1. In the water molecule, what does the term polar mean? ______________________________________
___________________________________________________________________________

2. What are the bonds called between water molecules called? _____________________________

3. Please sketch the molecular arrangement of water in its solid form:

4. What do salt crystals separate into when water is added? _________________________________

5. Sketch the ions from the between salt and water:

6. List the 5-6 state most affected by groundwater overdrafts: _______________________________

7. The EPA estimates at least how many underground tanks are leaking toxic contents into aquifers?

8. What are 3 possible sources of toxic contents? __________________________________________

9. What occurs when freshwater near a coast is withdrawn faster than its recharged?

10. What are seven detrimental effects of deforestation on an aquatic system?
   1-
   2-
   3-
   4-
   5-
   6-
   7-

11. In a tropical rainforest, how would the region change due to deforestation? ________________________________

12. In the stream pollution animation, describe the conditions of a healthy unpolluted river: DO ________
    BOD _____________

13. What are three possible sources of oxygen demanding wastes? ____________________________,
    ___________________________________, ____________________________________________

14. Sketch how dissolved oxygen and biological oxygen demand are affected from organic waste being dumped into the river:
Determining Ground-Water Contamination

Paul L. Garvin
Cornell College
Mount Vernon, Iowa

Objective
To determine, by preparing and analyzing contour maps, which way a plume of contaminated ground water will move, which drinking water wells will be affected, and how long it will take the contaminants to reach the wells.

Time required
Two to three class periods

Materials
per student
2 copies of Worksheet 2
Straight edge
3 pencils, different colors
Calculator
2 sheets of tracing paper (optional): 8 1/2 in. x 11 in.

Background
Note: Students should know basic procedures of contouring manually or by computer.

Students should understand the following terms (Figure 1):
ground water Water that accumulates beneath the ground surface and fills the available pore spaces.
water table The boundary between the area saturated with water (zone of saturation) and the overlying area containing air and water (zone of aeration).

Figure 1. Ground-water terminology.
Procedure

Underlying a military base in northeastern Michigan is a shallow sand and gravel aquifer, a subsurface layer that is permeable enough to conduct ground water and to yield water readily to wells and springs. The water table lies between 10 and 25 feet below the ground surface. A leak in a buried storage drum has allowed a toxic organic liquid to enter the aquifer. This contamination is a potential threat to drinking water supplies on the base.

Table 1 on Worksheet 1 lists the ground-surface elevation and depth to the water table for 55 wells on the military base. English units are used rather than metric units, because ground elevation data are given in feet. Conversion to metric units gives fractional elevation data that are more difficult to use. The wells were drilled for various purposes, and their locations are shown on the map of the base (Figure 2) on Worksheet 2.

1. Using the data in Table 1, calculate the elevation of the water table at each well by subtracting the depth to the water table from the elevation of the well at the ground surface. Record your answers in Table 1.

2. On the map on one copy of Worksheet 2 or on a tracing overlay, plot the elevation of the water table at each well.

3. Using one of the colored pencils, contour the water table elevation on the map or overlay. Use a contour interval of one foot. The contour lines you have drawn are called equipotential lines and show the general location of the water table.

4. The direction of ground-water flow is generally perpendicular to the equipotential lines, moving from higher to lower elevations. Using a second color, draw arrows (flow lines) at several places on the map or overlay to show the directions of ground-water movement.

Questions

1. Based on the direction of ground-water movement, which of the drinking water wells is likely to be contaminated by effluent, or outflow, from the leaking storage drum?

The pollution plume will spread quickly to a width of about 500 feet in the vicinity of the well. Shade in the area of the pollution plume.

2. The velocity of ground-water movement can be determined from Darcy’s law: \( V = K \frac{\Delta H}{\Delta L} \).

This equation shows that the velocity (V) of ground-water movement is a product of the hydraulic conductivity (K) and the hydraulic gradient (\( \frac{\Delta H}{\Delta L} \)). The hydraulic gradient is the ratio of the vertical drop of the water table in feet (\( \Delta H \)) to the horizontal distance of ground-water flow in miles (\( \Delta L \)). The hydraulic conductivity describes the rate at which ground water can move through the aquifer. It is determined by experiment and observation and depends on aquifer permeability and fluid properties. For the aquifer in this lab, it is 100 feet per day.

a. Determine the hydraulic gradient between the storage drum and the threatened well (in feet per mile). (Conversion factor: 1 mile = 5,280 feet.) Show your work. Round your answer to one decimal place.

b. Calculate the velocity of ground-water flow from the storage drum to the well (in feet per day). Show your work. Round your answer to one decimal place.

c. Using the formula, time = distance/velocity, determine how long it will take the contaminants to reach the well. (Assume no loss of contaminants by absorption.) Give your answer in years, and show your work. Round your answer to one decimal place.
Table 1
Ground-surface elevations and water-table depths for selected wells at the military base.

