is no substitute for a site visit. In fact, for some information (e.g., real time water quality measurements) site visits are the only way to determine this information. In this portion of the laboratory, you will spend a day evaluating the watershed by canoeing its dominant watercourse. In contrast to most river-based curriculum which measures water quality values at a single location accessed from shore, this activity places students "on the river" where they are better able to appreciate its dynamic and interconnected nature.

This trip will emphasize watershed concepts and provide students with a combination of observation and measurement experiences that will be used to evaluate watershed condition. The information obtained here will be used to supplement the information obtained in the first portion of this laboratory.

Objectives

Upon completion of this laboratory students should be able to:

1. Safely access several portions of a stream for observation and measurement
2. Properly collect water samples
3. Use appropriate instrumentation and technique to measure water quality parameters
4. Make and record relevant observations related to land use and water quality
5. Predict potential impacts of land use on water quality

Procedure

1. Review safety guidelines and prepare canoes for launch (see safety handout).
2. Establish groups of two to three students each and safely load and launch canoes.
3. Three sample points at upper, middle and lower reaches of the river have been identified. Water quality measurements will be taken at these points. Six water quality parameters will be measured - temperature, pH, dissolved oxygen, turbidity, phosphate and nitrate.
4. Proceed to the first sample point and prepare the *Orion pH/Temperature Meter* (or

similar instrument) for measurement.

5. At the approximate midpoint of the river collect a water sample with the small plastic water sampler and insert the probe to approximately 2 cm. Follow the instructions included with the instrument to properly take a measurement. Note that the readings may waver slightly until an equilibration point is reached. Wait for the meter to reach this point before a measurement is recorded. Record the resulting measurements for temperature and pH on the *Water Quality* section of the data sheet.
6. Follow a similar procedure for the remaining water quality parameters (dissolved oxygen, turbidity, nitrate and phosphate) using appropriate instrument(s). Record the resulting data on the *Water Quality* data sheet.
7. Repeat procedures #4 – 6 above for each of the remaining sample sites.
8. In addition to taking water quality measurements you will also be making observations of land use practices in the lands adjacent to the river. This is best accomplished while in transit between sample points.
9. Record any observations of land use practices and their potential impacts on water quality and riparian habitat along river by completing the chart entitled, “*Impacts of various land use on water and riparian area quality based on field observation*”. This is the same chart you completed in the previous lab based on your observation of remote sensing images. This time it will be based on observations in the field.
10. Although a formal scientific survey is beyond the scope of this study, you should be aware of the wildlife species that occur in this watershed. Record any relevant observations on the *Field Observations* data sheet. These may include wildlife sightings, restoration projects, etc.

Data Sheet

A. WATER QUALITY MEASUREMENTS

	Upper reach	Middle reach	Lower reach
pH			
Temperature (°C)			
Dissolved Oxygen (ppm)			
Nitrate (ppm)			
Phosphate (ppm)			
Turbidity (FTU)			

B. FIELD OBSERVATIONS

CATEGORY	SPECIES	COMMENTS (specific location, number seen, etc.)
Birds		
Mammals		
Fish		
Amphibians/ Reptiles		
Invertebrates		
Plants – native/invasive		
Restoration projects		
Other		

Impacts of various land use on water and riparian area quality based on field observation

Point Source					Non-point Source								
	Heated Effluent	Volume Extraction	Solid Waste Dumping	Indust. Effluent	Grazing	Inc. Temp.	Stream Channelization	Habitat Loss	Fertilizer runoff	Sediment runoff	Pesticide runoff	Livestock manure runoff	Introd. of invasive species
Forest													
Agricultural													
Urban													
Residential													
Industrial													
Disturbed													

Enter one of the following into each cell on the table:

- 0 = no negative impact
- 1 = minor impact
- 2 = moderate impact
- 3 = major impact
- X = unable to determine

NOTE: Brief descriptions of each of these impacts appear on the following page.

