Water Ways

A Minnesota Water Primer & Project WET Companion

Minnesota Department of Natural Resources

Minnesota Project WET Water Education for Teachers

Preface

Welcome to *Water Ways: A Minnesota Water Primer and Project WET Companion.* A publication of the Minnesota Department of Natural Resources.

If you're interested in learning about water in Minnesota, this primer is a great place to start your exploration of this fascinating topic.

If you're an educator, it will serve as a one-stop source for general information about water and provide useful specifics on water resources in Minnesota as well as suggestions on how you can customize national Project WET lessons for Minnesota learners.

It can also provide a context for those interested in protecting Minnesota's water resources.

Interested in learning even more? Visit the Minnesota Project WET website at www.mndnr.gov/projectwet/ for correlations with Minnesota academic standards, activity adaptations, Project WET workshop information, links, and more in-depth information on topics covered here.

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Finally, thank you to every person who cares about and for Minnesota's waters. Your efforts will ensure that this resource will be able to meet not only our needs today, but the needs of our children and grandchildren—and of all living things.

—April Rust,
Minnesota Project WET Coordinator
Water Ways Project Manager

How to Use This Book

Water Ways is specifically designed for use by classroom teachers, informal educators, and anyone interested in learning about water in Minnesota.

Read as much or as little of the background for your own information—as is pertinent to you and your existing knowledge.

If you're working with students, you'll find a variety of activities and suggestions for additional resources for learners of all ages. Feel free to copy the graphics as you wish for educational purposes.

If you're a Project WET user, you'll find this book to be a handy supplement to the information and activities presented in the national *Project WET K–12 Curriculum and Activity Guide.* Check each chapter for useful cross-references to specific lessons. Please note that activities referenced are from the 1995–2010 edition of the guide.

In addition to the book itself, this supplement is posted online for download and supported with additional information on resources, field trips, activities, and other topics: www.mndnr.gov/projectwet/waterways.

Whatever your interests and needs, we hope you find within these pages a rich opportunity for building knowledge and stewardship of Minnesota's waters. If particular parts are exceptionally helpful, or if you have suggestions for future editions, please contact us at www.mndnr.gov/projectwet/.

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NSSDC Photo Gallery, NASA

Chapter 1: Water Basics

Key Concepts

- Water is integral to life
- Minnesota is a special place for water
- How we treat water affects how well it can meet the needs of living things (including us)
- Water has unusual characteristics
- Water is found in many places and many forms (phases)
- All water is connected through time and space as water cycles from the atmosphere to and through the ground and back to the atmosphere again

WHAT DO YOU CALL the place where two rivers join? Water was so important to some Mdewakanton (med-WAH-ku-tun) Dakota that they named the confluence of the Mississippi and Minnesota rivers *Makoce Cokaya Kin*—the center of the universe.

If you think about it, water is that important to all of us.

Water is above us, below us, around us, inside us. It keeps our bodies and those of other living things alive and functioning properly. It builds and sculpts the nonliving world: Many of the characteristics of Earth's surface—hills, valleys, canyons, mountains, plains—were formed by water. Water shapes weather and climate. It affects where we locate our homes, businesses, and cities. It influences how we work and how we play. Sometimes water moves us from one place to another. Sometimes it stirs our emotions and moves us to the depth of our being. Water itself constantly moves from sky to land to water body to living creature and back again. Figuratively and literally, it permeates our existence.

There are many speculations about how life began. What many—if not all—of them have in common is the presence of water. Water (H_2O) as a chemical performs a variety of functions inside living things. Water as a component of the environment provides food, shelter, transportation, and more. Without water, life as we know it would not exist.

If water is a big part of life, then nowhere is it more so than in Minnesota. Minnesotans are literally swimming in water! Our state is bordered by the world's

Water is above us, below us, around us, inside us.

Confluence of Mississippi and Minnesota rivers.

Watercolor by Seth Eastman, Minnesota Historical Society.

largest lake (by surface area), Lake Superior, and contains the headwaters of our continent's most important river, the Mississippi. We are home to 11,842 lakes 10 acres or larger, 69,200 miles of natural streams (90,000 miles of total streams), and six groundwater provinces. Before people began draining them, Minnesota had more than 18 million acres of wetlands, including countless prairie potholes—small, soggy depressions in the landscape that provide valuable habitat for waterfowl and other water-loving animals and plants. The St. Croix was one of the first rivers in the United States to receive a National Wild and Scenic River designation from Congress. We are host to the 72-mile-long Mississippi National River and Recreation Area, the national park running through the Twin Cities metro region that represents the values of the Mississippi River. Voyageurs National Park in Northern Minnesota is the nation's only lake-based national park. Finally, the Boundary Waters Canoe Area Wilderness on the northern border of Minnesota is, perhaps the world's most famous lake-based wilderness area.

Explore Minnesota Tourism

Boundary Waters Canoe Area Wilderness

Amazingly, and importantly, they are all connected. The snow that falls on a farm field eventually melts and ends up in a lake, river, or aquifer. The water you flush today, a fish may swim in tomorrow. How we treat the water we encounter influences the quality and quantity of water available in other places and for other living things.

Because water affects all of us—and we all affect it—it's important that we know something about it. What is water? Why is it special? What should we, as fortunate citizens of a water-rich state, do to take care of it? That's what this book is all about.

Where Does Water Come From?

Water came from "outer space." Sound strange? Consider that water exists through much of the known universe. It is made from two of the most common atoms, oxygen and hydrogen. Scientists think it formed during the creation of stars, as heat and rapid movement of materials caused atoms to collide in ways that make them stick together to form molecules. Water is thought to have existed on Earth more than 4 billion years ago. However, scientists are still not sure how so much of it came to be here. It is also possible that water on the surface of the earth was formed by physical processes that occurred as the earth cooled, collisions with water-rich comets or other interstellar objects, and chemical reactions that make water from other molecules.

Water came from "outer space."

Although most of our planet is covered with water, only a small amount, 3 percent, is freshwater (water lacking the high salt content of oceans). Because so much fresh water is frozen in glaciers, less than 1 percent is available for human use.

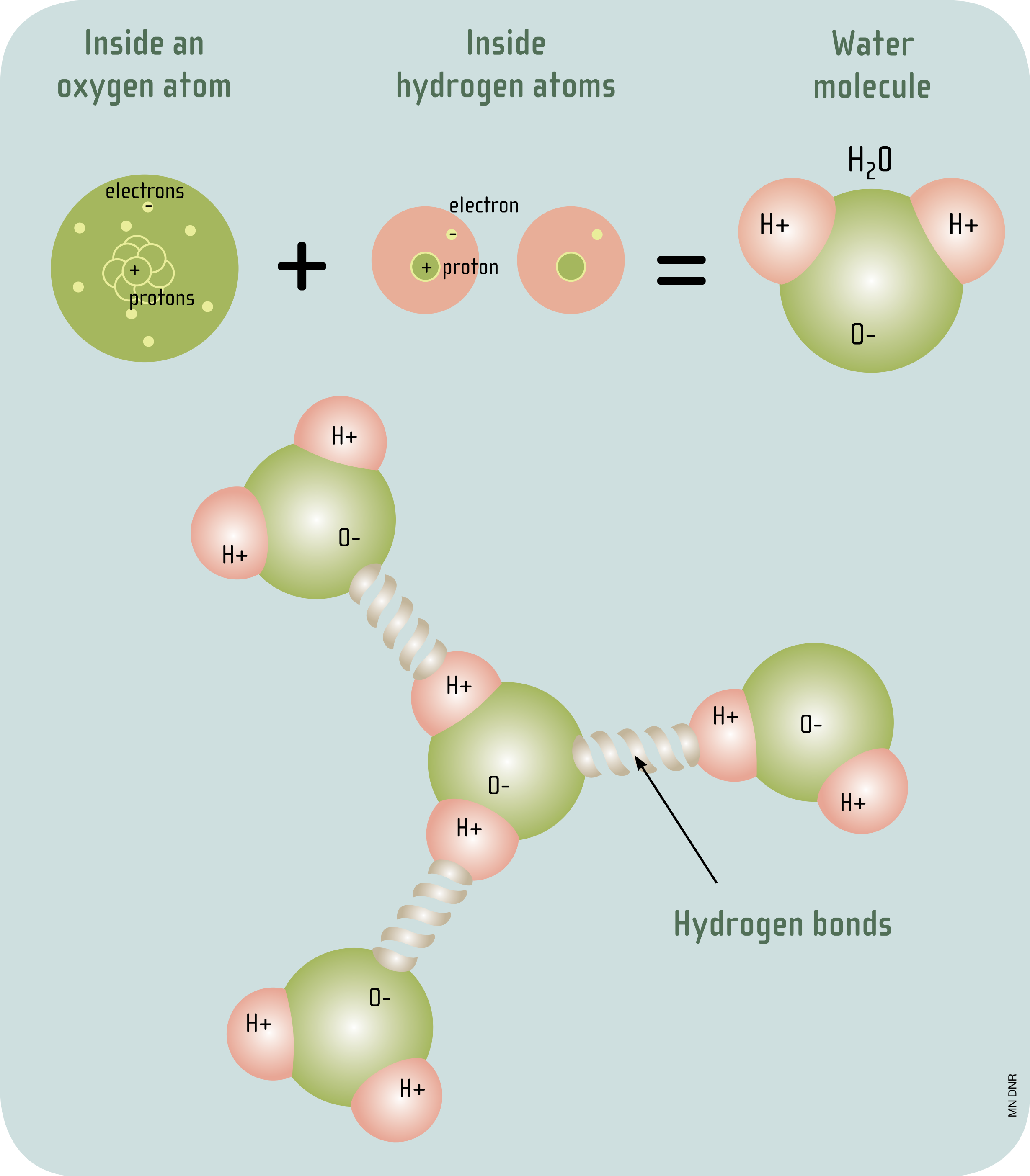
Water continues to be formed today by living things. When we extract energy from fats, proteins, and other molecules, we break them down into smaller molecules. One of the molecules they become is water.

Living things also turn water molecules into other kinds of molecules. When plants capture energy from the sun, they store it in chemical bonds made by converting water and carbon dioxide into oxygen and carbohydrates.

How Is Water Unusual?

Water is a common molecule with some very uncommon traits. Its unusual characteristics come from the chemical bond between the hydrogen and oxygen atoms that are found in the water molecule. The oxygen atom shares one of its electrons with each of the two hydrogen atoms. But the oxygen atom also has four electrons it doesn't share, causing the oxygen end of the molecule to be more negatively charged than the rest of the molecule. These unshared electrons *polarize* the molecule, with the oxygen acting like the negative pole of a magnet and the hydrogen atoms acting like the positive pole of a magnet. The hydrogen atoms from one water molecule then attract the oxygen atoms of another. This attraction, called a **hydrogen bond,** gives water unusual properties. Without these characteristics our planet would be a far different place than it is—and life, if it existed at all, would be far different than life as we know it.

Because of the unusual way in which electrons are distributed around the water molecule, water as a substance has some unusual traits. For instance:

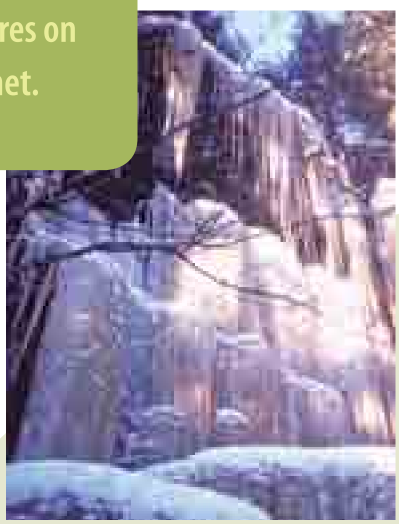


Three Phases

In the world around us, water exists as a solid, a liquid, or a gas, depending on the temperature and pressure. As a **solid,** molecules are packed together in organized patterns and don't move very much relative to each other; the water is frozen. When energy is added to frozen water in the form of heat, the molecules lose their organized pattern and begin to move around more, and become a **liquid.** In liquids, the molecules are farther apart and they slide over and around each other. Molecules are even more separated and more active as a **gas.**

Most molecules the size of a water molecule are a gas at temperatures commonly found on Earth. But because of their hydrogen bonds, water molecules have more of a tendency to stick together than do these other molecules. As a result, water exists as a liquid and a solid as well as a gas at everyday temperatures on our planet.

…water exists as a liquid and a solid as well as a gas at everyday temperatures on our planet.



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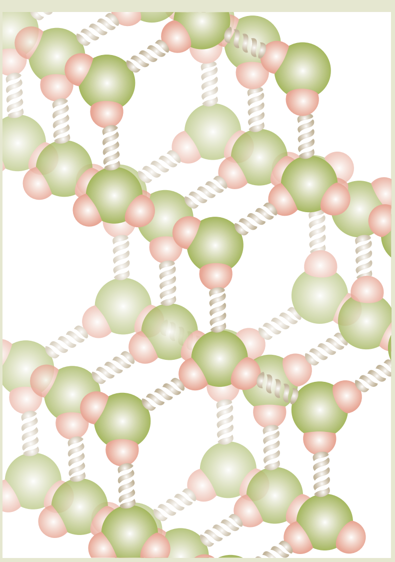
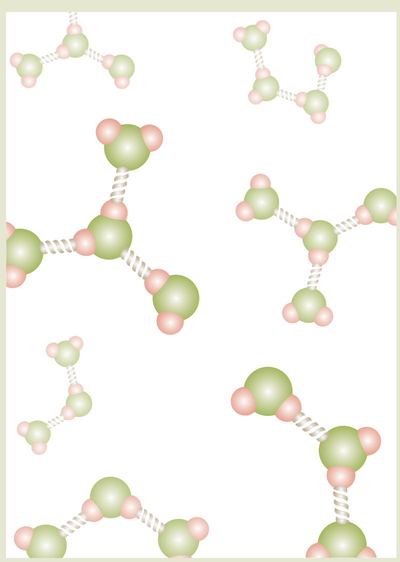
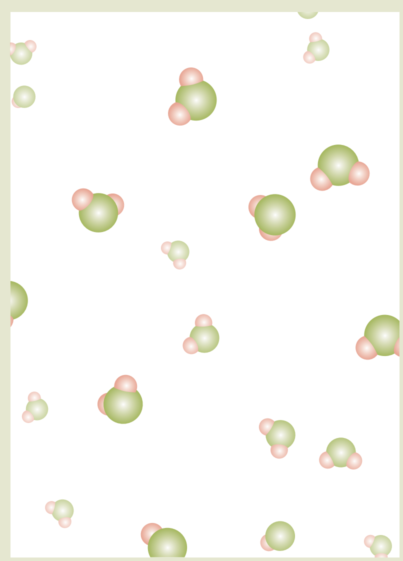
Solid