<table>
<thead>
<tr>
<th>Well number</th>
<th>Elevation of well (ft. ( ^* ))</th>
<th>Depth to water table (ft.)</th>
<th>Elevation of water table (ft.)</th>
<th>Well number</th>
<th>Elevation of well (ft. ( ^* ))</th>
<th>Depth to water table (ft.)</th>
<th>Elevation of water table (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AF 2</td>
<td>613</td>
<td>24</td>
<td></td>
<td>H 10</td>
<td>619</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 3</td>
<td>616</td>
<td>25</td>
<td></td>
<td>H 11</td>
<td>618</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 4</td>
<td>614</td>
<td>25</td>
<td></td>
<td>H 13</td>
<td>618</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 5</td>
<td>611</td>
<td>22</td>
<td></td>
<td>H 14</td>
<td>618</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 18</td>
<td>617</td>
<td>18</td>
<td></td>
<td>O 5</td>
<td>616</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 52</td>
<td>611</td>
<td>20</td>
<td></td>
<td>O 6</td>
<td>615</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>AF 61</td>
<td>619</td>
<td>21</td>
<td></td>
<td>O 8</td>
<td>615</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 62</td>
<td>613</td>
<td>20</td>
<td></td>
<td>O 9</td>
<td>611</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>AF 64</td>
<td>611</td>
<td>20</td>
<td></td>
<td>R 3</td>
<td>609</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>AF 70</td>
<td>615</td>
<td>18</td>
<td></td>
<td>R 4</td>
<td>612</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>AF 72</td>
<td>615</td>
<td>18</td>
<td></td>
<td>R 5</td>
<td>615</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>AF 74</td>
<td>615</td>
<td>20</td>
<td></td>
<td>R 6</td>
<td>617</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>AF 75</td>
<td>615</td>
<td>20</td>
<td></td>
<td>R 7</td>
<td>617</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>AF 76</td>
<td>614</td>
<td>21</td>
<td></td>
<td>R 8</td>
<td>616</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>G 7</td>
<td>619</td>
<td>19</td>
<td></td>
<td>R 11</td>
<td>615</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>G 8</td>
<td>616</td>
<td>24</td>
<td></td>
<td>R 17</td>
<td>617</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>G 9</td>
<td>609</td>
<td>21</td>
<td></td>
<td>R 18</td>
<td>617</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>G 10</td>
<td>615</td>
<td>26</td>
<td></td>
<td>R 21</td>
<td>618</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>G 11</td>
<td>608</td>
<td>20</td>
<td></td>
<td>R 23</td>
<td>617</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>G 12</td>
<td>614</td>
<td>23</td>
<td></td>
<td>R 25</td>
<td>613</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>G 17</td>
<td>618</td>
<td>22</td>
<td></td>
<td>R 76</td>
<td>613</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>G 20</td>
<td>615</td>
<td>20</td>
<td></td>
<td>R 77</td>
<td>613</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>H 1</td>
<td>621</td>
<td>17</td>
<td></td>
<td>R 78</td>
<td>608</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>H 2</td>
<td>621</td>
<td>17</td>
<td></td>
<td>R 79</td>
<td>614</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>H 3</td>
<td>621</td>
<td>19</td>
<td></td>
<td>R 80</td>
<td>614</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>H 4</td>
<td>621</td>
<td>19</td>
<td></td>
<td>R 84</td>
<td>613</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>H 5</td>
<td>621</td>
<td>20</td>
<td></td>
<td>Y 5</td>
<td>608</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>H 8</td>
<td>618</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: U.S. Geological Survey Water Resources Investigations Report 83-4002 (1983). Data were slightly modified to simplify the investigation.

*Elevations in feet above mean sea level.
Figure 2. Map of military base showing locations of selected wells; adapted from U.S. Geological Survey Water Resources Investigations Report 83-4002 (1983).
A well is scheduled to be drilled at P (Figure 2). Because of the high pumping requirement, the water table at the well is expected to be lowered by 15 feet. Table 2 shows water-table lowerings within the cone of depression, the area around the well where the water table will be affected. The cone of depression will extend to a radius of 1,000 feet around the well.

<table>
<thead>
<tr>
<th>Distance from well (ft.)</th>
<th>Average amount of water-table lowering (ft.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>250</td>
<td>10</td>
</tr>
<tr>
<td>500</td>
<td>6</td>
</tr>
<tr>
<td>750</td>
<td>3</td>
</tr>
<tr>
<td>1,000</td>
<td>1</td>
</tr>
</tbody>
</table>

a. On the other copy of Worksheet 2, use a third color to recontour that portion of the water-table surface affected by the new well. Show with arrows the direction of ground-water flow. Use a contour interval of two feet.

b. What effect will the new well have on the direction of movement of contaminants from the storage drum? What are the consequences of the change?

4. What have you learned from this exercise about ground-water movement and waste disposal?
Figure 2. Map of military base showing locations of selected wells; adapted from U.S. Geological Survey Water Resources Investigations Report 83-4002 (1983).
15. What is consuming all of the oxygen? ______________________________

16. How does the river recover? ______________________________________

17. List 4 indicator species if a healthy aquatic ecosystem: ________________, ________________, ________________, ________________

18. List 3 indicator species of an unhealthy aquatic ecosystem (decomposition or recovery zone):
    ________________, ________________, ________________

19. What can survive in oxygen levels below 2 ppm? ________________, ________________, ________________
Investigating Parts Per Million
Lab Sheet #1
Procedure:

1. Place clear plastic cups on sheet where they can be clearly labeled A-J.
2. Place 10 ml of 10% colored solution in the first cup (A).
3. Using an eyedropper, remove 1 ml of solution and place in the next cup (B).
4. Add 9 ml of water to cup B. Observe color and record in Data Table.
5. Using the eyedropper, take 1 ml of solution from cup B and place in cup C. Observe.
6. Repeat steps 4 and 5 for cups D through I. Observe and record.

