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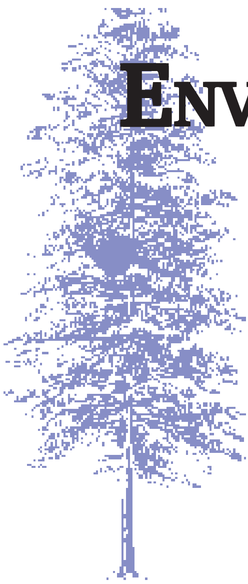

Environmental Science III

Northwest Center for Sustainable Resources (NCSR)
Chemeketa Community College, Salem, Oregon
DUE # 9813445

Funding provided by the National Science Foundation
opinions expressed are those of the authors and not
necessarily those of the foundation

Environmental Science III

The Northwest Center for Sustainable Resources is an Advanced Technological Education project funded by the National Science Foundation.

Environmental Science III was developed at Chemeketa Community College, Salem, Oregon, and was tested and revised at Everett Community College, Everett, Washington. Materials were prepared by Wynn Cudmore, Ph.D., Principal Investigator for the Center. Cudmore holds a Ph.D. in Ecology/Systematics from Indiana State University and a B.S. in Biology from Northeastern University.

Technology education programs in which this course is incorporated are described fully in the Center's report entitled, "Visions for Natural Resource Education and Ecosystem Science for the 21st Century." Copies are available free of charge.

Course materials will also be posted on our website:

www.ncsr.org

Please feel free to comment or provide input.

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Student Assessment

Environmental Science III
4 Credits–3 hrs. lecture/3 hrs. lab

INTRODUCTION TO ENVIRONMENTAL SCIENCE

Environmental Science was developed at Chemeketa Community College as a sequence of three courses that addresses environmental topics. Each 4-credit course requires a 3-hour lab that meets once per week and 3 hours of lecture. The courses are targeted towards several audiences including:

- students in natural resource areas (e.g., Forestry, Fish and Wildlife, Agriculture)
- transfer students in areas other than biology who need a lab science course or sequence
- biology majors who wish to broaden their background in environmental biology
- anyone interested in learning more about environmental issues

I consider the courses to be "Environmental Science for the Citizen," and emphasis is placed on those concepts and issues that in my judgement should be understood by all citizens. The approach is science-based, and a distinct effort is made to present opposing viewpoints in contentious environmental issues. The three-term sequence was added as a requirement for students in the Forest Resources Technology Program at Chemeketa, where it serves primarily to introduce students to basic ecological concepts and environmental issues that relate to natural resource management. The following goals have been established for the sequence:

- introduce students to science as a "way of knowing"
- introduce students to basic ecological concepts
- introduce students to environmental problems at local, national and global scales
- work cooperatively in small groups
- communicate effectively in written and oral formats
- apply appropriate technology to scientific exploration
- access and use supplemental information relevant to course topics
- engage students in hands-on, field and laboratory experiences that require critical thinking
- use ecosystem management as a major theme in natural resource management
- introduce students to societal aspects of environmental issues
- apply mathematical concepts to scientific inquiry

This document describes several laboratory activities that have been developed for *Environmental Science III* in an attempt to meet these general goals. It is my hope that others who have similar goals for related courses will find them useful.

TEXT: Botkin, D. and E. Keller. 2000. *Environmental Science: Earth as a Living Planet*. 3rd ed. John Wiley and Sons, Inc. New York. 649 pp.

COURSE DESCRIPTION

This course examines environmental problems and issues related to energy and environmental contamination such as air pollution, water pollution and solid waste management. The relationships between environmental problems and other aspects of society such as economics and public policy are also explored. Sustainability is a dominant theme.

PREREQUISITE

Bi 131 or Bi 101 or permission of instructor.

COURSE OBJECTIVES

Upon successful completion of the course, students should be able to:

1. Describe environmental issues that relate to energy production and use.
2. Evaluate alternative means of energy production.
3. Measure and evaluate pollutants in water resources.
4. Propose solutions to environmental problems related to environmental contamination.
5. Evaluate historical land use changes and their consequences.
6. Describe the political, social and economic consequences of environmental problems and their solutions.

STUDENT ASSESSMENT

Based on a point system with an approximate breakdown as follows:

Exam #1	100 points
Exam #2	100 points
Final Exam	100 points
Labs and related activities	150 points
	450 points total

The term's letter grade is based on a percentage of total points accumulated according to the following schedule:

90 - 100 %	A
80 - 89 %	B
70 - 79 %	C
60 - 69 %	D
<60%	F

TOPICS

I. Sustainability

A. Development of the concept of sustainability
B. Definitions and examples
C. Elements of a sustainable society

II. Energy

A. History of energy use

B. Energy sources and consumption

C. Fossil fuels—coal, crude oil and natural gas
1. Review of carbon cycle
2. Estimated reserves
3. Geographical distribution of reserves
4. Consumption rates and estimated duration of supply
5. Environmental and health concerns

D. Nuclear power
1. Natural radioactivity
2. Nuclear fission and nuclear reactors
3. Nuclear fusion
4. Environmental and health concerns
5. Nuclear accidents

E. Alternative energy sources—see "Alternative Energy Activity"
1. Solar thermal
2. Photovoltaic
3. Wind
4. Geothermal
5. Hydroelectric
6. Hydrogen
7. Biomass

III. Water Pollution and Treatment

A. Point source vs. non-point source pollution

B. Categories of pollutants
1. Oxygen-demanding wastes
2. Disease-causing agents
3. Inorganic nutrients
4. Inorganic chemicals
5. Organic chemicals
6. Sediment
7. Heat
8. Exotic species
9. Dissolved gases
10. Environmental hormones
11. Natural toxins

C. Wastewater treatment
1. Septic tank disposal systems
2. Wastewater treatment plants
3. Alternative methods
   a. land application
   b. aquaculture
   c. phytoremediation

IV. Air Pollution

A. Sources of air pollution
1. Human vs. natural sources
2. Major classes of air pollutants
3. Primary vs. secondary pollutants

B. Nuclear winter

C. Acid rain
1. Acid rain chemistry
2. Geographic and geologic factors
3. Ecosystem effects
   a. terrestrial effects
   b. aquatic effects

D. Solutions to air pollution

V. Ozone Depletion

A. Ozone chemistry

B. Measurement of stratospheric ozone

C. Evidence for depletion

D. Ozone depleting chemicals

E. Environmental and human health effects
1. Primary productivity
2. Skin cancers
3. Damage to eyes
4. Impact on immune system
5. Genetic damage in amphibians

F. Solutions
1. Montreal Protocol
2. Collection and reuse
3. CFC substitutes

VI. Solid Waste Management

A. Sources of solid waste

B. Traditional methods of managing solid waste
1. Dilute and disperse
2. Concentrate and contain

C. Integrated waste management
1. Source reduction
2. Recycling
3. Composting
4. Incineration
5. Sanitary landfill
   a. environmental impacts
   b. modern design
   c. location requirements

D. Ocean dumping

VII. Environmental Economics

A. Environment-Economy relationships

B. Free-market environmentalism
1. Definition and examples
2. Assigning value to externalities
3. Assigning value to ecosystem services

C. Economics of common resources

D. Environmental regulation
1. Command and control regulation
2. Free-market regulation

VIII. Land Use Planning

A. Goals of land use planning

B. Oregon's land use laws as a national model
1. Legislation
2. Philosophy and approach
3. Consequences of land use planning
4. Controversy of land use planning

C. Wetland Mitigation
1. Wetlands as a natural resource
2. "No net loss" policy
3. Wetland restoration, creation and enhancement
4. Successes and failures
5. Mitigation banks
6. Case studies

READING SCHEDULE (Botkin and Keller)

WEEK	CHAPTER	TOPICS
1	Chap. 15	Energy: Some Basics
	Chap. 16	Fossil Fuels and the Environment
2	Chap. 17	Alternative Energy and the Environment
	Chap. 18	Nuclear Energy and the Environment
3	Chap. 20	Water Pollution and Treatment
4	Chap. 20	Water Pollution and Treatment
5	Chap. 22	Air Pollution
	Chap. 24	Ozone Depletion
6	Chap. 23	Indoor Air Pollution
7	Chap. 27	Waste Management
8	Chap. 25	Environmental Economics
9	Chap. 29	Environmental Impact and Planning
10	Chap. 30	Integrating Values and Knowledge

NOTES: *From time to time additional readings are assigned to supplement reading material in text. These are generally given to students as handouts and used for class discussion and seminars.*

Environmental Science III—Detailed Schedule

Date	Topic/Activity
Week 1	Lecture 1 Course Introduction, Introduction to Energy
	LAB #1 Evaluation of Environmental Issues at Hanford Nuclear Reservation
	Lecture 2 Energy—Fossil fuels
	Lecture 3 Energy—Fossil fuels
Week 2	Lecture 4 Energy—Instructor-led seminar on *Energy for Planet Earth* article (*Scientific American*)
	LAB #2 Constructed Wetlands for Wastewater Treatment (Aquatic Ecology Laboratory)
	Lecture 5 Energy—Nuclear power and Introduction to Alternative Energy Sources activity
	Lecture 6 Energy—Alternative Energy Sources activity (Report out by students and discussion of U.S. National Energy Policy and Integrated Energy Management)
Week 3	Lecture 7 Introduction to Water Pollution
	LAB #3 Water Pollution—Aquatic Invertebrates as Bioindicators
	Lecture 8 Introduction to Water Pollution—Categories of Pollutants
	Lecture 9 Video—*We All Live Downstream*
Week 4	Lecture 10 Water Pollution—Categories of Pollutants (cont'd)
	LAB #4 Field Trip—Amphibians as Indicators of Environmental Quality
	Lecture 11 Water Pollution—Wastewater Treatment/Conventional methods
	Lecture 12 Water —Wastewater Treatment/Alternative methods Video—*Race to Save the Planet* series: *Waste Not: Want Not* (in part)

Week 5	Lecture 13 EXAM #1
	LAB #5 Mining Lab Activity—*Going for the Gold* *Frontline* videotape: *Public Lands, Private Profits* Students take measurements for Constructed Wetlands Lab
	Lecture 14 Air Pollution—Introduction and categories of air pollution
	Lecture 15 Air Pollution—Categories and nuclear winter
Week 6	Lecture 16 Air Pollution—Acid rain chemistry and terrestrial ecosystem effects
	LAB #6 Lichens as Bioindicators of Air Pollution
	Lecture 17 Air pollution—Acid rain and aquatic ecosystem effects
	Lecture 18 Ozone Depletion—Introduction Video: from *Race to Save the Planet* series: *Only One Atmosphere* (ozone depletion segment only)
Week 7	Lecture 19 Ozone Depletion
	LAB #7 Constructed Wetlands for Wastewater Treatment (Aquatic Ecology Laboratory)—Analysis and Interpretation
	Lecture 20 Air Pollution—Los Angeles Case Study and Indoor Air Pollution
	Lecture 21 Waste Management—Introduction
Week 8	Lecture 22 Waste Management—Integrated Waste Management Videotape—Oregon Field Guide: *Waste Management*
	LAB #8 The Use of Aerial Photography to Evaluate Land Use Changes—Lab I
	Lecture 23 Waste Management—Integrated Waste Management Seminar—Ocean Dumping
	Lecture 24 Exam #2
Week 9	Lecture 25 Environmental Economics—Video—David Suzuki lecture
	LAB #9 The Use of Aerial Photography to Evaluate Land Use Changes (continued)

	Lecture 26 Environmental Economics—Free-market environmentalism
	Lecture 27 Environmental Economics—Estimating the value of ecosystem services (handout)
Week 10	LAB #10 Field Trip—The Use of Permanent Plots to Monitor Long-term Changes in Vegetation, or H.J. Andrews Experimental Forest Field Trip
	Lecture 28 Land Use Planning—Goals and mechanisms and Environmental Regulation
	Lecture 29 Land Use Planning—Wetland mitigation and wrap-up

HANDOUT

CONDUCTING GOOD SEMINARS

Seminars are an attractive alternative to lectures that are used to exchange information and opinions in small groups. They are commonly used in scientific meetings and upper division college courses. Unlike lectures, seminars *engage all participants actively* rather than passively. They tend to be narrow in focus and allow the group to explore a topic in greater detail. From time to time in Environmental Science this term we will use the seminar format to examine various issues. A relevant article will be assigned for the group to read prior to the meeting. Typically the seminar leader will prepare a number of questions and will guide the discussion. Unlike a lecture where preparation is required only by the lecturer, in a seminar *all participants must arrive prepared.* This preparation is key to a successful seminar.

Responsibilities of the seminar leader

- choose the topic for discussion and assign any background reading for the group (I will generally do this for you whether I am leading the seminar or not)
- prepare a variety of *discussion-type questions* and present these to the group one meeting prior to the seminar

NOTE*: Questions that require only a single word or single sentence answer should be avoided like the plague! Consider questions that are most likely to stimulate discussion.*

- present an introductory statement that provides an overview of the topic at hand
- offer questions for discussion and solicit information or opinions from the group (the seminar leader is not expected to be an authority on the topic)

Responsibilities of the group

- complete the assigned reading prior to the seminar
- give some thought to the questions that have been presented by the seminar leader prior to the seminar
- remain actively engaged throughout the seminar by responding to questions, offering opinions and asking pertinent follow-up questions
- respect opinions of others

NOTES FOR INSTRUCTORS

As an alternative to lecture and discussion formats in Environmental Science, I occasionally have students conduct seminars on pertinent topics. Seminars seem to engage more students in active participation and place more of the responsibility for learning on their shoulders. I generally select an interesting and well-written article that relates to the Environmental Science topic under study. Copies of the article should be distributed to students at least one meeting prior to the seminar. Single students or small groups of students may be given responsibility for leading a seminar. Depending on how frequently the format is used, it should be possible that all students have led a seminar by the end of the term.

Since seminars are more typical of upper division undergraduate and graduate classes, students are unlikely to be familiar with the process. The preceding handout is designed to introduce students to the seminar format and to provide some guidelines to make it a successful exercise.

Evaluation of Environmental Issues at the Hanford Nuclear Reservation

The Hanford Nuclear Reservation was established in 1943 as a site for the production of high-grade plutonium for use in nuclear weapons. A site in southern Washington along the Columbia River was chosen due to its remote location and abundant supply of clean water. At its peak of operation the facility employed and housed 50,000 workers. In addition to the production of plutonium, huge amounts of nuclear waste were also produced and stored in steel and concrete tanks on site. Concerns of environmental contamination and human health effects have prompted governmental agencies responsible for management of the site to initiate the largest environmental cleanup project in the history of the United States.

PROCEDURE

View the following videotapes produced by Oregon Field Guide:

"Cleaning Up Hanford—A Special Report." Oregon Field Guide, 1994, 60 min.

"Hanford Nuclear Reservation as a Wildlife Refuge." Oregon Field Guide, May 1996, 10 min.

☞ *Use information from these videotapes and the accompanying article (Zorpette, 1996) to respond to the following questions:*

1. Which federal and state governmental agencies are responsible for overseeing the cleanup of Hanford?

2. What types of studies are being conducted to monitor the potential effects of environmental contamination from Hanford?

3. What are the results of these studies?

4. At the present time there is no long-term solution for dealing with radioactive waste. Describe the various methods that have been attempted to deal with radioactive waste in the short-term.

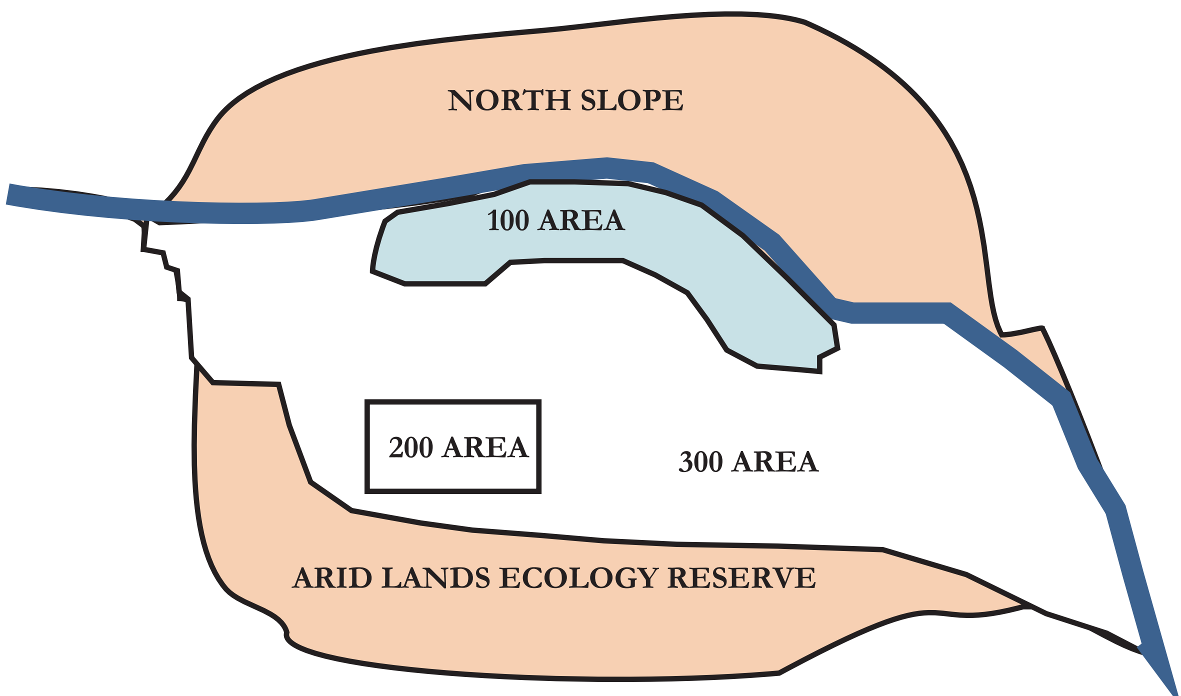
5. The storage tanks at Hanford are often described as containing a "witches brew" of chemicals. Besides radionuclides, which may release radiation into the environment, what other types of contaminants exist at the Hanford site?

6. What are the main concerns related to the contaminants you have listed in the question above?

7. The Hanford facility is divided into several different zones—each with a different history of use, level of contamination and potential for cleanup. These zones are illustrated in the figure below. For each of these zones describe:

A. How the area was used during the time Hanford was in full operation.
B. What types of contamination exist on the site?
C. To what degree are these contaminants "contained"? (i.e., are any leaking into the soil or groundwater?)
D. What are the cleanup plans for this area?
E. In your opinion, taking into account such elements as cost, human health and environmental degradation, what should be the ultimate fate of this zone?

HANFORD NUCLEAR RESERVATION



Record your answers on the pages that follow.

North Slope *and* Arid Lands Ecology Reserve

Original Use

Types of Contamination

Containment of Contaminants

Cleanup Plans

Ultimate Fate

100 Area

Original Use

Types of Contamination

Containment of Contaminants

Cleanup Plans

Ultimate Fate

200 Area

Original Use

Types of Contamination

Containment of Contaminants

Cleanup Plans

Ultimate Fate

300 Area

Original Use

Types of Contamination

Containment of Contaminants

Cleanup Plans

Ultimate Fate

NOTES FOR INSTRUCTORS

Prior to conducting the lab, small groups of students should be assigned one of the following contaminants to research. Each of these contaminants is mentioned in the videotape. Begin the lab by having each group report out to the class on the source(s), uses, and potential environmental and human health hazards of their contaminant.

Strontium 90, Iodine 129, Cesium, Plutonium, Carbon tetrachloride, Tritium

Also prior to lab, students should read:

Zorpette, G. 1996. *Hanford's nuclear wasteland.* Scientific American. May 96:88-97.

This article summarizes the history of Hanford Nuclear Reservation and documents the nature of hazardous waste that is stored on the site. It is a useful complement to the videotapes described below.

"Radioactive waste" conjures up images of radiation burns on the skin of Hiroshima survivors, formation of tumors induced by changes in DNA caused by radiation exposure, and mutant life forms portrayed in science fiction movies like *The X-Men*.

Since the 1960's in particular, nuclear energy has raised fear in minds of Americans. In more recent years, it appears that some of this fear is justified:

- Three-Mile Island, PA, and Chernobyl (Russia) nuclear accidents
- Since 1986, government studies and once-secret documents have revealed that most of the nuclear weapons facilities supervised by the DOE have been operated with disregard for the safety of their workers and people in nearby areas.
- Since 1957 large quantities of radioactive particles have been released into the air and tons of radioactive waste and toxics have been placed into creeks and leaking pits
- The EPA estimates that there may be as many as 45,000 sites in U.S. contaminated with radioactive materials (20,000 of these belong to DOE and DOD) with an estimated cost of cleanup at $270 billion.

Some are concerned that the situation is really worse than this. Will Congress appropriate funds for cleanup? Does the political will exist to clean up these sites?

The U.S. situation pales compared to other situations in other countries (former Soviet Union nations, in particular):

- The Mayak plutonium production plant in S. Russia released 2 ½ times as much radiation as Chernobyl into the air and nearby lakes. One lake is so radioactive that standing on its shores for 1 hour would be fatal!
- 15 defunct nuclear submarines dumped off the coast of Russia (3 were loaded with nuclear fuel)
- Thousands of containers containing nuclear waste were dumped off the Russian coast

In today's lab you will examine some of the issues surrounding the disposal of nuclear waste at the Hanford Nuclear Reservation in Southern Washington. The site was a plutonium-generating plant, but many of the same issues relate to nuclear energy power plants. (Nuclear energy as an alternative energy source will be discussed in lecture next week.)

Events and developments at the Hanford Nuclear Reservation appear frequently in recent news reports:

- October 1999: Local governments want control over *The Hanford Reach*, the last free-flowing portion of the Columbia River, and adjacent lands. Agricultural use, especially for irrigation, would be emphasized. Alternative plans proposed by the federal government and supported by Sen. Patty Murray and Rep. Norm Dicks of Washington state would designate the 51-mile stretch of river as a *Wild and Scenic River* and protect about 90,000 acres of federal land, mostly as a wildlife refuge.

- November 1999: President Clinton expanded the *Saddle Mountain National Refuge* along the Columbia River to include 57,000 acres of the Hanford Nuclear Reservation. The area is considered by environmentalists as an excellent example of shrub-steppe habitat. It harbors more than 200 species of birds and more than 40 rare plants and animals such as the long-billed curlew and the White Bluffs bladder pod.

- March 2000: Hanford Nuclear Reservation was designated as a repository for additional nuclear waste generated elsewhere in the United States. The state of Washington is appealing the decision.

Students should form groups of 3, answer and discuss questions, and submit one set of responses per group.

Have them describe each of the contaminants assigned to them—What are they? What are they used for? What are human health or environmental contamination concerns?

Strontium 90. Chemically similar to calcium; a common component of "nuclear fallout"; cows eat grass near sources➜milk becomes contaminated➜humans consume milk➜strontium concentrates in bones and may cause bone cancer. Half-life is approximately 30 years.

Iodine 129. Concentrated in thyroid (thyroxine hormone) the metabolic hormone produced by thyroid has iodine as the base for chemical structure. May cause thyroid problems; has a long half-life.

Cesium. A soft white metal, chemically similar to potassium, used in radiotherapy; Cesium 134 and 137 isotopes are radioactive.

Plutonium. A man-made silvery metal developed in 1940 for use in atomic weapons; 100,000 year half-life and *extremely poisonous.*

Carbon tetrachloride. A chemical solvent and suspected carcinogen; also causes kidney and liver damage.

Tritium. An emission product of nuclear weapons, short (12 years) half-life, rapidly diluted in one week to 10 days after release.

If the topic of radioactivity has not been discussed in lecture, the following information may be covered prior to showing the videotape:

Natural Radioactivity

Isotopes are elements that contain more than normal number of neutrons. Some of these are **radioisotopes** because they undergo radioactive decay, spontaneously releasing high energy particles at a fixed rate:

1. gamma rays: damaging high-energy radiation
2. alpha particles (2 P, 2 N)
3. beta particles (high speed electrons)

Each type of radioisotope decays spontaneously into a different isotope. The **half-life** of a radioisotope is the time required for half of radiation to be released (ranges from a few billionths of a second to several billion years). Known values of decay rates are the basis for the use of radioisotopes in dating of organic materials.

Nuclear Fission

Large mass isotopes (e.g., Uranium-235) are bombarded by neutrons and split apart. This splitting releases more neutrons which trigger additional splitting and large amounts of energy (in the form of heat). The reaction is analogous to throwing a ping pong ball into a room filled with set rat traps, each with 2 ping pong balls setting on the bar.

In a **nuclear fission bomb** (atomic bomb), this reaction is uncontrolled, resulting in an explosion. In a **nuclear reactor,** the reaction is controlled and heat energy is used to generate steam which turns turbines.

MATERIALS

A 1995 Oregon Field Guide Special on the Hanford Nuclear Reservation forms the basis for this laboratory. The video describes the history of Hanford, the types of contamination on the site and plans to clean up the contamination. A second videotape examines the biodiversity of the Arid Lands Ecology Reserve and the North Slope which served as buffers for plutonium production, and therefore, remain in an uncontaminated, pristine condition. The second video provides additional information to students as they decide the ultimate fates of each of the Hanford zones.

Both videotapes are available from:

Oregon Public Broadcasting Productions
7140 SW Macadam Ave.
Portland, Oregon 97219-3099
1-800-241-8123

Cleaning Up Hanford—A Special Report. Oregon Field Guide, 1994, 60 min.

Hanford Nuclear Reservation as a Wildlife Refuge. Oregon Field Guide, May 1996, 10 min.

OTHER REFERENCES

Hollister, C.D. and S. Nadis. 1998. *Burial of radioactive waste under the seabed.* Sci. Am. Jan. 1998:60-65.

Whipple, C.G. 1996. *Can nuclear waste be stored safely at Yucca Mountain?* Sci. Am. June 1996.

Zorpette, G. 1996. *Hanford's nuclear wasteland*. Sci. Am. May 1996:88-97.

Evaluation of Environmental Issues at the Hanford Nuclear Reservation

The following are some possible responses to questions for the Hanford lab:

1. Which federal and state governmental agencies are responsible for overseeing the cleanup of Hanford?

Environmental Protection Agency, Washington Department of Ecology, Department of Energy

2. What types of studies are being conducted to monitor the potential effects of environmental contamination from Hanford?

Monitoring of agricultural crops, air, the Columbia River, contaminant plumes in soil and groundwater

3. What are the results of these studies?

Monitoring of agricultural crops—no contamination in crops produced downwind

Monitoring of air—background levels only

Monitoring of Columbia River—contamination leaking into river is quickly diluted and currently having no measurable effects

Monitoring of contaminant plumes in soil and groundwater—several plumes of contamination threaten groundwater and Columbia River—Tritium, Iodine 129

4. At the present time there is no long-term solution for dealing with radioactive waste. Describe the various methods that have been attempted to deal with radioactive waste in the short-term.

Vitrification—encasing contaminants by converting contaminants in soil and converting to glass with high temperatures (or there is a new method that vitrifies using chemical reactions rather than heat)

Cover contaminated soil with gravel

Excavate contaminated soil and move to another area

Place in holding tanks or trenches

5. The storage tanks at Hanford are often described as containing a "witches brew" of chemicals. Besides radionuclides, which may release radiation into the environment, what other types of contaminants exist at the Hanford site?

Carbon tetrachloride, Hydrogen gas, Lead, Gold

6. What are the main concerns related to the contaminants you have listed in the question above?

Carbon tetrachloride—possible carcinogen, liver and kidney damage
Lead—toxic to nervous system
Hydrogen gas—explosive potential

7. The Hanford facility is divided into several different zones each with a different history of use, level of contamination and potential for cleanup. These zones are illustrated in the figure below. For each of these zones describe:

North Slope *and* Arid Lands Ecology Reserve

Original Use
A security buffer zone to the north and south of main facility with no contamination; relatively pristine environment since it has been largely untouched since 1943; some missile sites here

Types of Contamination
None or at least minimal

Containment of Contaminants
N/A

Cleanup Plans
Immediate cleanup planned

Ultimate Fate
Wildlife reserve?, park area?, industrial use?

