CORNELL SCIENTIFIC INQUIRY SERIES

STUDENT EDITION

# Watershed Dynamics

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06 05 04 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Watershed dynamics / by the Environmental Inquiry Leadership Team, William S. Carlsen ... [et al.].— Student ed.
p. cm. — (Cornell scientific inquiry series)
ISBN 0-87355-213-X
1. Watersheds—Study and teaching (Secondary)—Activity programs. 2. Watershed ecology—Study and teaching (Secondary)—Activity programs. 3. Water quality—Study and teaching (Secondary)—Activity programs. I. Carlsen, William S. II. Series.
GB1002.25.W28 2004
551.48—dc22
2004002042



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This material is based on work supported by the National Science Foundation under Grant No. 96-18142. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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# PREFACE

## WHY STUDY WATERSHED DYNAMICS?

Water is an important issue for every community, whether that community is a bustling urban neighborhood crowded with people, or a pristine marsh crowded with ducks, amphibians, and fish.

The water resource concerns of human communities vary greatly. In some regions, fresh water for drinking and similar uses is in very short supply. The conservation of water, the identification of new sources of water, and the protection of drinking water reserves are high on the policy agenda in such places. In other regions, water is *too* abundant, and flooding after large storms is inconvenient and expensive at best, deadly at worst. In still other places, water supplies may be contaminated by improper chemical disposal, or may serve as battlegrounds pitting farmers against recreational river runners, or developers against environmental activists. There are few places where water is not an important issue. The details may vary, but everyone needs enough—but not too much—clean, fresh water. Natural communities also need enough, but not too much, clean, fresh water. Such communities include the plants and animal assemblages living in lakes, rivers, ponds, and streams; less obviously, they include terrestrial communities. Many insect species and most amphibians, for example, spend a significant part of their lives underwater. As adults, they disperse widely, where they contribute energy and ecological function. For example, they may eat other insects (dragonflies) or serve as food for birds (mayflies).

Public participation in water resource management requires public understanding about how water functions in natural communities, and how human activities affect the distribution and quality of this precious resource. One challenge—a fascinating one—is that just as watersheds do not respect political boundaries, watershed science does not respect disciplinary boundaries. Understanding watersheds from a policy perspective requires understanding biology, chemistry, Earth sciences, mathematics, sociology, economics, politics … the list goes on and on. For that reason, the interdisciplinary study of watersheds is often considered an “advanced” topic. We believe, however, that if it is approached as a *foundational* topic, it can provide wonderful opportunities for original research—research that matters to communities of all kinds.

SECTION 1

# UNDERSTANDING WATERSHED DYNAMICS

# INTRODUCTION TO WATERSHED DYNAMICS

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**Topic:** watershed
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The title of this book, *Watershed Dynamics,* refers to the idea that streams, rivers, lakes, and other water bodies are dynamic systems, continuously changing in many ways—physically, chemically, and biologically. Have you ever wondered why some streams dry up during the summer while others continue to flow? Or where the water in a river comes from when the weather has been dry for several months? Have you wondered what sorts of organisms live in water, and why different varieties live in ponds vs. streams? Or how the fish and invertebrates you find in a stream during periods of low flow could possibly have survived the muddy, raging currents during spring runoff?

These are examples of the dynamic relationships that take place in water and the surrounding landscape. Every body of water interacts with the atmosphere, receiving precipitation and exchanging gases between water and air. Every water body also interacts with the surrounding landscape, receiving runoff along with sediments and dissolved materials that get carried along during rainfall or snowmelt events. Humans of course are an integral part of these dynamic systems, both affecting and being affected by water in all aspects of our lives.

When you turn on a kitchen faucet in New Orleans, Louisiana, some of the water that comes out has already been through several sets of human kidneys. The reason: New Orleans draws its drinking water from the Mississippi River, which extends 2350 miles upstream and gets used in many ways before making its way south to New Orleans. The river begins with rainfall and snowmelt draining into Lake Itasca, Minnesota. As it works its way downstream from Minnesota to Louisiana, Mississippi River water is used for drinking, bathing, washing, agriculture, and industry in over 70 communities along the way. In each city or town, some water drains directly back into the river after use, but much is routed through wastewater treatment plants. There, excess organic matter and other contaminants are removed before the water returns to the river and continues its journey downstream.

