Cumulative Impacts in a Watershed

Adapted from *Healthy Water, Healthy People Educators Guide* – www.projectwet.org

Students simulate development of a waterfront community to explore the possible effects of development on water quality and the surrounding watershed.

Contents

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Summary
Students simulate development of a waterfront community to explore the possible effects of development on water quality and the surrounding watershed.

Vocabulary: best management practices (BMPs), contaminant, nonpoint source pollution, point source pollution, storm water runoff, watershed

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Grade Level: 6–8, ages 11-14

Subject Areas: Environmental Science, Chemistry, Health Science, Geography

Duration:
Preparation: 30 minutes;
Activity: Part I: 50 minutes; Part II: 30 minutes

Setting: Classroom

Skills: Interpreting, Modeling, Researching, Applying Solutions

Objectives

Students will:

- distinguish between point and nonpoint source pollution.
- recognize that everyone contributes to and is responsible for water quality.
- identify causes of water pollution, the contaminants that are associated with pollutants, and the resulting health effects of pollution.
- identify Best Management Practices to reduce pollution.

Materials

Part I

- *Large sheets (6) of poster board, newsprint, or flipchart paper*
- *Copy of **Waterfront Properties** Teacher Resource Page*
- *Drawing pens and pencils*
- *Items from students' desks (e.g., pencil, paper clip, book)*

Part II

- *Copies of **Water Contaminants Worksheet** Student Copy Page (1 per group)*

Background

Maintaining good quality water in waterfront areas is important because tourism, recreation industries and fisheries all depend on it. All bodies of water are subject to pollution from many sources. The quality of water (like that of rivers and streams) largely reflects the land use practices on the surrounding land and the health of contributing watersheds. When watershed managers investigate land use practices that affect water quality they look for two general sources of pollutants: point and nonpoint source pollution.

Point source pollution involves pollutants that are discharged from, and can be traced back to, an identifiable point or source, such as a factory's discharge pipe or a sewage ditch. Nonpoint source pollution (NPS), on the other hand, cannot be traced to a single source, but is made up of many sources. Storm water runoff and ground water transmit both kinds of pollution.

While point source pollution, once identified, can be directly mitigated, managing nonpoint source pollution can be much harder. Stormwater runoff can pick up and carry contaminants from large areas, thus concentrating and then distributing these pollutants into a watershed. Because pollution comes from so many places and is of so many types, it is hard to manage and control. Polluted runoff can carry fertilizers, lawn chemicals, herbicides, road salts, oil and gasoline, untreated sewage and pet waste, among numerous other contaminants. It can even carry air pollutants like sulfur dioxides, nitrogen sulfides, and copper that precipitation has picked up from the atmosphere as it falls.

Polluted runoff can cause serious water quality and environmental problems for a watershed. Common problems are beach closings, fishery and shellfish bed closures, habitat destruction, and toxic algal blooms. (See *Pfiesteria* sidebar)

While large point source events like coastal oil spills and oil tanker disasters often attract more attention, it is contributions of oil pollution from individual actions in cities across the world that account for major oil pollution of a watershed. According to NASA (1995), the annual urban runoff from a city of five million people can contain as much oil and grease as a large tanker spill.

The economic impact of water quality and environmental problems is enormous. Beaches remain the primary destination for vacationers. The NRDC, National Resources Defense Council, (2001) rates the coastal tourist expenditures of sixteen states at US$104 billion dollars. Commercial fishing companies are also impacted when shellfish beds and fishing areas are closed due to bacterial contamination. For example, after the 1997 *Pfisteria*

Pfiesteria piscicida and Coastal Pollution

"Dinoflagellates are a natural part of the marine environment. They are microscopic, free-swimming, single-celled organisms, usually classified as a type of alga. Most dinoflagellates are nontoxic and obtain energy via photosynthesis. Others, including *Pfiesteria piscicida*, are more animal-like and acquire energy by consuming other organisms. *Pfiesteria piscicida* was discovered in 1988 and is believed to have a highly complex life cycle with 24 reported forms, a few of which can produce toxins" (Maryland Department of Natural Resources, 2000).