Liquid



Gas



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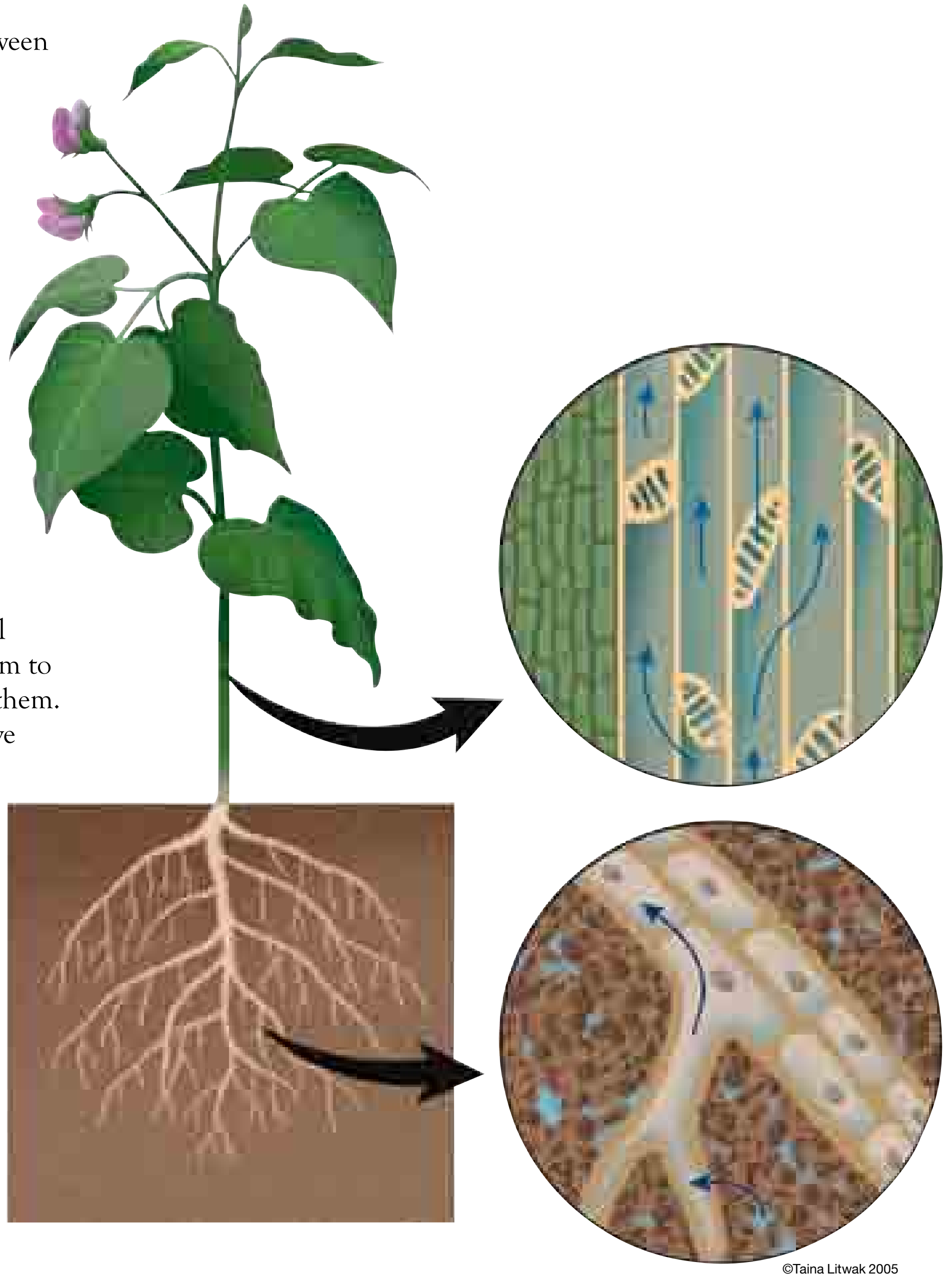
Clingy Molecules

The hydrogen bonds that form between water molecules cause the water molecules to cling to each other (called **cohesion)** and to other things (called **adhesion)**.

Cohesion and adhesion are responsible for many of the traits we observe in liquid water. They help it move through the environment. They help it carry out physiological processes inside animals, plants, and other living things. They help raindrops form and rivers flow.

When the forces of cohesion and adhesion work together in a small space, they create something called **capillary action.** As adhesion causes water molecules to cling to the material forming the space, cohesion causes them to pull other water molecules along with them. Together, the forces cause water to move into spaces that don't have water. Capillary action helps water travel up the stem of a plant. It also helps water move through soil.

The tendency of water molecules to cling to each other also creates a phenomenon known as **surface tension.** Because molecules at the surface of a body of water only have other molecules on three sides to interact with, the attraction is even stronger. As a result, water acts like it has a skin on it. Surface tension is why you can fill a glass of water past the top without having it spill over the sides.



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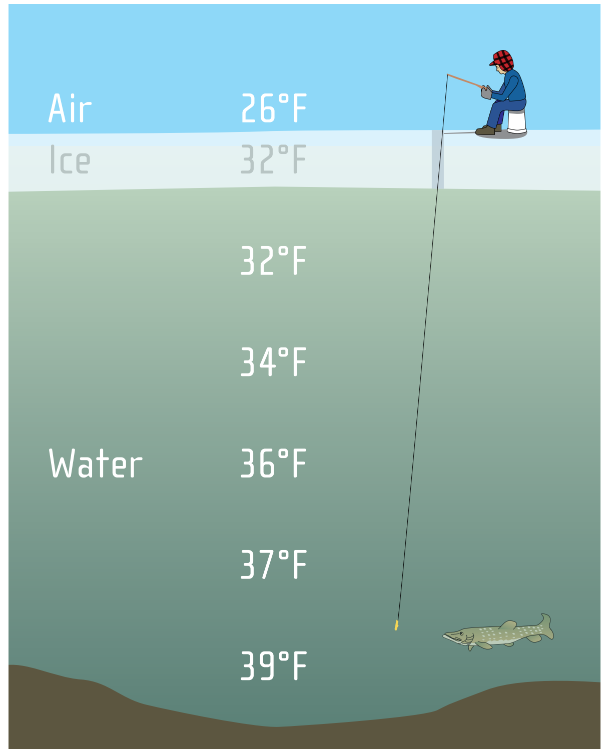
Walking on Water. An insect known as a water strider takes advantage of water's unique properties to literally walk on water. Surface tension gives it a tougher-than-your-usual-water surface to walk on. Tiny air bubbles trapped in microscopic hairs on its legs repel the water and help it "float" on top rather than sink.

Density Differences

For most substances, the solid phase is heavier than the liquid phase, because the molecules are packed together more closely. Surprisingly, this is not true for water. That's because, as liquid water molecules cool down, the pushing and pulling of their hydrogen and oxygen components cause them to line up in a lacy pattern with lots of space in between. As a result, water expands when it freezes. Instead of a tightly packed mass, water molecules forming their corresponding solid—ice—end up in a lightweight lattice pattern that is less dense than the liquid from which it formed. The molecules take up more space than they did in the liquid form, and ice is "lighter" than water, allowing it to float on water.

This property of water is very important to things that live in lakes. Water is most dense at about 39° F which means that colder, denser water sinks to the bottom of a lake. If ice didn't float and cold, dense water didn't sink, the water at the interface with cold air would freeze in winter and sink to the bottom. Eventually, the whole lake would be frozen. But because solid water is lighter than liquid water, ice stays on the top of the water. That allows fish and other water animals and plants to stay alive through the winter.



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The fact that water expands when it freezes also accounts for many of the changes in the world around us. When water freezes in cracks between rocks, it helps to break them apart. This is part of the process by which soil forms.

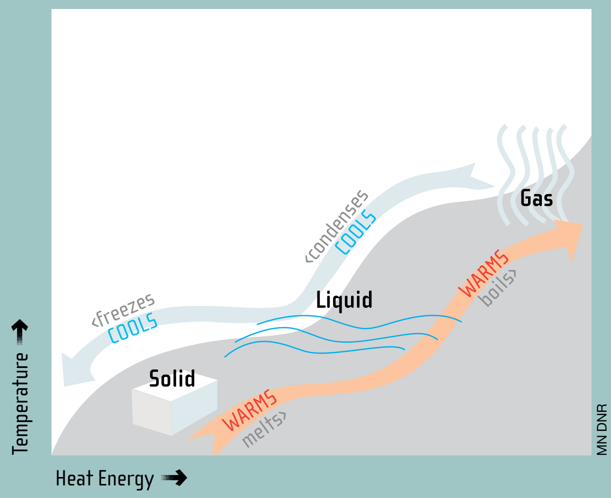
Snowflakes' Six Sides. Water molecules have three atoms. Snowflakes have six points. That's no coincidence. The shape of water molecules and their unusual properties are the reason snowflakes are shaped the way they are.


Ed Pembleton ©2010

Snowflakes start when a molecule of water freezes onto a tiny bit of dust in the atmosphere. Other molecules of water eventually freeze to that molecule, with oxygen ends attracted to hydrogens and vice versa. The result of the pattern of attraction is a lattice made up of six-sided rings, the same shape as honeycomb. As more and more water molecules join the crowd, the shape becomes a hexagonal prism. At a certain size (relative to the size of the individual water molecules) the whole structure becomes so unwieldy that it starts to grow arms instead of just adding more to the prism shape. As the arms add arms, the distinctive snowflake shape emerges.

The ultimate size and shape of each snowflake is related to the temperature and humidity of the air in which it forms. Scientists are still learning about the physics behind this relationship.

Truly Sublime. Water undergoes a number of familiar phase changes: melting, freezing, evaporating, condensing. Two less familiar changes are **sublimation** and **deposition.** Sublimation is the process by which water molecules move directly from the solid (ice) phase to the gaseous phase. On cold winter days when the sun shines, large amounts of snow and ice may be lost to this process. Deposition, the opposite of sublimation, occurs when gaseous water becomes a solid without going through the liquid phase. Snowflakes and frost crystals are both products of the deposition process.



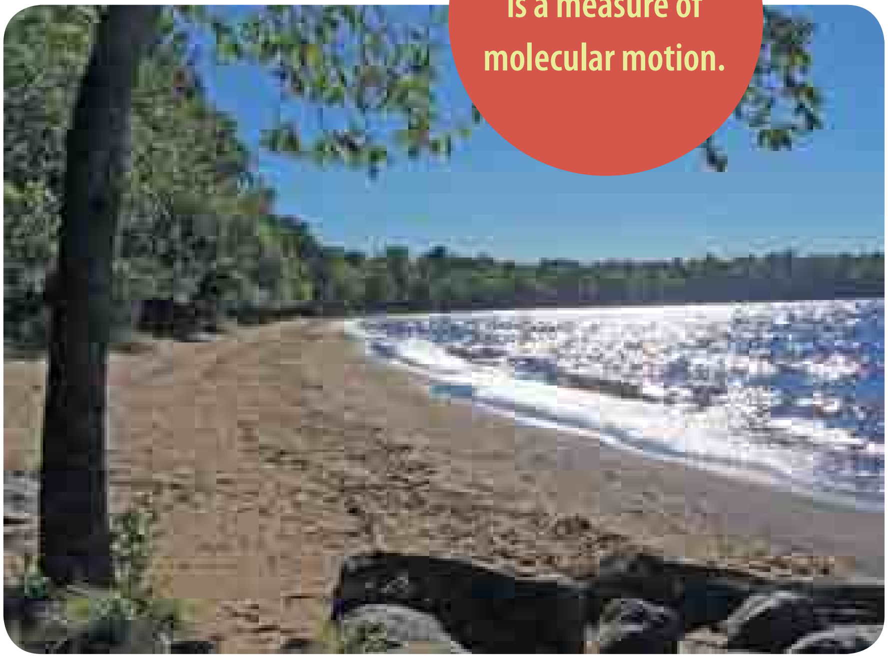
Heat Holder

Temperature is a measure of molecular motion. When you add energy in the form of heat to a liquid, the molecules move around more and the temperature goes up. In liquid water, the hydrogen bonds keep the molecules from moving around as much as they otherwise would. As a result, water has a high **specific heat capacity**—you need to add a relatively large amount of heat energy to water in order to cause the temperature to increase. Think of the difference between the water and the sand at a beach. When the sun shines on it, sand becomes very hot. But the water stays cool.

Every kind of substance requires energy to change from a solid to a liquid and from a liquid to a gas. Because of its hydrogen bonds, water takes more energy than most substances to change from one form to another. Water takes a lot of heat energy to turn from solid to liquid **(heat of fusion)** or from liquid to gas **(heat of vaporization).**

This ability to absorb heat helps protect Earth from extreme temperature changes from night to day and summer to winter. It keeps the temperature of the oceans relatively constant and the temperature of lakes from swinging as widely as do air temperatures from season to season.

Temperature is a measure of molecular motion.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Super Solvent

Because water molecules have partly positive and negative ends, they attract other kinds of molecules. As a result, it's easy for many other substances to dissolve in water. Water dissolves more substances than any other liquid. In fact, scientists call water the "universal **solvent.**" That's good news when we think about water carrying needed substances through our bodies, or nutrients to plants and animals that need them. It's not so good when water dissolves polluting chemicals and spreads them from one place to another.

Water dissolves more substances than any other liquid.

Buoyancy

Another property that affects living things' interaction with water is **buoyancy**—the upward force a liquid exerts on an object that is immersed in it, counteracting the downward force of gravity. Because of buoyancy, ducks, people, logs, fish, air-filled boats, and other objects less dense than water are able to float in it.

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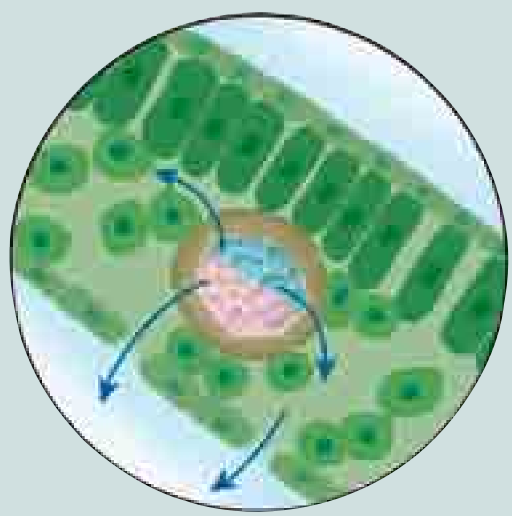
The Inside Story. Water plays an important role in helping living things, including you and me, stay alive. For example:

- Adult humans are typically 50 to 60 percent water. Our blood plasma is about 90 percent water. It carries oxygen-bearing cells, immune cells, fats, and other molecules around our bodies.
- In vascular plants, water carries nutrients from the roots to the leaves and food from the leaves to the rest of the plant.
- Water in plant cells makes them rigid, allowing them to stand upright.
- Water is one of the ingredients plants use to make sugar from sunlight.
- Water in the form of urine helps transport toxins out of animals' bodies.
- Fish and other animals that live in water can extract oxygen gas dissolved in the water.

Water and sunlight enter the plant—sugar is made by the plant and oxygen is released.