<table>
<thead>
<tr>
<th>CUP</th>
<th>COLOR</th>
<th>CONCENTRATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td>0.1 (100,000 ppm)</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>0.01 (10,000 ppm)</td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td></td>
<td></td>
</tr>
<tr>
<td>E</td>
<td></td>
<td></td>
</tr>
<tr>
<td>F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td></td>
<td></td>
</tr>
<tr>
<td>H</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Indicate which cup represents a lethal concentration of:

NaCl (salt) ___________  Silver ___________
Iron ___________  Mercury ___________

Lethal concentrations of common heavy metals and salt. Compiled from 1996 EPA quotations.

MERCURY  0.0005 mg/l
SILVER  0.005 mg/l
IRON  1.0 mg/l  Cup F - 1 ppm
NaCl (Salt) 200.0 mg/l 200 ppm = 1/5 of a gram
   (1 gram mass of a small paper clip)

The EPA concentrations represent mg/l. A milligram is 1/1000 of a gram, and there are 1000 ml in a liter. Since water is the solvent we are considering, and one liter of water has a mass of 1000 grams (density of water is 1 g/ml), we can calculate 1 mg/l to equal 1 ppm.
Think About It!
1. Does a dissolved toxin ever disappear? Completely?

2. When the color disappeared from the cups, was there any colored solution still in the cup?

3. Is dilution the solution to pollution? Be specific. If we just keep adding water to toxins, will the organisms be safe?

4. What is the acceptable level of arsenic allowed in drinking water for the United States; what does the WHO propose (page 496)?

5. Why should you care about arsenic in your water?

6. How much more would you be willing to pay on your water bill to implement the standard from page 496?
Investigating Parts Per Million (PPM)
Submitted by Pat Franzen, Madison Junior High School, District 203, Naperville, IL.

BACKGROUND

How much toxin can destroy a population? What is a lethal dose/lethal concentration?

This investigation is designed to help the student conceptualize one part of a million - a concept boggling to most adults! The exercise will allow students to visualize successive dilutions of a 10% solution of food coloring or dye until 1 ppm is established.

From that point, continued dilutions will be completed to simulate the conditions which would be toxic enough to kill at least 50% of a given population over a period of time. The relative concentrations derived will be corresponded with current EPA standards for common heavy metals often produced as by-products of industry. NaCL (table salt), an ingredient in ice-melting crystals used on our wintry roads and often found in "run off" that enters our waterways will be considered as well. (Lab Sheet 1.)

Lab Sheet 2 includes EPA figures representing "lethal concentrations" of various substances. A lethal concentration is the amount considered capable of killing 50% of a population over a period of time. The term "concentration" is used rather than "dose" because we are considering the concentrations of a liquid solution. "Dose" is typically used to refer to solids.

The EPA concentrations represent mg/l. A milligram is 1/1000 of a gram, and there are 1000 ml in a liter. Since water is the solvent we are considering, and one liter of water has a mass of 1000 grams (density of water is 1 g/ml), we can calculate 1 mg/l to equal 1 ppm. (See Lab Sheet 2.)

Grade Level: Junior High - High School

Objectives: · Students will develop operational definitions of "ppm" and "lethal concentrations."

Students will understand the concept of successive dilutions.
Students will refine appropriate lab procedures and techniques.
Students will relate information presented to local and global pollution concerns.

Materials: For each group of two students you will need:

Powdered dye such as Rit or liquid food coloring of approximately a 10% solution
Water in 500 ml beaker (or similar-sized container.)
Medicine dropper - pre-calibrated by teacher (see above).
10 small clear pre-calibrated medicine dispensing cups or plastic beverage cups (pre-calibrated).
10 ml graduated cylinder (or calibrated cups)
Lab sheets.
Teacher Preparation:

1. Make a 10% powdered dye and water solution by mass. 1 part solute (dye) to 9 parts water. Alternative -
commercial food coloring can be used. I have found that the concentration is approximately 10%, but brands
vary. A colorless liquid should be reported in cups E, F, or G. (Student error is to be expected!)

2. Measure 1 ml of water in an eye dropper and use a permanent marker to indicate the appropriate level on all
the droppers.

3. If you do not have access to a 10 ml graduated cylinder per pair of students, the plastic cups can also be
marked at the 10 ml level.
4. Instruct students to follow the directions presented on lab sheet.

Think About It! (For Teachers)

The student section on Lab Sheet 2 includes a "Think About It!" section. Here's some input, about the responses for teacher background:

1. Does a dissolved toxin ever disappear? Completely? (No, the toxin may not be visible, but since matter cannot be created or destroyed, it will always be there. Only the state of matter may change.)

2. If 50% of the population of the organism you studied was killed, how might that affect the ecosystem? (Answers will vary.)

3. When the color disappeared from the cups, was there any colored solution still in the cup? (Yes. The particles are still present. They are in small concentrations that are not visible to the unaided human eye.)