Although the dinoflagellate *Pfiesteria piscicida* has been around for thousands of years, it has only recently become a major problem. *Pfiesteria* can be a nontoxic predator of organisms such as bacteria, algae, or small animals, unless its environment is overly enriched with nutrients, particularly phosphorus. The excess nutrient load is a direct result of nonpoint source pollution from runoff carrying fertilizers and animal wastes downstream. *Pfiesteria piscicida* can multiply in the presence of increased phosphorus levels, and suddenly secrete harmful toxins. Major fish kills are associated with *Pfiesteria piscicida* and *Pfiesteria*-like organisms. Ulcerative lesions and lethargy leave fish helpless to predators. Humans can also have severe reactions to *Pfiesteria piscicida*.

outbreak, the Maryland Sea Grant Program estimated losses of $43 million in seafood revenue (National Oceanographic and Atmospheric Administration [NOAA], 2002).

On February 15th, 1996 the 147,000 ton oil tanker Sea Empress ran aground on Britain's coast. Heavy seas had prevented the tanker from being docked, but insufficient safety measures such as not having a heavy tug in the area were also to blame. It took over 24 hours for a heavy tug to reach the Sea Empress and by that time the weather had worsened and off-loading of the oil still aboard did not start until February 24th. The Sea Empress lost around 70,000 tons of her cargo of North Sea crude oil. This type of oil is relatively light and gives out its most harmful toxins into the water and air within a short time. The Sea Empress lost almost double the cargo spilled by the Exxon Valdez into Prince William Sound in 1989 which killed half a million seabirds and countless fish. Tourism was also badly affected, as the Pembrokeshire Coast National Park is usually visited by 500,000 people a year. The thought of oily beaches and polluted seas greatly deterred many people from visitng the area.

In the U.S. in 2000, ocean, bay, lake, and freshwater beaches were closed or had swimming advisories for more than 11,000 days. Eighty-five percent of these closures were due to bacteria levels exceeding allowable water quality standards for human contact. In contrast, eight percent of the closures were due to known pollution events, such as sewage treatment plant failures or leaks. Six percent were precautionary closures due to a known pollution-causing event such as a rainfall overwhelming a treatment plant. Two percent of the closures were due to other causes, such as algal blooms, chemical spills, fish kills, strong waves, no lifeguards, or others (NRDC, 2001).

Water pollution in Egypt is also increasing over time. The low level of sanitation service especially in rural areas (7% at most) makes nearby streams (either canals or drains) the perfect places for inhabitants to dispose their sewage. Many of the Industrial establishments do not comply with the law, dumping their wastewater untreated into surface water bodies as well as injecting it into ground water. Excessive use of fertilizers and pesticides is another major source of water pollution despite the success in reducing the level of use of agro-chemicals during the past decade considerably. Extensive drainage

Best Management Practices for Reducing NPS Pollutants	
Source	**Best Management Practices**
Roads and Streets	• Dispose of paints, solvents, and petroleum products at approved disposal sites—not in storm drains or street gutters. • Fix automobile oil and fuel leaks. • Stop oil dumping on rural roads. • Use non-chemical deicers (sand and ash) on roads, walkways, and driveways. • Construct a sediment catch basin to collect storm water runoff. • Reduce road construction runoff by building terraces and catch basins, by using sediment fences, and by planting cover crops.
Construction	• Implement a sediment control plan. • Plant ground cover to reduce erosion. • Dispose of solvent, paint, and other wastes at approved disposal sites. • Build small, temporary dikes to slow and catch runoff. • Build berms to filter runoff before it enters waterway. • Trap sediment with straw bale barriers.
Residential	• Use non-chemical deicers (sand and ash) on residential driveways and walkways. • Read labels prior to using pesticides and fertilizers. • Clean up pet wastes and dispose of them in a landfill or compost pile. • Use non-chemical fertilizers (compost) on gardens. • Dispose of hazardous household waste, including motor oil, at approved sites. • Maintain vegetation buffer strips along waterways. • Channel runoff through vegetation to slow the water and to filter sediment and contaminants. • Maintain septic tanks. • Keep grass clippings and yard debris out of waterways.
Recreational Boating	• Dispose of human waste at proper onshore sewage disposal facilities. • Minimize petroleum spills from bilges or when filling the tank. • Use care when applying hazardous maintenance products, such as marine paints and engine treatments. • Pack all trash and litter back to shore for disposal.

reuse within the Nile delta and direct drainage spillage into the Nile River along the valley increase the effect of agricultural pollution as well. Current development plans show that more land will be reclaimed and more industrial areas will be constructed which will add more pollutants to the system if the effluents from these areas are not treated (Said A. et. al, 1999).