Brief descriptions:

- Heated Effluent** - waste water released from a pipe or ditch at a temperature higher than ambient water temperature
- Volume Extraction** - removal of water from river for irrigation or industrial use
- Solid Waste Dumping** - deposits of usually non-toxic materials (e.g., tires, old appliances)
- Industrial Effluent** - discharge from any industrial facility (e.g., sewage treatment, chemical plant)
- Grazing** - livestock access to river or riparian zone
- Increased Temperature** - resulting from removal of shading
- Stream Channelization** - straightening and/or deepening of streams by excavation or levees
- Habitat Loss** - removal or disturbance of any aquatic habitat or vegetation in riparian zone
- Fertilizer runoff** - observed/inferred runoff from agricultural or residential lands
- Sediment runoff** - observed/inferred runoff from disturbed lands resulting in increased turbidity
- Pesticide runoff** - observed/inferred runoff from agricultural or residential lands
- Livestock manure runoff** - observed/inferred runoff from agricultural lands used for grazing livestock (or livestock access to river)
- Introduction of invasive species** - observed establishment of non-native, invasive species in river or in riparian zone

Assessment

Students should submit completed data sheets (*Water Quality Measurements and Impacts of various land use on water and riparian area quality based on field observation*) as well as any other field observations. This information will be used to respond to questions in the follow-up laboratory or incorporated into the student report.

Materials

- 8 Canoes and accessory equipment (see "Accessories" p. 47)
- 3 *Hanna* Nitrate ion-specific meters
- 3 *Hanna* Turbidity meters
- 3 *Orion* or *LaMotte* pH/temperature meters
- 3 *Orion* or *LaMotte* dissolved oxygen meters
- 8 De-ionized water in *Nalgene* squirt bottles (to rinse meter electrodes between readings)
- 8 5-gallon plastic buckets (to store equipment in canoes)
- 24 Binoculars (optional)
- 24 Data sheets (copied on *Rite-in-the-Rain* paper)
- 24 #2 Pencils
- 24 Clipboards
- 8 Laminated photographs or topographic maps of study site (one per group of students)

Notes to Instructors

The selection of water quality parameters to be measured in the field may be adjusted according to local conditions, time available and the accessibility of water quality instruments. There are a number of reliable and easy-to-use instruments available for field measurement. *Hanna*, *Orion* and *LaMotte* (see vendors list below) all manufacture suitable water quality meters or test kits designed for student use. Since different instructors will select different instruments, detailed instructions on their use is not provided in this module. Instructors should copy the instructions provided with the instruments they choose to use and make these available to students. Students should be given the opportunity to become familiar with the proper operation of each instrument prior to the field portion of this exercise.

Some instructors may choose to expand the field portion of the activity to include a more comprehensive evaluation of the watershed under study. There are a number of resources available that describe more detailed procedures. The Environmental Protection Agency, for example, has developed “rapid bioassessment protocols” that evaluate water quality “using biological surveys and other direct measurements of resident biota in surface waters” (Barbour, et al. 1999). These protocols have been implemented across the nation and therefore, comparison of results with other locations is a possibility. State agencies with responsibilities for monitoring water quality also frequently develop protocols for watershed evaluation (see, for example, Bauer, et al. 2000), which may be modified for this activity.

Resources

Barbour, M.T., J. Garrison, B.D. Snyder, and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

www.epa.gov/owow/monitoring/rbp/

Bauer, C., et al. 2000. Stream crossing watershed survey procedure. Surface Water Quality Division, Michigan Department of Environmental Quality. 40 pp.

Vendor's List for Water Quality Instruments

Hach Company www.hach.com

Hanna Instruments www.hannainst.com/usa/

LaMotte Company www.lamotte.com

Thermo Electron Corporation (Orion) www.thermo.com/

YSI Environmental www.yei.com/index.html

SESSION 3: Analysis

Introduction

At this point in the activity, students have examined the watershed using remote sensing imagery (week 1), and completed observations and measurements of the watershed in the field (week 2). This component of the exercise is dedicated to the interpretation of water quality measurements and final analysis.