4. Is dilution the solution to pollution? Be specific. If we just keep adding water to toxins, will the organisms be safe?
The Wastewater Treatment Plant

Introduction

For thousands of years, civilizations have used water to carry wastes away from homes and workplaces. In the past, the guiding principle was that the "solution to pollution is dilution". No matter how dirty something is, if you throw enough water at it, it will disappear. Modern science has shown us that simple forms of waste treatment like dilution only solve a small part of the problem.

Task

You will investigate the differences between modern wastewater treatment methods, the effects of those methods on the environment, and predict the future evolution of wastewater treatment as our government debates the seriousness of current water pollution. You will produce an inventory of water polluting practices and substances that could be distributed to homes in your neighborhood.

The Process

A. What activity takes place from flushing to when the water reaches the treatment plant?

B. Describe the location of the sewage treatment plant. Include in your answer how close the plant is to your city and to waterways.

C. Are there separate systems for storm runoff and raw sewage? Are they combined? What is the main disadvantage of a combined system?

D. What is removed during the primary treatment?

E. What happens to the sewage during secondary treatment?

F. What happens to what's removed?

G. What is the tertiary treatment, if any?

H. What is done with the sludge, could it be recycled in your opinion? Explain your reasoning.

I. How often are tests carried out to monitor and test efficiency of the plant?
J. Under what circumstances, if any, does the liquid discharge from the plant NOT meet minimum standards?

K. What special training do the workers at the sewage treatment plant receive?

L. Diagram a simple “flow chart” tracing the sewage from its source to its place of discharge from plant. Indicate all physical and chemical treatments used.
**Chapter 14: Water Resources**

Water and Grains Import Wars in the Middle East
- Instead of oil, future war could be fought over water scarcity, ten countries share water from the Nile Watershed, upstream diversion has added to water stress

14.1 Water Properties
1. Why is water so important?
   - _______ of animal makeup is water, necessary for food production, shelter, other needs and wants
2. What are some important properties of water?
   - Hydrogen bonding- very difficult to break/ Liquid stage- 0-100 C, remains liquid for most climates/
   - _________ Capacity- moderates Earth’s Climate, Used in many power plants/ Ice Freezes- lower density= floats on top of liquid water, if not lakes would freeze solid= no life would survive/ Major source of weathering and erosion

14.2 Water Resources
1. How much fresh water is available?
   - 2.6%, most locked up in _________, remaining available= .014%, countries are divided into haves/have nots
2. What is surface water?
   - Precipitation that doesn’t infiltrate the ground, 2/3 lost to floods, 1/3 reliable runoff
   - Watershed- general drainage area set to geographic boundaries
3. What is ground water?
   - H2O percolates downward, bedrock is impermeable/ zone of saturation- above bedrock called the water table
   - _________- water saturated layers, spongelike, recharge area- water passes through no faster than 1ft/day
4. How much water are we using?
   - 30% of runoff is available, we use half; most runoff is in remote areas, not near populated areas
5. How do we use fresh water?
   - 70%= irrigation, 20% = industry, 10% = residential
6. U.S. Case study
   - East- H2O used for energy production and manufacturing; flooding and pollution are main problems
   - West- 85% used in irrigation, not sustainable in the arid environment; water tables have dropped due to overuse and drought

14.3 Too Little Water
1. Why are there freshwater shortages?
   - Dry climate, ____________ (drying of soil due to overgrazing and deforestation), Water stress (increased demand)
2. How can we increase freshwater supplies?
   - Build dams and reservoirs, bring in freshwater desalination; ____________

14.4 Dam and Reservoirs for Water Supply
1. Pros- Controls floods, hydroelectric power, irrigation, recreational use
2. Cons-Interrupts H2O cycle and ecological services
3. Case Study- Three Gorges Dam
   - World’s largest PROJECT= 20 large powerplants in capacity, located on _________ River (historically and violently floods) ; 150 million people get electricity from; displaced 1.9 million people
4. Egypt’s Aswan High Dam
   - Provides ½ of Egypt’s power, allows for year round irrigation and flood control
   - Doesn’t allow annual flooding of crop lands, Mediterranean and Nile ecology damaged= fishing industry suffers