The protection of a watershed from NPS pollution presents an enormous challenge because of the widespread and diverse nature of the problem. Land and water managers rely on methods called *Best Management Practices*, or BMPs, to describe measures designed to reduce or eliminate NPS pollution problems. A list of nonpoint source pollution sources and suggested BMPs can be found in the chart on the left.

Procedure

Preparation

Draw the outline of the waterfront properties (shown on the ***Waterfront Properties*** *Teacher Resource Page*) onto a poster board, sheet of newsprint, or flipchart paper. Color in the water with a blue marker. The number and type of land structures (treatment plant, parking lot, etc.) can vary from the chart. Improvise by leaving more areas free of development or adding structures that correspond with local conditions (e.g., fishing access, marina, etc.). There is no maximum number of sheets required for this activity so add as many as needed to the suggested materials.

Divide the paper into equal parts giving each part some waterfront and some land. Number the sheets in the upper left corner; this will allow the students to align their properties in the proper order to create an entire waterfront community. Make numbers readable but not prominent. The number of sections should correspond with the number of student groups.

Warm Up

Ask how many students have ever attended a large gathering (concert, sporting event). What happens to all of the garbage left behind? Where did all of that garbage come from? Explain that each individual may have left just a little trash on the ground, but when it's combined with the trash of many others, the volume can be staggering. Water pollutants build to problematic size in a similar fashion—many small sources accumulate until the amount becomes a water quality issue.

Ask students if they have ever gone to a beach to go swimming; only to find it closed. Why was the beach closed? Ask students to brainstorm other reasons a beach might be closed for swimming (e.g., sharks, weather, pollution). List their ideas on the board.

The Activity

Part I

1. Divide students into cooperative groups of three to five and tell them that they have inherited a piece of waterfront property and one million dollars. Have them list ways they could use the money to develop their waterfront.

2. Distribute a "piece" of the previously prepared waterfront property along with drawing implements to each group. Instruct students to draw how they plan to develop their land using their one million dollars. Some of the properties already have structures on them, including a wastewater treatment plant, a pet play park, a parking lot, and a boardwalk with public toilets. Some properties have no structures on them.

3. When the drawings are complete, ask students to identify possible sources of water pollution on their property. How have their development ideas affected water pollution?

4. Once they have identified their sources of water pollution, have them look in the upper left-hand corner of their property for a number. Explain that each piece of property is actually a part of a larger puzzle. Have students assemble their pieces numerically to create a stretch of shore.

5. Each group should then describe how they developed their land and discuss any resulting sources of water pollution. Have them use items from their desks (e.g., book, pen, coin, paper clip, etc.) to represent these pollution sources. As they describe the pollutants, the representative items should be placed directly on their property at the pollution source (e.g., paper clip on the parking lot to represent the runoff of petrochemicals from vehicles). Be prepared to mark other pollution sources that the students have overlooked.

6. After the students have described their properties, have them move their pollution tokens into the water adjacent to their land. Then mix them into one pile.

7. Explain that rivers, oceans, and lakes often have currents, and the current along this shore moves from the property with the pet play area toward the opposite end. Ask students how this affects their plans to use their land. Did they plan on having clean water adjacent to their property? Move the representative objects in the direction of the current until they are all in one pile at that end.This indicates the accumulated pollution from all their properties.

8. Have the students try to reclaim their specific items. The items that are easily identifiable as theirs (e.g., keys, wallet, personalized items, unique pens or pencils) simulate point source pollution. Items that are not so easy to identify as theirs (e.g., rubber bands, paper clips, coins, cans, common pens and pencils) simulate nonpoint source pollution: those pollutants that come from multiple, not readily identifiable sources.

Part II

1. Hand out the *Water Contaminants Worksheet* to each group. Have students compare the pollutants from their property to those listed.