Objectives

Upon completion of this laboratory students should be able to:

1. Evaluate the potential impacts of land use on water quality parameters
2. Compare predicted water quality impacts with measured impacts
3. Make recommendations for interventions that could be made to improve water quality

Procedure

To complete this portion of the exercise you will need the following:

- Two completed charts entitled, “Impacts of various land use on water and riparian area quality”
- Your predictions of water quality measurements from Session #1
- Your water quality measurements from Session #2
- Field observations
- Any additional information

Respond to the questions below using all information available to you.

1. Compare the two completed charts entitled “Impacts of various land use on water and riparian area quality” – one completed after remote observations in the laboratory and the other completed based on field observations and measurements. What differences and similarities exist between these two charts?
2. What do you think accounts for the differences between the two charts?
3. What are the strengths and weaknesses of the two methods (analysis of satellite and aerial imagery versus direct observation and measurement) of observation we have used?
4. What impacts were better analyzed from satellite/aerial imagery than direct observation and measurement?

5. What impacts were better analyzed by direct observation and measurement?
6. Compare your *predicted* water quality values from Lab #1 with your *actual* measurements from Labs #2 and #3. What *trends* were correctly predicted?
7. Interpret your water quality measurements using the information provided in the handout, "*How should we interpret water quality measurements?*" What impacts, if any, would you expect from the water quality measurements we obtained?
8. Based on your analysis of both satellite/aerial imagery and direct observation/measurement, what do you think are the major water quality issues in this watershed? Explain.
9. Generate a list of fish and wildlife species most likely to be impacted by the land use you have observed in the watershed. Use both your "field observations" (see Session II) and any information you were able to obtain by accessing web sites (see Session I). For each species you have listed, indicate the specific land use characteristics that could potentially result in an impact.
10. What specific recommendations would you make to improve water quality or riparian habitat in this watershed?

How Should We Interpret Water Quality Measurements?

Water quality measurements from various sections of the river under study will be compared to determine whether or not land use practices in the watershed have an impact on water quality. The parameters that have been selected for measurement are representative of some of the best indicators of water quality. The following descriptions provide an indication of why these parameters are important and how the values you obtain might be interpreted.

A. pH

pH is a measure of the hydrogen ion (H^+) concentration in a solution. Acid strength is based on how readily it releases hydrogen ions in water - strong acids release lots of H^+ , weak acids release smaller amounts. A pH reading of 7 indicates neutrality (neither acidic nor basic); numbers less than 7 are acids, greater than 7 are bases (alkaline). Since the pH scale is logarithmic, a change of one pH unit represents a ten-fold change in the acidity of the solution. Most species can tolerate pH values from 6 to 8; optimal levels for most fish are between 7.1 and 7.8 (Table 1). Values above or below these values may affect some species. Amphibians and some aquatic insect larvae are particularly sensitive to acidic conditions.

Table 1. Lethal pH Limits for Some Aquatic Organisms

(Adapted from Murdoch and Cheo, 1996)

pH Value	Impacts
4.0 to 4.5	all fish, amphibians and many invertebrates dead
4.5 to 5.0	caddisflies and mayflies dead
5.0 to 5.5	salmonid eggs and alevin dead, decomposing bacteria decline
5.5 to 6.0	most fish and amphibians decline
6.0 to 6.5	snails and tadpoles decline
6.5 to 8.2	most species can tolerate
8.5 to 9.0	salmonids begin to decline with prolonged exposures
> 11.0	salmonids dead
> 11.5	most fish dead

Most biochemical reactions that occur in living organisms are sensitive to pH. Therefore, pH values that lie outside of a species range of tolerance can have direct effects on survivability and

overall health of the organism. In addition to these direct effects of pH changes, there are indirect effects as well. Acidic conditions (low pH) can increase the release of metals such as aluminum or copper from sediments and increase their concentration in the water. These metals can disrupt gill function or cause deformities in fish. Another indirect effect is illustrated by the relationship between pH and ammonia. Ammonia in water may occur either as ammonium ion (NH_4^+) or ammonia (NH_3). NH_3 is highly toxic to fish and other aquatic organisms. As pH levels increase, a greater portion of the ammonia exists in this toxic form.