14.5 Transferring Water from One Place to Another- Large Scale Water Transfers
1. - Pros- CA- 74% of water from north transferred to southern arid CA for water use
2. Cons- most water used in agriculture, degrades Sacramento river, threatens fisheries, prevents filtration of San Francisco Bay
3. The Colorado River Basin-
   - 14 Dams, provides water for much of the west, most years rivers does not reach Gulf of California
   - Water Rights in the U.S.- Doctrine of __________ Rights- all users are entitled; principle of prior appropriation- users upstream have 1st priority
4. The James Bay Watershed Transfer Project
   - $60 billion, 50 year project to harness rivers that flow into northern Canada’s bay, Phase I complete other phases TBD?
5. The Aral Sea Water Transfer Disaster
   - Irrigation has shrunk its surface area by 54%, major ecological and economic problems with this project
14.6 Tapping Groundwater and Converting Salt Water to Fresh Water
1. Withdrawing Groundwater
   - Pros- Can be removed year-round, not lost to evaporation, less expensive to develop
   - Cons- lowers water table, depletes aquifers- leads to subsidence, intrusion of salt water, lowers stream flow
2. Mining Groundwater: The shrinking Ogallala Aquifer
   - World’s largest __________ in Midwest US, used for irrigation, produces 20% of US agricultural output, nonrenewable aquifer-fed during last ice age and slow recharge rate
   - By 2020 25% of aquifer will be depleted, take 1000s of years to replenish, farmers need to use more efficient means of irrigation
3. Desalination
   - Removing dissolved salts by distillation (evaporation) or ___________ osmosis (high pressure; lot of energy required)
   - Disadvantages- expensive, lots of waste water (brine)
4. Can clouding seeding and towing icebergs improve water supplies
   - Not practical ideas with current technology
14.7 Using Water More Efficiently
1. What are the benefits of reducing water waste?
   - Water saving technologies will reduce burden on wastewater treatment plants, expensive dams, slow depletion of groundwater, save energy and $$
2. How is it wasted?
   - 70% lost to evaporation, leaks, consumers not aware due to prices artificially LOW (govt. subsidies to farmers in arid environments
3. Water rights in the U.S.
   - East- Doctrine of riparian rights-anyone along stream can use water as long as some is leftover for those downstream
   - West- Principle of ________________- first come, first served! Doesn’t work well with arid regions
4. Solutions to wasted irrigation water
   - Center pivot sprinklers, better low energy precision application sprinkles, soil moisture detectors
5. (The Promise of Drip Irrigation)
   - Only used by 1% of farmers due to price, uses system of plastic tubing that doesn’t overwater crops
6. Solutions to wasted industry, home and business water
   - Redesigning manufacturing processes, drip irrigation, fixing leaks, using water meters, water conservation, water-saving toilets and showerheads; recycling of water, capturing rain water, ____________ (native vegetation use)
7. (Las Vegas)
   - Growing city that will run short of water within 5-10 years; Tucson, AZ a better model for water conservation
14.8 Too Much Water
1. Causes and Effects of Flooding
- Caused by heavy rain or rapid melting; humans increased flood severity by removing water-absorbing vegetation, draining wetlands and living in floodplains

2. (Living Dangerously on Floodplains in Bangladesh)
- 128 million people live on it, very poor, increased flood risk due to population growth, deforestation and overgrazing

3. Solutions to reduced flood risk
- Channelization—deepen, widen streams (drawbacks—removes vegetation, increases stream velocity)
  - Levees—walls designed to prevent flooding
- Flood plain management—flood frequency _________—use historical records and examine vegetation= determine flood frequency then whether to build or not

14.9 Solutions: Achieving a more sustainable water future
- Not depleting aquifers faster than replenished, preserve ecological health of aquatic ecosystems, marketing of water rights, conserving water, decrease govt. subsidies for wasting water increase for conservation of water, slow population growth

**Chapter 19: Water Pollution**

1. Learning Nature’s Ways to Purify Sewage
   - Microorganisms, aquatic plants and animals filter out sewage into clean water

19.1 Types and Sources of Water Pollution
1. Types
   - Bacteria, viruses, protozoa, inorganics (acids, toxic metals, salt), organics (oil, gasoline, detergents), plant nutrients (ammonium), _________ (soil, salt), radioactive (iodine, radon), thermal pollution (heat—leads to thermal shock in aquatic life)

2. How do we measure water quality?
   - Measuring ____________, chemical analysis, pH, indicator species, temperature, etc

3. Point and Nonpoint Sources
   - Point—factories, oil tanks, sewage treatment plants
   - Nonpoint—runoff from farms, logged forest, parking lots

4. Connections: How might projected climate change affect water pollution?
   - Some areas will receive more/less precipitation/drought—leads to more infectious disease outbreaks, warmer water= lower DO levels= less life

19.2 Pollution of Freshwater Streams
1. Stream problems
   - Streams and rivers can recover quickly by dilution and bacterial decay, point sources can be detected by dissolved oxygen and ________________

2. What progress has been made?
   - Since 1970s, control laws have dramatically increased Ohio’s Cuyahoga River 1959

3. How might projected climate change affect water pollution?
   - Some areas will experience increased/decreased precipitation and droughts, causing water pollution issues to only rise

4. Hurricanes, Hog Farms and water pollution in Eastern North Carolina
   - 2nd largest hog producer, 1999 record rainfalls lead to large spills of raw sewage into rivers, causing major watershed disaster

5. The bad news
   - Streams passing through industrial and urban areas are exposed to organic and inorganic chemicals, sewage treatment, nonpoint runoff of pesticides; Dilution—effective—days to weeks

6. Pfiesteria Cell from Hell
   - Single celled organism is the result of nitrogen and phosphorous form hog farming

19.3 Lake Problems
1. What are pollution problems of lakes?
   - Dilution—ineffective—1-100 years, more vulnerable to toxic substances due to little _________ mixing of layers and flow
2. What is cultural eutrophication?
   - Eutrophication - nutrient enrichment due to natural erosion
   - Cultural eutrophication - accelerates input of nutrients such as nitrates and phosphates - causes overpopulation of algae, cyanobacteria; when algae dies, decomposition occurs from aerobic bacteria depletes DO; leads to fish kills and all aerobic aquatic organisms = and __________ zones

3. How can cultural eutrophication be prevented or reduced?
   - Advanced waste treatment plant, land use control cleanup, remove excess weeds, pump air to increase DO

4. Case Study – Great Lakes
   - Suffer from severe cultural eutrophication, $206 billion in pollution control - upgraded sewage treatment plants, banning of phosphate detergents, certain household cleaners

19.4 Groundwater Pollution and its Prevention
1. Why is it a serious problem?
   - Almost all drinking water comes from __________ sources of contamination: landfills, septic tanks, waste dumps, gas stations, etc.
   - Easy to pollute because of slow recharge, 1400 years compared to 20 days for a river!