It may seem distasteful to think of drinking water that has been "treated" by kidneys and sewage treatment plants. Perhaps you'd rather drink "pure" water—say, the water melting from a 10,000-year old glacier or a prehistoric, deep underground aquifer. Unless you live in a very unusual place, this probably isn't possible. The water that we all drink *has* been recycled through natural processes, human-engineered systems, or both. All of our water, whether it comes from a reservoir, a well, or even a bottle, is affected by how people use the land through which that water once flowed.

Protection of water resources is vital but also complicated. People have wide-ranging interests and concerns about land use and water resources, and management decisions are made based on combinations of science, politics, and values. For some people, the top priority is economic development, with the goal of creating jobs and encouraging commercial, industrial, and residential growth. In this case, abundant, inexpensive water is a high priority. Other people focus on preserving wild spaces and natural ecosystems, or protecting the purity of drinking water. These people are likely to want to restrict rather than promote construction of new development projects. The goal of watershed management is to balance multiple, competing demands, using scientific studies in combination with human judgment to make decisions about various watershed management options.

## WHAT IS A WATERSHED?

**A *watershed* is the region of land draining into a stream, river, pond, lake, or other body of water.**

A *watershed* is the region of land that contributes water to a stream, river, pond, lake, or other body of water. The boundary around a watershed is called the *watershed divide*. This is the line that divides one watershed from the next. Rain that falls on one side of the divide will drain into a stream in one watershed, and rain falling on the other side will drain into a different watershed.

One way to think of a watershed is to imagine a bowl. The body of water—such as a pond—is at the bottom of the bowl. The sides of the bowl represent the land draining into the pond, and the top edge is the divide that defines the boundaries of the pond's watershed. Of course, actual watersheds are not circular. Instead, they have irregular boundaries that follow the topography of the land. Using Protocol 3 (p. 57), you will learn how to delineate watershed boundaries by connecting the points of highest elevation in the land surrounding a stream or other water body.

Every land area, regardless of its location, is part of a watershed. As you might imagine, watersheds vary widely. Some are hilly and others are relatively flat. Some are forested and others contain cities. Some cover vast areas of land, and others are much smaller. The headwaters of a small stream near the top of a mountain may have a watershed the size of several football fields.

In contrast, the watershed of the Mississippi River covers about 40 percent of the lower 48 states! Of course, the Mississippi River is supplied by thousands of tributary streams and rivers, each of which has its own watershed. When considering huge watersheds such as that of the Mississippi River, the numerous smaller watersheds within it are called *sub-watersheds* (see Figure 1.1).

**FIGURE 1.1.**
**The Mississippi River watershed is made up of many smaller sub-watersheds.**


No two watersheds are exactly alike. The boundaries and characteristics of a watershed depend on many factors, including the geology of the region. What type of bedrock lies under the soils? Is the terrain steep and hilly, or broad and flat? Are there volcanoes in the area? Have glaciers covered the land in the distant past, leaving behind vast deposits of sand and gravel?

Climate also plays a major role in defining watershed characteristics. How much precipitation occurs per year? Does it occur primarily during a few wet months, or is it evenly distributed throughout the year? How warm are the summers, and how extreme are the winters? How strong are the winds? What types of vegetation are able to survive?

Vegetation is another key characteristic of watersheds. Because roots absorb water and anchor soil, the types of plants growing in a watershed determine how much—and how quickly—water runs off after storms or spring snowmelt. The vegetation in a watershed also affects the types of habitat available for animals and other organisms.