100 Area

Original Use
Location of 9 reactor buildings that have been shut down; remains of old town of Hanford; close to Columbia River

Types of Contamination
Nuclear fuel is still stored under water in "K-west" and "K-east"; solid radioactive objects are buried adjacent to all reactors

Containment of Contaminants
Fuel rods are protected by submersion in water; some fuel rods have leaked into bottom of concrete containment tanks; there is now a radioactive sludge at bottom of tanks

Cleanup Plans
Highest priority for cleanup, removal of waste to "200 area"; storage of nuclear fuel in Nevada and other states; demolition of "clean buildings" and recycling of metal and cinder blocks; stop tank leakage

Ultimate Fate
Wildlife reserve?, industrial use?, agriculture?

200 Area

Original Use
9 miles from the Columbia River, West and East 200 areas used for long term storage of nuclear waste plus a buffer zone around these two sites; original site for plutonium storage; concrete tanks, trenches and contaminated soil; site of 5 reprocessing plants (in huge concrete buildings called "canyons") which processed plutonium from irradiated nuclear fuel

Types of Contamination

Area contains about 70% of Hanford's waste sites; approximately 210,000 cubic meters of highly radioactive nuclear waste from reprocessing (I^{129}, Tritium, Strontium^{90}) in 177 concrete tanks, barrels in trenches, a "witches brew" of unknown mixture of chemicals; some contamination in buildings (air ducts, air filters, etc.); radioactively and chemically contaminated wastewater dumped on soil; 1,900 capsules containing Cesium 137 or Strontium 90 that were removed from high-level waste tanks in an earlier effort to reduce temperature and radioactivity

Containment of Contaminants

Leakage or suspected leakage from 67 storage tanks and resulting contamination plumes of all of above contaminants; heat and flammable gases building up in some; soil contamination is not contained; contamination in "canyons" is so high instruments are unavailable for precise measurement; Cesium/Strontium capsules are housed in water-filled pools that emit bright blue glow

Cleanup Plans

Vitrification?, will be used as a repository for contaminants removed from other zones (a "national sacrifice area"); stop leaking from tanks; bury the cores of the nuclear reactors by 2070

Ultimate Fate

Depends on level of cleanup; probably will never be suitable for human habitation; consolidate and contain as much waste as possible

300 Area

Original Use

Mostly unused but scattered areas of contamination in waste dumps and pits; WPSS nuclear power plants that are mothballed; six small test reactors, experimental facilities, laboratory, site for nuclear fuel fabrication; some contaminants simply dumped on ground

Types of Contamination

Plutonium and other radionuclides but generally less concentrated than 200 area; uranium-bearing liquids, contaminated coolants from reactors, barrels containing waste were dumped on ground and/or buried, carbon tetrachloride, "glove boxes" in research facility

Containment of Contaminants

Much is not contained, soil and groundwater contamination

Cleanup Plans

Locate and dig up contaminated areas, then confine in "200 area" or cover with gravel; attempt to stimulate bacteria to process waste

Ultimate Fate

Contentious, but appears that it at least a portion will be designated as a wildlife refuge, agriculture?

FINAL NOTE: *If possible, provide a field trip opportunity for students to visit a nuclear power plant or facility that deals with radioactive waste.*

How Can We Evaluate Alternative Energy Sources?

INTRODUCTION

This handout is designed as a supplement for Botkin and Keller's *Environmental Issue* on p. 359. In this activity you are asked to evaluate alternative energy sources (i.e., those sources other than traditional fossil fuels) in an objective manner. Upon completing this evaluation, you should be able to rank the various alternative energy sources using several criteria.

I. ENVIRONMENTAL IMPACTS SUMMARY

The first step in this analysis is to examine the environmental impacts of each alternative energy source. In the table below, list the "pros" and "cons" for each energy source. Wind power has already been completed as an example.

NOTE: *Omit "Combined Cycle Coal" from this analysis.*

	PROS	**CONS**
Wind	Non polluting	noise, kill birds, land disturbance, scenic degradation
Geothermal		
Photovoltaic		
Solar Thermal		
Biomass		
Nuclear		

II. RATING ALTERNATIVE ENERGY SOURCES

Complete the following:

1. As described on page 359 of your text, assign a score of "1" (worst rating) to "10" (best rating) for each column on the following table entitled "PRE-WEIGHTED TOTALS." Use only whole numbers. Since you will lack complete information for some energy sources, you will have to use your best judgement. Use your analysis of "Environmental Impacts" on page 1 of this handout to complete the last column. Leave the "Weights" row empty for now.

2. Although we could evaluate alternative energy sources on this information alone by summing up the scores on the chart, you may find that not all of these criteria carry equal weight. For example, you may feel that the cost to produce a particular energy source is much more important than its environmental impact. We can take this into account by assigning "weights" to each of the criteria.

3. To keep results consistent from one student to the next, assign weights that are some fraction of 1.0 to each of the criteria according to their importance. For example, if you feel that all criteria carry exactly the same importance (highly unlikely), you would assign a weight of 0.142 ($1/7^{th}$) to each criterion. The total of all of your weights should be exactly 1.0.

Enter these weights on the chart entitled "PRE-WEIGHTED TOTALS."

4. Now you can apply these weights to each of the numbers on the chart. Simply multiply each score you have assigned to the criteria by the weighting factor and enter this new number in the chart entitled "WEIGHTED TOTALS."

5. Add the weighted totals for each energy source, enter these numbers on the chart in the appropriate column.

6. Rank each energy source according to these numbers. Assign a #1 rank to the highest number, a #2 rank to the next highest, etc. You have now created your personalized priority list for alternative energy sources.

Use all of this information to form a *national energy policy for the future* (see chart on following page).

PRE-WEIGHTED TOTALS

	U.S. Recoverable	Costs	Land Use	Carbon Reduction	Carbon Avoidance*	Jobs	Environmental Impacts
Weights							
Wind							
Geothermal							
Photovoltaic							
Solar Thermal							
Biomass							
Nuclear							
Hydroelectric							

*Carbon avoidance cost is a way to estimate the cost of replacing coal-fired electric generating plants with an alternative energy source. Fuel, operating costs and environmental pollution for a coal plant are estimated to be 3.5 cents, so anything above this amount is considered to be a cost for C-avoidance. NOTE: lower numbers indicate lower cost to avoid release of C into the environment.

WEIGHTED TOTALS

	U.S. Recoverable	Costs	Land Use	Carbon Reduction	Carbon Avoidance	Jobs	Environmental Impacts	Weighted Total	Rank
Weights									
Wind									
Geothermal									
Photovoltaic									
Solar Thermal									
Biomass									
Nuclear									
Hydroelectric									

Now assume that you are designated the "U.S. Energy Czar" for the next 100 years. In this position you are responsible for designing and implementing an integrated energy policy that takes into account all of the factors examined above. *What would your policy look like?* In the table below indicate changes that would take place in energy production over the time frame indicated across the top.

Coal, for example, currently accounts for 28% of energy generation in the United States. What would this number be according to your policy for the years 2010, 2050 and 2100? The eyes of the public will be upon you—*so be prepared to defend your numbers!*

	2000	2010	2050	2100
Wind	0.1			
Geothermal	0.1			
Photovoltaic	0.1			
Solar Thermal	0.1			
Biomass	2			
Coal	28			
Nuclear	6			
Petroleum	38			
Hydropower	7			
Natural Gas	19			
Hydrogen	0			

III. ALTERNATIVE ENERGY SOURCES—ANALYSIS

A. Narrative

Use the chart you have prepared on the previous page to prepare a short narrative that describes your energy policy in words. Be sure to include your rationale for changes in energy sources over the duration of your reign as "Energy Czar." Use the space below.

B. Questions

Answer each of the questions below as completely as possible in the space provided.

1. A number of different criteria (cost, environmental impact, etc.) have been used to evaluate alternative energy sources. In your opinion, are there any criteria that are missing from the evaluation? What are they?

2. What factors did you assign the greatest weight in your evaluation of alternative energy sources? Why were these factors important to you?

3. Examine the rankings of alternative energy sources generated by other students. Does there appear to be "a consensus view"?

4. Where would you place "Coal" in your rankings? Explain.

5. If a safe way for disposing of nuclear waste were found, would this change your ranking for this energy source? Explain why or why not.

6. If energy from nuclear fusion were available for commercial use tomorrow, what alternative energy sources would you eliminate, and why?

7. Which energy sources would you favor if one of your main objectives was to reduce global warming due to the greenhouse effect? Explain why.

8. If the analysis was done on a regional scale rather than a national scale, as we have done, the rankings may change. Some regions of the country, for example, have better access to solar energy while others may have readily available sources of coal or hydropower. What would your rankings be for the two regions listed below?

Southwestern U.S.	Willamette Valley, Oregon
1.	
2.	
3.	
4.	
5.	
6.	
7.	

9. What could be done to encourage the development and use of alternative energy sources?

REFERENCES

The following resources are but a small sample of articles that have been published regarding the future of various energy sources.

Campbell, C.J. and J.H. Laherrere. 1998. *The end of cheap oil.* Sci. Am. Mar.1998:78-83.

Dunn, S. 1999. *King coal's weakening grip on power.* WorldWatch Sep./Oct. 1999:10-19.

Flavin, C. and N. Lenssen. 1999. *Nuclear power nears its peak.* WorldWatch July/Aug:36-38.

Flavin, C. 1996. *Power shock: The next energy revolution.* WorldWatch Jan/Feb.1996:10-21.

Flavin, C. 1996. *Wind power: Small but growing fast.* WorldWatch Sep/Oct. 1996:35-37.

Fouda, S.A. 1998. *Liquid fuels from natural gas.* Sci. Am. Mar. 1998:92-95.

Gibbons, J.H., P.D. Blair and H.L. Gwin. 1989. *Strategies for energy use.* Sci. Am. 261:82-89.

Rist, C. 1999. *Why we'll never run out of oil.* Discover June 1999:79-87.

Weinberg, C.J. and R.H. Williams. 1990. *Energy from the sun.* Sci. Am. Sept. 1990:147-155.

American-Indian Cultural Perspectives
Energy Resources
Developed by NCSR Tribal partners

Objectives

1. To introduce students to Native American cultural perspectives regarding energy production, particularly coal mining, and effects on water and land resources on Indian reservations.

2. To present historical and anecdotal information on these topics, regarding their place in indigenous culture; including social, religious, and economic significance.

3. To make students aware of energy/ore production, problems, and concerns now occurring on Native American reservations. Tribal examples include Hopi and Navajo in Arizona; Lakota Sioux in South Dakota; Gros Ventre/Assiniboine at Ft. Belknap; and Crow and Northern Cheyenne in Montana.

Introduction

"Hopi Indian Religious Leader's Letter to the President of the USA"
Last year the Peabody Coal Company, a subsidiary of Kennecott Copper Company, began stripping coal from 65,000 acres it has leased from the Navajo and Hopi tribes. Company officials declared that this mining would not damage Indian lands and in fact would improve the lives and subsistence of many Navajos and Hopis. In disagreement with this action a group of high spiritual leaders of the Hopi wrote the following letter to President Nixon (In McLujan, T.C. ***Touch The Earth****. New York: Simon & Schuster, 1971, pp 170-171).*

Dear Mr. President:

We, the true and traditional religious leaders, recognized as such by the Hopi People, maintain full authority over all land and life contained within the Western Hemisphere. We are granted our stewardship by virtue of our instruction as the meaning of Nature, Peace, and Harmony as spoken to our People by Him, known to us as Massau'u, the Great Spirit, who long ago provided for us the sacred stone tablets which we preserve to this day. For many generations before the coming of the white man, for many generations before the coming of the Navajo, the Hopi People have lived in the sacred place known to you as the Southwest and known to us to be the spiritual center of our continent. Those of us of the Hopi Nation who have followed the path of the Great Spirit without compromise have a message which we are committed, through our prophecy, to convey to you.

The white man, through his insensitivity to the way of Nature, has desecrated the face of Mother Earth. The white man's advanced technological capacity has occurred as a result of his lack of regard for the spiritual path, and for the way of all living things. The white man's desire for material possessions and power has blinded him to the pain he has caused Mother Earth by his quest for what he calls natural resources. And the path of the Great Spirit has become difficult to see by almost all men, even by many Indians who have chosen instead to follow the path of the white man….

Today the sacred lands where the Hopi live are being desecrated by men who seek coal and water from our soil that they may create more power for the white man's cities. This must not be allowed to continue for if it does, Mother Nature will react in such a way that almost all men will suffer the end of life as they now know it. The Great Spirit said not to allow this to happen even as it was prophesied to our ancestors. The Great Spirit said not to take from the Earth—not to destroy living things. The Great Spirit, Massau'u, said that man was to live in Harmony and maintain a good clean land for all children to come. All Hopi People and other Indian Brothers are standing on this religious principle and the Traditional Spiritual Unity Movement today is endeavoring to reawaken the spiritual nature in Indian people throughout this land. Your government has almost destroyed our basic religion, which actually is a way of life for all our people in this land of the Great Spirit. We feel that to survive the coming Purification Day, we must return to the basic religious principles and to meet together on this basis as leaders of our people….

Discussion

Historical and anthropological records, and numerous government documents, have clearly demonstrated that there has been a continuous conflict of values between traditional Native-American cultures and Western society: clashes among *spiritual versus economic* values. This conflict of values and perspectives, and resulting political-legal issues are very evident in concerns over the needs, utilization, and management of natural resources and energy. Many natural resources, including energy resources, are found on or near Indian reservations. Examples of reservations with energy resources include: the Hopi and Navajo located in the Four Corners region that includes Arizona; the Lakota Sioux in South Dakota; and the Assiniboine and Gros Ventre, the Crow, and the Northern Cheyenne tribes of Montana.

Native-American people residing in such areas often live in extreme poverty, suffer very poor health, and live in isolation. As a consequence, education levels are very low, while unemployment rates are among the highest in the nation. To survive and raise standards of living, tribal people must have jobs; hence, vast deposits of natural energy, minerals, ores and metal resources not only offer the opportunity for tribal economic development, income, and employment, they also create a dilemma for the Indian people in terms of values conflict. These conflicts arise among "progressives" and "traditionals"— tribal "progressives" are usually those who are more educated, and who have a tendency to sit on administrative positions of authority and power for the tribe, and who strongly advocate economic exploitation and development of the resources. Tribal "ttraditionals" are generally less educated in "Western Knowledge" and values, and are frequently the spiritual and religious leaders for the tribe; often they strongly argue against exploitation while warning about the possible dangers of environmental pollution, health hazards, and spiritual reprimand.

Tribal Case Studies

Hopi, Navajo, and Lakota Sioux

See the reference on the Hopi, Navajo, and Lakota Sioux by Ward Churchill and Winona LaDuke (Chapter VIII, pp 241-266).

Navajo Uranium Operations: From studies conducted between 1964 and 1981, the rate of Navajo newborn birth defects in the Shiprock Uranium Mining area was two to eight times as high as the national average. Microcephaly and Down Syndrome, among other birth defects, had tripled since the commencement of uranium mining and milling activities in the area.

Cheyenne

For Cheyenne perspectives and information, refer to the article by Gail Small (Small, Gail. *War Stories.* The Amicus Journal. Spring, 1994. Vol. 16.).

Crow

Refer to *The Oil Daily*. Dec. 20, 1984. p.2.

A joint venture partnership was reported between the Crow Tribe and three independent oil and gas producers for the first time, giving the tribe an equity interest in energy exploration. This partnership may be used as a prototype for future mineral rights agreements between Indians and energy companies.

Raven Oil Company formed under the aegis of the **Indian Mineral Development Act**, and was approved by the Bureau of Indian Affairs. Raven Oil consists of the tribe and Buffalo Exploration Company, which is a partnership of companies. The agreement gave control of Raven to the tribe, which would receive 51 percent of all profits, plus the normal 16 percent royalty that tribes have traditionally received for leasing their oil and gas resources. Buffalo Exploration receives 49 percent of the profits.

Raven is run by a management committee, consisting of four Crow representatives, and three from Buffalo Exploration.

Assiniboine and Gros Ventre

Zortman-Landusky Mines, (In) National Wildlife Federation Newsletter, 1997.

Spirit Mountain, a sacred site to the Assiniboine and Gros Ventre tribes of north-central Montana, was laid waste by bulldozers for [Western] society's passion for gold, and thus it was no longer available for Native American traditional ceremonies and vision quests. It has been replaced by the Gold Bug Pit, its summit destroyed, its flanks scarred, and its rivers and wildlife polluted.

When gold was discovered in the Little Rocky Mountains in the late 1880s, in an area formerly part of the Fort Belknap Indian Reservation, the Federal Government pressured the tribes to cede the gold-bearing land areas of the reservation to the United States. Small-scale gold mining occurred in the area until the late 1970s, when Zortman-Landusky Mines, Inc. (ZMI) began operating in 1979. The use of cyanide heap-leach technology facilitated large-scale mining of low-grade ores found in these Mountains. Numerous expansions of mining operations created environmental problems, ranging from cyanide spills, to leach pad stability failures, and to bird and wildlife deaths. A series of lawsuits by the Tribes regarding these problems alleged numerous, significant and ongoing water quality violations, resulting in a Consent Decree in which legal actions which required ZMI to pay over $29 million for water quality violations, water quality studies, and other tribal amenities.

In 1992, ZMI applied once again to expand its operation from the then-400 to over 1200 acres. In 1996, after four years and preparation of an Environmental Impact Statement (EIS), the Department of Environmental Quality (DEQ) approved the ZMI's permit to expand. In 1997, the tribes and conservation organizations filed suit against Montana's DEQ, citing, among other issues, these problems with the EIS:

•The EIS fails to address possible contamination of local aquifers, even though the DEQ recognizes that such groundwater contamination may already be occurring on the Fort Belknap Indian Reservation.

•The EIS contains no mitigation measures.

•The mine expansion would continue over 100 years of significant disruption to Native-American traditional cultural practices in the Little Rockies. It would impact 41 cultural sites, including vision quest and fasting sites, rock art sites, and a pow-wow grounds. The EIS fails to discuss these concerns.

•It lacks comprehensive study of impacts on wildlife. The expansion would cause cumulative loss of over 10% of existing wildlife habitat in the Little Rocky Mountains.

•Air emissions resulting from the expansion would violate federal and state air quality stan dards.

Questions/Assignments

Using resources and readings provided, research the following and prepare a research report:

1. The United States of America (the "dominant Western society") needs energy and related ore resources, and impoverished Native-American people need employment and a steady source of income. Research and discuss how the differing value systems among tribal and non-tribal individuals might be resolved in such a way as to meet all the needs; and, if not, what alternatives do you suggest?

2. What forms of energy, ore, mineral, and metal resources are located on or near Indian reservations? Describe energy resources in detail for one of the reservations listed. Include examples of past and current problems, concerns, and issues involving energy resources on that Indian reservation.

3. In what ways would conversion to "alternative" forms of energy (i.e., geothermal, wind, solar, etc.) impact Indian society and reservation lands? Include both positive and negative impacts.

SUGGESTED TEXTS, REFERENCES, AND INTERNET RESOURCES

Churchill, Ward and Winona LaDuke (ed. Jaimes, M. Annette). *Native North America: The Political Economy of Radioactive Colonialism*. Chapter VIII, pp 241-266.

The State of Native America. Boston: South End Press, 1992.

Montana Library Network – Academic Libraries.

High Country News, P.O. Box 1090, Paonia, Co. 81428 (970-527-4898).

Link, Terry. *Environmental Racism/Environmental Equity: A Bibliography*. Green Library Journal. 1993. 2(1): 17-22.

Small, Gail. *War Stories.* The Amicus Journal. Spring, 1994, Vol. 16. (www.mineralpolicy.org/bittersweet.html)

LaDuke, Winona. *The Council of Energy Resource Tribes: An Outsiders View In*, (In) Joregson, Joseph (ed). *Native Americans and Energy Development II*. Anthropological Resource Center/Seventh Generation Fund. Cambridge, Mass. 1984.

Harold, Tso and Laura M. Shields. *Navajo Mining Operations: Early Hazards and Recent Interventions*. New Mexico Journal of Science, Vol. 20, No.1, June, 1980.

Sorenson, J.B. *Radiation Issues: Government Decision Making and Uranium Expansion Mining*, Black Hills/ Paha Sapa Report, Vol. 1, No.1, 1979.

Samet, J.M., et.al. *Uranium Mining and Lung Cancer in Navajo Men*, New England Journal of Medicine, No.310, 1984, pp. 1481-84. (And) Barry, Tom. *Bury My Lungs At Red Rock*, The Progressive, Feb.1979, pp. 25-27.

Irvin, Amelia, *Energy Development and the Effects of Mining on the Lakota Nation*, Journal of Ethnic Studies, Vol. 10, No.1, Spring, 1982.

Women Of All Red Nations, *Radiation: Dangerous To Pine Ridge Women*, Akwesasne Notes, Rooseveltown, N.Y. Spring, 1980.

Films:

Paha Sapa: *The Struggle For The Black Hills*; Navajo: *The Last Red Man;* The Four Corners: *A National Sacrifice Area* (all from Earth Image Films).

Internet searches:

1982 *Indian Mineral Development Act* (www4.law.cornell.edu/uscode/25/2101.html)
U. S. Code, Title 25, Indian child welfare (www4.law.cornell.edu/uscode/25/ch3.html)

Native Americans and the Environment Bibliographies (www.Indians.org/library/biblios.html)
Native American Environmental Enforcements (www.mineralpolicy.org/bittersweet.html)

Indian Country Today

Obtain past reports and articles related to Indian tribes, and problems or accomplishments concerning energy, ore, mining, environmental hazards, and pollution. Visit the newspaper's website at: www.indiancountry.com

NOTES FOR INSTRUCTORS

This activity was adapted from Botkin and Keller's *Environmental Issue* on page 359 and is designed to guide students through an objective evaluation of alternative energy sources. Upon completion of this evaluation, students should be able to rank the various alternative energy sources using several criteria. Student rankings can then be used as the basis for a discussion concerning energy management policy.

The activity is completed over an extended period. At the first class meeting, students are given the handout and told to read Chapter 17 in Botkin and Keller for the next class meeting. They should also complete the first page of the handout which summarizes the "pros" and "cons" of the various alternative energy sources. The second class meeting is devoted to ranking alternative energy sources as outlined in the remainder of the handout and then using this ranking to create energy policy 10 years, 50 years and 100 years into the future. Students work in small groups and are encouraged to exchange any pertinent information. In the third class meeting, four or five volunteers are asked to present their energy policy for discussion. Strengths, weaknesses, differences and similarities of the various proposed policies are discussed.

The discussion is then directed towards "Integrated Energy Management" and the components of a "National Energy Policy." The main points for discussion are as follows:

Integrated Energy Management (IEM) recognizes that no single energy source can possibly provide all energy needs in both the developing and industrialized world. The primary goal of (IEM) is to provide sustainable energy that:

- is reliable and affordable
- is environmentally benign at local, regional and global scales
- ensures that future generations inherit an Earth in which all of its systems and components are intact

At present, the U.S. does not have a National Energy policy although periodically the president releases the administration's position on the future of energy in the U.S. These statements are generally status quo and promote the proliferation of fossil fuels.

QUESTIONS FOR DISCUSSION

Can we rely on governments to have the foresight to establish an energy policy for the future? Or, for that matter, can we expect the government to establish a forest policy, land use policy, grazing policy, etc. If not the government, then who?

Should we have a National Energy Policy?

PRO: Environmental degradation has resulted from unwise use of energy (oil spills, global warming, air pollution, acid rain, infringement on natural habitats, etc.)

CON: There may be negative economic consequences if we move away from the status quo.
If we did have a "Sustainable National Energy Policy," what components would be included?

Two important focal points—energy conservation and energy sources

We must decrease demand for energy while at the same time increase the environmental acceptability of fuels.

The appropriate mix of energy sources depends on time frame since reality suggests that we cannot totally abandon fossil fuels immediately. For example, at present, the Pacific Northwest produces 80% of its electricity and 39% of its energy overall from hydropower. The remainder is a mixture of primarily fossil fuel-generated energy.

Energy mix must be site specific due to uneven distribution of fuels. The following policy was developed specifically for the Willamette Valley in Oregon:

1. Decrease demand by increasing efficiency and conservation measures, for example:

   - fuel efficient vehicles and residences
   - designing equipment to produce more work with less energy input
   - different settlement patterns that maximize accessibility to services and minimize the need for transportation
   - new agricultural practices that emphasize locally grown and consumed foods and emphasize foods that require less energy input
   - new industrial practices that minimize consumer waste (e.g., reduce packaging)

2. Cogeneration collects waste that is currently lost during the process of conventional energy generation. Cogeneration could supply 10% of our energy needs.

3. Hydrogen developed and promoted as a fuel

   - as versatile as oil but non-polluting
   - can be produced by electrolysis of water
   - electricity produced by renewable energy resources should be used
   - water vapor and small amounts or NOx result when burned

4. In the short-term, encourage the substitution of natural gas for oil and coal

   - cuts air pollutants by 90-99% and CO_2 emissions by 30-65%
   - more abundant and more widely distributed than oil
   - natural gas will be a transition fuel between fossil fuels and renewables

5. In the long-term, place greater emphasis on solar and wind energy as alternatives

- Columbia Gorge is among windiest locations on Earth
- but, the area is also a wild and scenic area

What are the strengths and weaknesses of this policy?
Students individually submit the completed exercise at the following meeting.

AMERICAN-INDIAN PERSPECTIVES

A special section is included, produced by the Center's tribal partners. Instructors are encouraged to have students do activities.

Also, available free of charge from the Center is a publication titled, "American-Indian Perspectives: Nature, Natural Resources and Natural Resources Education."

Constructed Wetlands for Wastewater Treatment

INTRODUCTION

The treatment of wastewater from municipal, agricultural and industrial sources is of primary concern in modern societies. Water that contains pollutants from raw sewage to chemical contaminants must be processed before entry into natural waterways to avoid environmental contamination and resulting threats to environmental quality and human health. For years, modern societies have constructed large, centralized wastewater treatment facilities that treat large volumes of water using both chemical and biological processes. The utility of such facilities has come into question lately, particularly when considering their high cost and increased demands put upon them by growing populations. Consequently, there has been a great deal of interest in the development of alternative methods of treatment that capitalize on natural processes that occur in ecosystems. Among these alternatives is the use of natural and constructed wetlands to replace or (more commonly) augment the actions of technology-based wastewater treatment plants. Arcata, California, for example, has used a wetland for treatment of domestic sewage from that community since the 1970s. More recently, the city of Salem, Oregon has proposed a 630-acre plantation of poplar trees to treat cannery waste. Large-scale efforts often provide secondary benefits as well such as wildlife habitat or even recreational opportunities.

In this lab, you will evalute how effectively a constructed wetland (a "wetland mimic," so to speak) is able to treat agricultural wastewater. This laboratory was developed for Chemeketa Community College's *Aquatic Ecology Laboratory*; your instructor will provide background on your particular study site.

PROCEDURE

This laboratory begins a six-week study which will culminate in a final report. In today's laboratory we will:

- Learn and practice the protocols to be followed for water quality measurements in a constructed wetland
- Measure the initial conditions in the wastewater
- Discuss the experimental design of the study

I. Preparation of Wastewater

Two tanks (B4 and B5) were prepared as agricultural wastewater by adding 400 g of 16-16-16 pelletized fertilizer to each of these 300-gallon tanks. Tank B4 was designated as the **source tank**, which contains water to be processed by the wetlands. Tank B5 was designated as the **control tank**, and will be used to monitor water quality changes in wastewater that is *not* processed by the wetlands.

II. Measure Initial Conditions in Wastewater

Protocols (step-wise instructions) have been developed (see handout) that describe *how* each of nine water quality measurements should be taken.