2. What is the extent of groundwater pollution?
   - 25% of groundwater in U.S. in contaminated, 100% of NJ, mainly due to pesticides

3. How can we protect groundwater?
   - Almost impossible, large volume, inaccessibility, slow movement; __________ of contamination, monitor landfills and aquifers, leak detection systems are effective

4. How much arsenic should we allow in drinking water?
   - Natural element found in rocks but released by coal burning, copper/lead smelting, incinerators and pesticides; causes cancer, skin lesions and diabetes; acceptable levels: __________

19.5 Ocean Pollution
1. How much can they tolerate?
   - Ultimate Sink for waste due to dilution, dispersion, some scientists disagree about dumping waste into the oceans because little is known about deep oceans

2. How do pollutants affect coastal areas?
   - Coastal areas take the brunt from various sources - industry, cities, urban sprawl, construction, farms, __________ - Release large amounts of nitrates, phosphates causes algae blooms and oxygen depletion areas (hypoxic zones) Gulf of Mexico

3. The Baltic Sea
   - 79 million people and 15% of world’s industry surrounds Baltic Sea, very vulnerable to pollution - PCB’s, cultural eutrophication, hazardous chemicals, oil are the main pollutants
   - Helsinki Convention - world’s first international agreement to reduce marine pollution

4. Case Study: The Chesapeake Bay
   - Largest U.S. __________, receives wastes from point and nonpoint sources, 1985-1993 Chesapeake Bay Program (integrated coastal management); population growth around bay is major obstacle

5. Bring back the oysters
   - Oysters filter entire Chesapeake in 3-4 days, population has been reduced to 1%, now need a year to filter all water, methods to increase population - introduce Asian oysters (disease resistant, good idea?); recreating reefs, set up sanctuaries, increase $$

6. What pollutants do we dump into the ocean?
   - Sludge - sewage treatment plants - banned in the U.S., dredge spoils - maintain of river shipping channels

7. What are effects of oil on Ocean ecosystems?
   - Most oil is released from __________ oil operation not accidents; crude oil - marine life recovers in 3 years; refined oil - marine life recovers in 10 years

8. How can oil spills be cleaned?
   - Mechanical - floating booms contain spill, vacuums, absorbent pads
Chemical coagulating agents make oil clump, fire burn oil but causes other pollution.
-Time wind and waves eventually disperse soil

9. How can we protect coastal waters?
- Separate sewage and runoff lines along coast, double hulls for tankers, runoff containment

19.6 Solutions: Preventing and Reducing Surface Water Pollution
1. Nonpoint sources, what can we do?
- Use slow-release ____________, not on steep slopes, alternate crops, integrated pest management, reforesting watersheds

2. Point sources, what can we do? (legal approach)
- Clean water act of 1972- river quality improved from 32% to 62
- Act needs to be strengthened through better funding and enforcement
- local authorities, state, etc.

Should we strengthen or weaken the U.S. Clean Water Act?
- Some complain act is too strict, want to fill in wetlands; environmentalists: not enough funding towards CWA

4. Point sources (technological approach)
- Primary sewage treatment- filter debris, separate sludge to a settling tank, removes 60% of suspended solids and 30% of organics
- Secondary- biological- aerobic bacteria break down 90% of organic wastes
- ____________ sewage treatment- after primary and secondary, treatment removes specific pollutants
- Enforce 3-5 year service of all septic tanks (25% of US has them)

5. Solutions to sewage sludge?
- Toxic goo applied to fertilizer, rest placed in landfills or incinerated
- Redesigned system with goal of preventing hazardous waste from reaching waste water treatment plants

6. How can we treat sewage naturally?
- Wastewater gardens- artificial wetlands; Double vault treatment plants- use compost, sewage walls into local gardens

7. Using wetlands to treat sludge
- Sewage settles out in a tank, pumped into ponds and treated by bacteria, released a month later into artificial marshes then chlorinated and released into waterways

19.7 Drinking Water Quality
1. Is the water safe to drink?
- 25% of world doesn’t have access to safe drinking water, technologies- ________________, horseradish! and slimes

2. How is drinking water purified?
- Filtered, settled like a waste water treatment plant

3. How is drinking water protected?
- ____________enforces but Congress is pressured by industry to weaken Safe Drinking Water Act

4. Should the U.S. safe drinking water act be strengthened or weakened?
- Congress is pressured by water polluting industries to weaken Safe Drinking Water Act

5. Is Bottled water the answer?
- Check for IBWA seal of approval not as regulated as local tap water!
- Have your water tested and get a water purifier

6. What is the next step? Individuals Matter
- Reduce ______________, prevent groundwater contamination, reducing wastewater, work with nature to treat sewage.
Water Use Survey and Exercise

Name __________________

Part 1 - How much water does your family use?
1. To answer this question, obtain a water bill. What is your household daily average? ___________ gallons (attach water bill copy)
2. How many people are in your household? ___________
3. What is average use per person in your family? ___________ gallons
4. In California, there is an average of 150 gallons delivered per person per day. How does your family compare? ___________
5. If your family is significantly higher or lower than the California average, what factors do you think are responsible?