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The Water Cycle

Water's ability to exist in solid, liquid, and gas phases at temperatures we experience on Earth means it moves from place to place and phase to phase. The journey water takes as it travels from one place to another across our state and around the globe is called the **water cycle.**

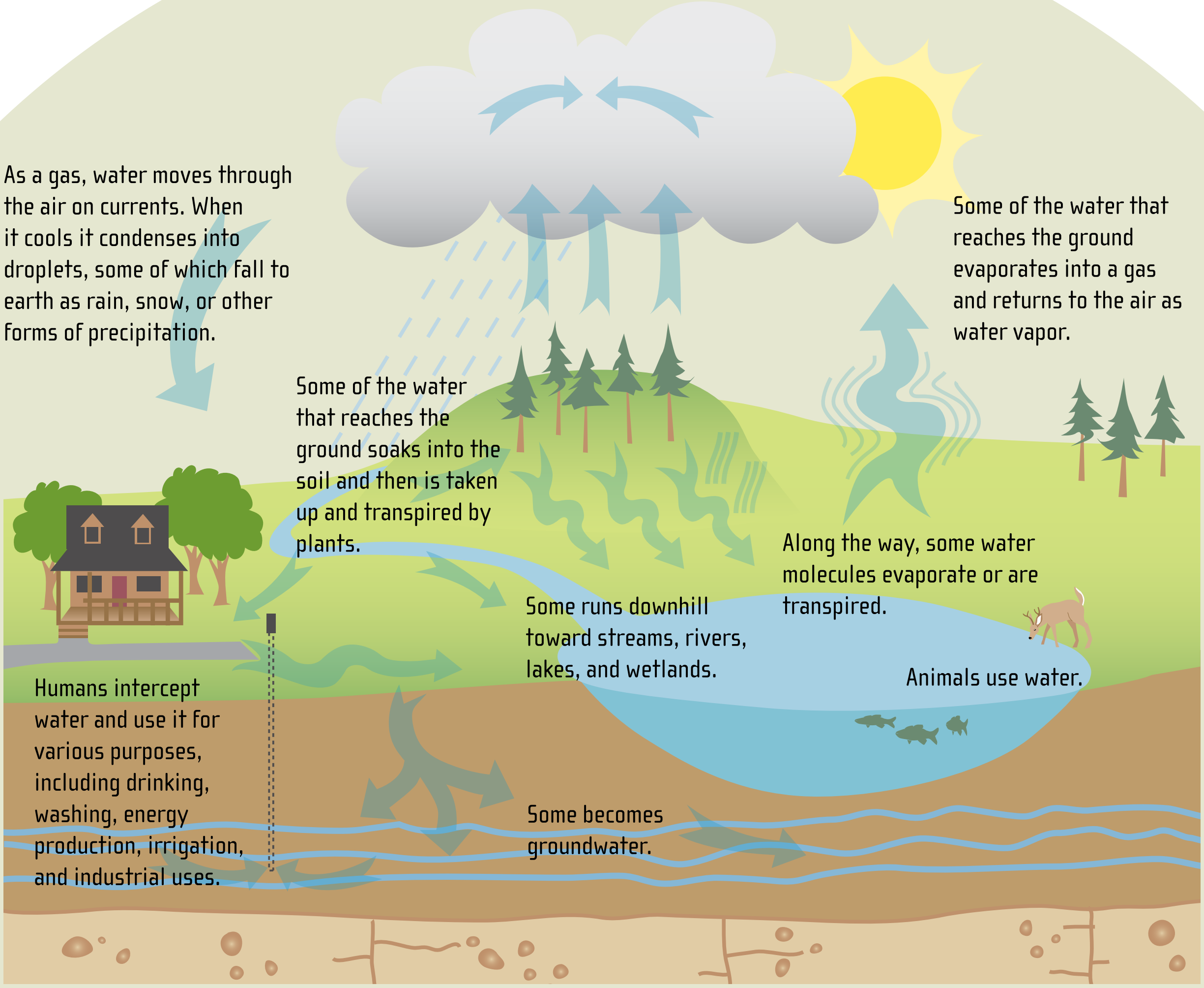
Imagine yourself a water droplet, falling from the sky onto the head of a squirrel gathering nuts in a park in a small town in northern Minnesota. You trickle down its forehead, onto its nose, then drip off the tip onto the grass at its feet.

Then what? Perhaps you slip through the grass and soak into the soil, traveling downward until you meet the body of water that permeates soil and rock below. Perhaps you are sucked up by a plant root, travel up the stem and are transpired back into the air as vapor. Perhaps you run off the grass into the street, into the storm sewer, into a nearby creek that empties into a larger creek that empties into the Mississippi River, which empties into the Gulf of Mexico—if you don't first get evaporated by the heat of the beating sun, or removed by a water intake for a power plant or city water system, or sucked in by a fish or frog, or splashed onto shore. In Minnesota, the amount of precipitation that becomes **runoff** ranges from about 20 inches per year along the steep slopes of the North Shore of Lake Superior to only 2 inches in the flat, absorbent western part of the state.

In the water cycle, the possibilities truly are endless. Unless the water molecule itself is broken and rebuilt into something else along the way, it eventually, invariably, ends up back in the sky—and then back on land, and, back in the water, and back in the sky again. This process could take a matter of hours, or thousands of years.

When it rains or snows, water soaks into the ground and fills up lakes, rivers, and oceans. Plants continually absorb water. Eventually the same water will evaporate back into the sky, becoming clouds. As the clouds grow thicker, they will again release water as rain or snow back down to the ground.

In the next chapter, we'll look at the various components of the water cycle in Minnesota and how water moves among them.



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CAREER PROFILE

Kristine VanWilgen-Hammitt
Science Teacher,
Bemidji High School
Bemidji

Lakes, snow, and students are a big part of Kristine VanWilgen-Hammitt's work day. She teaches environmental science, biology, and exercise science at Bemidji High School.

VanWilgen-Hammitt's environmental science class includes units on water quality and bioindicators. She and her students study principles of fisheries management and lake management in spring. In winter, they learn about snow and water purification, and study the effect of road salt on water quality. Along with teaching, VanWilgen-Hammitt also adapts curriculum for special education and gifted students to ensure each student is challenged and learning.

To VanWilgen-Hammitt, being a teacher is much more than knowing and passing along information. Every day she thinks about what each student needs to learn most. "The thing I love about teaching is that every day is different," she says.

VanWilgen-Hammitt encourages young people who are interested in teaching as a career to volunteer at a variety of places—science centers, youth organizations, community education classes, on the field or track. That will help them learn what it's like to work with students and decide whether it's right for them.

Related careers:
college professor,
environmental educator,
naturalist

Suggested Project WET Activities & Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water is essential for all life to exist

Let's Even Things Out (solutions, osmosis) EL, MS, HS

Thirsty Plants (transpiration, water cycle) MS

Water connects all Earth systems

Imagine!* (water cycle) EL, MS - Water cycle script modified for Minnesota geography.

The Incredible Journey* (water cycle) EL, MS - Water cycle dice are available for the three major Minnesota watersheds with local place names.

Old Water* (Age of water, geology) EL, MS – Timeline of history of Minnesota's water.

Poetic Precipitation (condensation, precipitation) EL, MS

The Thunderstorm (weather, precipitation) EL, MS, HS

Water Models (water cycle) EL, MS

Wet Vacation (climate, tourism) MS

Water has unique physical and chemical characteristics

Adventures in Density (density) EL, MS, HS

H_2Olympics (cohesion, adhesion) EL, MS

Hangin' Together (polarity) EL, MS, HS

Is There Water on Zork? EL, MS, HS (water properties, inquiry, experimental design)

Molecules in Motion (states of water) EL, MS

Water Match* (states of water) EL - game cards have pictures of Minnesota water in different states.

What's the Solution? (solutions, solvents) EL, MS

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at http://www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Water Connections: Have students each think of a Minnesota-related object—any object—and write it down or draw a picture of it. After they have made their choices, have them brainstorm (and research, as appropriate for your circumstances) how water has affected that object, and how that object might affect water.

Water Stories: Water is a common theme in literature. Has your class read a book or short story set in Minnesota? How was water part of the story—in concrete or metaphorical terms? See some examples at www.mndnr.gov/projectwet/waterways.

Map Scavenger Hunt: Minnesota is all about water! Our state's name comes from a Dakota term meaning "sky-tinted water." Hand out state highway maps, and challenge students to find as many communities as they can with water-related names.

Water Poetry: Invite students to imagine where the water inside them has been. Have them draw pictures or write a story or poem that illustrates their imaginings.

Where is Water Droplet? Invite younger students to build a story together of the adventures of a water droplet. Hold a cutout of a water droplet in your hand, and start the story by describing the fall of a water droplet named Drip from the sky during a rainstorm. Pass the cutout to a student, and invite him or her to describe what happened next. Keep passing the cutout until everyone has had a chance to add to the story. Does Drip go into animals or plants and out again? Does Drip end up back in the air? At the bottom of a lake? There is no end to the places a drop called Drip can go!

Frozen Cars: Explore with very young students how water behaves differently under different circumstances by freezing small toy cars into a few of inches of water in two identical containers. Remove the car-ice blocks from the containers and put them side by side in a larger container. Add salt to one of the blocks. Talk about what might happen. Give students the opportunity to return to the display over the course of the day so they can observe melting in action.

Out and About

Scavenger Hunt: Take students on a water scavenger hunt or a winter water scavenger hunt. Go on a 30-minute hike outside your school. Have each record any water they see. When you get back, list all of your "finds" on the board. How many were solid? Liquid? Gas? Don't forget to include clouds, squirrels, frosty breath, blades of grass, and other less visible sources of water as well as puddles, holding ponds, and streams.

Water Properties: Use the book, *A Drop of Water: A Book of Science and Wonder* by Walter Wick to have students see pictures of different states and properties of water in action. Challenge students to re-create demonstrations of the same properties. If you have access to cameras, have your students take pictures of water properties or different states of water outside and create a presentation to share with their classmates.

A few excellent resources:

1. *A Drop of Water: A Book of Science and Wonder* by Walter Wick (1997). This book pairs amazing photos and descriptions of water properties like evaporation, condensation, surface tension.

2. *Water Dance* by Thomas Locker (2002). Beautifully illustrated picture book describing the water cycle with more in-depth information on the last two pages.

3. *The Snowflake: A Water Cycle Story* by Neil Waldman (2003). Another great water cycle picture book, focused on winter and snow.

4. SnowCrystals.com website. http://www.its.caltech.edu/~atomic/snowcrystals/ An excellent website with photos, activities and snowflake physics descriptions.

5. *Snowflake Bentley* by Jacqueline Briggs Martin (1998). A Caldecott Award Winning picture book that shares the story of the first person to photograph a single snow crystal in 1885, Wilson A. Bentley.

6. Minnesota State Climatology Office website. http://climate.umn.edu/ offers current climate conditions, historical data (like monthly precipitation totals), "create your own" climate calendars, and many more facts about climate throughout the state.

7. *The Urban Water Cycle,* MN Department of Health and Hamline University's Center for Global Environmental Education. http://www.health.state.mn.us/divs/eh/water/urbancycle/index.html An online student program with videos, diagrams, maps and games for students to investigate how our drinking water, wastewater and stormwater systems work. Also includes supporting classroom curriculum for teachers.

8. *The Story of Snow* by Mark Cassino and Jon Nelson (2009). This book investigates how snow crystals form, what shapes they can take and other exploration of the science of snow.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET Activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books


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Chapter 2: Minnesota Waters—Atmosphere, Rivers, Lakes

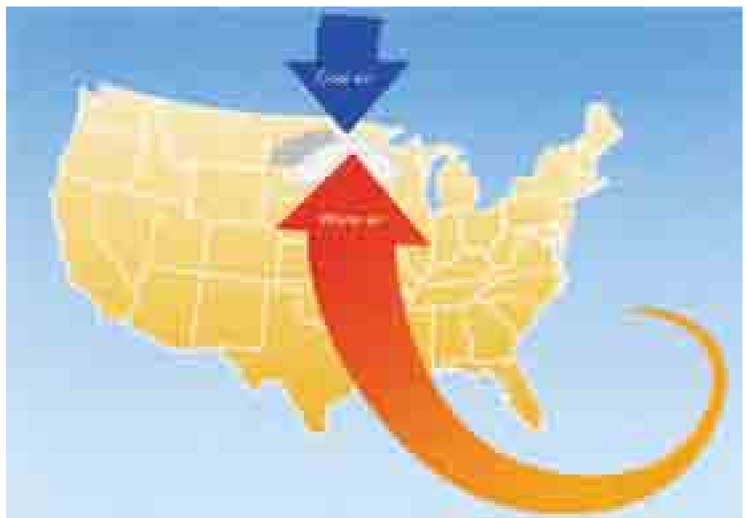
Key Concepts:

- Minnesota has bountiful supplies of water, but it's not equally distributed
- Water in Minnesota exists in many forms and locations
- The abundance of water in various locations varies with time and place
- Minnesota's lakes and rivers are many and varied
- By studying lakes and rivers, we can learn things that help us keep them healthy

MINNESOTA IS A WATER-FULL STATE. One out of every five square miles of surface area in Minnesota is covered by lakes, streams, or wetlands. Of all of the states, the U.S. Census Bureau ranks Minnesota eighth in the amount of surface area covered by water—and that's not counting numerous wetlands, bogs, and lakes smaller than 40 acres. Let's take a trip around the water cycle to see where and how water permeates our state.

Water in the Air

Where does Minnesota water come from? Most of the water that enters Minnesota is water vapor that is carried on the wind from the Gulf of Mexico.



Rob Blair, University of Minnesota

Even on days when there is not a cloud in the sky, there is water in the air. Water molecules float around among the nitrogen, oxygen, carbon dioxide, and other gas molecules that make up the atmosphere around us.

How does water get out of the air? One way is through a process called **condensation**—turning from a gas into a liquid. The trigger for doing so is a combination of temperature and the presence of a surface on which the water molecules can gather.

Minnesota Water Facts

Number of lakes 10 acres or larger: 11,842

Miles of natural streams and rivers: 69,200

Acres of wetlands: 9.2 million

Amount of water that falls on Minnesota each year: 38,000,000,000,000 gallons

Sometimes this surface is a big one—a windowpane on which fog forms, or a blade of grass that gathers dew. Other times the gathering place may be very small. Rain droplets and snowflakes form when water molecules condense around tiny specks of dust or other matter, called **condensation nuclei,** floating in the sky. Eventually enough water may accumulate into clouds that it falls from the sky as rain.

Another way water leaves the gaseous state is when it turns from a gas into a solid—a process known as deposition. Snowflakes, window frost, and *hoarfrost* are all products of deposition.

Because of its crystalline structure, snow takes up more space than liquid water. As a result, an inch of snow contains less water than an inch of rain. The amount of water in snow varies, depending on weather conditions. It takes about 20 inches of the light, fluffy new snow that falls at 14° F to equal 1 inch of rain. About 5 inches of the heavy, wet snow that falls right around freezing temperature would equal 1 inch of rain. A general rule many people use is that 10 inches of snow equals 1 inch of rain.

On average, precipitation equal to 27 inches of rain falls on Minnesota each year. This is three times as much as Nevada, which receives only 9 inches annually—but only a fraction of Hawaii's hefty 70 inches.

Because southeastern Minnesota is closer to the Gulf of Mexico than northwestern Minnesota is, it tends to receive more precipitation. Average annual rainfall equivalent in Minnesota ranges from 32 inches in the southeastern part of the state to 19 inches in the northwest. Most of the precipitation our state receives falls during May through September. Only 8 percent falls in the winter months of December through February.

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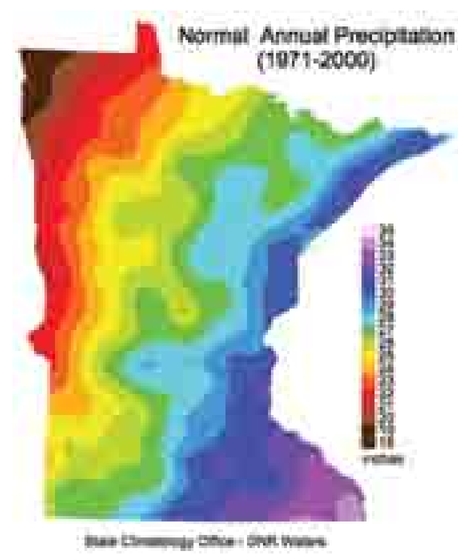
Hoarfrost on trees.