Each group should carefully examine and test each of these protocols using water samples taken from source tank B4. These measurements will represent the initial conditions in the source tank prior to treatment.

IMPORTANT NOTE: *Be sure that by the end of today's lab, every group member knows how to take each measurement according to the protocols.*

The wastewater should be carefully mixed before measurements are taken. (*Don't overdo it!* Vigorous mixing could add oxygen to the water and influence the dissolved oxygen measurement.)

Take initial measurements on wastewater carefully following "Water Quality Measurement Protocols." Enter your data on the data sheet provided.

III. Experimental Design

The overall goal of this study is to test the effectiveness of constructed wetlands in the improvement of water quality. The approach is quite simple—agricultural wastewater containing high levels of phosphates and nitrates is added to a constructed wetland. Water quality parameters are monitored in samples that have passed through this wetland over a period of approximately 4 weeks. These results are compared to water quality changes in identically prepared wastewater that just sits in a control tank without a wetland.

The main elements of the experimental design are as follows:

- Six identical constructed wetlands (Tanks C1 ➜ C6) will be used to treat the wastewater
- Each lab group will be assigned to one of these tanks
- One tank (B4) will be used as the source water to be treated
- One tank (B5) will be used as a control

- At the start of the study, wastewater will be added and the first sample will be taken (see start-up section below)
- Consequent measurements will be taken on a weekly basis
- All water samples must be taken and analyzed prior to preparing the final report

IV. Measurement start-up

On the first day, follow this procedure:

1. Drain existing water in wetlands (water can run out on gravel)
2. Close spigot
3. Add wastewater from Tank B4 to your tank in the following manner:
   - dump water *gently* along edge of wetland
   - bring volume up to one inch above level of soil shelf
4. Water samples for testing will be taken through spigot after allowing 5 seconds of free flow first (return this water to the tank)
5. Take all measurements as indicated in "Water Quality Measurement Protocols"
6. Record all information on data sheets provided
7. Your signature on the data form indicates that you have taken those measurements
8. Submit your original data sheets with your final report

On all subsequent sampling days, follow steps 4 through 8 above.

NOTE: *Sampling should be done on at least a weekly basis. Including the first sample, there should be a total of six measurements made over about four weeks.*

V. Control Tank Measurements

In addition to measurements made on wastewater that has been treated by each of your tanks, identical water quality measurements will also need to be taken on the control tank (B5). These measurements should be made simultaneously with measurements from your tanks. To spread out the work load, each group will have the responsibility of taking control tank measurements *once* during the study. The schedule is indicated below. Find the date that you will be responsible for control tank measurements and be sure that they are taken.

If your tank is:	You will take control tank (B5) measurements on:
C1	Day 1
C2	Day 3
C3	Day 8
C4	Day 15
C5	Day 22
C6	Day 29

VI. Other Data Collection

All of the measurements described in the "Water Quality Measurement Protocols" are taken on the treated water after it exits the wetlands. There are additional variables that we may want to measure to monitor the effectiveness of the wetlands. Some examples include:

- Rainfall
- Solar radiation
- Air temperature
- Relative humidity

These variables will be recorded automatically by the Environmental Monitoring Equipment permanently installed in the *Aquatic Ecology Laboratory*. Later in the term we will discuss how the measurement of these variables might be used in our study.

IMPORTANT NOTES: *Complete and accurate data collection is an essential element of this study. Since each student will be using class data to prepare his/her report, missing or inaccurate data has consequences for everyone. For this reason, there will be point deductions for your group's failure to provide complete and accurate information.*

Constructed Wetlands for Wastewater Treatment
Data Sheet

Date	Tank#	Signature of Observer(s)	pH	Water Temp (ºC)	D.O. (ppm)	Turbidity (%T)	Algal Conc. (%T)	Phosphate	Nitrate	Odor	Comments

Constructed Wetlands for Wastewater Treatment
Data Sheet for Control Tank

Date	Tank#	Signature of Observer(s)	pH	Water Temp (^{0}C)	D.O. (ppm)	Turbidity (%T)	Algal Conc. (%T)	Phosphate	Nitrate	Odor	Comments
	B5										
	B5										
	B5										
	B5										
	B5										
	B5										

Constructed Wetlands for Wastewater Treatment
Data Sheet for Control Tank

Date	Tank#	*Chlamydomonas*	*Euglena*	*Chlorella*	*Oscillatoria*	*Lepocinclis*	*Chlorogonium*	*Pandorina*	*Scendesmus*

Record "percent of individuals" in the appropriate box. Add additional species to top row if necessary.

Constructed Wetlands for Wastewater Treatment
Data Sheet for Control Tank

Date	Tank#	*Chlamydomonas*	*Euglena*	*Chlorella*	*Oscillatoria*	*Lepocinclis*	*Chlorogonium*	*Pandorina*	*Scendesmus*
	B5								
	B5								
	B5								
	B5								
	B5								
	B5								

Record "percent of individuals" in the appropriate box. Add additional species to top row if necessary.

Final Report Guidelines

GENERAL GUIDELINES

The final report for the Constructed Wetlands Project will be due upon completion of data collection and analysis (in about six weeks). Each student will prepare an individual written report which will summarize what was learned about the effectiveness of constructed wetlands for the treatment of wastewater.

Important points:

- Reports will be due later in the term; late reports will not be accepted
- Reports should make use of *all* information available (i.e., all water quality measurements from replicates and controls, weather data collected by the monitoring station at the quatic Ecology Lab, plus other pertinent resources).
- Prepare graphs and tables of data using *EXCEL* or any other spreadsheet program where appropriate
- You will find all the Constructed Wetland lab handouts very useful (e.g., original "Constructed Wetlands for Wastewater Treatment" handout, *How should we interpret water quality measurements?*)
- The report must be typewritten, and include 4-5 pages of narrative plus tables, graphs, and figures

FORMAT

I. INTRODUCTION (1 paragraph). Use this section to briefly set the stage for what the report will cover Briefly describe what a constructed wetland is, why the study was done, what your major hypotheses were (i.e., What did you expect to find?), and what applications there might be for the study.

II. METHODS AND MATERIALS (1 to 2 paragraphs). Use this section to describe the experimental design of the study and procedures you have followed to obtain the data you have collected. *Include sufficient detail such that another researcher could duplicate your efforts.*

NOTE: *Rather than describing the intricate details of the procedure for each water quality parameter, simply provide an overview and cite the "Protocols" sheet for the details.*

III. RESULTS (2 to 3 paragraphs—plus graphs, charts, etc.). This section should include only data that were collected during this study. Information for this section should come from summarized class data. Where possible, summarize information in tables, charts and graphs that *help to visualize* the data (i.e., provide a graph that illustrates turbidity levels vs. time). Data from control tank and test (wetland) tanks should be put on the same graph for easy comparison. Where possible, enter your data into a spreadsheet program such as *EXCEL* and use the software to generate the graphs. Be sure to reference your tables, charts and graphs in the body of this section by indicating *major trends* (e.g., do not try to recount every item in tables, charts and graphs). No graph or table should stand alone without being referenced in this section.

Example:
"Turbidity levels remained high for the first two weeks of the study, declined rapidly and then dropped to near zero for the remainder of the sampling period (Table 1)."

IV. CONCLUSIONS and **DISCUSSION**. In these sections, you will summarize your conclusions (logically drawn from the RESULTS section).

Example:
"We have obtained some evidence that constructed wetlands could be used to treat agricultural wastewater. Turbidity levels were significantly lower in water that had been in the wetlands at least two weeks and nitrate levels declined from an initial value of 40 ppm to a final value of 2 ppm."

To help guide you, answer the following:

- Which of your findings were unexpected?
- Which hypotheses were supported by the data? Which hypotheses were not supported by the data?
- What changes or improvements would you make in your experimental design if you were to duplicate the study?

Also, attempt to place your findings into a broader context and apply them to real-world situations (i.e., answer the question, "*So what?*"). Here are some *examples* of questions that might be addressed in this section:

- What applications might your findings have to farmers who must meet environmental regulations for the release of agricultural wastewater?
- What other benefits might be achieved by constructing wetlands besides treating wastewater?
- What limitations are there on the use of constructed wetlands for the treatment of wastewater?
- Should natural wetlands be used for treating wastewater?

MATERIALS

Quantity	Materials and Equipment
6	LaMotte's Limnology Test Kits
1	Orion Portable pH Meter
1	Orion Portable Dissolved Oxygen Meter
2	Hanna Ion Specific Meter (Phosphate)
2	Hanna Ion Specific Meter (Nitrate)
6	Wash bottles
12	250 ml bottles with screw cap
3	Spectronic 20 Spectrophotometers
12	Cuvettes for Spec-20
6	Alcohol thermometers
25	Microscope slides
25	Coverslips
6	Algae guides (e.g., Rainis and Russell 1996 or Palmer 1977)
6	Funnels
12	De-ionized water in wash bottles
12	250 ml beakers
1	Large capacity digital balance
2	2000 ml beakers
2	2000 ml (approx) glass jar with screw lids (to transport water samples)
24	Pasteur pipettes and bulbs
6	5-gallon buckets

HANDOUT
WATER QUALITY MEASUREMENT PROTOCOLS

IMPORTANT NOTE: *It is imperative that each group follow the same procedure each time the measurement is taken!*

pH

Follow the procedure described in the Limnology Test Kit to determine the pH of the wastewater.

1. Take sample from spigot in 300 ml beaker after allowing 5 seconds of free flow
2. Return free flow to tank
3. Thoroughly mix sample
4. Rinse a test tube (from Limnology Test Kit—pH Test) with the water sample
5. Fill tube to 5 ml line with water sample
6. Add 10 drops of indicator solution while holding dropper bottle (or pipette) vertically
7. Cap and invert several times to mix
8. Insert test tube into comparator and match sample color to color standard
9. Record pH (measurements can be verified with the Orion pH Meter.)

Temperature

1. Obtain sample from spigot in a 300 ml beaker
2. Place a thermometer into the beaker about half way down
3. Allow to sit for one minute
4. Pull out thermometer and record temperature

Dissolved Oxygen

NOTE: *Numbers in parentheses refer to part and reagent numbers in the LaMotte's Limnology Test Kits.*

1. Thoroughly rinse 25 ml sampling bottle (#0688-DO) with sample water
2. Fill 25 ml sampling bottle completely with sample water
3. Gently tap sides of sampling bottle to dislodge any bubbles

NOTES: *Be careful not to introduce air into the sample while adding the reagents in the following steps. Simply drop the reagents into the sample, cap carefully, and mix gently.*

4. Add 8 drops Manganese Sulfate Solution (#4167)
5. Add 8 drops Alkaline Potassium Iodide Azide (#7166)
6. Cap and mix by inverting sample several times and allow particles to settle below shoulder of sampling bottle before proceeding.
7. Use the 1.0 g spoon (#0697) to add 1 g Sulfamic Acid Powder (#6286)
8. Cap and mix until reagent and precipitate dissolves (sample is now "fixed")
9. Fill titration tube (#0299) to 20 ml line with the fixed sample; then cap titration tube
10. Fill Direct Reading Titrator (#0377) with Sodium Thiosulfate (#4169)
11. Add one drop at a time to sample and swirl between each drop until color is faint yellow
12. Remove titrator and cap
13. Add 8 drops Starch Solution (sample should turn blue-black)
14. Replace cap and titrator

15. Continue to add Sodium Thiosulfate until the blue color *just* disappears
16. Read the total amount of Sodium Thiosulfate added where plunger tip meets the scale. This reading is equal to dissolved oxygen concentration of the sample in ppm.

NOTE: *Each minor division on the Titrator scale equals 0.2 ppm.*

NOTES: *If the plunger tip reaches the bottom line on the titrator scale (10 ppm) before the endpoint color change occurs, refill the titrator and continue adding drops. When recording the test result, be sure to include the value of the original amount of Sodium Thiosulfate added (10 ppm).*

17. Record dissolved oxygen (measurements can be verified with Orion D.O. Meter)

Turbidity

A device called a "spectrophotometer" will be used to estimate turbidity and algal concentration. 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 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. We will use two wavelengths─one for turbidity and one for chlorophyll. The proper use of the spectrophotometer will be demonstrated in lab.

1. Turn on the spectrophotometer and allow it to warm up for 10 minutes
2. Select a wavelength of 550 nm and select correct filter position (if so equipped)
3. Set spectrophotometer to 0% Transmittance using knob on left
4. Place distilled water in cuvette (= blank) and wipe clean
5. Insert the blank into spectrophotometer, lining up the white lines on the cuvette with indicator line on spectrophotometer
6. Adjust spectrophotometer to 100% Transmittance with light adjustment knob on right
7. Remove blank
8. Place cuvette with water sample in spectrophotometer
9. Close lid and read % Transmittance from scale to tenth place.

Record data.

Algal Concentration

1. Turn on spectrophotometer and allow it to warm up for 10 minutes
2. Select a wavelength of 660 nm and select correct filter position (if so equipped)
3. Set spectrophotometer to 0% Transmittance using knob on left
4. Place distilled water in cuvette (= blank) and wipe clean
5. Insert the blank into spectrophotometer lining up white lines on cuvette with indicator line on spectrophotometer
6. Adjust spectrophotometer to 100% Transmittance with light adjustment knob on right
7. Remove blank
8. Place cuvette with water sample in spectrophotometer
9. Close lid and read % Transmittance from scale (to the tenths place)

Record data.

Phosphates (Orthophosphates only)

We will use a high range ion-specific meter made by *Hanna Instruments, Inc.* for phosphate measurements. Follow the instructions provided with the meter.

If we are unable to obtain accurate measurements with this meter, we may use the test provided in the Limnology Test Kits as an alternative. The instructions for this test follow:

1. Fill test tube (#0844) to 10 ml line with sample water
2. Use the 1.0 ml pipette (#0354) to add 1.0 ml of Phosphate Acid Reagent (V-6282)
3. Cap and mix
4. Use second 0.1 g spoon (#0699) to add one level measure of Phosphate Reducing Reagent (V-6283)
5. Cap and mix until dissolved. Wait 5 minutes
6. Remove cap. Place into Nitrate and Phosphate Comparator (#3120) with Axial Reader (#2071). Match sample color to color standard on reader

Record data as ppm phosphate.

Nitrates

We will use a high range ion-specific meter made by *Hanna Instruments, Inc.* for nitrate measurements. Follow the instructions provided with the meter.

If we are unable to obtain accurate measurements with this meter, we may use the test provided in the Limnology Test Kits as an alternative. The instructions for this test follow:

1. Fill test tube (#0844) to 2.5 ml line with sample water
2. Dilute to 5 ml line with Mixed Acid Reagent (V-6278)
3. Cap and mix. Wait 2 minutes before proceeding
4. Use the 0.1 g spoon (#0699) to add one level measure of Nitrate Reducing Reagent (V-6279)
5. Cap and invert 30 times in one minute. Wait 10 minutes
6. Mix and remove cap. Insert test tube into the Nitrate-N and Phosphate Comparator (#3120). Match sample color to a color standard

Record data as ppm Nitrate-N.

Odor

1. Smell the water sample for any odor
2. Record in classes:
    - 3 - "strong" (*Yuk!*)
    - 2 - "moderate" (easily detectable but not obnoxious)
    - 1 - "slight" (barely detectable)
    - 0 - "none" (not detectable)

3. Identify odor as:
   "Rotten egg" (Hydrogen sulfide)
   "Musty" (Molds)
   "Raw sewage" (Organic waste and bacteria)
   "Frog pond" (Algae)

For example:

A sample that had a barely detectable odor that smelled like raw sewage would be recorded as "*Raw sewage - 1*." Additional categories of odors may be added, if needed.

Microscopic Examination

1. Take one 100 ml sample from spigot in a small beaker
2. Allow the sample to settle for 5 minutes
3. Using a Pasteur pipette, extract a small sample from anywhere in the beaker where algae has settled (look for areas of green)
4. Prepare a wet mount using a microscope slide and coverslip
5. Examine at 100X and 450X using a compound microscope
6. Use identification guides to identify algal species
7. Record approximate "percent of individuals" for each species on data sheet provided
8. Note whether species are indicators of clean water, slightly polluted water, or heavily polluted water (see available references)

NOTES:*You will almost certainly encounter microscopic crustaceans and protozoans cruising around in your microscopic samples. You are not required to estimate percent of individuals for these species, but it may be useful to identify them and record their presence or absence on the data sheet.*

HOW SHOULD WE INTERPRET WATER QUALITY MEASUREMENTS?

As we proceed with experiments designed to determine the effectiveness of constructed wetlands to treat agricultural wastewater, we will be comparing the initial conditions of the wastewater with the conditions of water that has been treated by the wetlands. 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 7.0 indicates neutrality (neither acidic nor basic); numbers less than 7.0 are acids, greater than 7.0 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 6.0 to 8.0; 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

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 small ponds is closely tied to ambient temperature. Temperatures influence those organisms that can occur in ponds (Table 2). Since most aquatic organisms are cold-blooded, water temperature controls metabolic rate and, often, the timing of reproductive activities. In our area, 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 "coolwater species" (coho, chinook, cutthroat, sturgeon, mayflies, caddisflies, stoneflies)
5 to 13	41 to 55	optimum for "coldwater species" (steelhead, all salmon, most trout, most mayflies, caddisflies, stoneflies)

C. Dissolved Oxygen (DO)

Dissolved oxygen is measured in parts per million (ppm) with a dissolved oxygen meter or chemically with a Winkler Titration (Note: The procedure we used in the Limnology Test Kits is a modified version of this test). 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 the tanks are photosynthetic production by algae and higher plants and diffusion from the air above the water surface. 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 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 to 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:

Percent Saturation = (8.0/9.07) X 100 = 88.2 %

Table 3. Maximum Dissolved Oxygen Concentration

Temperature (ºC)	Dissolved Oxygen (ppm)	Temperature (ºC)	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 turbidimeter in nephelometric turbidity units (NTU). Drinking water is generally very clear and would have a turbidity measurement less than 10 NTU. Very cloudy water would read about 1000 NTU. 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. Algal Concentration

Algae can have both positive and negative impacts on aquatic ecosystems. Algae produce oxygen through photosynthesis during the day — thus increasing dissolved oxygen concentrations. They also absorb both ammonia and nitrate and use them as nutrients. However, when algal blooms occur, turbidity is increased and algal die offs consume oxygen and release toxic substances such as ammonia, methane and hydrogen sulfide. The concentration and type of algae in a water sample can be used as indirect measures of water quality. High algal concentrations generally indicate abnormally high levels of nutrients — typically nitrates and phosphates.

Algal concentrations will be measured in a manner similar to that which we have used for turbidity. Chlorophyll is the primary pigment in water samples that contain algae and the intensity of the color can be used as a rough measure of algal concentration. Although there are several types of chlorophyll, each with its own spectral properties, we will estimate the abundance of "chlorophyll a" which absorbs best at 660 nm.

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 by following the procedure described in the Limnology Test Kit.

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.

G. Phosphorus

Phosphorus 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. Phosphorus levels as low as 0.01 ppm can have an impact. Phosphates (inorganic phosphates only) can be measured by following the procedure described in the Limnology Test Kit.

H. Odor

Unpolluted water should be odor-free. Any noticeable odor in the water supplies may be due to contamination caused by chemicals, raw sewage or action of anaerobic bacteria. A "rotten egg" smell, for example, usually indicates the presence of hydrogen sulfide (H_2S), a common byproduct of anaerobic breakdown of organic matter.

I. Microscopic Examination

The type of algae and protozoans in a water sample often provide some indication of water quality. Some species are tolerant of conditions found in polluted water while others are far less tolerant. Table 4 lists some species that are used as indicators of water quality. A more compete list and identification aids can be found in the reference cited below.

Table 4. Algal species Used as Indicators of Water Quality in Freshwater (from Palmer, 1977)

Unpolluted Water	Polluted Water
Cladophora	*Euglena*
Ulothrix	*Chlamydomonas*
Rhizoclonium	*Chlorella*
Surirella	*Oscillatoria*
Pinnularia	*Chlorogonium*
Phacotus	*Anabaena*
Meridion	*Lepocinclis*

Although there are a number of methods available to measure the quantity of algal species in a water sample, we will simply estimate the "percent of individuals" for those that can be readily identified. Wet mounts of water samples will be prepared and examined at 100X and 450X with a compound microscope. Use the available guides to identify algal species and estimate the percent of each species. Record this information on the data sheet.

REFERENCES

Aquaculture

These resources specifically address the various aspects of raising aquatic organisms (primarily fish) in artificial environments.

ag.ansc.purdue.edu/aquanic/
AquaNIC (*Aquaculture Network Information Center*) - An excellent source for aquaculture curriculum, publications, media and career opportunities; thousands of links to related sites.

Huet, M. 1986. Textbook of fish culture - Breeding and Cultivation of Fish, 2nd ed. Fishing News Books, Ltd. Farnham, England.

Kosinski, R.J. 1993. Fish Farm - a simulation of commercial aquaculture. The Benjamin/Cummings Publishing Co. Redwood City, CA. 98 pp.

Van Gorder, S.D. and D.J. Strange. 1992. Home Aquaculture: A guide to backyard fish farming. Alternative Aquaculture Association, Inc. Breinigsville, PA 136 pp.

Mesocosms and Microcosms in Ecological Research

Constructed ecosystems at meso- and micro-scales have been used to test a number of hypotheses at population, community and ecosystem levels. These resources are but a small sample of such studies.

Blaustein, A. and D.B. Wake. 1995. The puzzle of declining amphibian populations. Sci. Am. April 1995:52-57.

Carpenter, S.R., S.W. Chisolm, C.J. Krebs, D.W. Schindler and R.F. Wright. 1995. Ecosystem experiments. Science 269:324-327.

Larsen, D., P.F. Denoyelles Jr., F. Stay, and T. Shiroyama. 1986. Comparisons of single species microcosm and experimental pond responses to atrazine exposure. Evironmental Toxicology and Chemistry 5: 179-190.

Lawton, J.H. 1995. Ecological experiments with model systems. Science 269:328-331.

Roush, W. 1995. When rigor meets reality. Science 269:313-315.

Rowe, C.L. and W.A. Dunson. 1994. The value of simulated pond communities in mesocosms for studies of amphibian ecology and ecotoxicology. J. of Herpetology 28(3):346-356.

Wilbur, H. 1987. Regulation of structure in complex systems: experimental temporary pond communities. Ecology 68: 1437-1452.

Wilbur, H.M., P.J. Morin and R.N. Harris. 1983. Salamander predation and the structure of experimental communities: Amphibian responses. Ecology 64:1423-1429

Wetland Creation and Restoration

Wetland creation, enhancement and restoration projects are routinely conducted to mitigate the loss of natural wetlands due to development. Our knowledge of the effectiveness of these efforts, however, is very limited. These two resources provide some information on the "science of wetland creation and restoration".

Kuster, J.A. and M.E. Kentula. 1990. Wetland creation and restoration - The status of the science.

Mitsch, W.J., X. Wu, R.W. Nairn, P.E. Wiehe, N. Wang, R. Deal and C.E. Boucher. 1998. Creating and restoring wetlands. Bioscience 48 (12): 1019-1030.

Waste Treatment by Constructed Wetlands

Constructed wetlands have been used to treat industrial, agricultural and municipal wastewater. These sources provide a sample of some of these efforts.

www.waterrecycling.com/index.htm
Triangle School Water Recycling Project (North Carolina State University) - A detailed description of an ecological wastewater recycling system in Chatham County, North Carolina that uses constructed wetlands.

Mitsch. W.J. 1993. Ecological engineering: a comparative role with the planetary life-support system. Env. Sci. and Tech. 27:438-445.

Brown, K.S. 1995. The green clean. Bioscience 45(9): 579-582.

Carnevale, E. 1995. Cattails treat leachate and save thousands. Environmental Protection Nov. 1995:35-36.

EPA. 1993. Constructed Wetlands for Wastewater treatment and wildlife habitat: 17 Case studies.

Kadlec and Knight. 1996. Treatment Wetlands. CRC Press, Inc.

Hammer, D.A. 1989. Constructed wetlands for wastewater treatment. Municipal, Industrial and Agricultural. Lewis Publishers, Inc.

gus.nsac.ns.ca/~piinfo/resman/wetlands/anno/annobib.html
Wetlands for Waste Treatment - An annotated bibliography of resources on the use of wetlands for waste treatment.

Lesley, D., H. Van Zee and J.A. Moore, eds. 1993. Constructed wetlands wastewater treatment systems: How do they work? Oregon State University Extension Service Misc. Publication 8543.

Moore, J.A. 1993. Using constructed wetlands to improve water quality. Oregon State University Extension Service # EC 1408. 4 pp.

Soil Conservation Service. 1982. Ponds - Planning, Design, Construction . Agriculture Handbook No. 590. 51 pp.

www.usouthal.edu/usa/civileng/wetlands.htm
USA Constructed Wetlands Page.

h2osparc.wq.ncsu.edu/info/wetlands/index.html
A comprehensive site for natural and constructed wetlands (definitions, processes, functions, importance, human impacts, management, mitigation).

www.towtrc.tamu.edu
Texas On-Site Wastewater Treatment Research Council. Constructed wetlands fact sheet can be downloaded from this site. Describes components, design, operation and maintenance of constructed wetlands for wastewater treatment.

www.humboldt.edu/~ere_dept/marsh/ownmarsh.html
Humboldt State Environmental Engineering Department. Includes some general guidelines for constructed wetland design (soil, plants, etc.)

www.enn.com/search/search.asp
The Environmental News Network posts current and archived articles on environmental issues from a variety of sources. A search for "constructed wetlands" articles will yield a number of pertinent articles (including some on "phytoremediation" - the use of plants to uptake contaminants from soils or water).

General References on Wetlands

Niering, W. 1995. Wetlands. Alfred P. Knopf, Inc. New York, NY

Mistsch, W.J. 1993. Wetlands. Van Nostrand Reinhold, New York, NY

Schodari, P.F. Wetlands protection: The role of economics. Environmental Law Institute, Washington, D.C.

EPA. 1995. Wetlands Fact Sheets. EPA Office of Wetlands, Oceans and Watersheds.

EPA. 1993. Natural Wetlands and Urban Stormwater: Potential Impacts and Management. EPA Office of Water.

EPA. 1988. America's Wetlands: Our vital link between land and water. EPA Office of Wetlands Protection.

Lewis, M. 1998. Plants do the dirty work: Cleaning wastewater, saving the environment. Nation's Cities Weekly 19 (38) p: 1-5.

www.nwi.fws.gov
U.S. Fish and Wildlife Service National Wetlands Inventory.

www.enn.com/newslenn-stories/020298/chevron.shtm

www.waterrecycling.com/soilfilt.htm

www.sws.org/wetlandweblinks.html
Another comprehensive wetlands site with lots of links to other sites (agencies, publishers, universities, sites designed for middle school and high schools students).

Wetland Plant and Algae Identification

Activities in model aquatic ecosystems usually require the identification of native species of plants, animals and algae. Also, plant selection for the construction of these systems often requires identification of native plants. These references will be particularly helpful in the Pacific Northwest.

Guard, J. B. 1995. Wetland plants of Oregon and Washington. Lone Pine Publishing, Redmond, WA. 239 pp.

Palmer, C.M. 1977. Algae and water pollution: An illustrated manual on the identification, significance and control of algae in water supplies and polluted water. EPA-600/9-77-036, U.S. Environmental Protection Agency, Cincinnati, Ohio. 123 pp.

Pojar, J. and A. MacKinnon. 1994. Plants of the Pacific Northwest coast. Lone Pine Publishing, Redmond, WA. 527 pp.

Rainis, K.G. and B.J. Russell. 1996. Guide to microlife. Franklin Watts Publishing, Danbury, CT. 287 pp.

Water Quality Testing

Laboratory activities that use model aquatic ecosystems frequently require the measurement of physical and biological water quality parameters. These resources describe some of the parameters that may be measured along with descriptions of their ecological impacts.

American Public Health Association. Standard Methods for the Examination of Water and Wastewater.