Part 2 - Your Shower
1. Run your shower
2. Place a bucket and collect the water for ½ minute. (note, if your bucket is not large enough, you may have to adjust to ¼ minute)
3. Determine how much water was collected in ½ minute in gallons (there are 4 quarts to a gallon)
4. Your shower delivers water at ___________ gallons/minute
5. Time yourself as you take a typical shower. Don’t forget to include the time the shower runs as the water warms up ______ minutes
6. How often do you shower? (use a fraction if you shower every other or every third day) ______
7. How much water do you average per day by showering? ____________ gallons/day
8. If you want to decrease the water use from showering, you have a number of options. Name at least three reasonable options.
   1.
   2.
   3.

Go to:

1. Where does the water for Warrington come from?

2. List at least six contaminants in drinking water:

3. What are the probable sources of:
   Fecal coliform and E. coli ________________________________
   Turbidity ________________________________
   Chlorine ________________________________
   Lead ________________________________
   Radium ________________________________
   Organic Carbon ________________________________
Watersheds Worksheet

Watershed Boundaries — use the map of the Lenape River and answer the following questions.

1. What is the scale and contour interval of the map?
2. Name the stream that flows into Crystal Lake.
3. What is the elevation of the gravel pit?
4. Which lake has marshy areas around it?
5. Follow the procedure below to determine watershed boundaries:
   a) divide Lenape River or one of its tributaries into at least 5 sections of equal length
   b) at each division, draw a line at right angles to the stream bed
   c) to establish the boundaries of the watershed, follow each line you drew upslope, away from the stream bed, until the elevation is at a maximum (use contour line readings). Mark this for both sides of the stream
   d) put a point at the highest elevation above the headwaters also
   e) now connect each of these "ridge" points to outline the boundaries of the watershed.
6. What happens to water that falls within those boundaries?
7. What happens to water that falls outside those boundaries?
8. How did you know when you located a point of maximum drainage distance from the stream?
9. Is the slope of the land uniform throughout the watershed area?
10. What is the highest elevation in the watershed? Where is it located?
11. What is the lowest elevation in the watershed? Where is it located?
12. Where is the stream’s velocity the greatest? Where is the stream’s velocity the lowest?
13. Are any smaller watersheds contained in the area you outlined? Where?
14. What stream order is the Lenape River where it flows off the western edge of the map?

Watersheds and People
1. Where does surface runoff have the highest contamination from: a) fertilizer? b) sediment? c) human waste?
2. What portion of the river is most vulnerable to flooding?
3. How do you think all of the above can affect the water quality within the watershed?

Water Quality In a Watershed — follow directions on the water quality chart.

1. Describe the locations of the three sample sites on your answer sheet.
2. Two of the sites have human-made problems. Discuss ways to improve or maintain the water quality at these sites. Why is the third site relatively problem free?

Utilize your answers to all the previous questions, the topographic map, and the chart on water quality to answer the questions below. Consider water quality, the different habitats that are apt to be along different parts of the streams (field, forest, marsh, etc.) and slope as well.

1. Where in the Lenape River Watershed would you prefer to live? Why?
2. How would land use next to water channels affect water quality and why?
3. How would land contours contribute to what you could do on that land?
4. What type of land use would not be compatible with the area where you chose to live and why?
5. What type of practices would need to be implemented to maintain or improve the quality of life in the watershed?
6. How does maintaining a healthy environment benefit the other living organisms in the watershed? How does maintaining a healthy environment benefit people?
Water Quality in a Watershed

Using the Commonly Measured Water Quality Parameters chart below and the map of the Lenape Watershed, determine where these samples came from in the watershed.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Site One</th>
<th>Site Two</th>
<th>Site Three</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemical Test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D.O.</td>
<td>6.60 ppm</td>
<td>2.20 ppm</td>
<td>10.0 ppm</td>
</tr>
<tr>
<td>B.O.D.</td>
<td>1.80 ppm</td>
<td>10 ppm</td>
<td>0.5 ppm</td>
</tr>
<tr>
<td>Phosphates</td>
<td>0.40 ppm</td>
<td>2.0 ppm</td>
<td>0.02 ppm</td>
</tr>
<tr>
<td>Nitrates</td>
<td>1.01 ppm</td>
<td>0.5 ppm</td>
<td>0.3 ppm</td>
</tr>
<tr>
<td>S.S.</td>
<td>61.00 NTU</td>
<td>17.00 NTU</td>
<td>6.0 NTU</td>
</tr>
<tr>
<td><strong>Biotic Index</strong></td>
<td>Class I n = 1 Class II n = 4</td>
<td>Class I n = 0 Class II n = 0</td>
<td>Class I n = 9 Class II n = 8</td>
</tr>
<tr>
<td></td>
<td>Class III n = 8</td>
<td>Class III n = 5</td>
<td>Class III n = 4</td>
</tr>
</tbody>
</table>