Weather vs. Climate. What's the difference between weather and climate?

Weather is what happens in a specific place at a specific time. Today the weather may be rainy, or windy, or cloudy, or cold. In addition to using words, we describe weather with specific numbers, such as temperature, atmospheric pressure, wind speed, and relative humidity. Weather can change quickly.

Climate, on the other hand, is the characteristics of the weather at a particular location based on many observations of weather over many years. The words we use to describe climate can be similar to the ones we use to describe weather—humid, or mild, or cold, or wet. The numbers we use to describe climate, however, are likely to be ranges or averages rather than "here and now" quantities.

So, if we say we have snowy weather, that means it's snowing. If we say we have a snowy climate, I may not need a shovel right this moment, but chances are good I will at some point!

Clouds. A cloud is a collection of water droplets clinging to condensation nuclei. As the water droplets gather, they create an opaque area in the atmosphere that we call a cloud.

Some clouds are big and billowy. Others are light and wispy. What makes clouds different? The answer has to do with the conditions under which they were formed.

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Clouds that are formed high in the sky—20,000 feet or more above the surface of the earth—are made of ice crystals and tend to be thin and feathery.

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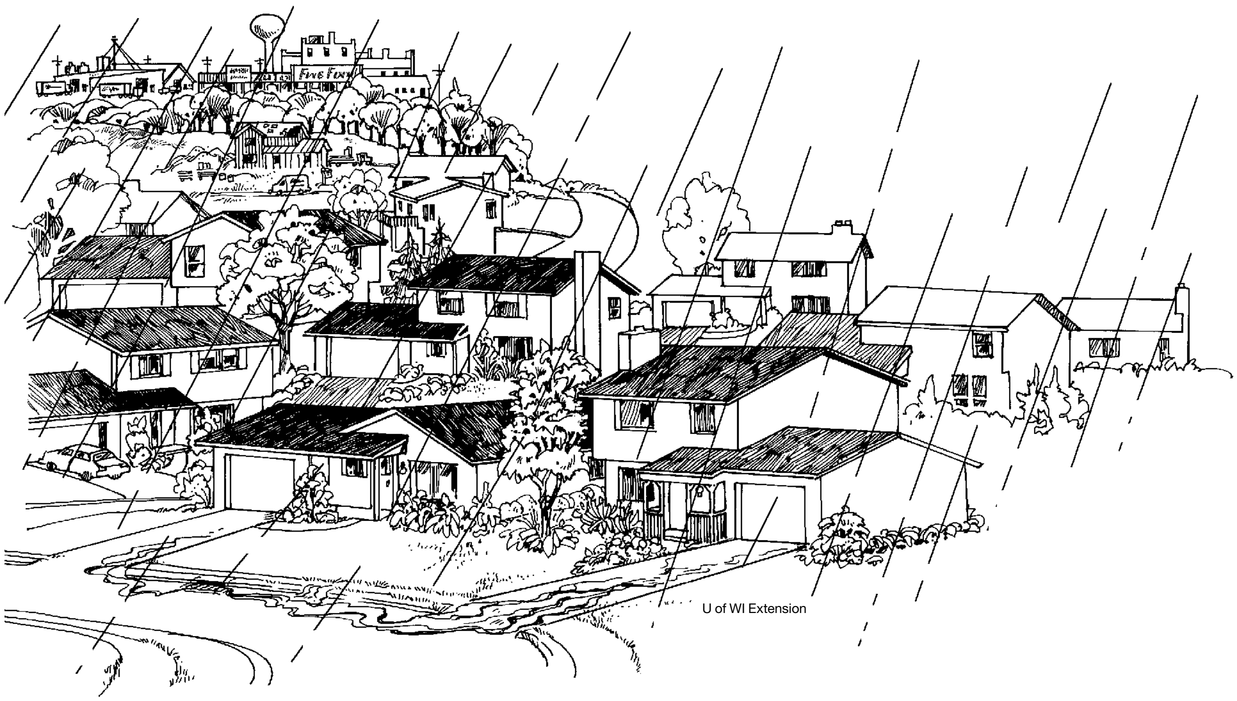
Clouds that are formed closer to earth are mainly water and have a more solid appearance.

Hydrology is the science of water and how it is distributed and moves in the air, on land, and in the ground.

Water in Transition

What happens to water when it leaves the air as rain or snow? Often it doesn't immediately soak deep into the ground or flow toward surface waters (and eventually the sea), but stops temporarily at a place in between—a snow bank, a puddle, a plant, or a person.

On land, variations in the Earth's surface can slow water's journey downstream. These variations give the water time to soak into the soil and supply moisture to the soil itself and to the groundwater system. Some of these features are natural, while others were built by people. Natural low points in fields and forests and manmade reservoirs and retention ponds gather water during storms and as snow melts.



Benefits of Shoreland Vegetation.

Riparian zones, or buffers, along the banks naturally consist of deep-rooting, flood-tolerant plants and trees that provide multiple benefits:

Bank stabilization

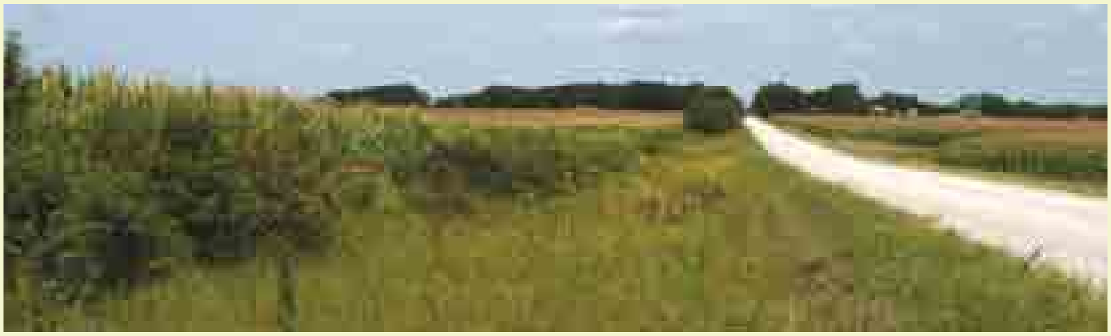
- Native riparian vegetation has dense, deep, intertwined root systems that physically strengthen soils.
- Riparian root systems remove excess moisture from the soil, making banks more resistant to erosion or slumping.
- Exposed root systems provide roughness that dissipates the water's erosive energy along the banks while the plant stems and leaves provide roughness during flood flows.

Water quality protection

- Vegetated buffers intercept and filter out much of the overland flow of water, nutrients, sediment, and pollutants; accordingly, wider corridors are more effective at protecting water quality and promoting ground-water recharge.

Riparian habitat benefits

- Diverse riparian vegetation provides shade, shelter, leafy or woody debris, and other nutrients needed by fish and other aquatic organisms.
- Wide, continuous, vegetated floodplains help dissipate flood flows, provide storage for floodwaters, retain sediment and nutrients, and provide shelter, forage, and migration corridors for wildlife.



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Links to Land. Where water travels once it hits the surface of Minnesota depends on the kind of surface it meets. Forests, wetlands, and vegetated croplands tend to absorb water. Impervious surfaces like roads, sidewalks, rooftops, compacted soils and bare rock shed water.

The amount of precipitation that soaks into the soil also depends on the time of year. Precipitation in July and August is more likely to be used by plants than to infiltrate into the soil. In the fall, after plants have stopped growing, more precipitation will soak into the ground rather than be pulled into the roots of plants. Precipitation that falls on frozen ground, snow, or ice, is not as likely to soak in as precipitation that falls on warm, permeable soil. As a result, a larger proportion of water that falls in winter is likely to run off into lakes and streams rather than soaking into the soil.

Living things can also slow water's journey downstream. In living things water performs many functions. It provides the hydrogen atoms that plants need to make carbohydrates during photosynthesis. It carries substances, like nutrients, from one place to another. It provides lubrication to help body parts move smoothly. It dissolves biological chemicals and helps them interact with each other. It moderates fluctuations in body temperature and dilutes waste products. Some water that enters living things is transformed into other kinds of molecules, and living things make some water out of other molecules.

Eventually water leaves living things. It might move on as molecules that evaporate from the surface of a plant or from the sweat of an animal—a process called **transpiration.** It might be part of the organism's fluids—sap, saliva, sweat, tears, and so on. One way or the other, it ends up in the atmosphere or as part of a body of water continuing the journey toward the sea.

On average, 76 out of every 100 drops of water that fall on Minnesota find their way back into the atmosphere, either evaporated or sublimated from the surface or transpired by trees, grass, and other plants.

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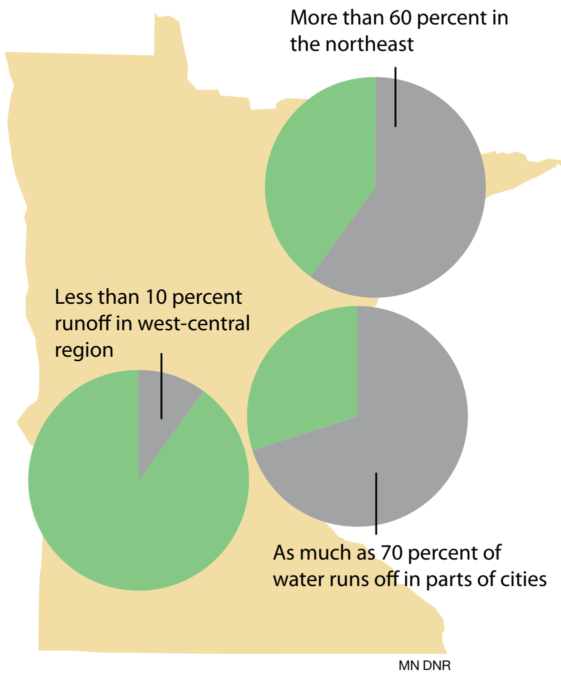
Running Water

Another 22 out of 100 drops of water that fall on Minnesota end up traversing the land in a pattern that is determined by rock, soil, and landforms. Statewide, the amount of annual precipitation that ends up running off the surface rather than soaking in ranges from more than 70 percent in parts of cities, to more than 60 percent in the steep, rocky, river-etched northeastern part of the state, to less than 10 percent in the flat, porous-soiled west-central region.



Some people brag about sports teams. Others take pride in cars or clothes. What gives Minnesota hydrologists big heads is our abundance of running water. All together, Minnesota has 69,200 miles of streams and rivers. End to end, they would stretch around the earth two and a half times!

When rain falls or snow melts, whatever doesn't soak into the soil or evaporate back into the atmosphere eventually moves to lower ground, drawn by the force of gravity. What starts as a drip turns into a trickle. As more water flows from across the landscape, the trickle grows into a small stream. Two streams may join to form a larger one. Eventually a major river is formed.

The Nature of Rivers

In the same way you might describe other people by their gender, the color of their hair, what they are wearing, their height, and so on, scientists describe streams and rivers by traits that vary from one to another. Traits used to describe rivers include:

- size, shape (sinuosity) and slope of the channel
- channel material (sand, cobble, boulders, bedrock)
- stream order (see side bar *2+1=2)*
- amount of dissolved oxygen and water temperature
- amount of nutrients and sediment being carried along or deposited
- discharge rate—the volume of water that moves through it in a specified amount of time.

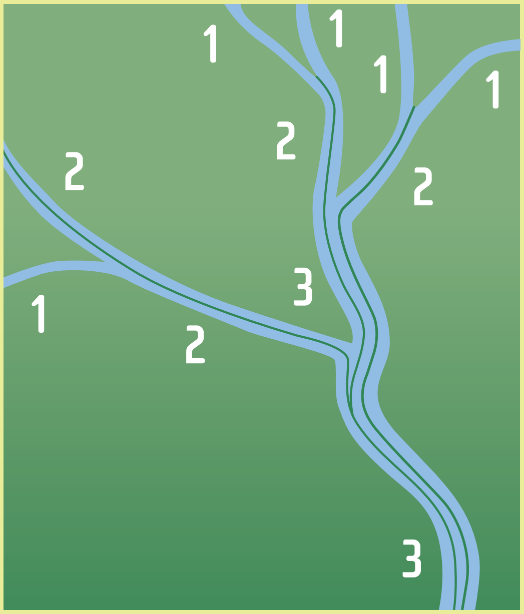
Depending on where you are in Minnesota, you may use different terms to describe the streams. For example, in a "flashy system" such as those found in southeastern and northeastern Minnesota (due to exposed bedrock and steep bluffs), water runs off the land and into the nearby stream quickly. The water rises and velocity increases rapidly and also retreats very quickly. This can cause flash flooding and erosion issues. Southwestern Minnesota, on the other hand, tends to have systems that are slower to respond, with gently rolling hills with deep glacial tills and more wetlands that store the water longer and recharge groundwater.

2 + 1 = 2. Streams and rivers are assigned a ranking called an "order" that describes their relationship to other streams and rivers flowing into them. Different things live in different stretches. The biggest rivers in Minnesota—the Red, Minnesota, lower Mississippi, lower St. Croix—tend to have stream orders on the range of 7 to 10. They move slowly.

To calculate stream order, follow these two simple rules:

1. If two streams of the same order meet, the stream they form together is one order higher (2+2=3)

2. If two streams of different orders meet, the stream they form together takes on the order of the higher of the two (2+1=2)



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Anatomy of a Stream

A body of flowing water is called a stream. Think of a stream you know. What is it like?

Your answer probably depends on which stream and even which part of the stream you are thinking of. The characteristics of Minnesota streams vary from one region of the state to another. In addition, the source of a stream, where water first gurgles from a spring or seeps from the side of a hill, is far different from the wide, mature river it becomes downstream. Not surprisingly, seasons and weather make a big difference, too. Most Minnesota rivers, for example, experience peak flows in spring as snow and ice melt into liquid water. Because of the timing of spring thaw, such peaks tend to occur in April for the southern half of the state and May in the north.

The science of lakes, rivers, wetlands, and other freshwater bodies is called **limnology.** By studying bodies of water, we can learn what conditions they need to stay healthy, and what we can do to help them.

What's In a Name? What's the difference between a stream and a river? How about a brook or a creek? Though the exact usage may vary from place to place, in general a **stream** is any natural waterway that contains flowing water at least some of the time. A *brook* or a *creek* is a small stream. A *river* is a large stream. Other names for running water used around the country include *kills, rills, cricks,* and *sloughs.*

Minnesota Rivers

Minnesota rivers are rushing and lazy, shallow and deep, clear and muddy, narrow and broad. Some are just a foot or two wide. Waters at the head of a river tend to be cool, fast flowing and clear. Those downstream tend to be warmer, slower and generally contain more sediment. In other words, different rivers—and even different stretches of the same river—have their own unique characteristics. The nature of those characteristics is related to many factors, including geology, biology, land use, topography, and time of year.

Along the Minnesota portion of the north shore of Lake Superior, where the state's highest point (Eagle Mountain, elevation 2,301 feet) is less than 15 miles from its lowest point (Lake Superior, elevation 602 feet), sharp drops and unyielding rock create narrow, steep slopes for water rushing toward the big lake and eventually the Atlantic Ocean via the Great Lakes. Exposed bedrock provides hard surfaces over which waters flow. As a result, features like rapids and waterfalls are common in rivers like the Cascade River and Baptism River on the North Shore of Lake Superior. Trout can be abundant in these steep, fast, channels with their cool water and high oxygen levels derived from the aeration effect of turbulence.