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**Topic:** water cycle
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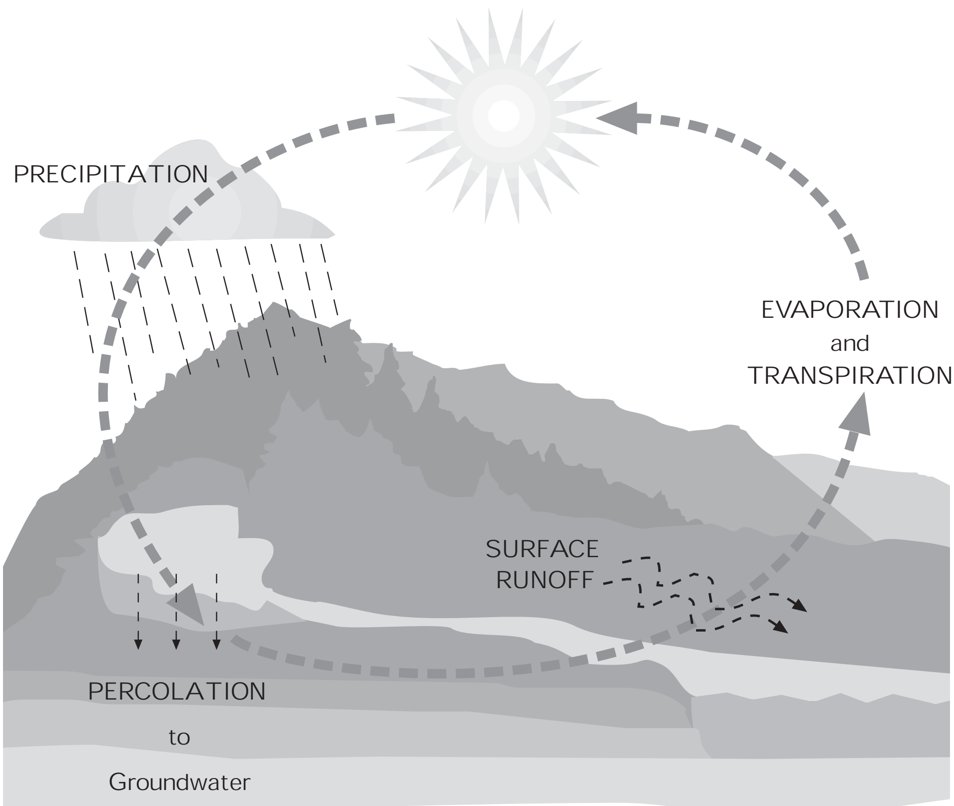
## THE WATER CYCLE

On Earth, water shifts continuously between gaseous, liquid, and solid forms—between water vapor in the atmosphere and rain or other forms of precipitation falling on land or into the sea (Figure 1.2). When precipitation falls onto land, it can return to the atmosphere, percolate into the soil, or run off into surface water bodies such as streams, rivers, lakes, or wetlands. Water flows downhill through watersheds, emptying into larger bodies of water and eventually into an ocean. At all stages along the way, water vapor returns to the atmosphere through evaporation from land and water surfaces.

**FIGURE 1.2.**
**Water cycles between land, water, and the atmosphere.**




Some of the water that soaks into the ground percolates downward to become groundwater. Groundwater trickles in a general downhill direction through layers of crushed rock, gravel, soil, or other permeable material. Depending on factors such as soil type, geologic conditions, and precipitation patterns, the velocity of groundwater flow can range from several meters per day to only a few meters over the course of an entire year. Groundwater is the source of water for wells and springs, and it also slowly feeds into lakes, streams, and rivers. During periods with no rainfall, streams that receive groundwater are less likely to dry up than those fed solely through surface runoff.

Not all of the water that soaks into the ground becomes groundwater. Plants take up the water they need to sustain life. Through a process called *transpiration,* plants release water vapor back into the atmosphere. Gradually clouds form and grow, and the water cycle continues as precipitation once again falls to the Earth.

***Transpiration* is the process through which plants release water to the atmosphere.**

Of all the water on Earth, 97 percent is in the oceans and only 3 percent is fresh water. Of the fresh water, less than one percent is found in lakes, rivers, and other surface water bodies. Most fresh water is stored in ice caps and glaciers, or underground in the form of groundwater (Table 1.1). Nevertheless, the tiny fraction of the Earth's water that actively circulates as fresh water plays an incredibly important and dynamic role in life on Earth, sustaining human life and the lives of all other land-dwelling and fresh-water species.

**TABLE 1.1**
**Distribution of Fresh Water on Earth**

| Water Source | % of Fresh Water on Earth |
|---|---|
| Ice caps, glaciers, permanent snow, and permafrost | 69.6% |
| Groundwater | 30.1% |
| Lakes, rivers, wetlands, and other surface water | 0.30% |
| Soil moisture | 0.05% |
| Atmosphere | 0.04% |

Source: Gleick, P. H., 1996: Water resources. In *Encyclopedia of climate and weather,* ed. by S. H. Schneider, New York: Oxford University Press, (2) 817–23.