High acidity (low pH) in waterways can be caused by carbon dioxide dissolved in water, tannic acid from the decomposition of conifer needles and bark, acid rain, coal mining operations and industrial pollutants.

B. Water temperature

Water temperature in rivers and streams is influenced by a number of factors, several of which are related to land use. Heated effluent from industry or runoff from urban streets, for example, may increase stream temperatures directly. Also, the loss of shading provided by trees in the riparian zone or increased turbidity due to agricultural runoff may result indirectly in increased stream temperature. Stream temperatures are also influenced by ambient air temperature and the water source (e.g., springs, snow melt, and runoff). Temperatures influence those organisms that can occur in streams (Table 2). Since most aquatic organisms are ectothermic ("cold-blooded"), water temperature controls metabolic rate and, often, the timing of reproductive activities. In most areas, thermal pollution (high temperatures) is generally more limiting than low temperatures. Aquatic organisms are generally more susceptible to the influences of toxic chemicals, parasites and diseases at temperatures at the upper end of their range of tolerance. Water temperature also influences dissolved oxygen levels (see discussion below).

Table 2. Optimal Temperatures for Some Aquatic Organisms

(Adapted from Murdoch and Cheo, 1996)

Temperature Range		Species
°C	°F	
>25	>77	lethal for salmonids and some aquatic insects
20 to 25	68 to 77	optimum for "warm water species" (bass, bluegill, carp, catfish, suckers, dragonflies, true flies, few caddisflies)
13 to 20	55 to 68	optimum for "cool water species" (coho, chinook, cutthroat, sturgeon, mayflies, caddisflies, stoneflies)
5 to 13	41 to 55	optimum for "cold water species" (steelhead, all salmon, most trout, most mayflies, caddisflies, stoneflies)

C. Dissolved oxygen (D.O.)

Dissolved oxygen is measured in parts per million (ppm) with a dissolved oxygen meter or chemically with a Winkler Titration. Dissolved oxygen levels of 7-10 ppm are typical in unpolluted water and generally considered adequate for most aquatic life. In salmonid streams, dissolved oxygen requirements are higher. Salmon embryo and larval stages can show some impairment at DO levels as high as 8 or 9 ppm. In other aquatic habitats, levels below 4.5 ppm can cause acute mortality of fish and invertebrates. The primary sources of oxygen in streams are photosynthetic production by algae and higher plants and diffusion from the air above the water surface. Diffusion rates increase in turbulent waters such as those created by wind action, rapids, and waterfalls. Dissolved oxygen levels may fluctuate significantly throughout the day especially in bodies of water with extensive plant growth. For this reason, if dissolved oxygen levels are to be compared through time, samples should be collected at approximately the same time of day, at the same water depth, and under similar conditions of light intensity. Levels rise from morning to afternoon as a result of photosynthesis, reaching a peak in late afternoon. Photosynthesis then begins to shut down as light intensity decreases. At night photosynthesis stops but plants and animals continue to respire thus consuming oxygen. Dissolved oxygen levels typically decline at night.

Low dissolved oxygen levels generally indicate polluted water and high Biological Oxygen Demand (BOD). Low dissolved oxygen readings can be expected in stagnant water with large amounts of organic material. As the organic material decomposes, oxygen is consumed in the process. Dissolved oxygen can influence the species that occur in a body of water. When dissolved oxygen levels drop below a critical level, fish, amphibians, aquatic invertebrates and aerobic bacteria which rely on this oxygen for aerobic metabolism will decline and eventually perish. Additionally, at low dissolved oxygen levels, anaerobic bacteria proliferate and break down the remaining organic material producing toxic gases such as hydrogen sulfide and methane.