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Baptism River

To the west, on the border with North Dakota, the Red River of the North flows out of Lake Traverse and Mud Lake. This flat river runs along the Minnesota–North Dakota border with a vertical drop of just over 6 inches per mile. Ancient glacial Lake Agassiz created this extremely flat area that floods regularly. Floods provide the benefit of leaving behind rich, black soil for crops, but also create big challenges for those who live there, too.

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Spring flooding in Grand Marais Creek, 1 mile upstream of confluence with Red River.

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Dry August conditions in Grand Marais Creek.

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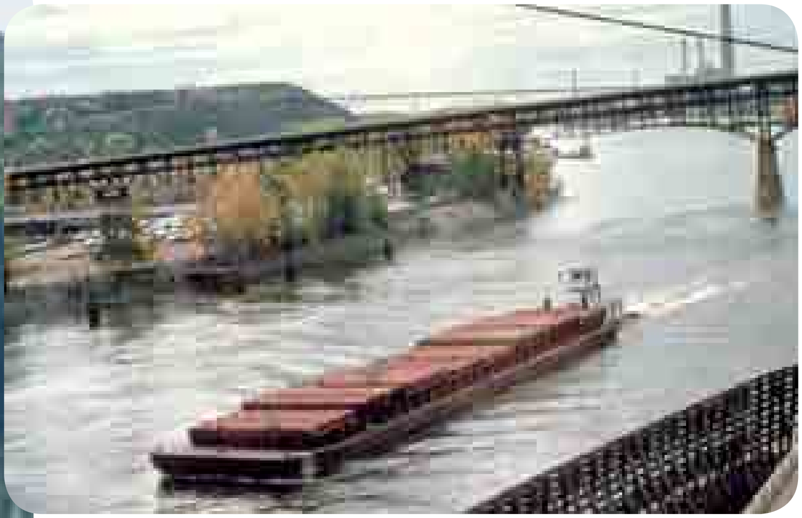
Minnesota River



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Mississippi River

In southwestern Minnesota, rivers often drain relatively flat land (rolling hills, glacial terrain), much of it agricultural fields with exposed soil. Four major rivers in this area, the Cottonwood, Redwood, Yellow Medicine, and Lac qui Parle, all drain into the Minnesota River, which in turn drains into the Mississippi. These waters tend to transport sediment and nutrients (such as nitrogen and phosphorus from fertilizer) into the Minnesota River and then into the Mississippi River. Many glacial advances and retreats left behind deep deposits of soil, called glacial till, good for farming. The streams can meander in a sinuous water course and down cut through this till, eroding banks and taking sediment downstream to the Minnesota River.

Land in southeastern Minnesota has been etched by rivers into hills and valleys. Along the Mississippi River, some bluffs stand hundreds of feet above the surface of the river. This part of the state is famous for its karst topography—landforms shaped by underground water etching through limestone and creating caves, sinkholes, springs, disappearing streams, and other irregularities above and below ground.

Karst topography is why this area has few lakes, but plenty of springs and beautiful, cold-water trout streams. It's also why water pollution is a particularly powerful threat in this area: Contaminants reaching surface or groundwater in one area can travel rapidly through the interconnected mazes of surface and groundwater to harm other waters far away.

Southeast Minnesota is famous for its karst topography.

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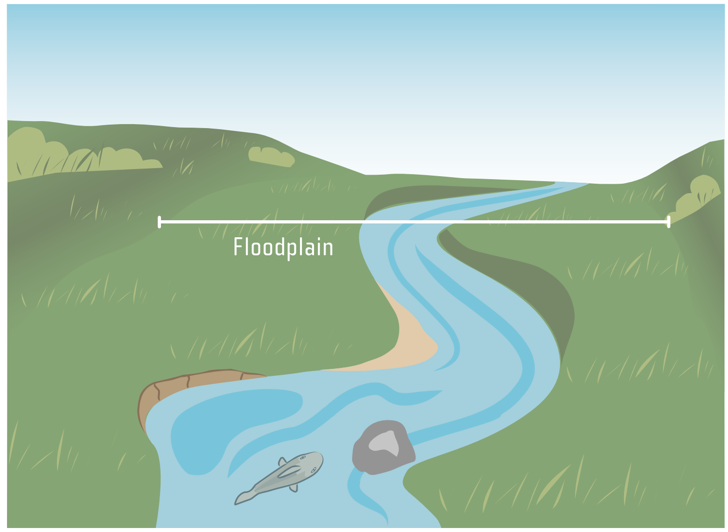
Trout Waters. Northeastern and southeastern Minnesota streams tend to have cool water with lots of dissolved oxygen, perfect conditions for trout. High oxygen content is due to two factors: the water temperature (cold water holds more oxygen than warm water) and the turbulence of the fast-flowing streams, which gives the oxygen in air opportunity to mix in with the water.

Overflow Lot



An important component of streams and rivers, but one we don't always think of, is the part they use only part of the year. Known as the **floodplain,** this area is the "overflow parking lot" for water rushing downstream during snowmelt or in times of heavy rain.

Floodplains are flat areas of land along the side of a river and vary in width depending on the geology of the area. They tend to have rich soil because of the nutrients deposited by floodwaters. They not only hold large quantities of water during flooding events, but also are home for many plants and animals. Their backwaters act as nursery areas for river fish. Rivers and their floodplains have a critical ecological relationship, and many plants and animals depend on the seasonal "pulse" of both flooded and low-water conditions.

Floodplains are often used as farmland and parklands. This land use allows the area to still flood and provide water storage when needed without causing damage to buildings and other structures. In drier times, floodplains can provide other benefits such as food production or recreation. For example, after the flood of 1997 many homes along the Red and Red Lake rivers in East Grand Forks were replaced with a greenway called the Red River State Recreation Area. As a result, flooding was transformed from a major property and safety threat in an inhabited neighborhood, to a natural regeneration of health and life to the riverside habitat whose inhabitants include river otters, bald eagles, and an abundance of warblers and other songbirds.

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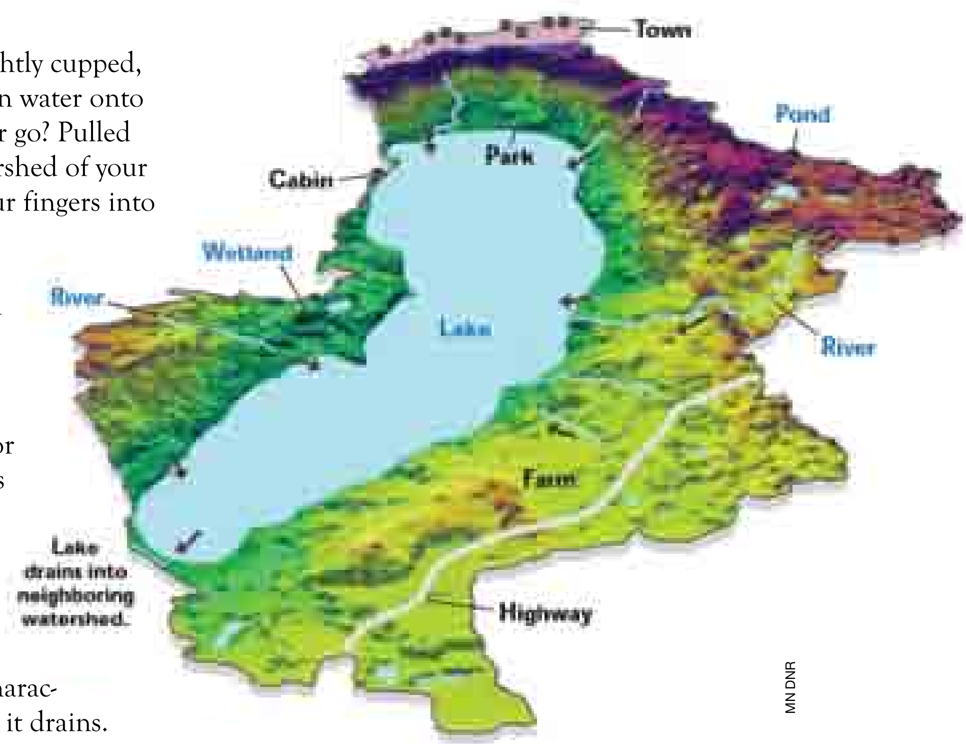
Red River Blues. One of the reasons the Red River in western Minnesota is so susceptible to flooding is that it flows north. When spring arrives, the more southerly upstream watershed thaws first, sending ice chunks and meltwater rushing into the still-frozen portions to the north. The result is a backlog of water and ice that disrupts the normal downstream flow of water, sending it out into the floodplain instead. Another major reason for the "Red River Blues" is the loss of wetlands due to agricultural drainage. This not only reduces the landscape's capacity to hold water in wetlands, but delivers runoff water more quickly through ditches and underground drainage. Minnesota is unusual in that very little water flows into the state. This means that our lakes and rivers for the most part are not recipients of water pollution from other states.

What Is a Watershed?

Hold out your hand palm up, slightly cupped, with your fingers tightly together. Run water onto your fingertips. Where does the water go? Pulled by gravity, it travels through the watershed of your hand, down the valleys shaped by your fingers into the "lake" of your palm.



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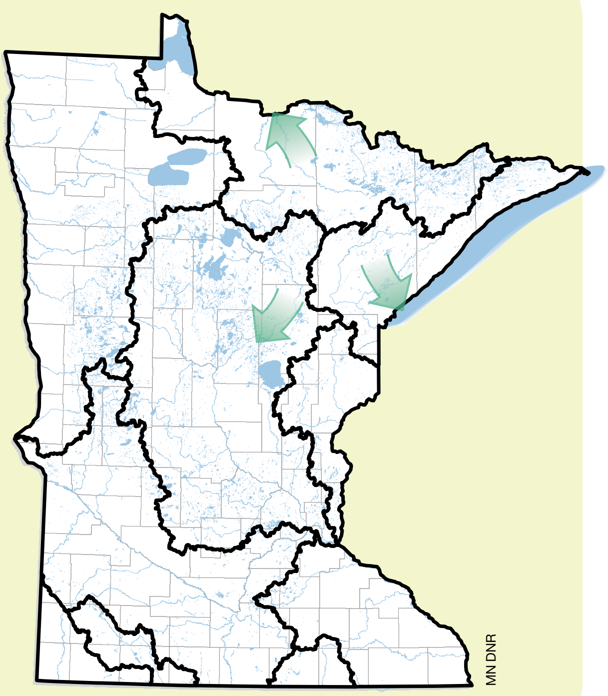
All of the land area that drains into a particular river or lake is called its **watershed.** The watershed creates a common connection among places on the landscape—the connection of contributing water to a specific lake or stream. Watersheds can be as small as the area around a pond or as large as hundreds of square miles that drain to a major river. Whether the land is bare or full of plants, flat or steep, rocky or boggy or something entirely different determines many characteristics of the water body into which it drains. If a lake's watershed includes peat bogs, the water entering into it will be stained with acids, giving it a rich brown color. If the watershed contains a lot of bare land, the lake at the bottom of the watershed may take in silt and soil, clouding the waters with suspended solids. If the soils in the watershed are rich in phosphorus, the runoff will act as a fertilizer for aquatic vegetation, and the lake will grow lush with plants and algae.

On a big-picture basis, water that falls in Minnesota flows through one of three large watersheds: north via the Red River to Hudson Bay, east via the Great Lakes and St. Lawrence Seaway to the Atlantic Ocean, or south via the Mississippi River to the Gulf of Mexico.

Hill of Three Waters. Minnesota is home to a rare water feature known as a triple divide where three major watersheds diverge. At a spot near Hibbing in the northeastern part of the state (Section 26, Township 58, Range 21), two major watershed divides, the Northern Divide and the St. Lawrence Seaway Divide, intersect. As a result, water runs in three directions—toward the Gulf of Mexico, the Gulf of St. Lawrence, and Hudson Bay. Ojibwe Indians are said to have called the site "Hill of Three Waters" and used it for council meetings. The site is now part of the Hull Rust Mahoning Mine—one of the largest operating open pit iron ore mines in the world. A sign at the Anchor Lake rest area, about 33 miles southeast of the site, describes the triple divide. In addition to being a notable landmark, it is now also an example of how human actions can alter the location and movement of water across the landscape on a large scale.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The Minnesota Department of Natural Resources (DNR) categorizes Minnesota watersheds at different scales—the three large watersheds are subdivided into progressively smaller watersheds to define areas of the landscape where water runs downhill, forming creeks and rivers. There are 81 major watersheds in the state, defined by the river into which they drain. Each of these major watersheds can be divided into minor watersheds that feed water to a particular **tributary** of that major river.

Every Minnesotan has a watershed "address." Your watershed address is defined by where the water that falls on you eventually flows. For example, the watershed address of a person living in Ely might be Burntside Lake, Lac La Croix, Rainy River, Red River, Hudson Bay. The address of a person living in Northfield might be Cannon River, Mississippi River, Gulf of Mexico.

Lakes

When you think of water, what do you think of? Many Minnesotans think of lakes. Lakes get their water from different a variety of sources. Some comes from rain, snow, and other forms of precipitation. Some runs off from the land surrounding the lake. Some enters from other bodies of water: streams, wetlands, or groundwater. Lakes whose main water source is surface water are called *drainage lakes.* Lakes whose main source is groundwater are known as *seepage lakes.*

With more than 10,000 lakes, it's not surprising that a few might have to share a name. The most common lake names in Minnesota, along with the number listed under that name on DNR's Lake Finder : Long (119), Twin (89), Mud (87), Island (87), Bass (85), Rice (84), Round (50), Spring (39), Horseshoe (33), and Johnson (21) .

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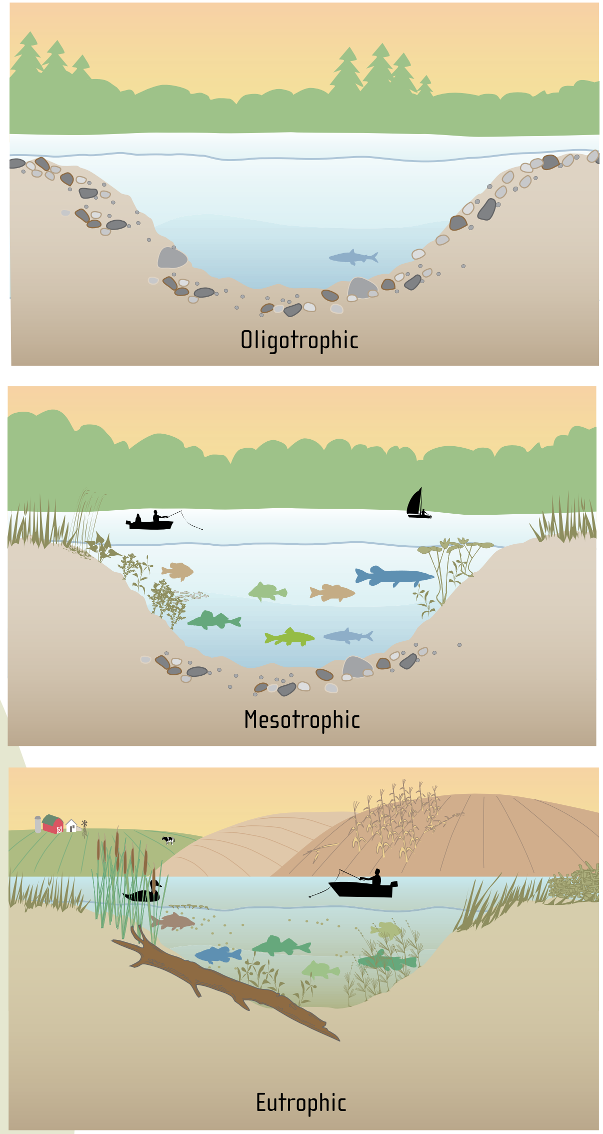
How We Describe Lakes

Like people and puppies, lakes come in many different varieties. Some are large, deep, and clear. Others are shallow and full of algae. Many are some combination of the two.