Campbell and Wildberger. 1992. The Monitor's handbook. LaMotte Company.

Mitchell and Stapp. Field manual for Water Quality Monitoring. GREEN Project.

Murdoch, T. and M. Cheo. 1996. Streamkeepers' field guide - Watershed inventory and stream monitoring methods. Adopt-A-Stream Foundation, Everett, WA. 296 pp.

esa.sdsc.edu/carpenter.htm
This Ecological Society of America report entitled "Non-point Pollution of Surface Waters with Phosphorus and Nitrogen" is an excellent review of ecological impacts of these contaminants.

h2osparc.wq.ncsu.edu/info/index.html
Water Quality and Land Treatment - Excellent site for description, measurement and interpretation of water quality parameters.

Other Aquatic Microcosm Laboratory Activities

A number of laboratory activities that use aquatic microcosms have been developed by other authors for students at all levels of education. The activities below represent a selection of activities that are appropriate for high school and college-level curriculum.

www.intercom.net/biz/aquaedu/hatech/
Hydro/Aquatic Technologies (a source for aquaculture-related curriculum).

Carlson, S. 1998. The pleasures of pond scum. Sci. Am. Mar. 1998: 96-98.

Koeniger, J. 1997. Making a splash in the classroom. Carolina Tips 60(1):1-8.

Marcus, B. 1994. Microcosms for lake acidification studies. The American Biology Teacher 56: 433-437.

Murphy, T.M., D. Canington and D.E. Walker. 1992. Herbivory, predation and biological control. The American Biology Teacher, 54:416-419.

Nicol, E. 1990. Hydroponics and aquaculture in the high school classroom. American Biology Teacher 52:182-184.

Porter, J.R. 1989. Herbivory-induced alteration of community structure - a classroom model. American Biology Teacher 51:300-302.

Yensen, N.P. 1988. Ecosystems in glass. Carolina Tips 51(4)13-15.

Measurement of Net Primary Productivity

Botkin, D. and E. Keller. 2000. Environmental Science: Earth as a Living Planet. 3rd ed. John Wiley and Sons, Inc. New York. 649 pp.

Brower, J.E., J.H. Zar and C.N. von Ende. 1990. Field and laboratory methods for general ecology. 3rd ed. Wm. C. Brown Publishers, Dubuque, IA. 237 pp.

Cox, G.W. 1990. Laboratory manual of general ecology. 6th ed. Wm. C. Brown Publishers, Dubuque, IA. 251 pp.

NOTES FOR INSTRUCTORS

NOTE: *For more information, refer to NCSR's* ***Aquatic Ecology Laboratory***.

In this lab, students should:

1. Learn about the use of constructed wetlands in testing wastewater treatment
2. Become familiar with test procedures for water quality measurements (protocols)
3. Measure initial conditions in wastewater and run tests over time
3. Think about experimental designs and results obtained

The lab is based on Chemeketa's *Aquatic Ecology Laboratory,* and I am including extensive notes for you regarding original set up and protocol development. Please read through these sections, and relay pertinent information to your students as needed.

BACKGROUND INFORMATION

THE AQUATIC ECOLOGY LABORATORY

Chemeketa's Aquatic Ecology Laboratory (AEL) provides us with an opportunity to study the design and effectiveness of constructed wetlands for wastewater treatment. The AEL is an outdoor laboratory on Chemeketa's Salem campus. Eighteen 300-gallon polyethylene stock tanks serve as simulated aquatic ecosystems. Six tanks contain constructed wetlands that were designed and planted in February 1998 (see section following, "Initial Conditions"). These simulated wetlands will be used to treat agricultural wastewater. Each of these tanks has an outlet at the bottom and flow can be regulated with a spigot. Drainage devices have been installed to facilitate drainage—an 18" length of 3" diameter, perforated PVC pipe has been fitted to the spigot at the bottom of each tank. Water that moves through the substrate should enter this pipe. We can then regulate the rate of water movement by opening and closing the spigot.

In addition to the tanks themselves, a chain-link fence encloses a storage building and covered bench tops for student work. Water and electrical service are provided to the facility. Electrical outlets are located along bench tops. We have also installed an environmental monitoring system that measures physical variables such as air temperature, rainfall, relative humidity and solar radiation. These data are recorded continuously and stored on the hard disk of a computer in the storage building. Using available software, this information can be displayed graphically and correlated with biological changes in the tanks during experiments.

INITIAL CONDITIONS

On the basis of student-conducted research (summarized next), six identical model wetlands were constructed on 24 February 1998 in Chemeketa's Aquatic Ecology Laboratory by the *Environmental Science* class. Photographs were taken during construction and at completion. Students were required to describe the initial conditions in the tank for future reference. This description follows:

Substrate

Two layers of substrate were placed in each tank:

- coarse sand/gravel (3/4" minus) mix—6"
- organic soil—11"

Since the tank height is 24", this left approximately 7" of head space at the top of the tank to allow for fluctuating water levels. The top layer of organic soil was slightly excavated. A 4" deep depression was created in the center of the tank, which was approximately 2' in diameter. This was done to create two different water depths and/or saturation levels of soil to accommodate the different tolerance of flooding and submersion of plant species.

Plants

Four species of obligate wetland plants were selected for planting. They all have extensive root systems and have been shown to have the capacity for absorbing large amounts of nitrate and phosphate nutrients.

1. Yellow iris (*Iris pseudacorus*)—a single plant was placed in the center of the wetland
2. Broadleaf cattail (*Typha latifolia*)—12 plants were placed in a roughly circular pattern around the iris at approximately 4" spacing
3. Smooth rush (*Juncus effusus*)—30 rushes were placed on the "shelf" at 4" spacing
4. Slough sedge (*Carex obnupta*)—30 sedges were placed on the "shelf" at 4" spacing

NOTE: *Rushes and sedges were planted alternately.*

Water

Rainwater that collected in other tanks was used to saturate the soils in the wetlands. The water level was brought up to approximately 10" below rim of tank which left some standing water in the center depression but did not cover the shelf. Water levels will be held relatively constant by either adding or draining water depending on inputs from rainfall and outputs from evaporation.

SUMMARY OF LITERATURE REVIEW

The following information was gleaned from student research conducted prior to the design and construction of the wetlands in February 1998.

1. *What is a "constructed wetland"?*

Constructed wetlands are manmade imitations of naturally found water habitats. They attempt to recreate the species diversity and ecological processes found in a natural wetland.

2. *What types of pollutants can be removed with constructed wetlands?*

- Organic materials such as sewage, animal manures and agricultural wastes can create a Biological Oxygen Demand in bodies of water. Their aerobic decomposition consumes oxygen which lowers dissolved oxygen levels.
- Nutrients—Nitrogen (as ammonia or nitrate), Phosphorus
- Metals (mostly from industrial waste)—some plants hyperaccumulate metals
- Sediment

3. *How do constructed wetlands work? What processes are involved in the removal of pollutants? Do these processes take place at the surface, in the water column, or in the soil?*

- Filtration/settling of sediment particles and nutrients (e.g., N, P, K) that are attached to these particles.
- Solid organic matter is mechanically filtered by soil in the wetland.
- Dissolved organic matter is consumed by microbes. Biological Oxygen Demand (BOD) requires an aerobic environment; microbes associated with roots of plants are most important as a symbiotic relationship is formed—microbes require oxygen while breakdown products are used by plants.
- Plant stems and roots provide surface area for communities of microorganisms which convert organic nitrogen into inorganic nitrogen
- Chemical reactions between sediments in water and oxygen (e.g., incoming sulfides may react with iron-rich soil to form iron sulfides which settle). Reaction rates are influenced by pH.
- Nitrification—ammonia combines with carbon dioxide to form nitrates and hydrogen gas. This process is aerobic.
- Denitrification—the conversion of nitrogen wastes to nitrogen gas which is released into the atmosphere. This process is anaerobic. An alternating aerobic and anaerobic environment is required to completely remove nitrogen from wastewater. This process may take several days. The availability of carbon in wastewater is a limiting factor.
- In the anaerobic environment below the water surface, plant roots exude oxygen, creating a "rhizosphere"—an active area for biological and chemical activity.
- Phosphorus chemically binds to soil, sand or brick (if used in substrate) under aerobic conditions, forming iron phosphate which locks up the phosphorus
- Evapotranspiration—loss of water to atmosphere from plants

All treatment processes work simultaneously so that by the time water flows out of the wetland the N, P, S and bacterial content can be greatly reduced. Rates of processing depend on the characteristics of the wastewater, climate, native vegetation and the amount of time spent in the system. Processes take place both within the water column and in the soil.

4. *As we monitor the effectiveness of a constructed wetland, what measurements should be taken? How often should these measurements be taken?*

Water depth (fluctuation)
pH
Water temperature
Dissolved oxygen (DO)
Total Suspended Solids (TSS)
Color
Odor
Soil saturation at different levels
Rainfall
Solar radiation
Growth rates of vegetation and density
Nitrate
Phosphorus
Sulfur
Metals
Photographs of tanks at various stages may also be helpful

Environmental variables should be measured twice a week (others once a week). NOTE: *our environmental monitoring equipment will automatically measure environmental variables every day; we will have to take all other measurements manually so practicality must be taken into account.*

5. *Is the selection of plants important? What plant species are typically used? At what density should they be planted?*

The type and amount of pollutants in wastewater will determine the best plants to use. Most systems use a variety of *native* aquatic plants, but there are some non-natives that may process certain contaminants more efficiently.

Plants should:

- have an extensive root system to support large colonies of microbes
- be able to tolerate expected temperature extremes
- remain active throughout the year
- have a high rate of water and nutrient utilization
- have a good ability to resist disease
- be "obligate wetland species"

Duckweed (*Lemma* spp.) and Pennywort (*Hydrocotyl* spp.) have a good capacity for nutrient absorption. Water lily and a variety of reeds, cattails, arrowhead, willows, sedges and rushes are commonly used.

6. *Is the composition of the soil important? We will have both organic soil and coarse sand available. What are the best depths for each? How should this be determined?*

Composition of soil may be an important factor in the functioning of the constructed wetland. There are two types—Free Water Surface Flow (in which water flows over soils) and Sub-surface Soil Flow (in which water is below the surface of the soils).

One system was designed as follows:

Coarse gravel near bottom: to allow water to pass through without being exposed to atmosphere
Sandy or clay loam: 16-24"—fertile soil for the propagation of plants
Organic soil: 2-6"—fertile soil with organics as a carbohydrate source

Another system:

Soils mimic permeable upland areas that soak up and cleanse runoff as it travels through the soil toward groundwater. Sand, crushed rock, brick and gravel are all used. One setup uses 12" of sand for drainage and filtration. Trial and error testing may be used to determine correct depth and composition.

7. *Should these constructed wetlands be static systems in which the treated water simply sits in the tank for a period of time or dynamic systems in which there is some flow in the system? What are the advantages and disadvantages of each?*

Static system—probably not a good system for treatment of agricultural waste. Plants may suffocate due to lack of water flow, and algae populations may explode due to high nutrient input. If water is high in sediments, then that sediment would collect at the entry point. A mini-dredging operation may be required.

Dynamic system—probably a better choice. Flow assists filtration, reduces algal growth. Plants will slow flow and allow for further deposition of sediments. *Dynamic is the way to go!*

8. *What wetland animals, if any, may be important to the process? What species could reasonably be introduced, considering the size constraints of these systems? (alligators are probably out of the question). How should they be introduced?*

Aquatic larval stages of mosquitos, gnats, midges, and dragonflies, as well as bacteria, break down complex organic molecules. Most of these species will either be present in the substrate, introduced in the construction process, or attracted to the wetlands soon after construction. Zooplankton samples from a local pond could be added to increase the probability of colonization.

OTHER NOTES

Use the laboratory and the following documents (included just after this section):

- Constructed Wetlands Lab
- Water Quality Measurement Protocols
- How should we interpret water quality measurements?

Provide a brief overview of constructed wetlands and their use for treating wastewater (agricultural, municipal, industrial)

- 6 identical constructed wetlands in 300-gallon tanks
- 1 tank of "agricultural wastewater" (400 g 16-16-16 fertilizer dissolved in 300 gallons which yields a nitrate level approximately 5X the standard for drinking water)
- 1 control tank (400 g 16-16-16 fertilizer dissolved in 300 gallons)
- Source tank and control tank were prepared 4 days prior to lab
- Review handouts, background information on wetlands and data sheets

Notes on Measurement of Initial Conditions:

- Stir source tank carefully
- Measure water temperature at the source tank and ambient temperature (record on data sheet)
- Take a sample of water from source tank and return to laboratory to complete tests listed on *Water Quality Measurement Protocols* handout

Further notes:

- Demonstrate addition of wastewater (to be done at a later date)
- Demonstrate sample collection technique
- Sampling responsibilities for each student group are outlined on handout
- Demonstrate use of microscope and preparation of microscope slide
- Demonstrate use of Spec-20: including basic principles of the spectrophotometer, the cuvette and blank (and distilled water), % Transmittance, Zero setting and wavelengths (550 nm for turbidity, 660 for chlorophyll a), inserting the blank and adjusting the light to 100 % Transmittance, inserting the cuvette with sample, reading % Transmittance

LAB PRODUCT

Students' final reports will be due following measurements and analysis. Describe the format of the report (included in the lab) to students.

Aquatic Invertebrates as Bioindicators of Water Quality

INTRODUCTION

As our knowledge of ecosystems increases, the impacts of human activities on ecological systems are being more carefully monitored. Waste products that result from a number of these activities may accumulate in natural systems to levels that are harmful to living organisms including ourselves. The combustion of fossil fuels, mining operations, landfills and agricultural practices, for example, may all generate waste products that result in pollution of soil, air and water resources. This pollution may cause a domino-like effect that impacts several components of an ecosystem.

Pollution may be evaluated either by direct measurement (using instrumentation that measures dissolved oxygen, toxin levels, etc.) or by examination of its effects on living organisms. Indicator organisms may be exposed to different concentrations of a pollutant to determine their toxicity. In Europe, for example, water quality is often evaluated by exposing trout to test water in an aquarium. Alternatively, the diversity and abundance of animal species such as aquatic insects, fish or amphibians may be used in the field as an indicator of environmental quality.

The presence of a diverse animal community that contains a number of species that are known to be intolerant of pollution indicates good water quality. The use of living organisms to evaluate environmental quality, or **biomonitoring**, has some advantages over direct measurement of pollutants, including:

- Less sophisticated instrumentation is required
- Costs are generally less
- Unlike direct measurement where contaminant levels are being measured at a single point in time, living organisms that are used in these monitoring programs (**bioindicators**) are exposed for long periods of time—often for their entire lives

In today's laboratory we will use a common freshwater crustacean, the water flea, *Daphnia magna,* as an indicator organism to investigate the effects of various pollutants. This species normally occupies freshwater sites with summer temperature of 15-25 degrees C and a pH range of 5.5-7.0. They are quite intolerant of chemical contamination—including pesticides.

NOTE: *pH is a measure of the acidity of a solution measured on a scale of 0 to 14; 7 indicates neutrality, numbers less than 7 are acids, numbers greater than 7 are bases.*

PROCEDURE

Each group will test the effects of temperature, pH and exposure to a dilute solution of an insecticide on the subject organism. Class results will be summarized and interpreted by each laboratory group. Conduct the following procedures, and record all of your observations on the data sheets provided:

1. Place a small sample of the *Daphnia* culture on a watch glass and observe the normal activity level and behavior of the species with a dissecting microscope.

NOTE: *An understanding of the normal behavior of the species is important for comparison to those individuals that have been exposed to pollutants.*

2. Set up three series of test tubes as indicated to measure the following:

A. Temperature

Three water baths have been set up at temperatures of 25, 30 and 35 degrees C. Room temperature is approximately 20 degrees C, therefore, four different temperatures are available for testing.

- Representing the 4 temperatures, mark 4 test tubes room temperature, 25^0C, 30^0C and 35^0C
- Add 15 ml of pond water (*not tap water!*) to each test tube and place it in the appropriate water bath (or leave it at room temperature) with the corresponding temperature.
- Allow at least 5 minutes for temperature equilibration.

B. pH

- Fill 5 test tubes with 15 ml of pond water (at room temperature) that has had the pH adjusted to pH 7, 6, 5, 4, and 3.
- Place these tubes in the test tube rack.

C. Pesticide (Diazinon) concentration

- Fill 4 test tubes with 15 ml of pond water at room temperature.
- Add the following amounts of the pesticide solution to the 4 tubes:

Tube #1: 0 pesticide solution
Tube #2: 5 drops pesticide solution
Tube #3: 10 drops pesticide solution
Tube #4: 15 drops pesticide solution

- Mark each test tube appropriately; stopper each test tube and mix thoroughly.

3. Add 10 *Daphnia* to each of the test tubes prepared in step 2. Gently extract them from the culture using a bulb pipette and quickly place them in the test tubes.

NOTES: *Be sure the Daphnia are alive and well at the beginning of the experiment. Record the exact time that the Daphnia were added to the test tubes (see data sheet).*

4. Observe the behavior and survival of the *Daphnia* in the tubes following exposure times of 15, 30 and 60 minutes. At each observation, record the number of living and dead *Daphnia* as well as any observations on behavior or activity level (see data sheet).

LABORATORY REPORT

The final product of this lab is a report that summarizes and evaluates the results this study. The following guidelines should help you in the preparation of the report:

Length
The report must be typewritten, 3-4 pages of narrative, plus tables, graphs, and other supporting information.

Format
I. Introduction (1 paragraph)

Use this section to briefly set the stage for what the report will cover. Briefly describe why the study was done, what your major hypotheses were (i.e., What did you expect to find?) and what applications there might be for the study.

II. Methods and materials (1 to 2 paragraphs)

Use this section to describe the experimental design of the study and procedures you have followed to obtain the data you have collected. Include sufficient detail such that another researcher could duplicate your efforts.

III. Results (2 to 3 paragraphs, plus graphs, charts, etc.)

This section should include only data that were collected during this study. Where possible, summarize information in tables, charts and graphs that *help to visualize* the data (i.e., provide a graph that illustrates temperature vs. *Daphnia* survival). Enter your data into a spreadsheet program such as *EXCEL* and use the software to generate the graphs. Reference your tables, charts and graphs in the body of this section by indicating *major trends* (i.e., do not try to recount everything in the tables, charts and graphs).

Example:
"Daphnia showed no response to temperatures below 30 degrees C, but temperatures above 30 degrees C were 100% lethal (Table 1)."

NOTE: *information for this section should come from summarized class data.*

IV. Conclusions and discussion

In this section you will summarize your conclusions (logically drawn from the *Results* section) and also attempt to place your findings into a broader context (i.e., answer the question, *"Who cares?"*). Here are some *examples* of questions that might be addressed in this section:

- What applications might your findings have to farmers who apply the insecticide you tested? to companies that transport the insecticide? to homeowners who use the insecticide?
- What implications do your results have for a power plant that releases warm water into a local river? predictions of global warming?
- What implication do your findings have for federal and state agencies that establish emission standards for sulfur dioxide and nitrous oxides from power plants? (e.g., since these emissions contribute to acid rain and therefore may influence the pH of a body of water)
- Which of your findings were unexpected?
- Which hypotheses were supported by the data? Which hypotheses were not supported by the data?
- What changes or improvements would you make in experimental design if you were to duplicate the study?
- We used "mortality" as an indication of the impact of a pollutant on a living organism. What are some other measures that might be more sophisticated or useful?

These questions are *only* suggestions—*do not* answer them in a sequential manner as you would on an exam. Rather, use them as possible topics for discussion in a series of well-constructed paragraphs. I encourage you to explore other topics for this section as well.

Show some creativity!

Data Sheet

I. Initial Observations of *Daphnia*.

II. Temperature Experiment

Temp (^{0}C)	Initial Time	15 min. Exposure		30 min. Exposure		60 min. Exposure		Comments
		#A	#D	#A	#D	#A	#D	

NOTE: #A = number alive; #D = number dead

III. pH Experiment

Temp (^0C)	Initial Time	15 min. Exposure		30 min. Exposure		60 min. Exposure		Comments
		#A	#D	#A	#D	#A	#D	

IV. Pesticide Experiment

Pesticide Conc.	Initial Time	15 min. Exposure		30 min. Exposure		60 min. Exposure		Comments
		#A	#D	#A	#D	#A	#D	

MATERIALS

Quantity	Materials and Equipment
4	*Daphnia magna* (Ward's 87W5210) large size culture
1	*Daphnia magna* (Ward's 87W5215) mixed size culture

NOTE: *large copepods or seed shrimp may be used as alternative subject organisms.*

24	250 ml beakers
200 ml	0.12% Diazinon solution (in dropper bottle)
12	Graduate cylinder - 25 or 50 ml
3	Hot water baths set at 25, 30 and 35°C
24	Eye droppers with bulbs
75	Test tubes - 20 X 150's
12	Test tube racks
12	Alcohol thermometers (we will be measuring 20-40 degrees C range)
35	Rubber stoppers (to fit test tubes)
500 ml ea.	Water adjusted to pH's of 7, 6, 5, 4 and 3
12	Watch glasses (coaster type)
12	Crystallization dishes
4	pH meters (Orion portable meter and pH testers)
48	10 ml beakers
2	2000 ml Erlenmeyer flasks
24	Beral pipettes
1 roll	Glassware marking tape
6	Sharpies (any color)

NOTE: *all solutions should use pond water or untreated well water as a solvent.*

NOTES FOR INSTRUCTORS

Show video, "The Willamette River—Currents of Change" (*Water Quality* and *Drinking Water* portions only—approx. 10 minutes).

Videotape summary:
After a feature article in National Geographic in 1972 portrayed the Willamette River as one of America's most polluted, then-governor Tom McCall committed the state to a major cleanup effort. Over the next decade water quality improved significantly. There are recent concerns, however, that water quality has steadily degraded since that time. In April of 2000, the Willamette River was identified as the 10th most polluted major river in America and the Environmental Protection Agency identified a portion of the Willamette River in Portland as a Superfund site. The Water Quality and Drinking Water segments of this videotape describe sources of pollution in the Willamette, monitoring efforts, and steps being taken to improve water quality.

Discussion points:
Water quality monitoring is a required component of any modern society and certainly one that is attempting to attain the status of a "sustainable society." News media regularly report events or conditions that have led to pollution of both surface and below ground water sources. The pesticide Diazinon, for example, was found in urban and suburban streams in King County, Washington and was eventually linked to homeowners trying to kill cranefly larvae in their lawns. In March 2000, an industrial sulfuric acid spill from the Mitsubishi Silicon America plant in Salem, Oregon lowered the pH of the water in Pringle Creek, resulting in a fish kill and a temporarily damaged ecosystem. Similar events occur across the country on a regular basis.

There are a number of ways to measure water quality depending on monitoring goals and suspected pollutants. A monitoring plan designed to detect the presence of *E. coli* in a municipal water supply used for drinking, for example, may be quite different than one that measures biological oxygen demand (B.O.D.) in a fish-bearing stream. Most monitoring methods, however, fall into one of two categories:

- **Direct measurement:** taking a sample, and using some device to test and determine levels of pollutants

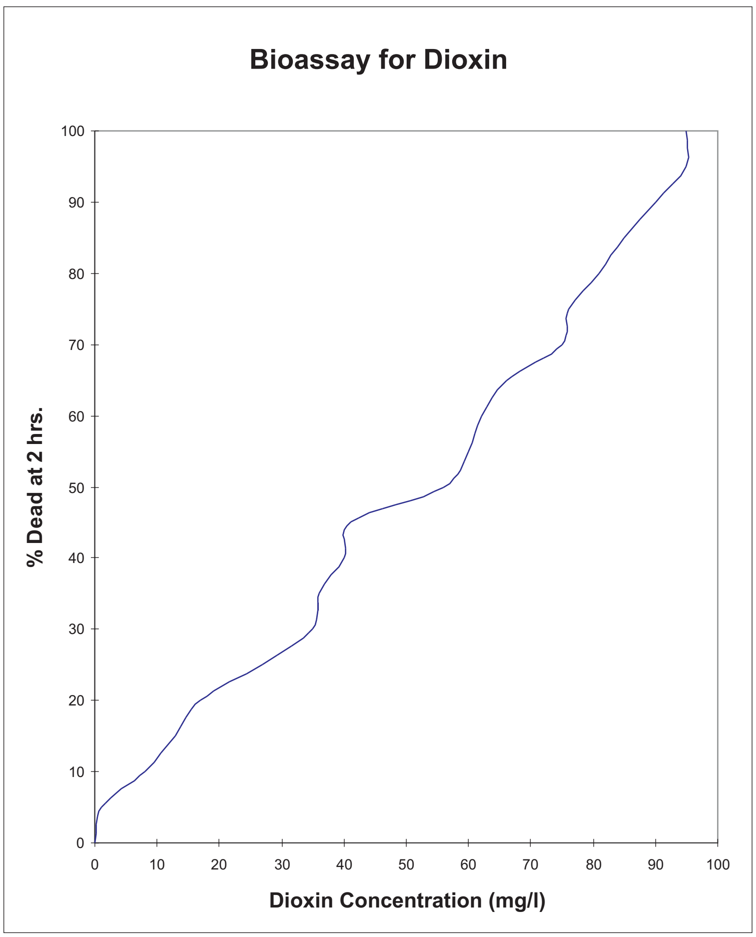
- **Indirect measurement:** using living organisms

Water quality monitoring programs often use both of these methods. Living organisms may be used in either bioassays or biomonitoring.

Bioassay—a test in which the quantity or strength of a substance is determined by the reaction of a living organism to it

- examples include drug testing, toxicity tests, skin sensitivity for cosmetics, etc.
- a common approach is to determine the LC-50 or the "lethal concentration for 50% of individuals"
- LC-50 is a commonly used standard for pollutants
- a specific time period must be specified
- *note that the "safe concentration" is much lower than the LC-50!*
- LD-50 ("lethal dose for 50% of individuals") is an alternative test in which an increasing *dose* of a pollutant or drug is administered, as opposed to simply exposing the subject to increasing *concentrations*

Use the figure below to illustrate the determination of LC-50 for dioxin:



Biomonitoring is the systematic use of biological responses to evaluate changes in the environment with the intent to use this information in a water quality program.

- **bioindicators** are organisms that are used in this type of monitoring
- aquatic invertebrates and algae are among the most sensitive indicators
- we will use a common freshwater crustacean, *Daphnia magna*, as our subject animal
- briefly discuss anatomy, behavior, role in ecosystems and trophic level of subject animal
- we will expose our subject animal to different levels of three pollutants—heat, pesticide and acidity (acid rain). Levels and times of exposure are described on handout
- as the experiments are completed, students will record data on their data sheets and on an overhead transparency (of the data sheet) at the front of laboratory. Thus, each student has access to class data which will be used in the laboratory report.

Sample data from previous classes may be used to discuss interpretation of results:

- are dosage (concentration) effects evident?
- is a time effect evident?
- is there evidence of tolerance to any of the pollutants tested by subject organism?
- are there other measurements to determine the effect of the pesticide on the subject organism other than "death" (behavior, reproductive effects, etc.)?
- how could this technique be used to determine "safe levels"?

Describe lab report (one per group or one per student, see guidelines on handout)

REFERENCES

Havel, J.E., M.C. Barnhart and J.S. Greene. 1997. *Experimental investigations of water quality: The bioassay*. The American Biology Teacher 59 (6):349-352.

VIDEO: *The Willamette River: Currents of Change*
9 April 1998
KGW Television
Northwest News Channel 8
1501 SW Jefferson St.
Portland, Oregon 97201
www.kgw.com

Amphibians and Other Species as Bioindicators of Environmental Quality

INTRODUCTION

As ecosystem management becomes the guiding principle of management on public and some private lands, more information is required to assure that ecosystem integrity is maintained. Human activities, including agriculture, development, logging, etc., must be evaluated in light of the potential impact on ecosystem processes and components, including impacts on individual species. **Environmental Impact Statements**, for example, must be submitted on some lands when there is a significant change in land use at the site. Impacts on soils, water, air and wildlife must be evaluated. If these impacts are judged to be greater than some previously defined level, a development project may be halted or altered in some way.