The amount of dissolved oxygen is also a function of water temperature - cold water is capable of retaining high amounts of dissolved oxygen, warmer water is less capable. This relationship is illustrated for temperatures from 10 - 41°C in Table 3. This information can be used to determine the **percent saturation** for dissolved oxygen in a water sample. Percent saturation is a measure of the amount of dissolved oxygen in a water sample relative to the maximum amount that **could** be in that sample. For example, suppose we obtained a dissolved oxygen reading of 8.0 ppm for a water sample and the temperature of the sample was 20°C. The percent saturation could be calculated by dividing your reading with the maximum dissolved oxygen concentration at 20°C ("9.07 ppm" from the Table 3) and multiplying by 100:

$$\text{Percent Saturation} = (8.0/9.07) \times 100 = 88.2 \%$$

Table 3. Maximum Dissolved Oxygen Concentration

Temperature (°C)	Dissolved Oxygen (ppm)	Temperature (°C)	Dissolved Oxygen (ppm)
10	11.27	26	8.09
11	11.01	27	7.95
12	10.76	28	7.81
13	10.52	29	7.67
14	10.29	30	7.54
15	10.07	31	7.41
16	9.85	32	7.28
17	9.65	33	7.16
18	9.45	34	7.05
19	9.26	35	6.93
20	9.07	36	6.82
21	8.9	37	6.71
22	8.72	38	6.61
23	8.56	39	6.51
24	8.4	40	6.41
25	8.24	41	6.31

Stream habitats are considered healthy at 90 - 100% saturation; levels for ponds are generally lower.

D. Turbidity

Turbidity is a measure of the "cloudiness" of the water. Sediment, algae, bacteria and zooplankton all contribute to what is technically known as the Total Suspended Solids (TSS) that increase the turbidity. As turbidity increases, the degree to which sunlight penetrates the water column declines. This obviously has an impact on photosynthetic rates in algae and submerged vegetation. High turbidity can also raise surface water temperature as suspended particles near the surface absorb more heat from sunlight. Suspended soil particles may also carry nutrients,

pesticides and other pollutants and they can bury benthic organisms. Turbid waters tend to be low in dissolved oxygen.

Turbidity can be measured with a turbidity meter in formazine turbidity units (FTU's). Drinking water is generally very clear and would have a turbidity measurement less than 10 FTU. Very cloudy water would read about 1000 FTU. We will use a Portable Microprocessor Turbidity Meter to measure turbidity in water samples. Alternatively, relative measures of turbidity can be obtained by using a "spectrophotometer". This device passes a known quantity of light through a sample in a glass tube called a "cuvette". A sensor on the opposite side of the cuvette detects the amount of light (% **Transmittance**) that passes through and displays this amount on a scale. The wavelength of light can be adjusted to measure the amount of various materials dissolved in the sample. The accepted wavelength for the measure of turbidity is 550 nm.

E. Phosphate

Phosphorus (P) usually occurs in natural systems as phosphate (PO_4^{-3}). This phosphate may be bound to organic compounds (**organic phosphate**) or inorganic compounds (**inorganic phosphate** or **orthophosphate**). Inorganic phosphate is the form most readily available to plants and therefore is generally of greater interest than organic phosphate. Phosphorus tends to be less abundant than nitrates in freshwater ecosystems and is, therefore, often a limiting factor for plant and algal growth. The addition of phosphorus (in the form of phosphates) commonly results in algal blooms (**cultural eutrophication**). Domestic sewage (particularly those containing significant amounts of laundry detergents) and agricultural runoff are important sources of phosphates. Most sewage treatment plants remove only about 50% of the nitrogen and 33% of the phosphorus from domestic sewage. The remainder is dumped in the effluent into surface water. In an effort to reduce the growth of nuisance aquatic plants and algae, the Environmental Protection Agency has established a desired goal of 0.05 ppm total phosphorus for streams entering lakes and 0.10 ppm for other flowing waters. At the height of phosphate-based detergent use in 1970, effluent from U.S. sewage treatment plants averaged 11 ppm. Reductions in the use of these detergents reduced this value to 5 ppm in 2002. Phosphorus levels as low as 0.01 ppm have been shown to have an impact on algae growth in ponds. Some scientists use phosphorus levels as an indication of whether a lake is oligotrophic (<0.01 ppm) or eutrophic (> 0.02 ppm). Phosphates (inorganic phosphates only) can be measured with an ion-specific meter.