The character of a lake depends on many things, beginning with how the lake was originally formed and the kinds of rocks and soils that surround and underlie it. Some of the many factors that affect the character of lakes are: its size and shape, the climate, the plants and animals that live in the lake, and the extent to which human activity influences the lake.

One way limnologists (freshwater scientists) classify lakes is by how nutrient rich they are. Lakes with few plant-supporting nutrients are called **oligotrophic.** Those moderate in nutrients are called **mesotrophic.** Those rich in nutrients are called **eutrophic.** The nutrient status of a lake depends on many factors: including the age of the lake, the size of the watershed, size and shape of the lake, characteristics of the surrounding land, and the amount and nature of runoff and other human-generated inputs it receives.



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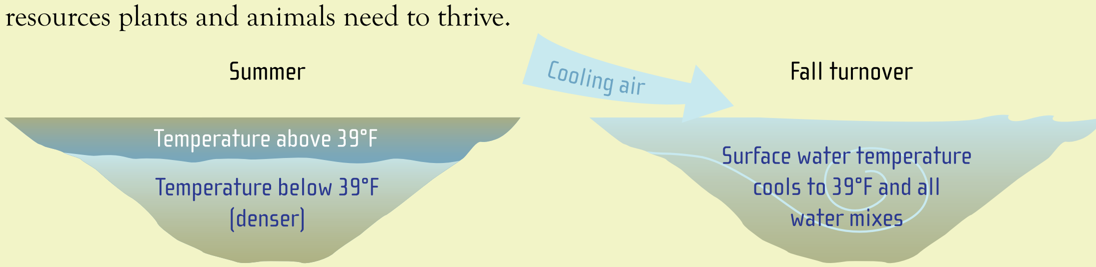
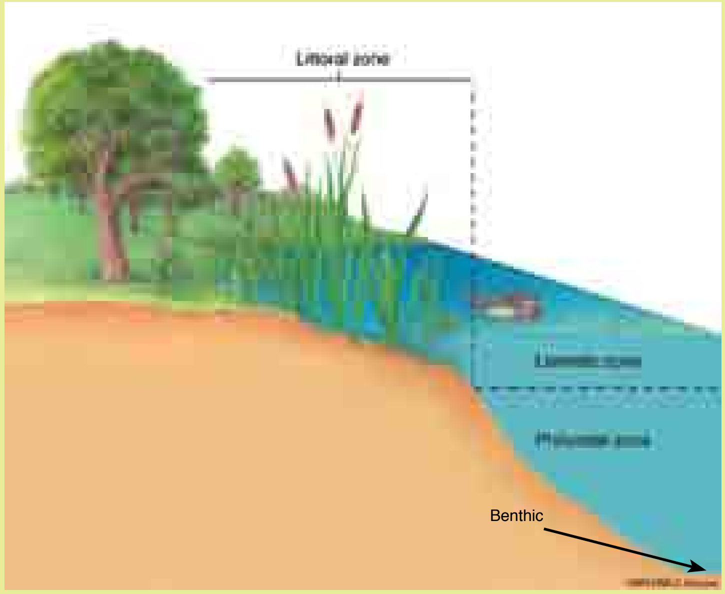
Layered Lakes. The fact that liquid water has different densities at different temperatures creates a fascinating phenomenon in many Minnesota lakes known as stratification. During the summer, the surface of the lake heats up. Because water above 39° F is less dense than water below 39° F, it tends to remain near the surface, mixed by the wind only with the water immediately below it. In the fall, cooling air causes the surface water to cool, too. As it does, it becomes heavier than the water below it and starts to sink. The water in the lake eventually mixes until it is all more or less 39° F, a process called the fall turnover.

During winter the water just under the ice is at freezing point—32° F. In spring, when the air warms, the ice melts and the surface water warms too. It eventually reaches 39° F and mixes with the water below it—creating a second (spring) turnover.

Spring and fall turnover help mix oxygen and nutrients through the lake, providing the resources plants and animals need to thrive.





Anatomy of a Lake. Just as lakes can be classified, parts of lakes are classified, too. One example is classifying by biological communities. The portion of the lake where light reaches all the way to the bottom is called the littoral zone. Rooted plants like wild rice and bulrush grow here, as do newly hatched fish, called fry.

Toward the middle of the lake, beyond the littoral zone, is the limnetic zone—the area of open water. Here fish and zooplankton such as daphnia and copepods thrive. Algae such as spyrogyra and cryptomonas capture the energy from sunlight. Below the limnetic zone, where insufficient sunlight penetrates for photosynthesis to occur, is the profundal zone.

The cold, dark bottom surface beneath the profundal zone is called the benthic zone. Invertebrates such as mussels and crayfish live here, nourished by detritus that floats down from above.

You can learn more about these zones of life in Chapter 4.

Another way lakes are classified is by how often the water within them turns over (see "Layered Lakes" sidebar). Some lakes, like Minnetonka in Hennepin County, turn over twice a year. These are known as **dimictic** lakes. Some, such as Mille Lacs, are **polymictic**—they mix many times over the course of a year. **Monomictic** lakes, including Lake Superior, mix one time per year. A few lakes are **meromictic**—they never mix completely. Deming Lake in Itasca State Park is an example of a meromictic lake. Relatively deep, with a small surface area and sheltered from the wind, it doesn't experience the conditions needed to mix all the way to the bottom.

Lakes also can be categorized by the kinds of substances that are dissolved in their water—which in turn is characteristic of the terrain that surrounds and underlies them. Lakes with a lot of calcium and magnesium are called *hardwater* lakes. Lakes with little of these minerals are known as *softwater* lakes. The hardness of a lake's water affects the impact pollutants have on it, as well as its ability to keep nutrients in solution where they can be used by plants.

Lakes Over Time

Minnesota lakes change markedly from season to season. In summer the water at the surface warms, plants are photosynthesizing rapidly. In winter the water cools and ice forms. The ice floats on top of the colder, denser water, reducing the exchange of gasses and heat between the water and the atmosphere. The ice provides a platform to hold snow, which covers and darkens the waters. With the changes in the environment, the location and proportions of living things changes, too. For example, in early spring and fall, **diatoms** are a prominent part of the phytoplankton. In early summer, green algae peak, and blue-green algae increase their populations in late summer. And, as every angler knows, where in the lake fish can be found varies from season to season as well.

Like people, lakes tend to change and grow old over time. Lakes tend to become shallower as soil and organic material wash in from the surrounding watershed. As the lake fills in, plants begin to take root beneath its surface, speeding the process. Under some conditions sphagnum moss creeps out over the water, and the open water surface shrinks. Eventually a lake may become a wetland and, ultimately, solid ground.

Minnesota's Lakes

Minnesota is widely known as the Land of 10,000 Lakes. But it's even better than that: According to the Minnesota Department of Natural Resources, the state is home to 11,842 lakes 10 acres or larger.

Why is Minnesota so rich in lakes?

Part of the reason is the amount of precipitation that falls here. Another reason is our state's geologic history.

Most of Minnesota's lakes formed as a result of the action of giant glaciers that shaped its surface tens of thousands of years ago. Some lakes were formed when a ridge of glacier-deposited material, called a moraine, blocked the flow of water. Others were created when water filled bowl-shaped depressions created by the melting of giant chunks of ice. An example of Minnesota lakes formed in this way is the Minneapolis chain of lakes (including Calhoun, Harriet, Lake of the Isles, and Cedar).

A few lakes were formed instead by the action of rivers. One example is Lake Pepin, a large bulge in the Mississippi River that formed when deposits of the Chippewa River partially blocked its flow downstream from its confluence with the St. Croix River. Other lakes are known as oxbow lakes. These lakes form when a river changes its course and leaves behind a pinched-off meander of

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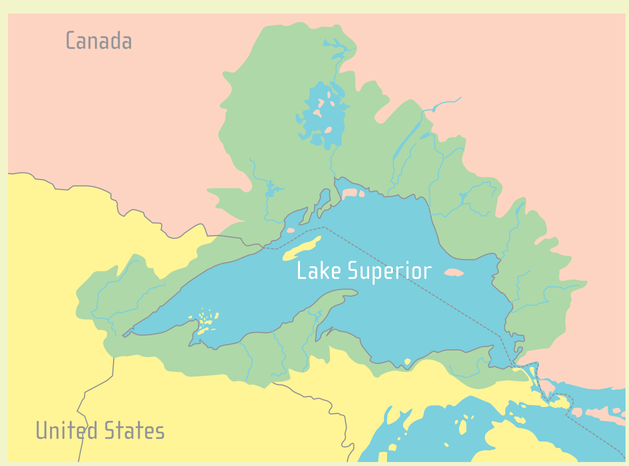
Satellite view of Minneapolis chain of lakes.

A Great Lake. Lake Superior, which forms part of Minnesota's eastern border, has the largest surface area of all freshwater lakes in the world at 31,820 square miles. Its volume is 2,900 cubic miles, and its shoreline covers 2,726 miles. Lake Superior holds 10 percent of all Earth's surface freshwater.



Explore Minnesota Tourism

Lake Pepin

itself. Big Logan, Little Logan, and Oxbow lakes in Aitkin County are all oxbow lakes, formed as the Mississippi River adjusted its course.

Some Minnesota lakes are formed by human action. Lake of the Isles in Minneapolis was just a shallow lake and wetland until engineers turned it into a 120-acre lake in the early 1900s. Pokegama Lake in Grand Rapids was created by a dam built across the Mississippi in the 1880s to control flooding. The Iron Range has lakes formed from water filling the pits left behind by iron miners. One of these, Portsmouth Mine Pit in Crow Wing County, is Minnesota's deepest lake, at 450 feet.

Ever since Minnesota lakes were formed, they have been slowly filling in with soil carried into them from the surrounding watershed. Some lakes are lined with 40 feet or more of sediment. Scientists use these layers of sediment to learn about the history of the area.

In northern Minnesota, lakes tend to be relatively clear, with few nutrients.

What Are Lakes Like?

Minnesota lakes are shallow and deep, large and small, nutrient rich and nutrient poor. In other words, our lakes vary a lot!

In northern Minnesota lakes tend to be relatively clear, with few nutrients. Lakes in the southern part of the state, where there is more nutrient-rich soil, more agriculture, and more human settlement, tend to have more nutrient inputs and thus more plant growth.

The color of the water in Minnesota lakes varies depending on other lake traits. Lakes with a lot of nutrients may be green from the algae that grow in them. Lakes with marl (a combination of clay, sand, and limestone) may appear turquoise. Some northern Minnesota lakes have brownish water. This color, called tannin, comes from materials produced when plants decompose in bogs. Also known as bog stain, the color is not harmful and is not an indication of poor water quality. It usually means there is a wetland in the lake's watershed.

Slice of Life. Do you enjoy a good story? Few are as detailed and fascinating as the ones the mud at the bottom of a lake has to tell. Scientists interested in learning the environmental history of an area extract long, cylindrical samples of sediment from the bottoms of lakes. By studying the physical and chemical properties and the remains of microscopic organisms and pollen embedded there, they can learn much about changes in the climate, pollutants, and other conditions through the millennia. Their science, called paleolimnology, is helping us to understand how Minnesota has changed in the past, how it is changing today, and how it is expected to change in the future as greenhouse gases and other human impacts alter the balance of nature.

CAREER PROFILE

Erika Rivers
Lakes Planner,
Minnesota DNR
Grand Rapids

Erika Rivers likes lakes, and she likes talking to people. As a DNR lakes planner, she spends a lot of time talking to people about how they can protect Minnesota's lakes by keeping the shoreline as natural as possible. Her work ranges from speaking at lake association meetings, to conducting research by surveying both people and lakeshores, and helping DNR revise shoreland rules.

"Minnesota is losing native habitat in and around our lakes and rivers at an alarming rate," Rivers says. "I encourage private shoreland homeowners, lake associations, and local government units to keep shorelands as natural as possible; to restore shorelands that have been altered by past development practices; and to enact shoreland ordinance protections that encourage native vegetation and minimize human impacts."

Rivers first became interested in shoreland protection after seeing native species disappear at the lake cabin she visited as a child. She encourages students who are interested in a career like hers to take lots of science and math classes in high school and both communication and science classes in college. She says a graduate degree is usually necessary for a natural resources career today.

Related careers:
community liaison,
extension educator,
natural resources specialist

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water connects all earth systems

Branching Out* (watersheds) MS – Maps of major MN watersheds.

Just Passing Through (erosion) EL, MS

Rainy Day Hike (stormwater pollution) EL, MS

Poetic Precipitation (condensation, precipitation) EL, MS

Stream Sense (stream study, inquiry, sensory observation) EL, MS

Water is a natural resource

Color Me a Watershed* (watersheds, mapping) HS – Aerial photos of MN major watersheds over time.

A Drop in the Bucket (global water distribution) EL, MS, HS

Great Water Journeys* (water ways) MS, HS – MN Water journey cards

Sum of the Parts (nonpoint source pollution) EL, MS

Water resources are managed

Back to the Future (analyzing streamflow data & floodplain planning) EL, MS, HS

Water resources exist within social constructs

Water Crossings* (rivers & history) EL, MS, HS – MN water crossings stories, maps.

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Watershed Address: Use a map to figure out your watershed address—starting at your school, show the path that a drop of rain would take on its way to the ocean. If it makes it all the way, how far does it travel? Invite students to think about what might happen to that drop of water along the way. In the spirit of *Paddle-to-the-Sea,* invite them to write stories describing the droplet's imaginary adventures as it journeys to the ocean.

Wet Calculations: Use water as a way to explore the application of mathematics concepts you are teaching. Are students practicing multiplication? Ask them to figure out how many water molecules are in a teaspoon, Converting units of measurement? Have them figure out how many liters of water are in Lake Superior.

Water Moving Mountains: Give younger students a chance to play with water and sand. If you pour a little bit of water onto of a mountain of sand, where does it go? If you pour a LOT of water onto a mountain of sand, then where does it go? With enough water and sand you can make rivers, lakes, groundwater, and even oceans of your own!

What's in a Name? Research the origin of the name of a lake or river near you. When did it get its name? Who named it, and why did they give it that name? Has it had other names?

Map Investigation: Distribute road maps of Minnesota to pairs of students. Ask each pair to think of a question about Minnesota's lakes or rivers they could answer using the map. Then have them use the map to find the answer to the question. Examples: Are there more lakes in northeastern Minnesota or in southwestern Minnesota? In which direction does the Mississippi River flow? How many cities and towns have the word "Lake" or "River" in their names? What proportion of the state's border is formed by water?

Roots of Water Words: Explore the ancient Latin and Greek roots of water-related terms and how those roots link them to other English, French, or Spanish words. What is the common connection between sinuosity, sinus, and sine? How about agua and aquifer? Hydrology and hydrant? Sediment and sedentary? Lac, laguna, and lagoon?

Out and About

Follow the Drop: Follow the water from your school roof as far as you can, then use maps and sources to find out the name of the major river through which it will travel.

Snow Gage: In winter months, keep a "snow gage" outside your classroom window. When it snows, measure the snowfall. Then bring the gage indoors and let the snow melt. Compare the ratio of snow volume to water volume for snowfalls at different temperatures. Is there a correlation?