Environmental quality can be measured in a number of ways, depending on the site and the objectives of the evaluation. Two methods commonly employed in aquatic environments include the measurement of physical parameters such as temperature, dissolved oxygen, pH, etc., and the use of living organisms present on the site as indicators of site conditions. Amphibians (frogs, salamanders and their relatives) are generally considered to be good indicators of environmental quality for a number of reasons:

1. They have permeable skin and would therefore be expected to absorb any contaminants on the site
2. Most species lay their unshelled eggs in water
3. Their life histories usually expose them to both aquatic and terrestrial environments
4. They are sufficiently abundant and widespread to use as indicator organisms
5. Most species remain in a fairly confined area their entire lives

Worldwide declines of amphibian populations have been documented by a number of scientists. Declines have been documented in both disturbed and pristine environments on all continents where amphibians occur. Although a definitive explanation for these declines has not yet been ascertained, there appear to be a number of likely causes, including habitat destruction, environmental contamination, fungal infections, diseases, overharvesting, predation by introduced species, and genetic damage due to elevated levels of ultraviolet radiation.

In today's laboratory, we will visit a local wetland to sample amphibians as well as other bioindicators by using various methods. We will also measure and discuss some of the factors that may influence amphibian abundance and diversity on the site.

PROCEDURE

I. Amphibians—Measuring diversity and abundance

A variety of methods will be employed to determine the diversity and relative abundance of the species of amphibians found at this site:

- **Minnow Traps**: these are cone-shaped, wire mesh traps which may be used to sample some aquatic amphibians. They may be set out in a systematic or random fashion, and should be left out at least one day prior to sampling.

  Six un-baited wire minnow traps were set in one of the larger ponds on the site one day prior to our visit. Aquatic salamanders such as rough-skinned newts (*Taricha granulosa*) and northwestern salamanders (*Ambystoma gracile*) can be sampled in this manner. The traps will be checked, and any captures will be recorded.

- **Dip nets and seines:** these are of various sizes, and may be used to sample aquatic salamanders and frogs (bullfrogs, *Rana catesbiana*; red-legged frogs, *Rana aurora*) and egg masses in shallow water along margins of lakes and ponds. Sampling may be done randomly or systematically, and is conducted by drawing these nets through the water.

For our purposes today, numbers of captures will be recorded (by species).

- **Time-constraint searches**: these sampling methods are conducted for a set amount of time (thus, "time constrained"). The sampling effort is recorded as "number of individuals per unit time," and can be used to compare relative population sizes at different sites. Logs, bark, rock, and other debris on the forest floor may be examined (i.e., by turning logs over) for terrestrial forms of amphibians (Pacific treefrogs, *Hyla regilla;* Ensatina, *Ensatina escholtzi*; and rough-skinned newts), and this is done during a pre-established sampling period (e.g., 15-, 30-, 45-minutes).

Since our ultimate goal is to measure the relative abundance of each species of amphibian at the site, it is important to have some approximate measure of *the effort required* to capture a given number of animals (see data sheets).

II. Preliminary Analysis of Water Quality

Although we will not have time for a detailed analysis of water quality, we will examine two factors that may influence amphibian diversity and abundance: 1) zooplankton diversity and abundance and, 2) pH.

Zooplankton: aquatic insect larvae, aquatic worms, and crustaceans such as copepods and clam shrimp are an important food source for salamander larvae. Also, some zooplankton are sensitive indicators of water quality. We will sample the diversity and abundance of zooplankton with a plankton net at each of the several small and large ponds. The sampling protocol will be designed and implemented by the group. Samples will be examined in lab at a later date.

pH: the measure of acidity in a solution. Amphibian egg masses, embryos and larvae are particularly sensitive to acidic conditions. We will measure pH with portable pH meters at each pond that is sampled for zooplankton. The sampling protocol will be designed and implemented by the group.

III. Rapid Biological Assessment (RBA)

Rapid biological assessment, as the name suggests, is a method of quickly evaluating the biological diversity of an area, typically where such information is not available. For instance, many pristine regions of tropical rainforests are being assessed today in this manner. These areas are experiencing such rapid losses of biodiversity that RBA provides the most efficient way to either catalog species which may be lost in the near future, or, to perhaps stop development in rare species' habitats.

RBA uses teams of experts in the identification and biology of plants, mammals, amphibians, insects, etc., being deployed to use specific sampling techniques over a short period of time. The results are entered in a common database for the site; this database should be archived and maintained to determine baseline levels of species occurrence (for future assessments). Today's field activity has much in common with RBA's.

NOTE: *Record all information from the sampling activities above on the attached data sheet.*

DATA SHEET

LOCATION:

DESCRIPTION OF HABITAT:

OBSERVERS:

DATE: AIR TEMPERATURE: WATER pH:

TIME: WATER TEMPERATURE:

WEATHER CONDITIONS:

Enter all observations or captures of birds, mammals, fish and amphibians in the table below:

SAMPLE METHOD	SPECIFIC LOCATION OF SAMPLE	SPECIES	NUMBER OF INDIVIDUALS

MATERIALS

Quantity	Materials
3	Plankton nets
12	Screw-cap jars (250 - 500 ml)
6	Binoculars
1	Orion pH meter
1	Orion dissolved oxygen meter
24	Clipboards
1	Seine (20-foot)
6	Plastic buckets (5-gal.)
25	Zip lock bags (1-gal.)
6	Minnow traps
6	Dip nets
6	Field thermometers
6	Thermohygrometers
6	Meter sticks
6	Tapes (30-m)
6	Stopwatches

NOTES FOR INSTRUCTORS

This field trip is designed to familiarize students with both direct and indirect measurement of environmental quality. There is an emphasis on water quality and students have the opportunity to use various measurement techniques in its evaluation. Although data are recorded there is no concerted study, rather the goal is to familiarize students with methods of measurement and some natural history of the area. Any natural area with open water is suitable for this field trip.

I take my students to the "Aumsville Site for Environmental Studies," which is a semi-natural wetland located approximately 1 mile southeast of Aumsville (near Salem) and is owned by Marion County Department of Public Works. The county uses the site for occasional dumping of organic debris and rock but remains largely unused. The site is approximately 40 acres of wetland with a series of 7 small (.25 - 1.0 acre) ponds that were used about 30 years ago as salmon-rearing ponds by Oregon's Department of Fish and Wildlife. Ponds have been abandoned since that time. The ponds are manmade, 4 to 8 feet deep and steep-sided and some are interconnected by a system of small canals. Beaver have dammed the canals at various points changing water flow somewhat and causing some seasonal flooding of private property. Property owners periodically dismantle these dams to prevent flooding. There is also an irrigation ditch along part of perimeter of property that is part of Santiam Water District System. Most of property is old field habitat with grasses and blackberry but there is also a small forested area (approximately 2 acres).

Marion County Department of Public Works has entered into an agreement with Chemeketa Community College that allows our use of the site in exchange for information that can be used to produce a long-term plan for the site. Today's activities will contribute to baseline data that will be used for comparison to later studies. In this manner the effectiveness of various management activities may be measured over time.

The following topics are addressed during the field trip:

1. Introduction to the study site

- ownership, historical use, land use designation, management goals
- importance of baseline data, long-term monitoring and adaptive management in natural area management
- role of "habitat island" small reserves in maintaining biodiversity

2. Amphibians as environmental indicators

- measurement of environmental quality; direct measurement vs. biological indicators
- characteristics of amphibians that make them good indicators
- causes for amphibian declines and malformations
- sampling methods for amphibians (minnow traps, seine and dip nets, time constraint searches, pit fall traps, egg mass counts); students implement several of these methods
- importance of conducting surveys several different times of year
- amphibian skin toxins

3. Zooplankton and phytoplankton as bioindicators

Students design protocols for plankton net sampling and implement these protocols in several different ponds. Samples may be examined back in lab.

4. Direct measurement of water quality parameters

Water temperature, pH, turbidity, etc.

5. Observations of mammals and birds

Various methods for sampling mammals and birds will be discussed. Records of species will be added to a database for the site that is being maintained to determine baseline levels of species occurrence.

Amphibian skin toxins:

Rough-skinned newts (*Taricha granulosa*) are probably the most commonly encountered amphibian in the region. The species has a dramatic defensive display that advertises its bright orange belly, warning predators of its potent neurotoxin—tetrodotoxin (TTX). The toxin causes paralysis s and death by blocking sodium channels, and thus impairing nerve impulse conduction. The toxin is the same one that is found in puffer fish which are served as sushi in Japan. Chefs are specially trained in the preparation of puffer fish, so that only a small amount of the toxin remains, providing the consumer of the meal with an apparently desirable numbing sensation. Occasionally, an excess of the toxin is left in the fish as it is served—killing the customer, *and not so good for return business!*

Similarly, there have been documented accounts of deaths caused by consuming newts (*a single newt contains enough poison in its skin to kill 25,000 mice!*). Interestingly, common garter snakes (*Thamnophis sirtalis*) seem to be immune to the toxin and are one of the few animals known to eat newts. There is still an effect on the snake, however—they have been known to remain immobile for up to 7 hours after ingesting a newt! But most animals that ingest newts will die, sometimes before the newt itself! It is not known how newts acquire their toxin but it may be produced by a symbiotic association with a bacterium.

There has been a tremendous amount of interest in examining amphibian toxins as potential therapeutic drugs. For example, modified versions of a painkiller derived from the tropical frog, *Epepedobates tricolor*, are now in clinical trials to test their effectiveness in the treatment of pain. The chemical derived from these frogs, *epibatidine,* is 200 times more powerful than morphine as a painkiller!

REFERENCES

Blaustein, A.R. and D.B. Wake. 1995. *The puzzle of amphibian declines.* Scientific American. April 1995:52-57.

Brodie, E.D. III and E.D. Brodie, Jr. 1999. *Predator-prey arms races*. BioScience. 49(7):557-568.

Lasley, E.N. 1999. *Having their toxins and eating them too.* BioScience. 49(12):945-950.

Olson, D.H., W.P. Leonard and R.B. Bury. 1997. *Samplng amphibians in lentic habitats.* Northwest Fauna Number 4. Society for Northwestern Vertebrate Biology. Olympia, Washington. 134 pp.

Gomez, D.M. and R.G. Anthony. 1996. *Amphibian and reptile abundance in riparian and upslope areas of five forest types in western Oregon*. Northwest Science. 70(2):109-119.

Going for the Gold!—
Environmental Impacts of Mining

After viewing the videotape, "Public Lands, Private Profits," please respond to the following questions:

1. Describe how the General Mining Law of 1872 works.

2. Under the Mining Law of 1872, the government cannot require mining companies to pay royalties for mine claims on public lands. The oil, coal, and gas industries, by contrast, pay a 12.5% royalty for use of federal lands. In the fall of 1993, the House of Representatives passed a bill that would require mine owners to pay an 8% royalty to mine on public lands. The bill did not pass the Senate, where some western senators attempted to reduce the royalty to 2%. Would you favor reform of the 1872 bill? If so, in what way?

3. Describe how sodium cyanide can be used to extract gold from low grade ore.

4. Describe the various environmental impacts of heap leach mining as described in the videotape. Address each of the following areas:

   - Air pollution
   - Water pollution
   - Land disruption
   - Wildlife endangerment
   - Water supply (consumption)

5. What efforts were made by Newmont Mining to address each of these environmental concerns? In your opinion, were these measures appropriate and adequate? Explain.

6. Mining creates 4,000 jobs directly and 11,000 indirectly in the area of the Carlin Trend, Nevada. Mine wages are the highest in the state of Nevada. Do you think the present situation represents the best possible balance between environmental concerns and economic conditions? What changes, if any, would you suggest?

7. Approximately 75-85% of gold is used in jewelry. Gold is also used as a monetary standard, an investment, and in the manufacture of electronics and other industrial products. Considering the environmental costs associated with gold mining and processing, do you consider gold mining to be a worthwhile endeavor? Explain.

NOTES FOR INSTRUCTORS

I briefly present mining as a topic a number of times throughout the year. In some areas (Nevada, Montana and Pennsylvania), in particular, mining is an important economic force yet it also has the potential for causing environmental harm. Mining activities can impact air and water quality and if reclamation is not conducted properly, long term degradation of the land can occur. Land use designations that allow mining must be considered carefully as impacts on wildlife, streams, soils and other natural resources can be significant. Additionally, mining activities often conflict with other human needs and, as we have seen with coal mining, there are some human health issues related to mining as well.

As an example, a mining operation near Butte, Montana changed its mining operations several years ago from underground shaft mining to open pit mining. This type of operation results in large pits that fill with water. Much of this water leaches toxic chemicals from surrounding tailings, resulting in badly polluted water. In the fall of 1996, a flock of migrating snow geese landed on such a pit, apparently mistaking it for a small lake, and all died as a result.

In today's laboratory we will examine environmental, economic and political aspects of mining. The issue will be explored using case studies that are portrayed on the videotape, "Public Lands, Private Profits," and the accompanying handout. Students should leave with an understanding of the environmental impacts of mining, the economics of mining, legislation that currently regulates the industry and proposed solutions to problems that have arisen as a result of mining practices.

After viewing the videotape, meet with student group members and discuss answers to questions on handout. Each group should submit thorough and thoughtful answers to these questions as a lab product.

NOTE: *In addition to completing this laboratory, students are also expected to take measurements on their tanks for the Constructed Wetlands Lab.*

REFERENCES

Videotape—"Public Lands, Private Profits," produced by *Frontline*, 24 May 1994, Corporation for Public Broadcasting, 1 hour.

Di Silvestro, R. 1997. *Is this a bad deal for the taxpayer?* National Wildlife Oct/Nov 97:36-39.

Moffat, A.S. 1994. *Microbial mining boosts the environmental bottom line.* Science 264: 778-779.

Lichens as Bioindicators of Air Pollution

INTRODUCTION

Lichens are among the most abundant living organisms in Pacific Northwest ecosystems. Epiphytic lichens often cover the stems and branches of trees where they are sometimes mistaken for mosses or other plants. Although highly variable in color, many common species are gray-green, readily distinguishing them from most mosses, which are usually brilliant green and have distinct leaves. Lichens are not plants, rather they are the result of a mutualistic symbiotic relationship between an alga (or cyanobacteria) and a fungus. Recent studies of lichen DNA suggest that the relationship has evolved multiple times throughout evolutionary history and that the various groups are not closely related. The alga or cyanobacteria is the photosynthetic partner producing carbohydrates which can be used by the lichen as an energy source. For this reason, lichens are sometimes considered "the fungi that have discovered agriculture." The fungal partner is responsible for anchorage to substrates and for retention of moisture. Lichens are not parasitic and do not harm their host trees.

Lichens obtain nutrients directly from rain water and nutrients suspended in the air rather than from the soil. They are quite efficient at absorbing nutrients for the air, but are equally efficient in absorbing non-essential or harmful substances. This characteristic has lead to their demise in areas where contaminants of various types are present in the air. They are particularly sensitive to acid pollution associated with high levels of sulfur dioxide. Great Britain, for example, has lost most of its epiphytic lichens, largely due to SO_2 emissions from coal-burning power plants. In northern Siberia, a particularly polluted region of the former Soviet Union, lichen diversity has declined from 50 to 3 species and production is about 2% of historic levels.

In addition to SO_2, lichens have been shown to be sensitive indicators of nitrous oxides, heavy metals, ozone—and even radioactivity. Part of the reason for their sensitivity is that, unlike many plants which become dormant or lose their leaves during at least part of the year, lichens remain active and exposed to potential pollutants throughout the year. In fact, the absence of lichens on trees often indicate highly air-polluted areas, and compared to sophisticated instrumentation required to monitor air pollution, lichens are an inexpensive alternative for monitoring air quality.

Lichen distribution studies have produced "lichen maps" that are among the most widely used bioindication models. The U.S. Forest Service has been checking lichens since 1994 at 1,200 sampling locations in Oregon and Washington. European scientists have even solicited the help of school children in England, Ireland and Italy to conduct lichen surveys in their local communities. These studies have helped identify air pollution problem areas.

In the Pacific Northwest, air quality is generally quite good, resulting in a high abundance and diversity of lichens. Over 1,000 species occur in Washington, Oregon, British Columbia and Alaska. In today's lab we will investigate the potential use of five of these species as bioindicators of air pollution.

PROCEDURE

1. Prior to lab read the article from Discover Magazine,"Prophets of Gloom" [Kiester, E. 1991. *Prophets of gloom*. Discover. Nov. 1991:53-56].

2. Samples of the following lichens were collected in the Oregon's Coast Range (east of Lincoln City, OR):

   Peltigera neopolydactyla ("frog pelt")
   Platismatia glauca ("rag bag")
   Lobaria pulmonaria ("lung wort")
   Lobaria oregana ("lobaria")
   Hypogymnia inactiva ("forking bone")

3. Using available resources, research the natural history information on these species, including their sensitivity to air pollution. Using this information, rank these 5 lichen species from "most sensitive" to "least sensitive" to air pollution. Enter these hypotheses on the data sheet provided.

4. Working in groups of 3-4 students each, select one of the lichen species for study. Using a cork borer, cut out enough disks from the lichen so that five disks can be placed in each chloride solution to be tested as well as five for a distilled water control.

5. Place all of the disks you have cut out into the methylene blue solution and let them absorb the blue dye for 30 minutes.

6. While waiting for the disks to absorb methylene blue, watch the Oregon Field Guide video, "Lichens in old growth," [31 January 1999 (12 minutes)] on lichen studies in old-growth forests. Note the methods that are being used to study lichens and what researchers have learned so far.

7. After 30 minutes, remove the disks from the methylene blue solution, place them in an aquarium net, and rinse off the excess methylene blue with distilled water.

8. Transfer five washed disks to each of the test tubes containing 7 ml of the various chloride solutions and one tube containing 7 ml of distilled water (the control). Allow them to soak in the chloride solutions for 60 minutes at room temperature, shaking them occasionally. During this period, the methylene blue **cations** (positive ions) previously absorbed by the lichens are released as they are replaced by metallic cations from the chloride solutions. This exchange results in the gradual development of a blue color in the solution.

9. After 60 minutes, evaluate the degree to which the lichen has absorbed the metallic cations by measuring the amount of methylene blue dye that has eluted out of the lichen disks into the supernatant. If a large amount of the metallic cation has been absorbed by the lichen, the supernatant will appear dark blue. Lighter colors of blue indicate smaller amounts of cation exchange.

10. The differences in supernatant color between the various chloride solutions can be quantified using an instrument called a **spectrophotometer**.

- Pour a sample of the supernatant in a sample tube called a **cuvette**.
- Set the wavelength at 540 nm on the spectrophotometer. This is the optimum wavelength for detection of methylene blue.
- Turn the instrument on by rotating the "0" control knob in a clockwise direction. Allow 5 minutes for the instrument to warm up.
- With the cover of the sample holder closed, adjust the "0" control knob until the needle is at the zero measurement on the transmittance scale.
- Fill a cuvette with the *test solution* (solutions in dropper bottles without disks), place the cuvette in the sample holder and close the cover.

IMPORTANT NOTES: *This cuvette is called the* ***blank*** *and is used to* ***calibrate*** *the spectrophotometer. In other words, it is telling the machine that "this is what the solution looks like before any methylene blue has leached into solution."*

Since each of the test solutions (NaCl, $CoCl_2$, $FeCl_3$, etc.) differs somewhat in color, the spectrophotometer must be calibrated before each test with a cuvette that contains ***only*** *that solution.*

- Now, rotate the light control knob so that the needle is at 100 on the transmittance scale (0.00 absorbance).
- Place the cuvette containing the *test sample* (the solution that has been soaking the lichen disks) in the tube holder and read the % transmittance and absorbence from the scale. The needle should return to zero when the tube is removed. Check the 0% and 100% transmittance occasionally with the **blank** to be sure the instrument is calibrated.

NOTES: *There may be slight imperfections in the cuvettes resulting from their manufacture or use (i.e., slightly different thicknesses or scratches on the surface). These imperfections may affect the % transmittance of light through them. It is therefore best practice to use the same cuvette for all readings.*

11. Record the % transmittance and absorbence for each of your samples and the control.

12. Using the standard curve generated for methylene blue, convert "absorbence" or "% transmittance" into mM. Your instructor will describe how this is done.

13. Use *EXCEL* to graph your results.

ANALYSIS AND INTERPRETATION

1. Obtain the results of other lichen species from other groups. Graph these results as you have your own. Submit all graphs as part of your lab product.

2. Which cations (metals) were most readily absorbed by each lichen species? Which were not very readily absorbed?

3. What are some of the potential sources of pollutants that would contain these readily-absorbed cations? (NOTE: *This may take some research on your part.*)

4. Of those lichen species we tested, which one(s) would be most useful as a bioindicator for air pollution? Use the results of these experiments and explain how you have arrived at this conclusion.

5. How do your results compare with your predictions of lichen sensitivity to air pollution? Discuss both correct and incorrect predictions. What might account for any discrepancies?

6. Describe a study of your own design that would use the information you have obtained in this lab to evaluate air quality in the local area. Include sufficient detail such that another scientist could duplicate your efforts.

DATA SHEET

HYPOTHESES

Based on information available in lab, our lab group predicts that these 5 lichen species will differ in their sensitivity to air pollution. The *predicted order* of this sensitivity is as follows:

1 (Most sensitive) ____________________________

2 ____________________________

3 ____________________________

4 ____________________________

5 (Least sensitive) ____________________________

RESULTS

	Lobaria oregana		*Lobaria pulmonaria*		*Hypogymnia inactiva*		*Peltigera neopolydactyla*		*Platismatia glauca*	
TEST IONS	**%T**	**A**	**%T**	**A**	**%T**	**A**	**%T**	**A**	**%T**	**A**
CONTROL										

%T = percent transmittance

A = absorbence

NOTES FOR INSTRUCTORS

NOTE: *This activity was adapted from a laboratory exercise originally developed by James E. Miller at Delaware Valley College in Doylestown, Pennsylvania.*

Prior to the laboratory, the instructor should collect five or six species of lichens. Those with broad, sheet-like thalli are probably the easiest to work with (cut disks from), but other growth forms may be used as well. If air pollution sensitivities are known for local species, a broad range of air pollution sensitivities should be represented. If this information is not known, the results of this laboratory could be a first step in providing that information. Students should be introduced to the use of lichens as bioindicators of air pollution and should read Kiester (1991) prior to lab.

Assign a different lichen species to each group of students. Have students cut out lichen disks and place them in the methylene blue solution at the beginning of the laboratory. The Oregon Field Guide videotape should be shown and discussed while the lichen disks are soaking up the methylene blue (approximately 30 minutes). Also during this time, students should formulate hypotheses concerning the sensitivity of the various lichen species to pollutants. McCune and Geiser (1997) or the U.S. Forest Service web site cited below will provide this information for lichen species in the Pacific Northwest.

A standard curve for methylene blue should be generated using concentrations of 0.01, 0.05, 0.1, 0.15, 0.20 mM so that students can convert spectrophotometer readings ("percent transmittance" and "absorbence") to concentrations of methylene blue—this should be set up by the instructor prior to lab, or as a demonstration during lab. Once this conversion has been done, students can graph the amount of methylene blue that has eluted out for each cation tested. Data for all species should be plotted on one graph so comparisons among species can be made.

MATERIALS

QUANTITY	ITEM
6	Distilled water in wash bottles
6	Test tube racks
60	Test tubes (13 X 100)—approx 10 ml
6	Small aquarium nets
6	Cork borers—size 4
5	Spec-20 spectrophotometers
24	Cuvettes
1 roll	Glassware marking tape
12	Graduate cylinders (10 ml)
6	Lichen guides (McCune and Geiser, 1994)—or local guide, if available
5	Nalgene aquaria
1 roll	Cellophane
12	50 ml beakers
6	Forceps
6	Needle probes
12	Rubber stoppers for test tubes (size 00)
500 ml	Methylene blue 5×10^{-4} M
50 ml ea	Methylene blue at 0.01, 0.05, 0.1, 0.15, 0.20 mM (for standard curve)

CHLORIDE SOLUTIONS

Have set up and ready: 200 ml ea of the following solutions in dropper bottles (10 mM concentration for each):

NaCl	$BaCl_2$
KCl	$CdCl_2$
$CoCl_2$	$MgCl_2$
$CaCl_2$	$FeCl_3$ (acidified to dissolve precipitate)
$AlCl_3$	$PbCl_2$
$CuCl_3$	

NOTES: *Any number of metal chloride compounds can be used based on availability and interest. I would suggest including a selection of mono-, di-, and trivalent chlorides.*

REFERENCES

Ferry, B.W., M.S. Baddeley and D.L. Hawksworth. 1973. *Air pollution and lichens*. Univ. of Toronto Press, Toronto, Canada.

Hawksworth, D.L. and F. Rose 1976. *Lichens as pollution monitors*. Edward Arnold Ltd., London, UK. 59 pp.

Stolte, K., et al. 1993. *Lichens as bioindicators of air quality*. General Technical Report RM-224. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO

Kiester, E. 1991. *Prophets of gloom*. Discover Nov. 1991:53-56.

McCune , B. and L. Geiser. 1997. *Macrolichens of the Pacific Northwest*. Oregon State University Press, Corvallis, OR 386 pp.

Sharnoff, S.D. 1997. *Lichens: More than meets the eye*. National Geographic 191(2):59-70.

Sillett, S.C. and P.N. Neitlich. 1996. *Emerging themes in epiphyte research in westside forests with special reference to cyanolichens*. Northwest Science. 70:54-60 (special issue on forest canopy research).

INTERNET RESOURCES

www.fs.fed.us/r6/aq/lichen/

This is the home page for the Air Quality Biomonitoring Program on Forests of Northwest Oregon and Southwest Oregon. It is a comprehensive site for the use of lichens as indicators of air quality that includes sensitivity ratings by species, drawings and photographs, searchable data bases, a literature review and links to other lichen information sites.

www.metla.fi/projects/elproject/elproject.html

This site presents the final report of the Lapland Forest Damage Project (1990-1995). The use of lichens as indicators of air quality in a study of forests in Finland impacted by air quality is included.

VIDEOTAPE

Oregon Field Guide, "Lichens in old growth," 31 January 1999 (12 minutes)

Available from:
Oregon Public Broadcasting Productions
7140 SW Macadam Ave.
Portland, Oregon 97219-3099
1-800-241-8123

This videotape describes cutting edge research on the ecological roles of lichens and serves as an excellent introduction to this laboratory. Stephen Sillett, an Oregon State University botanist, uses technical climbing equipment to study canopy lichens in old growth Douglas-fir forests where dominant trees can reach over 200 feet in height. The roles of lichens as indicators of air quality, as nitrogen fixers and as food sources for small mammals are discussed. Preliminary results of transplantation studies of old growth associated species suggest that these specialists can grow in younger stands. Establishment in these younger stands, however, may be impaired by forest fragmentation since these species have only limited dispersal capabilities. Additional details on this research can be gleaned from Sillett and Neitlich (1996) cited above.

Constructed Wetlands for Wastewater Treatment
Analysis and Interpretation

INTRODUCTION

For the past several weeks we have evaluated the effectiveness of constructed wetlands to treat agricultural wastewater. A number of water quality parameters have been measured at one week intervals from pre-treatment (initial conditions) to post-treatment (approximately six weeks).

In today's laboratory we will begin to interpret the results of this term-long study. You will work in small groups and identify major trends in the data and discuss possible reasons for these trends. A more detailed analysis will be presented in your written report for the project. Today's activity should give you some guidance on the "Results" and "Discussion/Conclusions" sections of your report.

You will find the following very useful in today's lab (bring them with you):

1. All handouts related to the constructed wetlands lab (including "Final Report Guidelines")
2. Handout: "How should we interpret water quality measurements?"
3. Any data that have not yet been submitted
4. Your Botkin and Keller text

PROCEDURE

1. Complete the final measurements on your wetlands as indicated in the water quality measurement protocols.

2. A table with all data you have submitted to date will be available. After you have taken today's measurements, enter your data on the table. This information will be made available to all groups.