Although wetlands contain only a tiny fraction of the fresh water on Earth, they represent an important component of the water cycle. Marshes, swamps, bogs, and other wetlands are heavily vegetated areas that are saturated with water for at least part of the year. They cover approximately 6 percent of the Earth's surface, ranging from tropical mangrove swamps in Panama to peat bogs in the United Kingdom.

SCILINKS THE WORLD'S A CLICK AWAY
**Topic: properties of water**
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Wetlands play vital roles in physical, chemical, and biological processes in the Earth's water cycle. Physically, wetlands help to reduce flooding by storing great volumes of water, slowly releasing it to downstream waters in the weeks and months after each storm. Because wetlands release water slowly over time, they help to maintain flow in streams and rivers during dry periods of the year. Wetlands also help to purify the water that flows through them. Sediments settle out and some dissolved pollutants get broken down or taken up by plants as water trickles slowly through wetlands. And finally, wetlands provide a rich variety of habitats that support a diverse system of living things. Migrating birds take advantage of the abundant food supplies they find in wetlands, as do many other forms of wildlife.

## COMPETING NEEDS FOR WATER

Although the Earth contains vast amounts of water, supplies are not always sufficient in any particular location to meet the needs of various competing uses. Humans use water to irrigate crops, generate power, and support a wide range of industrial, commercial, and agricultural applications. We also rely on it for recreational activities such as fishing, boating, and swimming.

In our homes, each of us uses an average of 300 to 400 liters of water per day for household uses (Table 1.2). This doesn't include all the water it takes to produce the food we eat and the products we use. For example, a cow drinks roughly four liters of water for each liter of milk produced. To manufacture a new car requires over 8,500 liters of water, much of which is used in making the tires.

### TABLE 1.2
Typical Water Use in American Homes

| Type of Use | Typical Water Use |
|---|---|
| Tap water (hand washing, tooth brushing, etc.) | up to 5 liters per minute |
| Dripping faucet | up to 55 liters per day |
| Toilet (installed before 1992) | 14 liters per flush |
| Toilet (low-flow) | 6 liters per flush |
| Shower | 8–20 liters per minute |
| Bath | 100–200 liters per bath |
| Clothes washer | 90–150 liters per load |
| Dishwasher | 20–60 liters per load |
| Lawn watering | 20–40 liters per minute |

Source: *www.h2ouse.org*, developed by the California Urban Water Conservation Council.

Competing with all of these water uses is our desire to protect habitats for a wide range of aquatic organisms. We choose to protect some species because of their value for human uses such as sport fishing. Others are targeted for protection because they are endangered or are particularly important in maintaining healthy ecosystems. To help meet critical habitat needs, many states have passed legislation specifying minimum allowable flow rates in designated rivers or streams. In some cases this means that water must be released from a reservoir to maintain downstream flows during dry seasons. In other cases, irrigation or other uses might need to be reduced in order to maintain critical levels of flow needed for survival of fish and other aquatic organisms.

Water policies often are controversial because they deal with conflicting needs and values. Which is more important—irrigating crops or providing high flows for recreational uses such as whitewater rafting? Which should take precedence—providing water for new residential development, or maintaining critical flows needed to preserve a valued wetland? Issues such as these are particularly difficult because the times when water is in shortest supply also are the times of greatest need for habitat protection as well as for residential, commercial, and industrial water uses.

## DISCUSSION QUESTIONS

- What would you say if someone told you that you were drinking recycled water that had already passed through several wastewater treatment systems?
- What is the source of water for your school or home? Does it come from surface or groundwater? Do you know the name of the watershed you live in?
- Historically, wetlands have often been considered "wasted" land that can be drained, filled, and used as "new" land for development and construction. What are some possible ecological consequences of this type of development strategy?
- Consider the water use data in Table 1.2. If your community were experiencing a water shortage, what water use restrictions would be most worth exploring, and why?

**Topic**: groundwater contaminants
**Go to**: *www.sciLINKS.org*
**Code**: WD04