Label Your Lake! If there is a lake within walking distance, visit it as a class. Use observation to learn as much as you can about it. Based on what they can see from shore, do students think it is oligotrophic, mesotrophic, or eutrophic? Can you characterize it and its watershed? Check the DNR website's Lake Finder or your local watershed district to learn more. Be sure to talk about water safety ahead of time and enforce water safety rules during your visit.

A few excellent resources:

1. Lake Finder Website, MN DNR. http://www.dnr.state.mn.us/lakefind/index.html The Lake Finder contains data for more than 4,500 lakes and rivers throughout Minnesota, including: lake surveys, lake depth maps, lake water quality data and lake water clarity data, satellite-based water clarity information, lake notes, invasive species information, and fish consumption advice.

2. Cooperative Stream Gaging Website, MN DNR & MPCA. http://www.dnr.state.mn.us/waters/csg/index.html This water data resource site provides access to near real-time and historical streamflow and water quality data.

3. Interactive map of Minnesota watersheds, United States Geological Survey. http://gisdmnspl.cr.usgs.gov/watershed/index.htm. This interactive web application displays the 84 major watersheds in Minnesota and allows users to zoom in and out to search minor watersheds and see maps and sizes of each.

4. Surf your watershed website, United States Environmental Protection Agency. http://cfpub.epa.gov/surf/locate/index.cfm This site allows you to look up any watershed in the nation to find community information like lists of local citizen based groups, water monitoring data, information on impaired waters, streamflow data, political boundaries, etc.

5. Google Earth, Google. http://earth.google.com/. Google Earth is a powerful web tool that lets students view any place on Earth via satellite imagery, maps, terrain. An excellent resource for watershed, land use and geography lessons.

6. Minnesota Lake Browser, University of Minnesota. http://water.umn.edu/lakebrows.html. This online, interactive lake water clarity mapping tool is based on satellite data from 1990, 1995, 2000 and 2005. Once you have found a particular lake, you can retrieve more detailed lake water information from the MPCA and DNR.

7. *Waters to the Sea CD-ROM,* Hamline University's Center for Global Environmental Education. http://www.hamline.edu/cgee/waters2thesea/. Virtual river journeys, led by historic guides, take you from prehistoric times up to the present. Videos, QuickTime VR movies, and engaging multimedia activities examine a variety of land-use themes in each watershed. Visits to a virtual water quality lab correlate land uses with water quality.

8. Healthy Rivers: A Watercourse, MN DNR. http://files.dnr.state.mn.us/assistance/backyard/healthyrivers/course/index.html An online interactive program designed to help students understand the ecology, management, and stewardship of river and stream systems. This multimedia tool includes photos, maps, animations, audio interviews, video clips, and excellent resources.

9. Watershed Assessment Tool, MN DNR. http://www.dnr.state.mn.us/watershed_tool/index.html. An online tool where students can access a large number of watershed data layers in a single mapping application and find summaries for the local watershed. Includes information on the ecological health of Minnesota's watersheds including scores and grades based on broad data inputs and models.

10. *Rivers: Make It Work* by Andrew Haslam (1997). This elementary level book explores rivers including diagrams, experiments, landscapes, maps, models, and projects.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

MN DNR

Chapter 3: Minnesota Waters—Wetlands and Groundwater

Key Concepts:

- Minnesota's wetlands and groundwater aquifers are numerous and varied
- Wetlands provide valuable functions in the water cycle: temporary storage, runoff filtration, unique habitats
- All of Minnesota is underlain by groundwater, held between grains of soil or in cracks within rocks and unconsolidated materials
- By studying wetlands and aquifers, we can learn things that help us keep them healthy—and keep us healthy, too!

LAKES AND RIVERS may be the most conspicuous bodies of water in Minnesota. However, plenty of water is to be found in two other less obvious but very important places: wetlands and groundwater.

Wetlands

Neither land nor lake, **wetlands** are defined as places where the soil is waterlogged at least part of each year. Characteristic suites of plants thrive in wetlands, and many wetland types are identified in part because of the plants that are present in them.

Minnesota is far soggier than most states. Before European settlers started draining the land for agriculture and urban development, 18.6 million acres of our spongy state were covered with wetlands. Today, some 9.3 million acres of wetlands dot the surface of the state. Most of those are found in the northwest, where vast acres of bogs and fens (types of peatlands) stretch for many miles.

Varieties of Wetlands

Wetlands vary widely from place to place, depending on the amount and chemical characteristics of the water present, the nature of the soils and topography, and the climate. Each wetland setting provides habitat for certain types of plants and animals.

Minnesota is far soggier than most states.

MN DNR

Seasonal wetlands are wet in spring after the snow melts but are drier during summer. Seasonal wetlands make great breeding grounds for frogs and other amphibians and resting places for waterfowl on their way north in the spring. In summer they may be dry enough to grow crops.

MN DNR

Wet meadows have soil that is often saturated with water—but not so much that water would often be above the ground surface. This category includes sedge meadows and some prairies. Wet meadows are wet in spring but tend to dry out over the summer because more water is used by plants in the warmer months. Sedges give wet meadows a "grassy" look.

MN DNR

Shallow marshes are nonforested wetlands where water may be up to 6 inches deep during the growing season. They are richly covered with emergent plants (which grow in standing water with stems emerging above the water surface) such as cattails, bulrushes, and arrowhead.

MN DNR

Deep marshes are similar to shallow marshes but soggier—6 inches to more than 3 feet deep during the growing season. They, too, feature abundant water-loving plants, including wild rice, bulrushes, and water lilies.

USFWS

Shallow open water areas provide important habitat for waterfowl and other living things. They are too deep and too permanent to host emergent plants, except around the edges, but aquatic vegetation such as pondweed, water lilies, and coontail will grow here. Prairie potholes are one example of this type of wetland. They dot much of the western Minnesota landscape, but many have now been drained for farming.

MN DNR

A **shrub swamp** is a wetland in which woody plants such as willow and alder thrive. Shrub swamps make superb habitat for many types of wildlife.

MN DNR

A **wooded swamp** is a wetland with trees. Because trees are sensitive to fluctuations in water level, and because water in wetlands can fluctuate dramatically, swamps may have dead as well as living trees. Wooded swamps often have open tree canopies and enough light reaches the ground to allow ferns, mosses, and other plants to grow in the moist soil. Hardwood swamps contain species such as black ash, red maple, and balsam poplar. Coniferous swamps may be thick with tamarack and cedar.

MN DNR

Bogs, a type of peatland, are wetlands in which partially decayed remnants of sphagnum moss, sedges, reeds and/or other wetland plants have formed a deep, spongy layer of organic material called peat. The water and soil in peat bogs are acidic. Plants found in bogs include sedges, cottongrass, and round-leaved sundew. Minnesota is home to a remarkable million acres of peatlands—more than any other state except Alaska. If you're interested in seeing one big bog, check out the 500-square-mile peatland in Big Bog State Recreation Area near Waskish.

MN DNR

Fens, another type of peatland, but with non-acidic water, are interspersed within the big bogs. They occur wherever groundwater interacts with the water at the surface to reduce the overall acidity of the peat. Plants found in fens include pitcher plant, bladderwort, and buckbean. Calcareous fens are a subcategory of fen that is very rare. Most calcareous fens are found in prairie settings apart from the other extensive peatlands.

Rare, Right Here. One of the rarest habitat types in the world is right in Minnesota's backyard. Known as calcareous fens, these odd wetlands form where groundwater constantly seeps to the ground surface with oxygen-poor, mineral-laden cold water. When the groundwater meets the oxygen in the air, reactions occur that lock nutrients away from the plants and that leave films of mineral deposits on the surface of the peat and on the plants themselves. Not surprisingly, it takes specialized plants to deal with those conditions. Those that can adapt, such as fen orchid, sterile sedge, grass of Parnassus, valerian, and small white lady's slipper, form communities that exist nowhere else. Calcareous fens are so rare—and the plants within them often so threatened—that Minnesota law specifically protects them.

Want to visit a calcareous fen? Three of the state's calcareous fens are located at DNR Scientific and Natural Areas: Seminary Fen SNA, Savage Fen SNA and Gully Fen SNA. Learn more at the DNR website.

Meadow Fern

Wanbun Fern

MN DNR

Fen Orchid

A Valuable Role

In the past, many people considered wetlands a waste of good land and a breeding ground for mosquitoes and other things they perceived as pests. In reality, wetlands play a huge and valuable role in the balance of nature and in keeping the natural systems we humans and other living things rely on healthy and whole. Wetlands:

- help control flooding by serving as a holding basin for water from heavy rains or snowmelt
- help slow runoff, reducing the loss of soil as water rushes toward streams and lakes, improving water quality
- provide valuable habitat and breeding grounds for amphibians, fish, other animals, and plants
- retain water on the landscape and release it slowly to other water bodies—reducing flooding when it's wet and providing moisture when it's dry
- contain plants that use up nutrients and keep them out of downstream lakes, resulting in less plant and algae growth
- have basins that trap sediment that has eroded from uplands, reducing sediment loads to streams and lakes
- add beauty and diversity to the landscape provide food for animals, including us! (Think cranberries and wild rice.)

What else do wetlands do? Add your own items to this list.

Groundwater

Out of every 100 drops of water that fall as rain or snow in Minnesota, as many as 20 can manage to seep down below the roots of plants and become **groundwater.** In sufficient quantities, the groundwater fills all of the spaces between soil particles and saturates the soil. Fill a drinking glass with sand. Now begin to pour water into the glass until it is half "full" of water. The sand in the bottom of the glass is saturated and while the top half may be wet, it is not saturated. The very upper surface of this saturated layer in the ground is called the **water table.** If you have ever gone to the beach at your favorite lake and dug a hole in the sand until there is water in the bottom of your hole, you have discovered the water table at that spot.

When precipitation is plentiful, water levels rise because more water is stored. Stored water, known as groundwater, moves from aquifers to lakes and streams through seeps, springs, and (thanks to humans) wells. Groundwater helps both natural systems and humans survive dry times. Minnesota is relatively rich in groundwater. However, the water beneath the surface of our state is not evenly distributed. The depth and abundance of groundwater varies from place to place.

MN DNR

What Is an Aquifer?

"Aquifer" comes from the Latin root words for "water bearer." Literally, an aquifer is water-bearing rock or sediment. An aquifer stores water and water flows through it because it is permeable. We can withdraw groundwater from an aquifer for human use, or it can seep out into lakes, streams, or wetlands naturally.

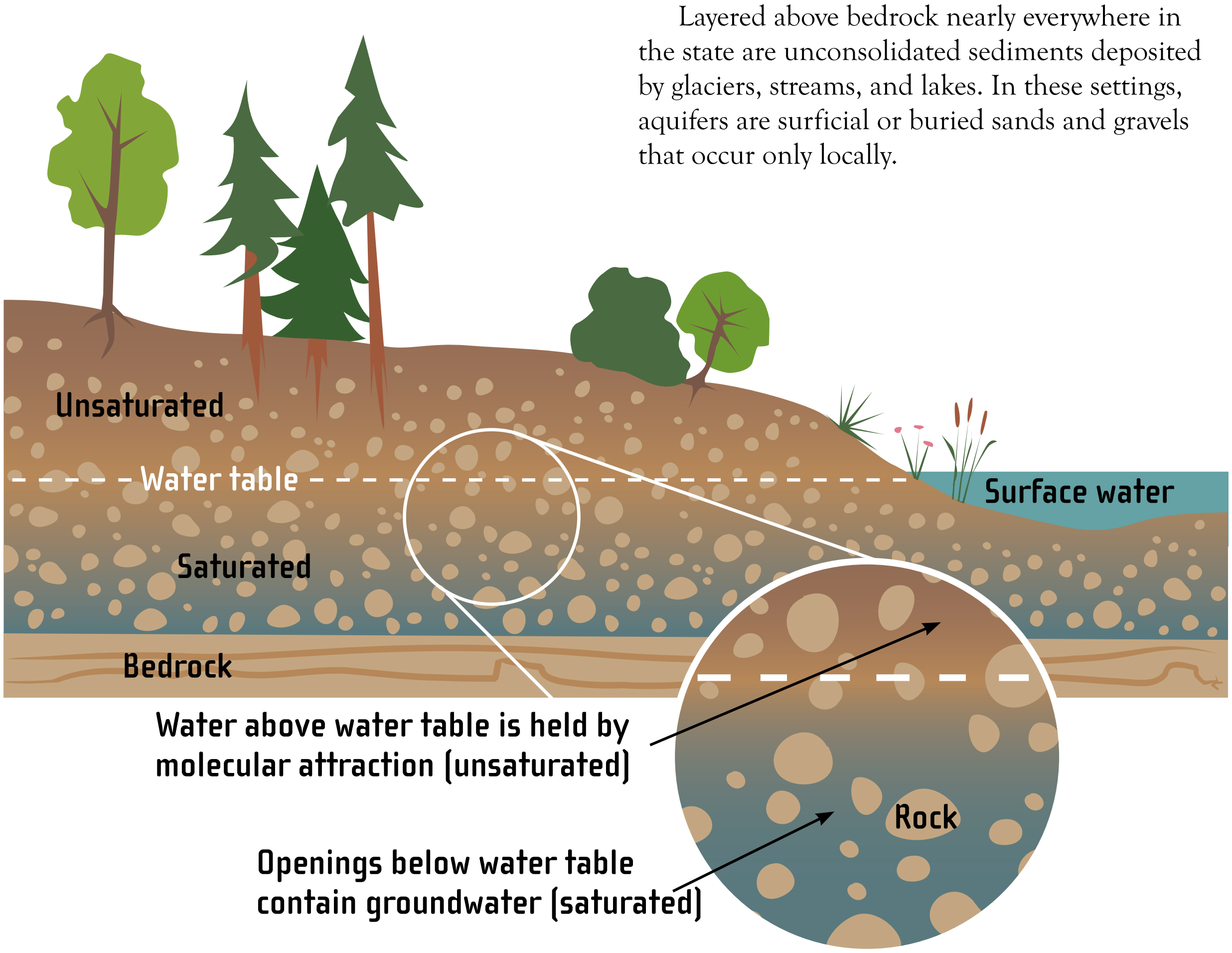
> Minnesotans extract more than 120 billion gallons of water each year from underground aquifers for household and industrial use.

Minnesota's Aquifers

Minnesota has bedrock aquifers and unconsolidated aquifers. Bedrock aquifers include a range of rock types, including igneous, metamorphic, and sedimentary, that have formed throughout geologic history. Water is stored in fractures or within pore spaces in what appears to be solid rock (e.g., St. Peter sandstone). Loose unconsolidated materials (sand, gravel, clay) deposited by glaciers, glacial meltwater, and present-day streams and lakes lie above the bedrock. Water in these unconsolidated aquifers is stored in pore spaces and may be much easier to find and withdraw.

In the southeastern part of the state, and underlying the Twin Cities, the bedrock aquifers include thick, continuous layers of sandstone and limestone that yield reliable, sufficient quantities of groundwater for municipal and private wells. Under most of the rest of Minnesota, the bedrock is igneous and metamorphic rock that has tight pore spaces and low permeability. Interconnected fractures may store enough water for human consumption. However, it may be hard to get much groundwater from these bedrock aquifers, and the water from them may be very high in dissolved minerals.