F. Nitrate

Nitrogen appears in several forms in water sources, including nitrate (NO_3), nitrite (NO_2) and ammonia (NH_3). Of these, nitrates are probably the most common inorganic pollutant tested in water. Ammonia is a product of the decomposition of plant and animal protein but tends to be taken up quickly by algae and plants. Nitrites tend to occur at fairly low levels in most water samples because they are readily converted to nitrates by bacteria. Nitrates are a common component of multi-nutrient fertilizers whose nutrient content is indicated by three numbers

called the "grade". The first of these numbers indicates the nitrogen content of the fertilizer. A fertilizer grade of 16-16-16, for example, contains 16% by weight nitrogen, 16% phosphate (P_2O_5) and 16% potassium (K_2O). Both nitrates and ammonia stimulate algal growth and may be responsible for causing cultural eutrophication. If ingested they are converted to nitrites in the intestines of humans where they combine with hemoglobin in red blood cells causing the oxygen-carrying capacity to decline. In infants this condition may be fatal. Contamination of groundwater by nitrates that are applied as fertilizer or runoff from feedlots and dairies is a widespread problem in agricultural regions of the country. Improperly treated sewage from sewage treatment plants and septic systems that finds its way into waterways is also an important source. Nitrates can be measured with an ion-specific meter.

The national drinking standard for nitrates in the U.S. is 10 ppm. Waters that have levels as low as 1 ppm, however, can be sufficiently polluted to cause algal blooms.

Literature Cited

Murdock, T. and M. Cheo. 1996. Streamkeeper's Field Guide. The Adopt-A-Stream Foundation. Everett, WA. 296 pp.

SUPPORTING INFORMATION

Why Canoes?

INTRODUCTION

The Northwest Center for Sustainable Resources (NCSR) develops, tests and disseminates ecosystem-based curricula for students in natural resource programs and in courses that support these programs. Field and laboratory experiences that actively engage students in the process of science form the basis of this curriculum. In the Pacific Northwest and throughout the nation, the management of water resources has become a central focus of society. Water quality and quantity issues, endangered species management, agricultural use and impacts, for example, predominate local, regional and national environmental concerns. Thus, any natural resource curriculum must include a substantial treatment of water-related issues.

We have developed an innovative way to provide students with field and laboratory experiences in water-related issues that are not available by other means. Our *Impact of Land Use on Water Quality - a Watershed Evaluation* instructional module engages students in a detailed analysis of the impact of non-point pollution on water quality. The field portion of the module uses canoes as a vehicle for the scientific exploration of various waterways in local environments.

RATIONALE

Streams, rivers, ponds, lakes and estuaries are not isolated entities. They are connected to each other and also to the land that surrounds them (the watershed). Modern natural resource management takes a broad-based watershed approach to the study and management of water resources. Most current methodologies for the study of aquatic ecosystems require access to a single or a few locations along a waterway. These sampling locations are restricted to public properties which often are limited in their availability. Students make observations and measurements at a single point in space and time resulting in an incomplete picture of the watershed as a system. In canoes, students have access to large portions of watersheds allowing for the study of waterways as complex, interconnected waterways that are influenced by land use on surrounding lands. In-depth study of local ecosystems is expected to enhance interest and learning by students who gain a greater appreciation for the ecosystems in which they live. Additionally, students will be attracted to the "recreational" nature of these activities.