**Commonly Measured Water Quality Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unpolluted Stream</th>
<th>Polluted Stream</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dissolved Oxygen (D.O.)</td>
<td>The higher the amount of O₂ the better the quality. Trout require 10 ppm</td>
<td>Fertilizer run-off or high bacteria populations can lower D.O.; less than 3 ppm is considered unacceptable</td>
</tr>
<tr>
<td>Biotic Oxygen Demand (B.O.D.)</td>
<td>The lower the B.O.D., the less organic matter in a stream. Clean water ≤ 0.03 ppm</td>
<td>High B.O.D. indicates large amounts of organic matter, often from sewage. Poor water quality ≥ 5 ppm</td>
</tr>
<tr>
<td>Phosphates (PO₄⁻³)</td>
<td>Clean water has low phosphates, ≤ 0.1 ppm</td>
<td>Higher reading indicates industrial waste, sewage, or detergents. Poor water quality ≥ 0.05 ppm</td>
</tr>
<tr>
<td>Nitrates (NO₃⁻)</td>
<td>Nitrates are necessary in small quantities for aquatic life. Clean water &lt; 0.1 ppm</td>
<td>High reading indicates same conditions as PO₄⁻³ plus fertilizer. Combined with phosphates, can cause algae blooms</td>
</tr>
<tr>
<td>Suspended Solids (S.S.)</td>
<td>S.S. cause turbidity of water. Clean water has low turbidity = 1-15 NTU</td>
<td>Caused by erosion or plankton growth, or waste water; &gt;50 NTU = turbid</td>
</tr>
<tr>
<td>Aquatic Organisms</td>
<td>Clean water has higher diversity of aquatic organisms (large number of different species, including those intolerant of pollution)</td>
<td>Number of organisms may be high but little variety (may be a high number of individuals, but of only a few, pollution tolerant, species)</td>
</tr>
</tbody>
</table>

* Aquatic organisms are often measured using a Biotic Index. The organisms are divided into three groups, determined by their ability to tolerate pollution. Class I is pollution sensitive, Class II is moderately tolerant, and Class 3 is pollution tolerant. Biotic Index = 2(n Class I) + (n Class II), where n = number of species.

**Index Values**

- Clean Stream = 10 or greater
- Moderate Pollution = 1-6
- Gross Pollution = 0

---

*The Delaware River Guide* is a project of the Delaware River Greenway Partnership*, in cooperation with the Delaware & Lehigh Navigation Canal National Heritage Corridor Commission, Bucks County Audubon Society's Honey Hollow Environmental Education Center, and the Pennsylvania Coastal Zone Management Program.

All other uses, including copying of these materials for resale, are prohibited.

© 1994. These materials may be duplicated for classroom teaching purposes only. All Project Directors: Nancy Jones, Delaware River Greenway Partnership, 215-345-7020
Sue Pridemore, Delaware and Lehigh Navigation Canal National Heritage Corridor Commission, 610-861-9345
Tina Spiegel, Bucks County Audubon Society/Honey Hollow Environmental Education Center, 215-297-8266

Delaware River Guide – Watersheds page 8
INVESTIGATION 13: WATER LOSS DROP BY DROP

Objective
To estimate household water loss from common leaks.
To extrapolate water loss to the surrounding community.

Introduction
Leaks in water lines waste an extremely valuable and diminishing resource. New York City’s Department of Environmental Protection estimates that leaks make up about 10% of the water demand of the city. Since 2000, New York City has examined 31 million feet (5871 miles) of the 33.6 million feet (6364 miles) of water mains and eliminated 89 million gallons per day in leaks. Boston Water and Sewer Commission surveyed 819 miles of its 1182 miles of water distribution mains and fixed 427 leaks out of 444 leaks found, saving 7.16 million gallons of water per day.

Water losses in the developing world are more severe. In Iran in 1997, for example, 30% of the 3.8 billion m³ (1 trillion gallons) of treated water for the public was lost. This loss took place in a desert community with a population growing at an annual rate of 1.75%.

It might seem that with such large-scale losses in distribution systems, little domestic leaks are of little consequence. This exercise will show that when minor events occur often and long enough, they result in large effects.

Problem Information
1) Determine the number of people living in your community (city).
2) Determine the number of people living in your county.
3) Assume the average household size is four people, and that there are approximately five water sources (faucets and toilets) in each household.
4) Assume that two of the faucets leak at the rate of 1 drop/sec.

Calculations – Always show your set-up, work, and units.
1) Calculate the volume of water lost by each household annually. Here are some useful conversion factors. Explain any other assumptions you make.
   20 drops = 1 mL
   3.78 L = 1 gal
   1 gal = 0.133 ft³

2) What is the total loss in your community (city)?
3) What is the total loss in your county?
4) What percent of the total water consumption does your community loss represent? Typical Floridians use 175 gallons of water per day, on average. The national average is closer to 100 gal/day.

5) Make an analogy to illustrate how much such a water loss really amounts to. The analogy should be an indication of the total volume.
6) Describe 10 actions you could take in your own home to conserve water. Estimate what percent of your total household water consumption your savings represent.