2. Instruct students to list the specific contaminants associated with their pollution sources. For example, if their land was a source of pet wastes, they should list the contaminants contributed by this pollution—nutrients (phosphates and nitrates) and bacterial contaminants (coliform bacteria).

3. If a group has a pollutant that is not listed on the *Water Contaminants,* have them conduct further research to find out about the specific contaminants and health impacts associated with that pollutant.

4. Have groups present their contaminants to the rest of the class. What contaminants tended to accumulate from different properties or from different pollution sources? What possible effects could the contaminants have on people using water? On the environment in the watershed?

Wrap Up

After all the contaminants have been identified, discuss the activity with the students. Who is responsible for the watershed pollution? Could a property on one end of a shore be affected by the actions of a property on the other end? How did those students who were down—current feel as they saw the accumulated pollution come by their property? How would this pollution affect their plans for using their property?

Ask students if they would swim in the water near their property considering the contaminants and their health effects. What steps could they take to reduce the contaminants and help ensure the water was safe?

As a follow-up, have each student write one paragraph detailing ways to reduce the pollution he or she contributed. (Share the *Best Management Practices for Reducing NPS Pollutants* from **Background.**)

Assessment

Have students:

- distinguish between point and nonpoint source pollution (***Part I***).
- identify causes of water pollution, the contaminants that are associated with pollutants, and the resulting effects on health from pollution (***Part II***).
- recognize that everyone contributes to and is responsible for their watershed (***Wrap Up***).
- identify *Best Management Practices* to reduce pollution (***Wrap Up***).

For further assessment, have students:

- design a waterfront community using Best Management Practices to minimize pollutants.

Extensions

Another option is to conduct the activity without the drawing and have students form a river, lake, or waterfront. For example, one student represents a lake. A group of students encircle the "lake" to represent houses around the lake. Other students, standing in lines extending from the lake, are streams flowing to the lake. Students pass their pollution tokens downstream and into the lake until the person in the middle (the lake) holds all the items.

Complete the main activity using examples of real water users in the watershed where students live. Or assign roles (farmers, suburban dwellers, etc.) to students and have them develop their land accordingly. How would they manage their land to protect water resources?

Resources

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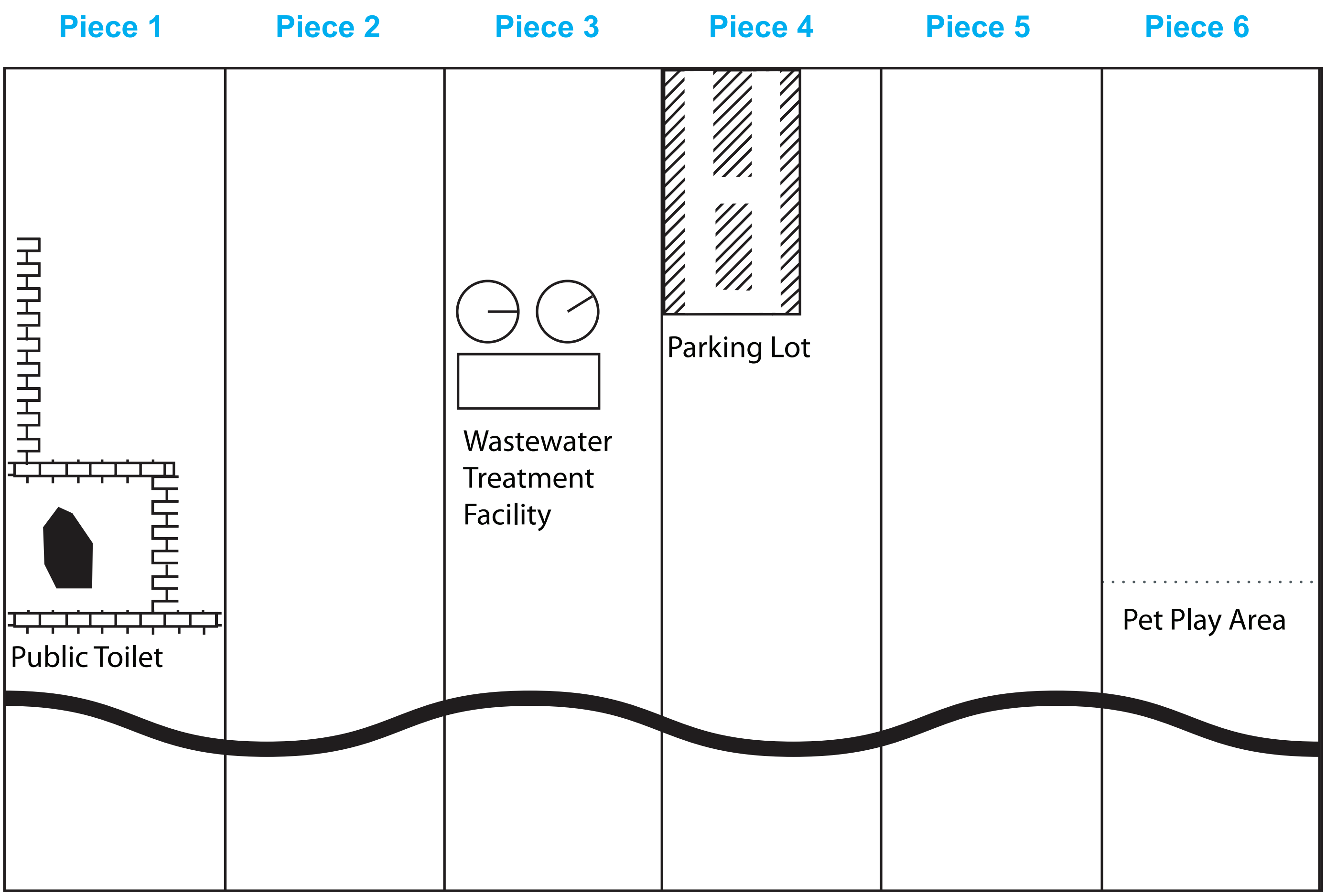
Waterfront Properties