3. Using class data, enter into *EXCEL* the values for *one* of the water quality parameters (pH, dissolved oxygen, etc.). Generate a line graph that illustrates the change in that parameter over the length of the study in both the control tank and the test tanks. Submit this graph with your lab product.

4. Examine the attached graphs and tables which were generated from a 1999 study similar to the one we have conducted. Use these graphs to respond to the questions below. Put all of your answers on a separate sheet. In all questions, “control tank” refers to Tank B5 and “test tanks” refers to the six tanks with wetlands that were used to treat wastewater (C1 through C6).

A. pH

1. Identify major trends in data.
2. Is there a difference between control and test tanks?
3. Explanation for these trends and differences (e.g., what do you think caused them?)
4. What is the biological significance of the range in pH observed?

B. Dissolved Oxygen

1. Identify major trends in data.
2. Is there a difference between control and test tanks?
3. Explanation for these trends and differences (e.g., what do you think caused them?)
4. What is the biological significance of the range of dissolved oxygen observed?

C. Turbidity

1. What is the relationship between Turbidity and % Transmittance?
2. Identify major trends in data.
3. Is there a difference between control and test tanks?
4. Explanation for these trends and differences (e.g., what do you think caused them?)
5. What is the biological significance of the range of turbidity observed?

D. **Algal Concentration**

1. What is the relationship between Algal Concentration and % Transmittance?

2. Identify major trends in the data.

3. Is there a difference between control and test tanks?

4. Explanation for these trends and differences (e.g., what do you think caused them?)

5. What is the biological significance of the range of algal concentrations seen here?

E. **Microscopic Examination**

1. Describe any changes in the algal community in the control and the test tanks as time progressed. Why do you think these changes occurred?

2. What does the change in algal species tell us about changes in water quality?

5. In a single paragraph, describe how effective the constructed wetlands were in treating agricultural wastewater in 1999. Select the most relevant evidence from #4 above to support your answer.

NOTES FOR INSTRUCTORS

MATERIALS

See materials list for first "Constructed Wetlands Laboratory."

This laboratory is designed to prepare students for summarizing and interpreting the data from the constructed wetlands laboratory which began approximately six weeks ago, Students have been collecting water quality data from their constructed wetlands and the control tank according to the schedule outlined in the Constructed Wetlands Lab. A final report that uses class data to report on the effectiveness of these constructed wetlands in the treatment of agricultural wastewater will be prepared by each group of students.

1. Data Collection and Entry

Students are required to submit data weekly to the instructor who summarizes class data on a spreadsheet. This "master sheet" should be available for the lab either as student handout or as a file on a floppy disk or on a hard disk in a computer lab. A transparency of the master sheet should also be prepared so students can enter final measurements taken today. All data except the final measurement should be represented on this master sheet. As students take their final water quality measurements on the constructed wetlands and control tank, these data should be added to the transparency. Therefore, students will have access to all measurements approximately one hour after the beginning of lab.

2. Final Report Guidelines

The final report is a group product worth 50 points. Students received a handout describing guidelines for final report several weeks ago. Each section should be reviewed with students and any questions concerning what goes in each section should be addressed.

3. Presentation of Data

Students should be familiar by this point in the term with the use of *EXCEL* to generate graphs from these types of data. Line graphs are probably most appropriate for these data since we are attempting to identify trends in water quality measurements over time. Examples of graphs from previous data can be used to illustrate format, proper labelling, the use of control tank data, etc. When class data from the present study are available, students should select one variable (e.g., dissolved oxygen) and generate a graph to be submitted with today's lab product. Similar graphs for other variables will be included in the "Results" section of their reports.

4. Interpretation of Data

Students should be given the opportunity to practice identifying trends in data similar to those that they have collected and then discussing their interpretation of these trends. I provide graphs of data from previous years for students to interpret. In general, students should be looking for differences between control and test tanks and thinking about what might be responsible for those differences. The references below provide some background on the processes in constructed wetlands that may influence water quality. Students should also consider differences between their initial expectations (hypotheses) and trends that show up in the data.

REFERENCES

Hammer, D.A. 1989. *Constructed wetlands for wastewater treatment—Municipal, Industrial and Agricultural.* Lewis Publishers, Inc.

Lesley, Van Zee and Moore, eds. 1993. *Constructed wetlands wastewater treatment systems: How do they work?* Oregon State University Extension Service Misc. Publication 8543.

Moore, J.A. 1993. *Using constructed wetlands to improve water quality.* Oregon State University Extension Service. EC 1408. 4 pp.

NOTE: *These references are made available to students for use in the preparation of their final reports.*

INTERNET RESOURCES

gus.nsac.ns.ca/~piinfo/resman/wetlands/anno/annobib.html
Wetlands for Waste Treatment - An annotated bibliography of resources on the use of wetlands for waste treatment.

www.usouthal.edu/usa/civileng/wetlands.htm
USA Constructed Wetlands Page

h2osparc.wq.ncsu.edu/info/wetlands/index.html
A comprehensive site for natural and constructed wetlands (definitions, processes, functions, importance, human impacts, management, mitigation)

www.enn.com/search/search.asp
The Environmental News Network posts current and archived articles on environmental issues from a variety of sources. A search for "constructed wetlands" articles will yield a number of pertinent articles (including some on "phytoremediation" - the use of plants to uptake contaminants from soils or water)

Using Aerial Photography to Evaluate Land Use Changes

INTRODUCTION

The sophisticated use of aerial photography was developed during World War II when it was used as an effective tool to gather intelligence data. Since that time, aerial photography has been applied to a myriad of nonmilitary uses including such diverse applications as fire monitoring, geologic studies, irrigation analysis, soil surveys, urban planning, wildlife protection, forestry studies, and land use analysis. Like other image-producing tools, such as microscopes, telescopes, and the like, aerial photographs heighten the power of observation and provide the observer with a perspective that cannot be obtained on the ground. With current trends in natural resources management leaning towards management on broader scales of time and space, aerial photography, particularly when paired with satellite imagery, other data bases, and use of GIS software, has become an indispensable tool in modern natural resources management. Aerial photographs permit a land area of significant size (typically 9-73 square miles per image) to be viewed and studied while retaining a significant amount of easily recognizable detail. With a little training and careful observation, common cultural and natural features can be readily identified and relationships between them understood.

Since aerial photography has been so widely applied, there is a great demand for high quality photographs. Consequently, several historical aerial photographs are commonly available for a given site. Observation of these photos allows the observer to interpret natural and anthropogenic (human-caused) changes in the landscape. In today's lab we will use aerial photographs to evaluate land use changes at six sites in the Salem area. These sites differ dramatically in historical use, future use, degree of human impact and ownership.

INTERPRETATION OF AERIAL PHOTOGRAPHS

A number of different attributes can be used to identify features on an aerial photo. The following is a brief description of some of the more useful ones:

1. *Size*. The size of an object is a useful clue to aid in identification. Cultural features such as houses tend to have some degree of uniformity of size while natural features generally do not. The scale of a photograph must be calculated prior to making any identifications based on size. A barn, for example, looks quite different on 1:20,000 scale vs. a 1:60,000 scale.

2. *Shape*. Keep in mind that features in an aerial photo are being viewed from an unusual perspective (i.e., top view). Many natural and cultural features have characteristic shapes. Consider for example the narrow bands with smooth gradual curves of railroads compared to the wider bands and sweeping curves of roads. Individual trees, various types of buildings, etc., can all be identified based primarily on shape.

3. *Tone*. In black and white aerial photographs, features are seen in various tones of gray. In general, objects that reflect a large amount of light will appear lighter than those that absorb light. Smooth surfaces such as open fields, clearcuts, mowed lawns, plowed fields and roads usually appear in light tones. Rough surfaces such as forests, mature crops and pastures will appear as darker tones. Water surfaces may vary considerably in tone depending on the angle of the sun at the time the photo was taken.

4. *Texture*. Texture is particularly useful in determination of various types of vegetation or soil characteristics. Subjective categories such as smooth, fine, rough, coarse, mottled, rippled, etc., are often useful. Mottled textures in agricultural fields indicate variations in soil moisture. A regular lined texture may be due to plowing or harvesting in parallel rows. Texture may therefore be used to determine the type of crop being grown in a field. Forested stands change with age from finely textured young stands to coarsely textured mature and old-growth stands.

5. *Pattern*. The spatial arrangement of objects is often a useful clue in identification. The regular pattern of fruit or nut trees in an orchard, for example, is readily distinguished from the irregular pattern of individual trees in a natural forest. Lines of windrows or the regular placement of bales in a field would readily identify a field as a hayfield. Patterns of buildings can often be used to distinguish between new residential areas, old residential areas, mobile home parks, etc.

6. *Association*. Association allows the observer to identify features based on their proximity to another object. In a cluster of farm buildings, for example, individual structures such as barns, sheds, silos, water tanks and farm machinery may be identified based on their close association with each other. Riparian forests dominated by cottonwood and alder are often associated with rivers, streams and the margins of wetlands.

7. *Season*. Most aerial photographs will have a date stamped on to the image. Knowledge of both natural and human-caused seasonal changes is often very useful in the identification of features. For example, the timing of agricultural activities such as plowing, harvesting, baling or agrochemical application may be used to determine the type of crop that appears in an aerial photograph.

PROCEDURE

Your group will be given a series of historical aerial photographs from a single site in the Salem area. These photos were obtained from the University of Oregon Map Library and will span a time from the late 1930's to the 1990's depending on map availability. You will also be given a topographic map of the area that includes your study area. Your report will be based on analyses of these photos, the topographic map and a site visit which will be done outside of scheduled lab time.

I. Determination of scale

To properly interpret the features on an aerial photograph, it is important to be able to estimate the size of various features. The difference between a house and a factory (or a goat and a cow, for that matter), for example, may be easily determined if the scale of the photo is known. There are a number of ways to accomplish this. One of the easiest is to identify your site on a topographic map (which has the scale identified) and then measure a linear feature such as a road or stream section that can be identified in each. Set up a proportion to determine the scale of the photo.

For example:

You measure a feature on an aerial photograph that is 3.25". The same feature measures 1.25" on a topographic map that has a scale of 1:24,000. Set up the following proportion and solve for X:

$$\frac{1.25''_{\text{TOPO}}}{3.25''_{\text{PHOTO}}} = \frac{1/24{,}000}{X}$$

Scales are normally reported as a ratio. A scale of "1: 20,000", for example, indicates that every inch on the photo represents 20,000 inches (or 0.316 miles) on the ground. *Large scale* images are taken at low altitudes and generally show greater detail of smaller geographic areas. *Small scale* images are taken at higher altitudes and show less detail of larger geographic areas. The photos you will be working with today are large scale photographs.

Using the method described above, determine the scale of one of your photos.

NOTE: *Since each of your photos was taken at a different time, using different photographic equipment and at different altitudes, the scales of each photo are probably somewhat different.*

II. Unique features

List any unique features that can be identified on your site (e.g., athletic facilities, clearcuts, drainage patterns, industrial buildings, mill ponds, etc.)

For each feature, briefly describe the type of information you have used to identify the feature (see INTERPRETATION OF AERIAL PHOTOGRAPHS above).

III. Estimation of land use change

1. For each of the photos available for your site, identify the major land uses present. Use the following classification:

Urban/Developed Land:
- ➢ **Residential**
- ➢ **Commercial and Services (businesses, schools, stores, libraries, etc.)**
- ➢ **Industrial (manufacturing, lumber mills, sewage treatment plants, etc.)**
- ➢ **Roads (or other transportation features)**

Agricultural:
- ➢ **Cropland and Pasture**
- ➢ **Orchards**

Forests:
- ➢ **Coniferous forest (young vs. mature)**
- ➢ **Deciduous forest**

Disturbed lands:
- ➢ **Recent clearcut**
- ➢ **Recent excavation (e.g. mining operation, excavation for buildings, etc.)**

Water:
- ➢ **Rivers and streams**
- ➢ **Lakes and ponds**

NOTE: *If land uses other than those listed above are easily identifiable, add them to your list.*

2. In each of your aerial photos, estimate the percent coverage for each major land use. Although there are a number ways this could accomplished, I suggest the following:

- ➢ Start by identifying the photo with the largest scale (i.e., the photo that covers the smallest geographical area). This must be done to assure that all areas of interest are covered by each photo.
- ➢ Select one land use category (e.g., "agricultural/orchards"), place a piece of acetate over the photograph and draw a boundary around each area covered by that land use category (i.e., "orchards") with a fine tip marker.
- ➢ After each area covered by this land use category on the photo has been delineated, place the acetate sheet over a grid and count the number of squares that are occupied by this category ("orchards" in this example).
- ➢ Continue this process for each major land use area on the photo.
- ➢ Repeat the process for each photo in the time series.

Your results can either be expressed as:

- percentages of each land use category

-or-

- actual measurements of area by converting the percentages to square miles or acres using the scale you developed for each photo

Enter your data into *EXCEL* and graph your data as a function of time. These graphs must be prepared for next week when each group will describe the results of this exercise for their site (see LAB PRODUCT below).

IV. Site Visit

1. Plan to visit your site at some time in the next two weeks to record land use changes that have occurred since your last available photograph. The site visit can also be used to confirm identification of features you have identified in aerial photos.

NOTE: *Although the site visit may be conducted at any time during the study, it is probably best to become familiar with the area through interpretation of the aerial photographs first.*

2. Plan to spend approximately 1-2 hours at your site. Make your observations from public roads and properties—*do not trespass on private property!* Bring a copy of the latest aerial photograph with you and record any changes that have occurred since that date. Possible changes are highly site specific, but may include the following:

- removal or addition of buildings
- implemented forest practices—cutting, replanting, etc.
- changes in agricultural practices
- changes in hydrology—e.g., removal or addition of ponds

3. Record these changes and be prepared to report your findings to the class next week. You will find this information useful in making projections concerning the future of this site.

LAB PRODUCT

Each group will describe their findings in an informal, group presentation next week in lab. All aerial photographs of your site and graphs you have generated to illustrate land use changes should be available. Your presentation should include all group members and describe the nature of land use change at your site.

Include the following in your presentation:

- What are the major trends indicated in your graphs?
- What external forces may have been responsible for the changes you have seen?
- What are the consequences to natural resources for the changes you have seen?
- What do you think your site looked like 50 years prior to your earliest photograph? 150 years prior to your earliest photograph? How would you get detailed information on this?
- Based on your site visit, what changes have occurred since the last photograph was taken?
- What is your projected future for this site? (use information from your site visit)
- Determine, where possible, the ownership of areas represented on your photos (private, county, state, federal). Topographic maps may be helpful. How has ownership influenced land use on the site?
- How do you think Oregon's Land Use laws have influenced the changes in land use at your site?

NOTES FOR INSTRUCTORS

NOTE: *prior to lab, students should have the lab handout and, if available, an article that addresses local land use issues. I use a series of articles recently published by the local newspaper for this purpose.*

Land Use as an Environmental Issue

Land use planning is an important element of a sustainable society. Choosing appropriate human uses of the land must be done to achieve a high quality of living for all members of a society. Land use planning strives to conserve natural resources and protect the environment while at the same time making required goods and services available to all citizens. However, such planning is not without controversy. The goals of individual property owners, for example, may not be compatible with the broader goals of a regional land use plan.

In this lab we will explore some of the issues related to land use planning using aerial photographs as a tool. Students will work in small groups analyzing photos and presenting their findings to the class.

The prominence of land use planning varies tremendously from state to state. Oregon's land use laws are considered to be a model for the nation but are frequently criticized by those who see them as too restrictive. There are a number of local and regional land use topics that students may find to be particularly interesting:

1. The loss of farmland/wetlands to development
2. Urban growth boundaries
3. Site selection for mines or landfills
4. Private property rights vs. public rights
5. Wetland designation and its consequences to private landowners
6. Role of the Land Conservation and Development Commission (LCDC) in Oregon land use planning
7. Zoning laws and urban land use planning
8. Development in coastal areas

VIDEOTAPE

The Willamette River: Currents of Change

Show two 5-minute segments entitled *Altered Landscapes* and *Population Growth*. These videotape segments address several land use issues specific to western Oregon. However, land use topics such as land conversion and population pressures are probably applicable to many regions throughout the U.S.

DESCRIBE PROCEDURE

1. Assign sites or have students choose them. Students work in small groups (6 groups/6 sites).
2. Each group gets 1 topographic map and 6 aerial photographs of a site representing a time series.
3. Each student should be familiar with aerial photo interpretation as outlined on handout.

DEMONSTRATE AERIAL PHOTOGRAPH (SLIDE)

Describe how both natural and human-made features such as rivers, ponds, riparian areas, forests, agricultural fields, residential areas and roads can be identified on aerial photographs. Use the attributes described on the handout (size, shape, tone, texture, etc.) to help identify these features.

Demonstrate method of analysis using this aerial photograph, a blank transparency and a grid. All six photographs should be analyzed by students using this method. Fewer photographs may be analyzed if time is an issue.

Challenges and Hints:

1. When measuring areas, estimate the *total area* first; then determine which land use classification is dominant; measure the 2nd, 3rd, 4th, etc., most dominant land use, and determine the area of the first (by subtraction).
2. Measuring the area of linear features such as roads and waterways can be tedious. Linear measurements can be taken and an "average width" applied to estimate area (rather than actually measuring each width).
3. When classifying residential areas be sure to include the areas surrounding the houses in addition to the houses themselves. Also, is not always possible to distinguish between houses and farm buildings in all cases (use *association* and *size*).

There are a number of ways to run this laboratory . I generally allow two laboratory periods as follows:

Week 1: Procedure 1. Determination of scale (15 minutes)
Procedure 2. Identification of unique features (15 minutes)
Procedure 3. Estimation of land use changes (2 hours)

Between weeks one and two, students are required to conduct a site visit as described on the handout and, if not completed in lab, prepare a graphical representation of land use changes based on their analysis of aerial photographs. Their data should be entered into an *EXCEL* spreadsheet.

Week 2: Report findings to group (lay out photos, report on site visit, brief history, future trends, etc.)
Discuss methods of representing data
Discuss differences between sites

I use the attached *student evaluation form* to evaluate student oral presentations. A written report may also be required instead of (or in addition to) the oral report. The written report should describe the results of the analysis for their site as outlined in the questions on the handout.

Alternatively, the activity could be done in a single laboratory period by having students analyze a smaller number of photographs (e.g., 3 per group), summarizing and discussing the results in that laboratory and dispensing with the site visit.

SITE SELECTION

The six sites selected for analysis using aerial photographs should represent a variety of land uses (historical, current and future), degrees of human impact and ownerships (private vs. public). The six sites I have selected include a national wildlife refuge, a community college building site in an urban setting, agricultural land in the riparian zone of a major river, a rural residential area, a newly-developed residential area and a county park. Aerial photographs are available for most of these areas beginning in 1936.

Land Use Lab
Student Evaluation by Instructor

Group: ______________________________

Site: ______________________________

❑ Graphs

❑ Major trends in graphs

❑ External forces

❑ Consequences to natural resources

❑ Site 50 years ago

❑ Site 150 years ago

❑ Source for info on past

❑ Site visit

❑ Changes since last photo

❑ Projected future

❑ Ownership

❑ Influence of ownership

❑ Influence of Land Use laws

•FOR INSTRUCTORS•

MATERIALS

QUANTITY	ITEM
6 series	Aerial photographs for six study sites
6 packs	*Sharpee* fine point felt pens (non-permanent)
12	Paper grids (graph paper 5 squares to the inch)
36	Acetate transparencies
6	USGS 7.5 minute topographic maps (one for each site)
12	Calculators
6	Magnifying glasses
1	Slide of an aerial photograph for demonstration
1 roll	Masking tape

Aerial photographs may be obtained from a number of sources. I obtained most of my aerial photographs from the University of Oregon Map Library (Eugene, Oregon) which has a mechanism in place for providing high quality color copies of these photos for a small fee. Most major universities have similar facilities. Additional sources of aerial photographs include state departments of transportation, forestry or agriculture, federal agencies such as the Natural Resource Conservation Service or the U.S. Forest Service and private aerial photography companies. I mounted the photographs on black poster board and had them laminated for durability.

Topographic maps are used to determine scale and to provide students with a view of where their photographs fit into the landscape. Seven and one half minute U.S. Geological Survey topographic maps can be ordered directly from the U.S.G.S. or they can often be purchased locally at office supply or outdoor sporting goods stores. Electronic versions of aerial photographs are also now available. At least one company, DeLorme® of Yarmouth, Maine, offers three-dimensional 7.5 minute topographic maps for each state stored on compact disks. Demonstration maps can be observed and maps can be ordered at:

www.delorme.com/quads

REFERENCES

Richason, B.F. (ed.) 1978. *Introduction to remote sensing of the environment*. Kendall Hunt Publishing, Iowa. 496 pp.

VIDEOTAPE

The Willamette River: Currents of Change
9 April 1998
KGW Television
Northwest News Channel 8
1501 SW Jefferson St.
Portland, Oregon 97201
www.kgw.com

Show two 5-minute segments entitled *Altered Landscapes* and *Population Growth*.

H.J. Andrews Experimental Forest Field Trip

INTRODUCTION

The H.J. Andrews Experimental Forest is located in the Cascade Mountains approximately 50 miles east of Eugene, Oregon. It is managed jointly by the U.S. Forest Service and Oregon State University as a Long-Term Ecological Research (LTER) site. Prominent scientists from around the world have conducted research here and much of what we know about the forests and streams of the Pacific Northwest is the direct result of their work.

This one day field trip is designed as a "capstone experience" that engages students in a number of activities that relate to environmental issues we have discussed in *Environmental Science* throughout the year. Activities and discussions concerning land use, forest management, biodiversity, riparian zone management, stream ecology and water quality are included.

PLANNED ACTIVITIES

1. Introduction to H.J. Andrews Experimental Forest and Central Cascades Adaptive Management Area.

2. Hike on Lookout Creek Old Growth Trail to review old-growth forest characteristics.

3. Visit log decomposition study sites to review log decomposition studies and the role of old-growth forests in global carbon budgets.

4. Lunch—please bring your own sack lunch and something to drink. Coolers will be provided.

5. Discuss stream ecology and the use of macroinvertebrates as indicators of water quality, and the role of streams and riparian areas in natural resource management.

6. Conduct amphibian sampling in stream and terrestrial environments.

Please bring the following:

- Lunch and drink
- Field notebook
- Rain gear/warm clothes
- Sturdy hiking boots
- Hip boots/waders
- Binoculars/camera

LAB PRODUCT

A field journal that provides an account of the days activities and discussions. The appropriate format will be described later.

SAFETY GUIDELINES

Students will be engaged in a variety of field activities, some of which may present potentially hazardous situations. Although I do not plan to expose you to unusually dangerous conditions, be aware that we will be working primarily in old growth stands which usually include the following hazards: slippery rocks, large fallen logs, large snags and dead limbs and an occasional yellow-jacket nest.

The following guidelines are established to reduce the likelihood of accidents and injuries:

1. *Know your limitations!* If you feel the work exceeds your physical limits (pace too fast, slope too steep, etc.) inform the instructor immediately.

2. *Be aware of your surroundings!* Old growth forests are *the ultimate* in a three-dimensional habitat.

3. *Do not jump off of fallen logs!* Watch your footing; moss-covered logs (especially those across streams) may be slippery.

4. *Wear comfortable, appropriate clothing and footwear*. Sturdy hiking boots are required.

5. *Drive vehicles cautiously*. Driving on logging roads is a new experience; assume there is a log truck coming around every corner.

6. *Yellow-jackets* are ground nesters and do not take kindly to having their nests disturbed—be aware! If you are allergic to bee stings, bring a bee sting kit and tell instructor how to use it.

7. *Do not enter stands alone!* All planned activities are *group* activities - please maintain sight contact with the group at all times.

8. R*ough-skinned newts* (*Taricha granulosa*) and some other amphibians have toxic skin secretions which may be irritating to the skin or eyes. These secretions are released only when the animal is mishandled and may be removed by wiping with a cloth or washing in water.

9. *In the absence of specific guidelines for a situation, common sense should prevail!*

MATERIALS LIST

Please pack for travel:

QUANTITY	ITEM
6 rolls	Flagging (any color)
20	Clipboards
6	Metric, 30 m tapes
20	1-gallon size plastic bags (Zip-lock or twist tie)
6	Potato rakes
6	Dipnets (large mesh, D-type)
6	Dipnets (small mesh, D-type, macroinvertebrate nets)
6	Small aquarium nets
6	Approx. 1/2 gallon plastic aquaria w/ snap lids
6	1 gal. plastic buckets w/ lids (animal feed buckets)
12	Forceps (tie small piece of flagging to each)
6	Ceramic/metal pans (white)
6	White plastic ice cube trays
6	Stream macroinvertebrate guides
1	Fluorescene dye
1	Stopwatch
1	Pack basket
2	Food coolers

FIELD TRIP ITINERARY

8:00 AM	Leave Chemeketa Community College
8:00 - 10:00	Travel to H.J. Andrews Experimental Forest, Blue River, Oregon
10:00 - 10:30	Introduction to H.J. Andrews and Cascade Center for Ecosystem Management
10:30 - 12:00	Lookout Creek Old Growth Trail—Old growth forest characteristics
12:00 - 2:00	Lunch at Log Decomposition Research Site—How forest ecosystems are studied, carbon budgets, the role of woody debris in forest ecosystems and terrestrial amphibians
2:00 - 4:00	Stream Ecology—riparian buffers, stream macroinvertebrates and aquatic amphibians
4:00 - 6:00PM (approximate)	Return to Campus

LAB PRODUCT

Your lab product for today's lab is a field journal that documents the day's activities. Natural resource technicians and researchers frequently conduct field activities and sampling that are used to evaluate the condition of natural resources. Although some information that results from these activities is likely to be recorded on formal data sheets, a field journal is often required as well. The purpose of a field journal is two-fold. First, it provides a written record of what was observed in the field and adds information that may not be included on data sheets. Second, it serves as a reminder to the observer about the day's activities.

Field journals should be *legible*, *organized* (clearly separate different activities), and *complete* (include all activities). Although formats vary with the activity being documented, all field journals should include: 1.] Header—*Who, What, When, Where?* and 2.] Body—Brief descriptions of specific activities, specific locations, observations, context of these activities and your personal reflections.

NOTES FOR INSTRUCTORS

This field trip is designed as a "capstone experience" to review with students the major course themes (listed below). Nothing beats a field experience to reinforce ideas, and perhaps, raise questions.

Many, if not most, community colleges or educational institutions can find access to a research facility like the Andrews. The website for the national LTER network is:

http://www.lternet.edu/

Major themes addressed in this capstone experience:

1. Interconnectedness
2. Ecosystem structure and function
3. Dynamic nature of ecosystems—floods, landslides, fires and recovery (ecological succession)
4. Biodiversity—ecological uniqueness of habitats (e.g., old-growth forests)
5. Sustainability

Using Permanent Plots to Monitor Long-term Changes in Vegetation

INTRODUCTION

You are already familiar with the concept of **ecological succession** which we described earlier as the changes in plant and animal communities that occur over time. In modern natural resource management, there is often a need for documenting these changes as part of a management plan.

Here are some examples:

Wetland Restoration	A wetland restoration project may be monitored to see if restoration efforts are resulting in an ecosystem approximating a natural wetland. The only way to document this is to take vegetation measurements over time and to compare vegetation changes with a natural wetland that is already established.
Wildlife Management	In wildlife management, late successional species may appear in a forested area only after certain structural characteristics such as snags, logs or large trees are established. Vegetation monitoring could be used to see how young stands are progressing towards this goal.
Timber Production	Vegetation monitoring can be used to document growth rates of trees after planting, thinning or some other forest practice has been implemented. Predictions can be made to see if trees in a particular stand will reach marketable size within a given time frame.