CURRICULUM

The *Watershed Evaluation* curriculum module was developed to make best use of this new tool. Sampling and observations are made from canoes along a waterway. Prior to that experience students analyze remote sensing imagery to predict the potential impact of surrounding land use. In addition to field analysis of samples, some samples may be brought back to the laboratory for additional analysis.

Canoe Safety

The canoe is one of the oldest means of water travel known to man and an ideal way to explore a variety of aquatic environments. Recognize, however, that placing students in canoes creates unusual and potentially hazardous situations. The safety of students and faculty is paramount in the development and implementation of these activities. The following guidelines have been established to minimize the risk of harm. While the college has taken steps to minimize risk, it is the responsibility of each individual to read, understand and follow these guidelines. If you do not understand any of these guidelines, please consult the trip leader.

Canoe Safety - Students

Prior to departure:

1. Inform the trip leader of any medical condition that may place you at greater risk than others while conducting on-the-water activities.
2. Waterways and water conditions for exploration have been carefully selected to minimize risk and maximize educational benefit. Stay with the group and do not venture out on your own. All activities are planned for "flatwater" (lakes, ponds, estuaries, and slow moving rivers and streams).
3. Prior to departure the trip leader will instruct you on safety procedures.
4. Prepare for dealing with the elements - rain, cold or warm temperatures, wind and sun. Bring layers of warm clothing, a hat, and sun screen.
5. Personal flotation devices (PFD's) must be worn properly at all times by all passengers - no exceptions. PFD's are adjustable and should fit snugly around the chest. All straps should be fastened and any loose ends tucked in to avoid getting hung up.
6. Check your equipment. Each canoe should be equipped with:
 - a personal flotation device (life vest) for each passenger
 - two paddles plus an extra (included in case of loss or breakage); extra paddle should NOT be lashed to canoe
 - a bail bucket
 - extra ropes or lines
7. Enter and exit canoes carefully. To get into your canoe, have someone hold it steady. As you step in, bend your knees and grab on to each side of the canoe for balance. Walk to your seat along the center of the canoe.

Once you are underway:

8. Remain on your seat or on the floor of the canoe. Do not stand or sit on the sides of the canoe. Keep your load balanced and avoid sudden movements or rocking from side to side.
9. Be aware of other boat traffic and keep an appropriate distance from other craft (including other canoes).
10. Be aware of water currents and try to keep your canoe at right angles to big waves (especially, wakes from motorboats).
11. Be aware of and avoid water hazards such as low branches, fallen trees, rocks and debris.
12. Keep your shoes on to avoid slipping or stepping on sharp objects near shore.
13. If your canoe tips over, don't panic! Stay with your canoe and paddle or push it toward shore. When you get to shallow water, flip the canoe with the help of another person and carefully climb back in. If you tip over in running water, stay on the upstream side of your canoe.
14. The trip leader may describe a formation or order of canoes. Follow this order and do not go ahead of the lead canoe.
15. Each canoe has a responsibility to the canoe behind it. Do not lose visual contact with the canoe behind you and point out any obstacles that you have encountered and successfully (or not) avoided.

Canoe Safety - Faculty/Staff

The safety of students, faculty and staff should be paramount in the development and implementation of any activities that involve canoes. The risk of danger can be minimized by following these guidelines:

1. Select waterways and water conditions for exploration that match your skill level and that of your students. In general, this means lakes, ponds, estuaries, and slow moving rivers and streams (i.e., "flatwater"). Avoid high water (flood) conditions, rapids, high winds and storms. The canoes we have purchased are among the most durable and stable on the market but, they are not designed for conditions other than those described above.
2. Pre-run your trip so that you can convey to the group the types of water and weather conditions likely to be encountered. Pay particular attention to the time required to complete the trip, obstacles encountered and the effects of tides and the weather. On the day of the trip, check the weather forecast and be prepared to alter or cancel the trip if weather conditions dictate.