Use this diagram as a template to create your own waterfront properties using one large piece of paper that can be cut into smaller pieces or using separate pieces of paper that can be numbered in order to represent the entire waterfront.

Water Contaminants Worksheet

Pollutant	Specific Contaminant	Possible Environmental and Human Health Impacts
Pet Waste	• Nitrate • Phosphate • Coliform bacteria	Algal blooms–dissolved oxygen depletion Algal blooms–dissolved oxygen depletion, *Pfiesteria* Human illness (watery diarrhea, fever, and dehydration)
Sediment	• Turbidity • Phosphate • Coliform bacteria	Blocks sunlight, kills submerged vegetation Algal blooms, dissolved oxygen depletion Human illness (watery diarrhea, fever, and dehydration)
Sewage	• Nitrate • Coliform bacteria	Algal blooms, dissolved oxygen depletion Human illness (watery diarrhea, fever, and dehydration)
Litter	• Coliform bacteria	Human illness (watery diarrhea, fever, and dehydration)
Parking Lot Runoff	• Petroleum products (benzene, toluene, organic lead compounds.)	Human illness (fever, chills, vomiting)
Fertilizers	• Nitrate • Phosphate	Algal blooms, dissolved oxygen depletion Algal blooms: human illness (respiratory illness)
Pesticides	• Chlorinated hydrocarbons, rhothane (DDD), lindane (HCH's), Atrazine	Human illness (headaches, dizziness, respiratory problems) Animal illness (muscle tremors, convulsions, tetanus)
Air Pollution	• Acid rain (sulfate aerosols, nitrogen oxides, copper, nickel, zinc) • Sulfur dioxide	Human illness (inherited heart defects, respiratory diseases, gastrointestinal disorders, skin and eye diseases, asthma, bronchitis, lung inflammation–asthma and emphysema) Acidifies waters (lakes, rivers, streams)
Boat Pollution	• Sewage waste (bacteria) • Nutrient loading • Litter • Oil spills	Human illness (watery diarrhea, fever, dehydration, dizziness, muscle aches, vomiting) *Pfiesteria piscicida* outbreaks; red-tide algal blooms Animal strangulation (can block digestive system when ingested) Human illness (cancer, sterility, brain dysfunction, fever, chills, ear discharge, vomiting)
Waterfowl	• Coliform bacteria	Human illness (watery diarrhea, fever, and dehydration)