In today's laboratory we will establish six permanent circular plots that will be used to monitor long-term changes in vegetation. We will also take initial measurements on these plots. These measurements will be repeated by future classes on an annual basis to document changes in trees and shrubs.

PROCEDURE

1. Work in groups of 3 or 4 and be sure that at least one member of the group is proficient in tree and shrub identification. Each group should also have an identification guide for trees and shrubs.

2. Centers of circular plots have been marked with flags at representative points within the field site. Identify your plot center and pound in your 5 foot length of rebar until a 2.5 foot length is protruding from the soil. Place the white PVC pipe over the rebar to permanently mark the site with an easily identified marker.

3. Flag out two circles—one with a 5.6 m radius (creating a plot of 100 m^2) and the other with a 12.6 m radius (500 m^2). The smaller plot will be used to measure the abundance of shrubs and ferns. The larger plot will be used to measure the abundance of trees.

4. Measure the trees in your plot first. Proceed through your large plot like the sweep second hand of a clock. One group member should stand at the origin and direct the measurement of trees to be sure that every tree in the plot is measured. Another should identify trees and measure the diameter at breast height (DBH) for every tree greater than or equal to 5.0 cm (see definition for "tree" below). Tree identifications should be confirmed by a knowledgeable group member or the instructor. A third group member should record data. Rotate group members between the various tasks and be sure to check each others' work.

NOTE: *A tree is "in" your plot if* **the center** *of the tree falls within the plot.*

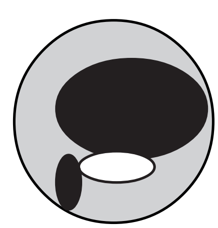
5. Measure the shrubs and ferns (see definitions below) in your smaller plot as follows:

   - Move through your smaller plot and identify the various shrub species. Identifications should be confirmed by a knowledgeable group member or the instructor.

   - Count the number of individuals for each species. A shrub or fern is "in" your plot if the base of the stem falls within the plot. Plants with multiple stems such as Sword fern and Western hazelnut are counted as a single plant if all stems seem to originate from a common base. Record numbers on the data sheet.

   - Then, estimate "percent cover" for each shrub or fern species. Imagine yourself perched about 20 feet directly over your plot. From this view estimate the percent of the plot that is covered by that species. It is usually best to start with the most abundant species and work your way down to the least abundant. Record data.

   - In the example at the right, percent covers are approximately:
     50% gray species
     40% black species
     10% white species



DEFINITIONS

Tree	any woody vegetation with a DBH (diameter at breast height) of 5.0 cm or greater; dead trees (snags) will be included here (if 5.0 cm or greater)
Shrub	any woody vegetation with a DBH less than 5.0 cm; note that small individuals of tree species are counted as "shrubs" by our definition (do not include dead shrubs)
Ferns	lady fern, sword fern or bracken fern

DATA SHEET
TREES

Group Members: ________________________________ **Plot #** _____ **Date** ________

Measure the DBH of every tree 5.0 cm DBH or greater that falls within your 500 m^2 plot. A tree is "in" your plot if the *center* of the tree falls within the plot.

Species	Diameter at Breast Height (DBH) in cm							
Douglas-fir								
Bigleaf maple								
Garry oak								
Wild cherry								
Oregon ash								
Black cottonwood								
Vine maple								
Red alder								
Grand fir								
Snags (any species)								

COMMENTS

____

____

DATA SHEET
SHRUBS AND FERNS

Group Members: ____________________________________ Plot # _____ Date _______

Count every shrub or fern that falls within your 100 m^2 plot. A shrub or fern is "in" your plot if the base of the stem falls within the plot. Plants with multiple stems such as Sword fern and Western hazelnut are counted as a single plant if all stems seem to originate from a common base.

Species	Number	% Cover	Species	Number	% Cover
English ivy			Snowberry		
Scotch broom			Poisonoak		
Himalyan blackberry			Black twinberry		
Holly			Red elderberry		
			Creek dogwood		
Sword fern			Salal		
Bracken fern			Cascara		
Lady fern			Pacific ninebark		
			Black hawthorn		
Vine maple			Thimbleberry		
Big-leaf maple			Pacific blackberry		
Red alder			Douglas' spiraea		
Garry oak			Oceanspray		
Oregon ash			Indian plum		
Douglas-fir			Mountain ash		
Black cottonwood			Willows		
Wild cherry			Red-flowering currant		
			Western hazelnut		

SPECIES LIST
TREES, SHRUBS AND FERNS

The following list of tree, shrub and fern species was developed from previous studies conducted at the Aumsville Site for Environmental Studies. Please consider it a starting point for those species we are likely to encounter. As new species are found on the site they will be added to the list. Species marked with an asterisk (*) are introduced (non-native) species.

TREES

Acer circinatum	Vine maple
Acer macrophyllum	Big-leaf maple
Alnus rubra	Red alder
Quercus garryana	Garry oak
Fraxinus latifolia	Oregon ash
Pseudotsuga menziesii	Douglas-fir
Populus balsamifera	Black cottonwood
**Prunus* sp.	Wild cherry

SHRUBS

Rhus diversiloba	Poison oak
**Hedera helix*	English ivy
Symphoricarpos albus	Snowberry
Lonicera involucrata	Black twinberry
Sambucus callicarpa	Red elderberry
Cornus stolonifera	Creek dogwood
Gaultheria shallon	Salal
**Cytisus scoparius*	Scotch broom
Rhamnus purshiana	Cascara
Physocarpus capitatus	Pacific ninebark
Crataegus douglasii	Black (Western) hawthorn
**Rubus discolor*	Himalayan blackberry
Rubus parviflorus	Thimbleberry
Rubus ursinus	Pacific blackberry
Spiraea douglasii	Douglas' spiraea
Holodiscus discolor	Oceanspray
Oemleria cerasiformis	Indian plum
Sorbus sitchensis	Mountain ash
Salix spp.	Willow species
Ribes sanguineum	Red-flowering currant
**Ilex aquifolium*	Holly
Corylus cornuta	Western hazelnut

FERNS

Athyrium filix-femina	Lady fern
Polystichum munitum	Sword fern
Pteridium aquilinum	Bracken fern

LAB PRODUCT

There is no formal lab product for this laboratory other than your active participation in the event. Future classes will be required to prepare a report that documents changes in vegetation over time.

MATERIALS

6	5' lengths of 5/8" rebar
6	5' lengths of 1 1/2" white PVC
6 rolls	flagging
6	Metal tags and wires (permanent markers)
6	Sharpies
6	30 m tapes
12	DBH tapes (metric)
12	Flagged pins (to mark temporary plot centers)
6	Clipboards
1	Fence post driver (or sledge hammer)

REFERENCES

The following Identification Guides are suggested for western Oregon and Washington:

Pojar, J. and A. MacKinnon. 1994. *Plants of the Pacific Northwest Coast.* Lone Pine Publ. Co., Redmond, Washington. 527 pp.

Petrides, G.A. 1972. *A field guide to trees and shrubs*. 2nd ed. Houghton Mifflin Co., Boston, Massachussetts. 428 pp.

Broskman, C.F. 1968. *Trees of North America*. Golden Press Western Publ. Co., New York. NY. 280 pp.

Preston, R.J. 1961. *North American Trees*. Revised edition. The M.I.T. Press, Cambridge, MA. 395pp.

Arno, S.F. and R.P. Hammerly. 1977. *Northwest trees.* The Mountaineers. Seattle, WA, pp. 222.

Ross, C.R. 1978. *Trees to know in Oregon*. Oregon State University Extension Service and Oregon State Forestry Department. Corvallis, OR. 96 pp.

Land Use Planning Presentations

Land use planning is an important element of a sustainable society. Choosing appropriate human uses of the land must be done to achieve a high quality of living for all members of a society. Land use planning strives to conserve natural resources and protect the environment while at the same time making required goods and services available to all citizens. However, such planning is not without controversy. The goals of individual property owners, for example, may not be compatible with the broader goals of a regional land use plan.

We will explore some of the issues related to land use planning through oral presentations by students. Students may work in pairs or singly in the selection of a topic, researching that topic and presenting their findings to the class. There are a number of local and regional land use topics that students may find to be particularly interesting:

1. The loss of farmland to development
2. Urban growth boundaries
3. Secondary lands—how should they be used?
4. Site selection for mines or landfills
5. Private property rights vs. public rights
6. Wetland designation and its consequences to private landowners
7. Role of the Land Conservation and Development Commission (LCDC) in Oregon land use planning
8. Zoning laws and urban land use planning

Other ideas for topics may be obtained by scanning recent issues of local and regional newspapers or from pages 624-635 in your text.

You will be evaluated as follows:

1. *Quality of Research* (15 points). How well have you researched the topic and prepared for the discussion? Each group should seek information from at least 5 substantial and current sources that address your particular issue. To document this research and assist you in the preparation of your presentation, first prepare a 1-page outline followed the next week by a 2-3 page summary that describes the main points you plan to address.

Suggested sources:

- Articles in resources available in the Chemeketa Library or Salem Public Library
- Interviews with knowledgeable persons (e.g., LCDC, city or county planning commissions, Division of State Lands)

2. *Quality of Presentation* (10 points). How well have you organized and presented the information you have collected? To get a maximum number of points:

- Each member should contribute during the presentation.
- Visual aids of some type should be used—overhead transparencies, videotape, poster, handouts, etc. *Please feel free to use your imagination!* If you need assistance with copying or production of any of these, let me know.
- Presentation should be clear and concise. Do not run past 15 minutes—practice and time your presentations. I would strongly discourage reading to your audience.
- Allow 5 minutes for questions after your 15 minute presentation and answer questions appropriately.

Timetable

Week One. Inform instructor of topic selection.

Week Two. Submit list of at least 5 resources that provide information pertinent to your topic.

Week Three. Submit a 1-page outline of your presentation.

Week Four. Present topic and submit a written 2 or 3-page summary of your topic.

Wastewater Use and Treatment in a Dairy Operation

We will visit a local, a state-of-the-art dairy. The owner has agreed to describe to us the day-to-day operation of the dairy and some of the environmental challenges that relate to its operation. The following topics have been provided to him as an outline for his presentation:

1. *Description of operation.*

   - how does operation work? feed, housing, products, etc.
   - history of operation
   - how much of feed is produced on-site/how much off-site?

2. *Production.*

   - how many cows? calves? how much milk?
   - production over a lifetime of a cow? daily?
   - meat production

3. *Environmental challenges.*

   - waste management—lagoons, irrigation of fields, nitrogen uptake by crops, salinization and mineralization of soils (accumulation of excesses from irrigation water)
   - manure, straw, others
   - soil and water analysis
   - water use and reuse
   - pesticide use (on crops/ on animals)
   - odors
   - public relations

4. *Environmental regulations.*

   - what agencies are involved in regulation?
   - what are concerns of the dairy? what could be done to change regulations to make farming easier for the dairy and/or better for the environment?
   - what has been done to meet regulations?

Consider this trip a "fact-finding mission" designed to determine the nature of the operation, environmental challenges, and how these challenges are being addressed. I would suggest developing a set of questions prior to the trip. I am particularly interested in your leaving with an understanding of the use and treatment of wastewater generated by the dairy operation.

Following the field trip, prepare a report that addresses the following:

1. How does this operation differ from traditional dairying? (i.e., the way the dairy was run in the past)

*2. What are the primary or "on-site" environmental effects of this operation? What are the secondary or "off-site" effects? (see text, p. 209)

*3. How is wastewater used as a resource by the operation?

*4. What are the primary environmental concerns related to land application of wastewater? How are these monitored?

5. What concerns do you think should be addressed in choosing future sites for dairies of this type?

6. Is this operation an example of sustainable agriculture? Do you have any suggestions for alternatives that might make the operation more "sustainable"?

* *Give these questions the highest priority.*

Study Guide Exam #1

COVERAGE

Botkin and Keller - Chapters 15, 16, 17, 18 and 20

Labs - #1 (Hanford Cleanup), #2 (Constructed Wetlands), #3 (Biomonitoring), #4 (Amphibian Survey)

Supplemental Readings: Hanford article, Exxon Valdez case study, Frog deformities article, Phytoremediation article

Videotapes - Hanford Cleanup, "We All Live Downstream", "Willamette River- Currents of Change", Water Treatment

BE FAMILIAR WITH THE FOLLOWING

1. The elements of a sustainable society.
2. The history of energy use in the U.S.
3. The role of fossil fuels in past, present and future energy production.
4. For each of the various fossil fuels be familiar with:
    - their formation
    - known supplies and sources
    - advantages and disadvantages as a fuel
    - environmental concerns and risks
5. Patterns of global energy use
6. Alternative energy sources - advantages and disadvantages of each
7. The basics of radioactivity and how it is used to generate useable energy
8. Be able to objectively evaluate or propose a comprehensive energy plan for the U.S. based on your understanding of various sources of energy and the activity on p. 359 in your text
9. The environmental concerns at Hanford Nuclear Reservation including types of contaminants, monitoring programs, short and long-term plans for cleanup and ultimate fate of various zones.
10. The causes and results of nuclear accidents such as Three-mile Island and Chernobyl
11. The interconnections between energy issues and other environmental problems
12. Why are amphibians useful indicators of environmental quality?
13. The use of living organisms to evaluate the toxicity of water pollutants and water quality - be able to design an experiment that uses a bioassay to evaluate toxicity.
14. The various categories of water pollutants - sources and environmental impacts
15. The Willamette River as a case study in water quality

16. Conventional methods of wastewater treatment - septic systems, municipal sewage treatment
17. Alternative methods of wastewater treatment that use natural processes - land application, aquaculture, bioremediation - limitations, advantages, disadvantages of each.
18. The specifics of wastewater treatment in the Willamette Valley - food processing plants, dairy operations and municipal sewage treatment
19. The use of constructed wetlands to treat wastewater - experimental design, methods of measurement, anticipated results, etc.

TERMINOLOGY

sustainable society
subbituminous
carbon cycle
overburden
nitrous oxides
coal gasification
hard path
coal
oil shale
renewable energy
passive solar energy
solar towers
wind power
breeder reactor
gamma rays
nuclear energy
radioactive decay
plutonium
tritium
contaminant plume
pH
bioremediation
pollutant
nonpoint source
biological oxygen demand (BOD)
recovery zone
typhoid
cultural eutrophication
turbidity
pseudoestrogens
BHA
secondary treatment
bioremediation
rhizofiltration
LC-50
red tide

cogeneration
bituminous
acid mine drainage
reclamation
carbon dioxide
methane
soft path
fossil fuel
biomass
nonrenewable energy
photovoltaics
tidal power
alpha particle
nuclear fission
half-life
neutron
rads
uranium
vitrification
reactor core
biomonitoring
Daphnia
Cryptosporidium
groundwater
dissolved oxygen (DO)
clean zone
cholera
PCB's
coral bleaching
environmental hormones
DDT
advanced treatment
phytoremediation
Arthrobacter
Pfiesteria

energy conservation
anthracite
strip mining
sulfur dioxide
heavy metal
natural gas
crude oil
hydrocarbon
geothermal energy
active solar energy
solar collectors
hydropower
beta particle
nuclear fusion
nuclear waste
radioisotope
rems
strontium
fuel rod
enrichment
bioassay
pesticide
point source
surface water
decomposition zone
pathogen
fecal coliform bacteria
biological magnification
nitrogen bubble disease
phthalates
primary treatment
aquaculture
phytoextraction
water reuse
POP's

Study Guide Exam II

COVERAGE

Botkin and Keller Chapters 22, 23, 24, 27

Labs - Mining videotape, Lichen adsorption lab

Supplemental Readings - *Going for the Gold*, *Prophets of Gloom*

Videotapes - "Public lands - Private Profits," "Only One Atmosphere" (ozone depletion), Oregon Field Guide - *Solid Waste Management* and *Lichen Biology in Forest Canopies*

BE FAMILIAR WITH THE FOLLOWING

1. Natural and human-made sources of air pollution
2. Trends in U.S. levels of various air pollutants over the past 50 years
3. Categories of air pollutants - sources and human health/ecosystem effects of each
4. The concept of "nuclear winter" and examples of how it has been studied
5. Atmospheric chemistry that produces acid deposition
6. Impacts of acid rain on terrestrial and aquatic ecosystems
7. Potential solutions to the acid rain problem
8. The most common sources of indoor air pollution
9. Sources and human health effects of radon gas
10. Environmental issues concerning mining - videotape and discussion questions
11. The Mining Act of 1872 - its implementation and reform efforts
12. Lichens as bioindicators of air pollution
13. Have a good understanding of the lichen adsorption experiments conducted in the laboratory
14. The various forms in which oxygen may appear in the atmosphere
15. The role of ozone in the lower and upper atmosphere
16. Trends in ozone depletion over Antarctica, Arctic and temperate areas
17. Proposed causes for ozone depletion and supporting evidence
18. Ozone depleting chemicals and the chemical reactions that result in the loss of ozone
19. Environmental and human effects of ozone depletion
20. Proposed solutions to ozone depletion
21. "Dilution and dispersion" waste management vs. "integrated" waste management
22. Considerations for sanitary landfill site selection, design and operation
23. The nature of the solid waste and hazardous waste problems in the United States
24. Ocean dumping as an environmental issue

TERMINOLOGY

Waldsterben
ozone
stationary source
non-point source
carbon dioxide
volatile organic compounds
pH
potassium
air quality standards
coal gasification
nitrogen cycle
methylmercury
chimney effect
catalytic converter
polonium
sodium cyanide
transmittance
supernatant
hazardous waste
land application
recycle
groundwater
ocean dumping
secure landfill
HCFC
ozone shield
UVA
monatomic
chlorine oxide
helium

sulfur dioxide
nitrous oxides
mobile source
primary pollutant
carbon monoxide
photochemical smog
hydrogen ion
aluminum
atmospheric inversion
scrubbers
heavy metal
lime
hydrocarbon
formaldehyde
alpha particle
standard curve
spectrophotometer
methylene blue
integrated waste management
leachate
sanitary landfill
surface water
capping
Dobson Unit
HFC
polar stratospheric clouds
UVB
diatomic
cataract
methyl bromide

hydrogen sulfide
particulates
point source
secondary pollutant
hemoglobin
asbestos
calcium
decomposers
buffers
sick building syndrome
magnesium
allowance trading
vapor-recovery systems
radon
heap leach mining
bioindicator
cuvette
composting
incineration
monitoring well
source reduction
landfill liner
surface impoundment
Montreal Protocol
ozone
polar vortex
UVC
chlorine
propane
photolyase

Study Guide
Final Exam

COVERAGE

Botkin and Keller - Chapters 25, 29 and 30

Aerial Photo/Land Use Lab, Constructed Wetland Lab, H.J. Andrews Field Trip

Supplemental Readings - Environmental Economics articles, Wetlands Mitigation article, Handouts from field trip

Video - Excerpts from David Suzuki lecture and "Willamette River - Currents of Change" (KGW-TV)

BE FAMILIAR WITH THE FOLLOWING

1. How does free-market environmentalism differ from the traditional relationship between the environment and the economy?
2. What are some of the pros and cons of assigning "actual cost" or "real value" to the goods and services we value?
3. What are some of the alternatives to "command and control" environmental regulation?
4. What is the relationship between good environmental policy and a strong economy?
5. What is the "Tragedy of the Commons" and how does it apply to environmental problems?
6. What are the various functions of "land-use planning"? How is land-use planning accomplished in Oregon?
7. What type of land use changes can be documented using historical aerial photos?
8. Why is land use planning a critical element of a sustainable society?
9. What are some of the strengths and weaknesses of wetland mitigation?
10. How could wetland mitigation be improved?
11. What is a lumber certification program and how does it relate to sustainable forestry?
12. The various ways human cultures have perceived the "human-nature" relationship.
13. The use of constructed wetlands in the Aquatic Ecology Laboratory for the treatment of agricultural wastewater:

    - initial conditions
    - experimental design
    - techniques for measurement
    - data collection and analysis
    - results and conclusions
    - strengths and weaknesses of model constructed wetlands

14. All aspects of the H.J. Andrews Experimental Forest, including:

- ecological characteristics of old growth forests
- log decomposition study
- terrestrial amphibian sampling
- stream ecology
- aquatic amphibian sampling

TERMINOLOGY

externality	internality	allowance trading
discount factor	risk-benefit analysis	commons
land use planning	urban growth boundary	EIS
compensatory mitigation	GIS	green plan
ecological restoration	adaptive management	sustainable forestry
forest analog	strip clearcutting	agroforestry
environmental ethics		

Exam #1

Multiple Choice (2 points each): Select the most appropriate answer and place the letter on the answer sheet.

1. Of the following energy sources, which one is not considered "renewable"?

A. wind
B. photovoltaic
C. natural gas
D. solar thermal
E. biomass

2. At present rates of consumption, known oil reserves will be depleted in approximately ________ years.

A. 45
B. 75
C. 125
D. 200
E. 500

3. The sulfur content of coal is of great concern when considering coal as a source of energy. When sulfur is burned it is converted to ________ which contributes to ________.

A. sulfur dioxide/global warming
B. carbon dioxide/global warming
C. carbon dioxide/air pollution
D. nitrous oxide/water pollution
E. sulfur dioxide/acid rain

4. Uranium-235 is described as a "fissionable radioisotope". This means that

A. it must be enriched to be a useable fuel
B. it can be split by neutrons to release energy
C. it can be used to produce an atomic bomb but not in a nuclear reactor
D. it has a very long half-life

5. Atoms of Deuterium and Tritium are forced together at extremely high temperatures and energy is released. This process best describes :

A. nuclear fusion
B. breeder nuclear fission
C. core meltdown
D. radioactive decay
E. radioactive dating

6. At the Hanford Nuclear Reservation in Washington there are various levels of nuclear waste stored on site. Among the most dangerous high-level wastes is the unused nuclear fuel, ________ , which is stored under water in the old reactor buildings.

A. Cesium
B. Uranium
C. Iodine
D. Plutonium
E. Tritium

7. Which of the following alternative energy sources converts solar energy into readily usable electricity?

A. solar tower
B. photovoltaic
C. geothermal
D. solar thermal
E. biomass burning

8. Which environmental pollutant may result in fish kills when large volumes of water pass rapidly over a dam?

A. oxygen
B. dioxin
C. nitrogen
D. carbon dioxide
E. BOD

9. In a conventional wastewater treatment plant, the chlorination of wastewater is considered to be part of:

A. primary treatment
B. secondary treatment
C. advanced water treatment
D. all of the above

10. Rhizofiltration, phytoremediation and phytoextraction are all methods to extract toxic chemicals using ________ (fill-in).

11. The abundance of insoluble particles of soil and other solids may decrease water quality dramatically. This characteristic is measured as ________ (fill-in).

12. What process is responsible for the harmful effects of high B.O.D. on water quality?

A. photosynthesis
B. decomposition
C. formation of nitrogen bubbles
D. biological magnification
E. rhizofiltration

13. Which of the following pollutants would most likely cause cultural eutrophication?

A. pesticide spill
B. heavy metals
C. coliform bacteria
D. oil spill
E. agricultural runoff

14. In the U.S., water quality would be most improved by decreasing non-point source pollution rather than point source pollution from their current levels.

A. True

B. False

15. Which of the following statements best describes the relationship between BOD and dissolved oxygen?

A. when BOD is high dissolved oxygen is also high
B. when BOD is high, dissolved oxygen is low
C. there is no clear relationship between BOD and dissolved oxygen

16. The recent spill by Mitsubishi into Pringle Creek in Salem resulted in dramatic change in which of the following water quality values?

A. dissolved oxygen
B. turbidity
C. nitrate level
D. pH
E. pesticide level

17. You are studying an aquatic ecosystem that was contaminated with PCB's back in the 1960's. In which of the following organisms would you expect to find the highest concentration of the pollutant?

A. Daphnia
B. killer whale
C. shrimp
D. algae
E. fish

18. Amphibians are considered to be good indicators of environmental quality because

A. they readily absorb pollutants through their thin skins
B. they are widely distributed
C. most species have aquatic and terrestrial stages in their life history
D. they are relatively long-lived
E. all of the above

19. A high fecal coliform bacteria count is found in a water supply that you are monitoring. Which of the following could explain this result?

A. human sewage has leaked into the water supply
B. runoff from a confined animal feeding operation has contaminated the water supply
C. an industrial oil spill has contaminated the water supply
D. both A and B are possible
E. all of the above are possible sources

20. According to recent research conducted by Andy Blaustein at Oregon State University, deformities in frogs may be caused by ________ in ponds used as breeding sites.

A. PCB's
B. nitrates and nitrites
C. petroleum products
D. high temperatures
E. low dissolved oxygen

21. When the *New Carissa* ran ashore off the Oregon Coast and began leaking oil into the Pacific Ocean, this was considered a _________ source of water pollution.

A. point
B. non-point

22. According to data compiled by the Environmental Protection Agency, which industry in Oregon is responsible for the greatest releases of toxic chemicals?

A. wood and paper products
B. silicon chip manufacturing
C. tourism
D. agriculture
E. health care

23. The Oregon Department of Environmental Quality is responsible for listing those rivers and streams in Oregon with degraded water quality. What is the most common reason cited for a stream or river being placed on this list?

A. pesticides
B. PCB's
C. heat
D. nitrates
E. exotic species

24. The Columbia Slough in Portland was listed in March 2000 as a "Superfund Site" by the Environmental Protection Agency. What pollutant is primarily responsible for this listing?

A. PCB's
B. nitrates
C. lead
D. DDT
E. Cryptosporidiosis

25. Which of the following produces a natural toxin that has been shown to cause shellfish poisoning in humans and 158 manatee deaths in Florida in 1996?

A. *Pfiesteria*
B. "red tide"
C. Elian Gonzalez
D. Cryptosporidiosis
E. *E. coli*

26. Environmental hormones (or "pseudoestrogens") are a relatively new category of pollutants that has been linked to developmental and reproductive effects in humans and animals. Which of the following pollutants is considered to be an environmental hormone?

A. brevitoxin
B. mercury
C. phosphate
D. DDT
E. nitrate

27. Based on discussions in class, which of the following is probably the most reasonable conclusion to draw from the results of the Diazinon trials in the Water Pollution Lab?

A. *Daphnia* and seed shrimp are unaffected by Diazinon
B. *Daphnia* and seed shrimp are highly susceptible to Diazinon
C. Diazinon has a low chronic toxicity
D. Diazinon has a shelf-life that exceeds 5 years
E. Diazinon is effective only in water that has a pH of approximately 7

28. In the Constructed Wetlands Lab we are using a spectrophotometer to measure:

A. dissolved oxygen
B. turbidity
C. phosphate level
D. pH
E. nitrate level

29. Which of the following Willamette Valley cities gets the majority of its drinking water from the Willamette River?

A. Salem
B. Eugene
E. Newberg
D. Corvallis
E. Portland

30. The Aumsville Site for Environmental Studies was recently surveyed for amphibian diversity. Based on our sampling, each of the following species occurs there, except:

A. Bullfrogs
B. Red-legged frogs
C. Northwestern salamanders
D. Rough-skinned newts

Short Answer - #31-33 (10 Points Each) Select **two** (and only two) of the following questions and answer on blank sheet

31. We have used the Willamette River in western Oregon as an example several times in our discussion of water quality. List 5 specific water quality problems that exist in the Willamette and describe what actions could be taken to improve these values.

32. List the methods employed in the containment and cleanup of the *Exxon Valdez* oil spill and comment briefly on their environmental impact and effectiveness.

33. Wastewater treatment facilities of Arcata, California and Lima, Peru were described in a videotape shown in class. Describe how each of these systems differ from conventional wastewater treatment facilities.

Essay Question (20 points) - Answer the following question on a blank sheet of paper.