3. Inform others at the College of where you are going and when you are expecting to return.
4. Check all equipment before departure. Be sure each canoe is in good condition and that the following accessory equipment is available for each canoe:
 - personal flotation device (life vest) for each passenger
 - two paddles plus an extra (included in case of loss or breakage); extra paddle should NOT be lashed to canoe
 - a bail bucket
 - extra ropes or lines

In addition to the items above, the lead canoe should carry a first aid kit in a waterproof container and a cell phone for emergency contact.

5. Prior to departure, the trip leader should instruct the group on the following safety considerations:
 - appropriate clothing and footwear
 - adequate food/drink
 - sun protection
 - proper method of entering and exiting canoe
 - no standing or sitting on sides of canoe
 - keep load balanced
 - avoid sudden movements or rocking from side to side
 - keep appropriate distance from other boats
 - keep canoe at right angles to waves (especially, wakes from motorboats)
 - be aware of water hazards such as low branches, fallen trees, rocks and debris
 - proper procedure for dealing with a capsized canoe
 - the trip leader should make it clear that his or her decisions in the interest of safety are final
6. Personal flotation devices (PFD's) must be worn properly at all times by all passengers - no exceptions. Trip leader should check PFD's for proper fit.
7. Assign formation positions to prevent canoes from becoming dangerously dispersed. Trip leader should hold the front position at all times and warn canoes behind him/her of any unexpected hazards.

Selecting and Purchasing Canoes, Accessories and Trailer

Once the decision is made to place students in canoes to engage them in educational opportunities, attention must turn to acquiring the most appropriate and safest equipment to accomplish this. Although there are probably many correct ways to approach these decisions, I will share the decisions we made and their rationale in hopes of helping you to avoid some pitfalls.

Canoe selection

We selected canoes on the basis of their durability, stability and cost. We wanted canoes sufficiently large so that they could accommodate 3 students each. There are a number of high quality manufacturers of canoes and selecting a brand can be a challenge. In the end, we decided to purchase 8 *Old Town Guide* 16' canoes in part because of the features mentioned above and in part because there was a local vendor we could work with. This canoe is designed for flatwater and exhibits excellent stability. The material used in the hull is a polyethylene synthetic with a foam core that provides durability and resistance to abrasion at a relatively low weight (82 lbs).

Trailer

Pre-manufactured trailers for multiple canoes can be purchased but we found that nearly all manufacturers were in eastern United States. Shipping costs for the trailers approached \$1000 which added significantly to the cost. Consequently, we decided to have a local machine shop manufacture a trailer to our specifications. As a result, we think we obtained a high quality product that includes exactly those features that we wanted. For example, there is a lock box on the trailer that will accommodate all 24 canoe paddles and other accessories. The machine shop also modified one of the college's vans (trailer hitch, light connections, etc.) for pulling the trailer. For educators in eastern U.S. pre-manufactured trailers may be a more attractive option.

Accessories

Flotation vests are required for each occupant. To accommodate a wide variety of student sizes we purchased 24 *Stearns* personal flotation devices (PFD Type III) in two sizes – “adult oversize” and “adult universal”. We also purchased three aluminum/plastic paddles per canoe and a 20' nylon rope which was attached to the canoe as a bow line. Eight removable vinyl seats were also purchased to accommodate a third passenger in each canoe. A local tent and awning manufacturer fabricated a vinyl cover for the canoes while they are on the trailer and not in use. The cover prevents exposure to ultraviolet radiation which may weaken and discolor the hull of the canoes. The tarp also adds an extra level of security.

Costs (as of 2006)

Number	Item	Unit Cost	Total Cost
8	Old Town Guide 160 Canoes	546.25	4,370.00
8	Added seats	40.49	323.92
24	Paddles	11.70	280.80
24	Life vests	17.99	431.76
1	Trailer	3,243.00	3,243.00
1	Van trailer hitch	702.00	702.00
1	Vinyl cover	570.00	570.00
TOTAL			9921.48