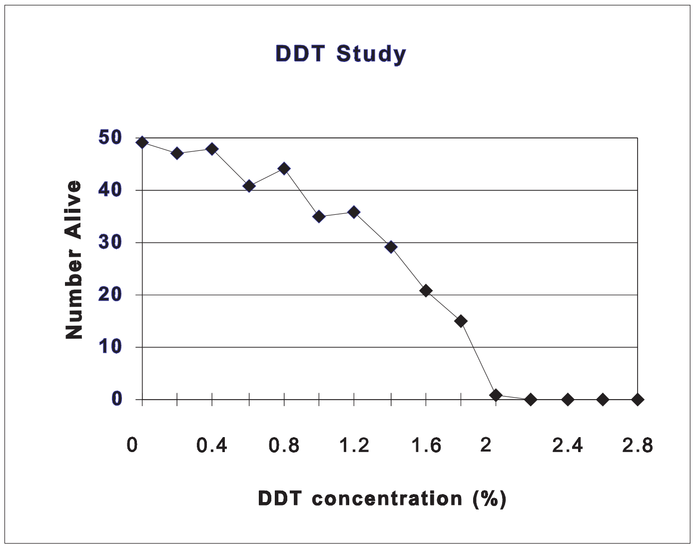
34. A hypothetical U.S. energy policy has been proposed by the Bush Administration that includes an estimate of the percent contribution by each energy source by the year 2010. These percentages are presented in the table below. Please comment on the strengths and weaknesses of this policy taking into account your knowledge of the elements of a sustainable society and the realities of the current energy situation. Use the knowledge you have gained from the Energy Policy Activity conducted in class as a basis for your answer.

	2000	**2010**
Petroleum	38	30
Coal	28	13
Natural Gas	19	30
Hydropower	7	10
Nuclear	6	6
Biomass	2	4
Geothermal	0.1	1
Solar Thermal	0.1	1
Photovoltaic	0.1	1
Wind	0.1	4

Extra Credit (5 points)

35. You have conducted a bioassay study to determine the toxicity of various concentrations of DDT. You subject 50 goldfish to concentrations that vary from 0% to 2.5 % DDT for 60 minute exposures. When the study is complete you submit your data to Wynn's Graphing Service which prepares the following graph.

A. Based on these data, what DDT concentration is 100% lethal to goldfish?
B. What is the "LC-50" for DDT?
C. If a similar test was run using dioxin rather than DDT and the LC-50 was found to be 0.4%, what would this tell you about the relative toxicity of DDT and dioxin?



Exam #2

Matching Questions (**2 points each**)

Select the most appropriate answer(s) and place the letter(s) on the answer sheet. Use the key below to answer #1-12:

A. sulfur dioxide (SO_2)
B. nitrous oxides (NO_x)
C. carbon monoxide (CO)
D. ozone
E. particulates
F. volatile organic compounds

For each of the descriptions below, indicate those pollutants to which the description applies. Letters may be used more than once and there may be multiple answers for each question. *Include all answers that apply.*

1. produced directly as a result of fossil fuel burning
2. a yellow-brown gas that contributes to photochemical smog
3. a colorless and odorless gas that readily binds to hemoglobin
4. a colorless and odorless gas that causes direct damage to lungs
5. contributes to acid deposition
6. pollutant most commonly associated with coal-fired electrical generation
7. a secondary pollutant
8. the only air pollutant that has not declined dramatically in the U.S. since 1970
9. combines with water to form sulfuric acid
10. airborne lead and asbestos are examples
11. proposed as the primary cause of "nuclear winter"
12. blocks UV-B radiation in stratosphere

Multiple Choice (2 points each): Select the most appropriate answer and place the letter on the answer sheet.

13. What chemical is missing in the reaction below?

VOC's + ______ + sunlight ➜ photochemicals

A. SO_2
B. O_3
C. CO_2
D. NO_x
E. UV-B

14. Acidification of most midwestern (e.g. Indiana, Iowa, Nebraska) lakes is generally not expected because:

A. coal-fired electric plants are intentionally located far from these lakes
B. the bedrock there has a powerful buffering effect
C. electricity is generated by technologies other than coal-burning
D. this region has strict air quality regulations
E. there are no mountain ranges in this region

15. You collect rainwater from a rain gauge in downtown Portland over several days and measure the pH of that water to vary from 5.6 - 5.8. What conclusion do you draw from this measurement?

A. this measurement falls within the normal pH range for rainwater
B. this measurement suggests acid precipitation
C. the water is unusually basic
D. the sample contains excessive hydrogen ions
E. none of the above

16. What observation is the direct result of the following chemical reaction?

$$H_2O + CO_2 \rightarrow HCO_3^- + H^+$$

A. the death of aquatic animals such as fish and amphibians
B. the natural acidity of rainwater
C. the accumulation of ozone at low elevations
D. the release of alpha particles

17. Radon has a half-life of about 4 days. Twelve days after a sample of radon gas is emitted into a sealed room, ________ of the original amount remains.

A. 1/2
B. 1/8
C. 1/16
D. 1/3
E. 1/12

18. Radon gas is considered to be a threat to human health because it:

A. causes lung cancer
B. causes birth defects
C. damages the immune system
D. binds with hemoglobin
E. causes skin cancer

19. Which of the following waste management options probably has the greatest negative impact on air quality?

A. composting
B. source reduction
C. landfilling
D. recycling
E. incineration

20. The major component of municipal solid waste in the U.S. is:

A. yard and food waste
B. paper
C. glass
D. plastic
E. construction debris

21. In a secure landfill for hazardous waste, an impermeable clay cap is often used to:

A. prevent infiltration of surface water
B. prevent leakage of leachate into underlying groundwater
C. monitor surrounding soil for possible contamination
D. collect leachate for removal and treatment

22. In the spring 1991, 610 oil wells in Kuwait were ignited, burning about 4.6 million barrels per day for several weeks. As a result of this event, each of the following occurred except:

A. a decline in average temperatures in Kuwait for several weeks
B. 75-80% blockage of solar radiation for several days
C. severe acid rain deposition in Kuwait
D. a small but measurable decline in global temperatures

23. Although lichens have been used to evaluate a number of components of air pollution, their most common use to date has been to detect harmful levels of:

A. nitrous oxide
B. hydrogen sulfide
C. methane
D. sulfur dioxide
E. particulates

24. Natural phenomena, as well as human-produced pollutants contribute to poor air quality in the Los Angeles area. Which of the following natural phenomena probably does not contribute to air pollution in LA?

A. mountain ranges
B. chimney effect
C. westerly wind direction
D. temperature inversions
E. volcanic eruptions

25. What is the main reason that ozone depletion will continue to occur for at least several decades, even if all production, use and emission of ozone depleting chemicals were stopped today?

A. once in the stratosphere, these chemicals can never be removed
B. developing countries will never agree to the ban
C. some ozone depleting chemicals have a long residence time
D. natural production of ozone depleting chemicals will continue
E. none of the above

26. The Antarctic ozone hole occurs in early spring; why does this phenomenon largely disappear later in the spring and summer?

A. there is more evaporation of water, which also blocks UV radiation
B. warmer temperatures increase the production of ozone
C. the sun heats up the air over Antarctica breaking up the polar vortex and stratospheric clouds
D. the input of UV radiation is reduced
E. anthropogenic emissions of ozone increase

27. Monitoring wells on modern sanitary landfills are designed to:

A. capture methane gas
B. detect the movement of leachate into the soil or aquifer
C. pump leachate out of the landfill
D. pump air into the landfill to increase aerobic decomposition
E. prevent the release of carbon monoxide gas from the landfill

28. The ozone problem results in excessive amounts of ________ reaching the surface of the Earth.

A. UV-A
B. UV-B
C. UV-C
D. UV-D
E. UV-E

29. When ultraviolet (UV) radiation contacts ozone in the atmosphere:

A. UV is reflected back into space and the ozone becomes CO_2
B. UV is converted into heat and the ozone becomes O_2 and O
C. UV is converted into light and the ozone becomes monatomic oxygen
D. UV is converted into infrared radiation and the ozone becomes water vapor
E. UV is scattered and the ozone remains unchanged

30. The ozone problem is sometimes described as an "ozone distribution problem". What is meant by this statement?

A. ozone is accumulating over tropical and temperate areas but declining over the poles
B. ozone is accumulating in the stratosphere but declining in the troposphere
C. CFC's are accumulating in the troposphere while ozone is declining in the stratosphere
D. ozone is declining in the stratosphere but accumulating in the troposphere
E. ozone is declining in the stratosphere but ultraviolet radiation is increasing in the troposphere

31. Which of the following statements best describes the significance of the chemical reaction below?

$$ClO + O \rightarrow Cl + O_2$$

A. ozone is being chemically broken down as a result of this reaction
B. ozone is being generated as a result of this reaction
C. chlorine is being produced which can cause further breakdown of ozone
D. chlorine is being produced which can absorb UV-B radiation
E. oxygen is being produced which can form additional ozone

32. All of the following chemicals have been proposed as replacements for CFC's except:

A. methane
B. HCFC's
C. helium
D. propane
E. HFC's

33. There is evidence to support all of the following consequences of increased ultraviolet radiation except:

A. the decline of amphibian populations
B. the decline of primary production in marine ecosystems
C. the increase of melanomas in humans
D. the increase in lung cancer rates in humans

Questions 34-36 refer to the incomplete reaction below:

$$\_\_\_\_\_\_\_ + O_3 \rightarrow ClO + O_2$$

34. What is the missing element in the reaction above? (Fill in)

35. What is the source of the missing element in the reaction above?

A. CFC's
B. methane
C. ozone
D. propane

36. The reaction above, when completed, is best described as the reaction that causes:

A. ozone depletion
B. global warming
C. AIDS
D. the production of ozone
E. the absorption of UV radiation

37. A short video describing current research on lichens in forest canopies was shown in lab. Preliminary results from this research suggest that lichens normally found only in old-growth forests die when transplanted to younger stands.

A. True
B. False

38. Heap leach mining allows mining companies to extract gold from ore that contains only tiny amounts of gold. What chemical is used in this process?

A. sulfur dioxide
B. cyanide
C. radon
D. ozone
E. sulfuric acid

39. The Mining Act of 1872 allows for the purchase of federal lands by private mining companies at levels far below current market value.

A. True
B. False

40. You are using a spectrophotometer to measure the amount of methylene blue in a dilute solution of lead chloride. What should you use as your "blank"?

A. distilled water
B. lead chloride
C. methylene blue
D. any of the above could be used

Essay Question - #41 - 42 (10 points) - Answer **one** (and only one) of the following questions on a blank sheet of paper.

41. Describe the difference between "ozone depletion" and the "greenhouse effect". In what ways are these two global phenomena connected?

42. Describe the effects of acid rain on terrestrial ecosystems.

Analysis - 10 points

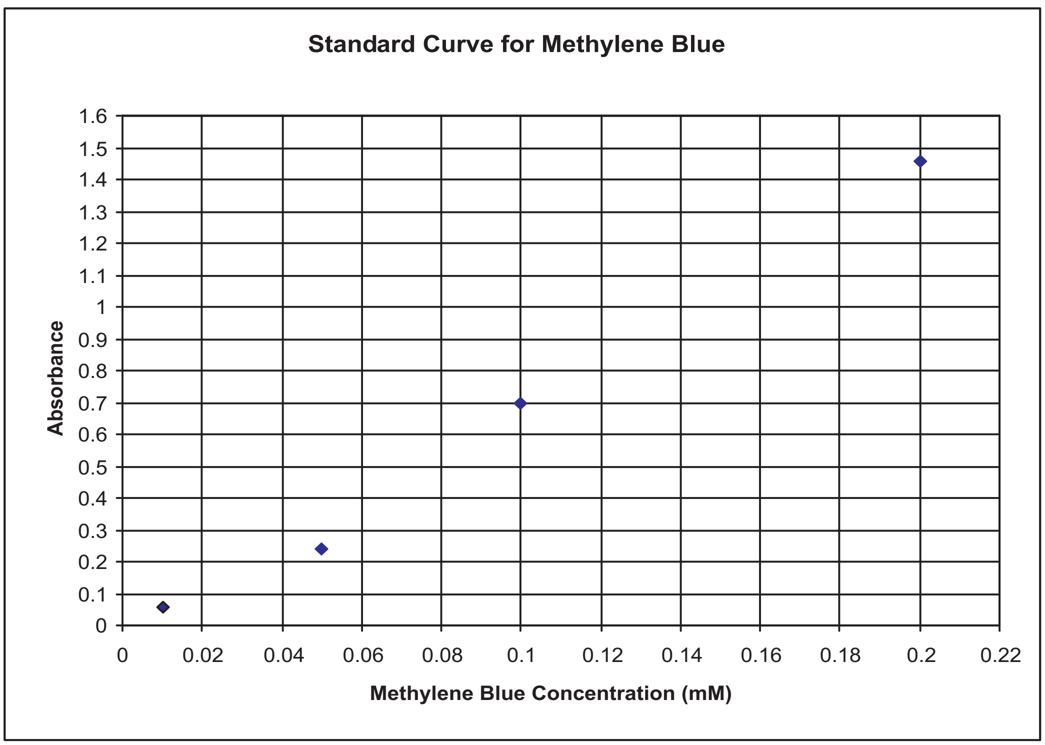
43. You are hired by the Environmental Protection Agency to evaluate the effects of a major industrial park on air quality in a large metropolitan area. The industrial park contains several factories suspected of releasing a variety of pollutants. Since your budget is limited and you lack the funds to purchase expensive air monitoring equipment, you have decided to use lichens as indicators of air quality.

Before you can begin field studies, however, you must decide which species are the best indicators of air quality. To do this, you evaluate the degree to which various metallic ions are absorbed by 3 species of lichens that occur locally. Since you have successfully completed Cudmore's *Environmental Science* course you already know how to conduct such experiments using cation exchange between metallic ions and methylene blue. You measure the degree of cation uptake by each lichen species using spectrophotometry and you obtain the following data:

% TRANSMITTANCE

Cation Tested	Species A	Species B	Species C
K^+	95	90	90
Na^+	90	95	95
Pb^{++}	55	85	75
Co^{++}	45	75	90
Al^{+++}	45	65	70
Fe^{+++}	35	50	65
Distilled water	98	99	98

You also generate a "standard curve" for methylene blue using known concentrations of methylene blue:



Answer the following questions using the information above:

- Use the data above to generate a graph that illustrates the amount of lead (Pb^{++}) absorbed by each of the three lichen species. Graph paper will be provided. *Hint: Use methylene blue concentration as an indirect measure of lead absorbed. Also, graph only the data for lead, not all cations.*

- Of the three lichen species you have examined, which one appears to be the best candidate for a bioindicator of air pollution? Explain your answer.
- What is the function of the "distilled water" in this experiment?
- The use of leaded gasoline was phased out from the early 1980's to the present time. Describe the changes in the relative amounts of each of these lichen species that might be expected as a result of this policy.

Extra Credit (5 Points) - Answer the following question as completely as possible on the blank sheet.

44. Integrated waste management (IWM) has been proposed as a sustainable approach to solid waste management. List and briefly describe the most important components of IWM in order of their priority.

Final Exam

Multiple Choice (2 points each): Select the most appropriate answer and place the letter on the answer sheet.

1. An economic policy of "free-market environmental regulation" attempts to assign "true costs" to consumer products or services.

   A. True
   B. False

2. In Oregon, the sprawl of residential and industrial areas around cities is limited by establishing a(n) ________ (fill-in).

3. According to your text, land-use planning is most directly in conflict with which of the following?

   A. agricultural use of the land
   B. urban uses of the land
   C. uncontrolled development
   D. rights of property owners
   E. maintaining esthetic value

4. Agricultural uses and ________ have similar land requirements; therefore, most farmland that is currently being converted into non-farm use goes into this land use (fill-in).

5. Which of the following phrases best describes a "rhizosphere"?

   A. a fungus associated with the root of a tree
   B. a root that is in the shape of a ball
   C. an oxygen rich zone that surrounds a root
   D. the above-ground portion of a wetland plant

6. Oregon's Land Use Policy was established in 1973 during Tom McCall's term as governor. This policy represents a fundamental shift in responsibility for land use planning from the ________ to the ________ level.

   A. local, state
   B. state, local
   C. county, local
   D. local, federal

7. One of the reasons that modern civilization has had large impacts on the environment is that civilization has tended to put value on the environment only for ________ reasons.

A. esthetic
B. moral
C. ecological
D. utilitarian

8. The "land ethic" as proposed by Aldo Leopold affirms the right of all resources to continued existence. This ethic was largely designed to change the prevalent view of natural resources and the environment as :

A. commodities
B. objects of fear
C. a fruitful garden
D. wilderness
E. inexhaustible supplies

9. In the current U.S. economic system, commercial enterprises maximize profits by paying ________ costs and ignoring ________.

A. indirect; direct costs
B. direct; externalities
C. direct; the discount factor
D. intangible; externalities
E. mandatory; supply and demand

10. The "Tragedy of the Commons" explains why individuals don't always act in such a way as preserves the environment. At its core, the principle states that:

A. individuals are interested in the short-term, not the long term
B. benefits go to the individual; costs go to society as a whole
C. common land is valued less highly than private land
D. governments don't do enough to instill environmental values
E. people would rather clean up environmental degradation that prevent it in the first place

11. In an analysis of the total costs of developing a new coal mine, which of the following would be considered an externality?

A. the market price of coal
B. the cost of diesel fuel to run mining machinery
C. the cost of operating a public relations center at the mine
D. damage from acid rain downwind of coal-fired utilities
E. the cost of treating and disposing of mining tailings

12. A person living in the United States who never intends to visit China may nevertheless be willing to pay a certain amount of money to preserve Giant panda populations. When circumstances like this occur, the commodity (in this case, the panda) is said to have _________ value. (Fill-in)

13. Who is best known for the statement: "Visit our state of excitement again and again, but for heaven's sake, don't move here to live"?

A. Ron Wyden
B. Tom McCall
C. Mark Hatfield
D. John Kitzhaber
E. Bob Straub

14. A wetland mitigation site in San Diego Bay has failed to meet one of its performance standards - to create nesting habitat for the light-footed clapper rail. What ecological factor has been the primary cause for this failure?

A. an introduced predator
B. lack of water
C. growth of invasive wetland plants
D. low nitrogen levels in soil
E. toxic pollutants

15. Which of the following groups is most likely to have made the following statement?

"The land use system has become very rigid, very inflexible, and very unreasonable... The objective has become not protecting prime farmland, but prohibiting living in the country"

A. 1000 Friends of Oregon
B. Oregonians in Action
C. Earth First!
D. American Civil Liberties Union
E. National Wildlife Federation

16. There have been a number of efforts in recent years to assign value to ecosystem goods and services. In this analysis, which of the following ecosystems has the greatest value when expressed as "$ per acre"?

A. open ocean
B. coastal ecosystems
C. grasslands
D. wetlands
E. Cudmore Forest

Questions #17 - 25 pertain to the "Constructed Wetlands Lab":

17. Name one process that took place in the constructed wetlands that resulted in improved water quality (fill in).

18. The "rotten egg" odor associated with polluted water is caused by hydrogen sulfide. Some groups reported this odor in their tanks and it was also detected in the control tank. What does the production of hydrogen sulfide indicate?

A. decomposition by anaerobic bacteria
B. a rapid increase in photosynthesis by algae
C. nitrogen fixation by bacteria
D. the consumption of algae by copepods and other aquatic invertebrates

19. Assuming that the constructed wetlands were effective in the treatment of agricultural wastewater, which of the following statements makes the most sense?

    A. *Chlamydomonas* appeared in samples from both test and control tanks throughout the study
    B. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in the control tank
    C. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in the test tanks
    D. *Chlamydomonas* appeared in samples from both test and control tanks early in the study but then disappeared in both

20. What is the primary difference between the "control" tank and "test" tanks?

    A. Test tank measurements were taken by students, control tank measurements were taken by the instructor
    B. Test tanks contain a wetland, control tank does not
    C. There were six test tanks and only one control tank
    D. Wastewater in control tank was more concentrated than wastewater in test tanks
    E. Control tank was exposed to greater solar radiation than test tanks

Identification (one point each) #21-25
In a brief phrase or single sentence, describe what each of the following look like. Please answer on blank sheet.

21. *Chlamydomonas*
22. Tailed frog tadpole
23. *Pteranarces* stonefly
24. Spectrophotometer
25. End point of dissolved oxygen test

Matching (one point each) #26-30 (Each letter is used once)

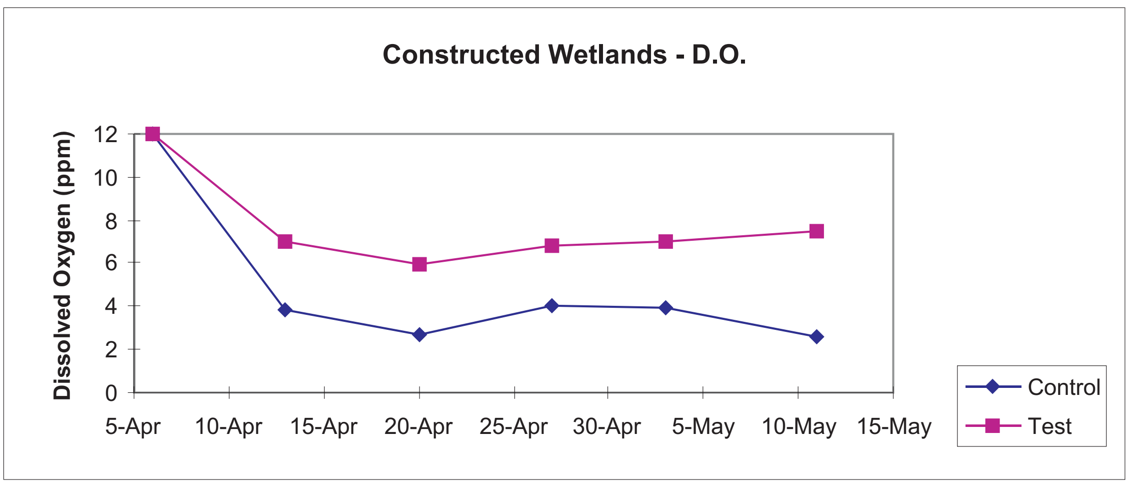
26. Pacific giant salamander	A. Most closely associated with large decaying logs
27. Tailed frog	B. Preferred habitat is the splash zone along streams
28. Dunn's salamander	C. One of very few of its kind that practices internal fertilization
29. Rough skinned newt	D. The major predator of small western Cascades streams
30. Oregon slender salamander	E. A generalist species found in old growth forests as well as a number of other habitats

Analysis - (20 points)

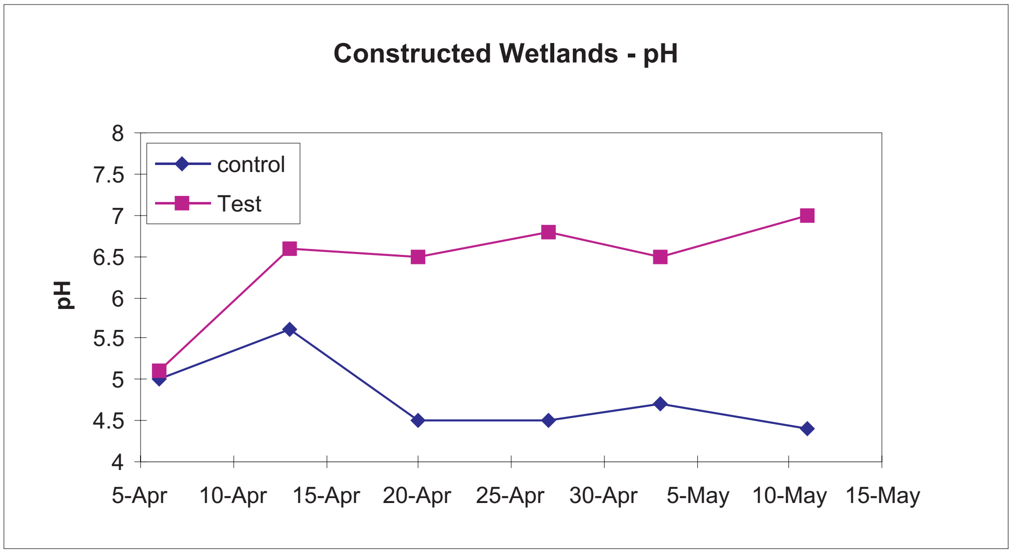
31. The following graphs were generated from data collected by a hypothetical *Environmental Science* class in Portland. Students conducted a study of the constructed wetlands that was identical to ours - six constructed wetlands were used as models to study the effectiveness of wetlands in the treatment of agricultural wastewater. Agricultural wastewater (400 g fertilizer/300 gallons water) was added to each tank and water quality was measured at approximately one week intervals. A control tank contained only this wastewater and whatever algae and bacteria that decided to call this "home".

For each graph, describe the **major trends** that appear in the data. Then, explain **your interpretation** of these trends and their **significance**. Answer on a blank sheet.

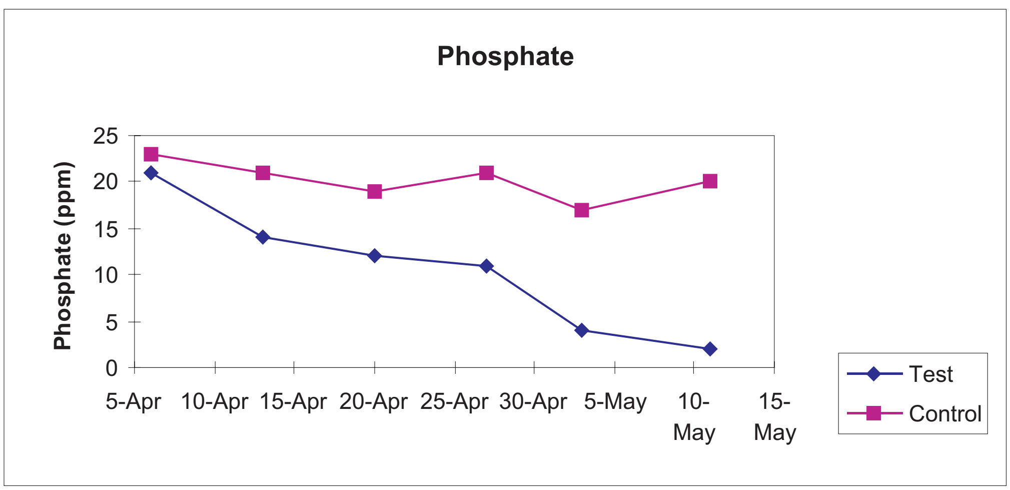
A. Dissolved Oxygen Measurements



B. pH Measurements



C. Phosphate Measurements



D. Describe modifications to the experimental design in the Constructed Wetlands Lab that would be required to answer the following question:

"What is the maximum capacity of these constructed wetlands to treat agricultural wastewater?"

E. Select one (and only one) of the parameters below and generate a graph or table that would support the following statement:

"Constructed wetlands are an effective way to treat agricultural wastewater".

Algal concentration
Turbidity
Algal species
Odor

Short Answer - (5 points each) The following questions (#32 and #33) relate to the H.J Andrews Field Trip. Please answer both on the blank sheet.

32. Describe the relationship between the following terms:

flourescene - macroinvertebrate - stream flow - stream ecology

33. Describe the relationship between the following terms:

log decomposition - forest management - respiration - terrestrial amphibians

Essay - (20 points) - #34-36 Choose **one** (and only one) of the following questions and answer as completely as possible on a blank sheet of paper. Use specific information from text readings, supplemental readings, videotapes, class discussions and laboratories where appropriate.

34. Describe in detail how "wetland mitigation" works. What changes in the current process would you offer to make this a more "ecologically sound" practice? Explain the benefits of these changes.

35. The "free-market" has recently been proposed as an alternative to "command and control" mechanisms for environmental regulation. Describe in detail two specific examples of attempts to "protect the environment with the power of the market".

36. What are the various goals of "land-use planning"? How has Oregon addressed these land use goals through its land use planning legislation? How would Oregon be different today if these land use laws had not been adopted?

EXTRA CREDIT - 5 Points

37. When we first entered Lookout Creek Old Growth Trail at H.J. Andrews Experimental Forest, I asked you to do something I had never before tried with a class. Explain this experience and describe the impact that this course had on it (if any).