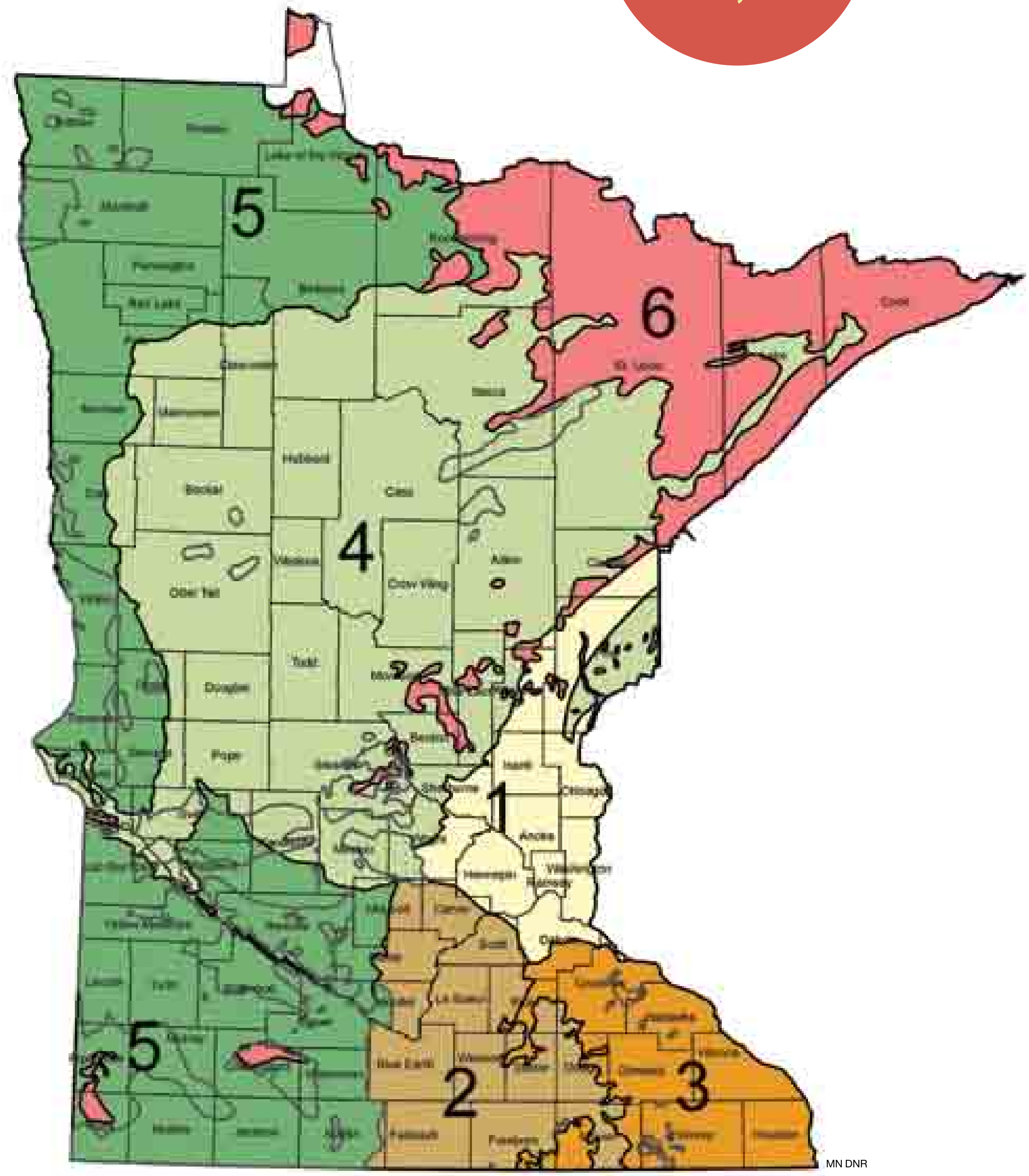
Layered above bedrock nearly everywhere in the state are unconsolidated sediments deposited by glaciers, streams, and lakes. In these settings, aquifers are surficial or buried sands and gravels that occur only locally.



Groundwater Provinces

Minnesota's bedrock and unconsolidated aquifers can be combined to make up six groundwater provinces—areas in which the source and availability of groundwater are similar. The six provinces are 1) Metro, 2) South-Central, 3) Southeastern, 4) Central, 5) Western, and 6) Arrowhead. They are defined by the nature of the bedrock and unconsolidated aquifers.

Wherever you are in Minnesota, there's groundwater beneath your feet.



MN DNR

Groundwater on the Move

Water moving into an aquifer is called recharge; water moving out of an aquifer is called discharge. Recharge is greater where there is more precipitation and where the soil at the surface is more permeable. An area with sandy soils in central Minnesota might receive 30 inches of rain, and as many as 6 inches of it might end up recharging the water table aquifer. An area with clayey soils in western Minnesota might receive 20 inches of rain, and in some years none of it will get past the plant roots into the aquifer beneath. Groundwater recharge occurs through streambeds and lake beds whenever the water levels in the surface water are higher than the water levels in the groundwater system.

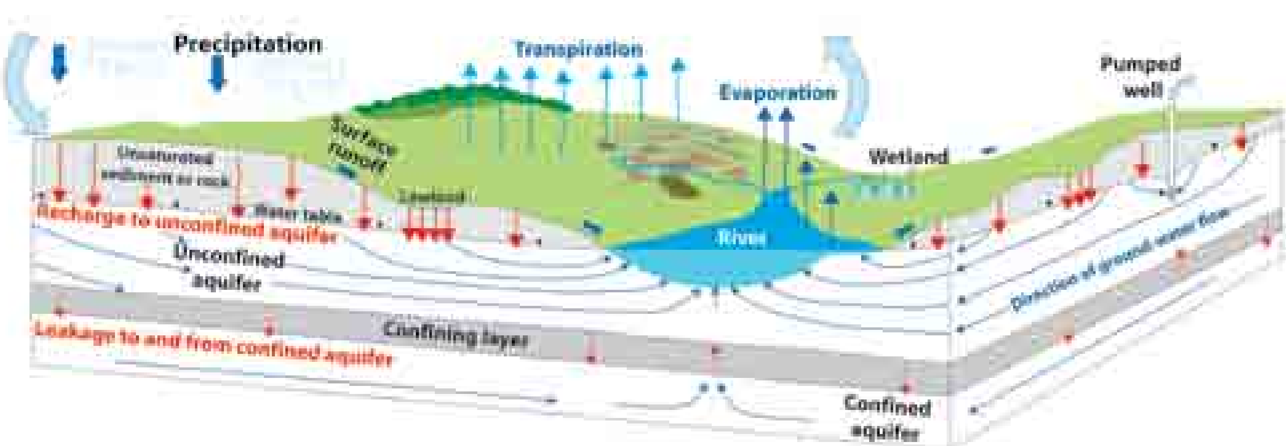
Water moves horizontally through an aquifer from areas of high head (high pressure) to areas of low head (low pressure). The rate at which the water moves through the aquifer depends on the permeability or interconnectedness of the pores or fractures. This rate is expressed in units of length over time (e.g., feet per day). In highly permeable aquifers such as coarse sand and gravel, water can move many feet per day. In a deposit of tight clay or shale where the space between the particles is much smaller, water may only move a few inches in a century. Such formations are not considered aquifers because they do not produce water. They are referred to instead as aquitards and generally restrict or confine the flow of groundwater.

Whether they are made of bedrock or unconsolidated material, there are two specific types of aquifers: unconfined (water table) aquifers, and confined aquifers.

Unconfined aquifers are directly connected with surface water and the overall water table mimics the surface of the land. Groundwater flows from areas of high topography to areas of lower topography where it generally flows out to surface water features such as lakes, streams, or wetlands.

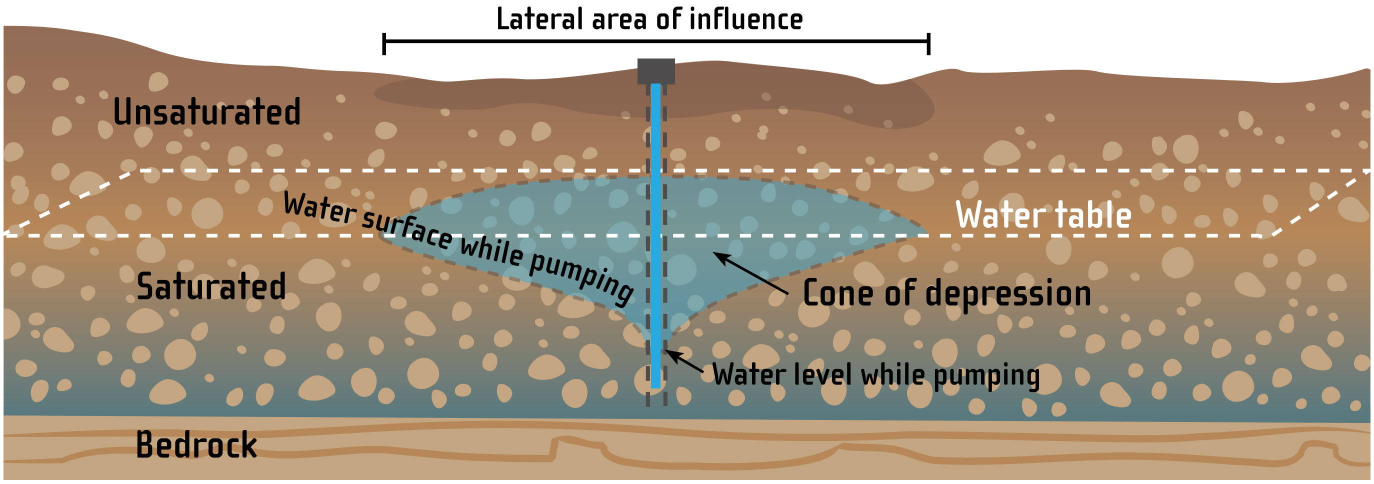
A **confined aquifer** is located beneath an **aquitard** or confining unit. The water that is stored in a confined aquifer is under pressure; if a well is installed, the water level in the well will rise above the top of aquifer to a level that equals the pressure in the aquifer. This elevation is called the pressure head. In a confined aquifer, water moves from areas of high head to areas of low head, which does not necessarily follow the topography of the land. Hydrologists use groundwater maps and conceptual models to determine the direction of groundwater flow.

More than 70 percent of Minnesotans use groundwater for drinking, bathing, washing clothes, and other household uses.



Source: USGS

If water is withdrawn from an aquifer at a high rate—say to provide water for irrigating extensive farm fields, or to provide drinking water for a city—the resulting low pressure will form a cone of depression around the well. The cone of depression will grow and draw more water from the area until there is enough water moving toward the well to match the pumping rate. The size of the cone is determined by the pumping rate of the well and the ability of the aquifer to move water (transmissivity.) As the water level in the aquifer is lowered around the well, it can potentially impact water levels in nearby wells and surface water features.



Caves. We've seen how water shapes the surface of the land, carving valleys and streambeds as it moves toward the ocean. Less visible but just as real is how it shapes what lies beneath. When water moves through limestone, dolomite, or sandstone underground, it can dissolve some of the rock, creating spaces known as caverns or caves. Throughout most of Minnesota, many such layers that existed have either been scraped off by glacial action or been buried by thick glacial sediments. But in southeastern Minnesota, which was not blanketed by the most recent glaciers, the layers of rock susceptible to cavern-carving still lie close to the surface. Signs that caves might be found in a particular area include springs, disappearing streams, and sinkholes.

MN DNR

Disappearing stream.

C A R E E R P R O F I L E

Jennifer Olson
Water Resources Specialist,
Emmons & Olivier Resources, Inc.
Oakdale

Can we build roads, houses, office buildings, and industrial parks and still protect the environment? Helping make sure water resources stay safe during development is something geologist Jennifer Olson does every day. When people decide to make a change to the landscape, they call on a water resource specialists like Olson or someone like her to look at the water resource in the area and help plan ways to protect it.

You might think Olson's job would involve getting her feet wet. But most days you're more likely to find her at a computer than in a creek. When a new project is proposed, she looks up information about water resources in the area, teams with colleagues to put together a water protection plan, then works with government agencies and others to turn the plan into reality.

"I've always been an environmentalist at heart, starting back when I was a little girl," Olson says. "I remember reading stories in National Geographic and thinking I wanted to do something that would make a positive impact on the environment."

To get where she is today, Olson pursued a college degree in hydrogeology and environmental geology. That gave her a solid understanding of science and of how water and land interact. She recommends that others interested in following in her footsteps get a good education both in science and in the social aspects of water resources. Also important, she says, is "a willingness to try new things, and a dedication to making a difference."

Related careers:
hydrologist,
engineer,
planner

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water is essential for all life to exist.

Life in the Fast Lane (wetland species needs) EL

People of the Bog (bogs, decomposition) MS, HS

Water connects all Earth systems.

Capture Store and Release (wetlands) EL

Get the Groundwater Picture (groundwater) MS, HS

Great Stony Book (geology) MS

Wetland Soils in Living Color (wetlands and geology) EL, MS, HS

Water resources are managed.

A Grave Mistake* (groundwater) MS, HS – case studies of Minnesota groundwater contamination.

The Pucker Effect (groundwater) MS, HS

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Charting Wetland Types: Work in small groups or as a class to develop "compare and contrast" charts for various wetland types. Based on research, have students identify traits that wetlands share, and traits that distinguish them from one another. Make observations on how and why they vary.

How Much Water Can it Hold? Use sponges to demonstrate the water-holding capacity of a wetland. Provide groups of students with a dry sponge on a plate and a water dropper. (Use a variety of sponges with different characteristics if possible.) Invite students to add water drop by drop to the sponge until it begins to pool on the plate. How many drops were they able to add before the sponge's capacity was reached? Where was the water? Why did it stay there instead of flowing through onto the plate? (Review traits of water from Chapter 1.)

Local Groundwater: Ask your local watershed district or soil and water conservation district for information about aquifers in your area. Is there an aquifer under your school? What is its name? What kind of aquifer is it? Where does it get its water? Where does water go when it leaves the aquifer?

Pore Space: Fill jar with rocks and ask students how much space is left. Pour in sand to fill up the spaces between the rocks and ask the same question again. Then pour in water, to show there is still pore space available. Help students see that groundwater exists in pore spaces between soils and rocks.

Where Does it Flow? Ask students where they think the water that lands on your school ultimately flows: into the Red River of the North, the Great Lakes, the Mississippi River, or the Missouri River. Use maps to figure out the correct answer.

Water Observations: For very young students, take a variety of items, such as a piece of plastic, a wooden plank, a pan with some rocks, and a pan with soil. Add a cup or two of water to each sample and have the students observe what happens to the water—does it run off? Form puddles? Soak in? Erode the objects? Have the students continue to observe changes for a day or two.

Out and About

Wetland Walk: Take a walk to a wetland near you. Discuss: What type of wetland is it? Where does the water in the wetland come from? Where does it go? What kinds of plants and animals live there? How does the wetland benefit your students and their families?

Perc Test: Have students contact a local septic system installer who performs "perc" tests (percolation tests) to demonstrate and explain his or her findings and why it's important to perform such a test before building on a site.

Groundwater Treasure Hunt: If you live in an area where the water table is fairly close to the surface, take a shovel out onto your school property and dig a hole until you hit water. (Be sure to check with the power company first!) If you have time, try various spots: high spots, low spots, spots near a drainage ditch or pond. Is water always the same distance below the surface? Are there any springs nearby? What would happen if you tried this another day? Be sure to get permission first, and fill in your holes when you are done!

A few excellent resources:

1. *WOW! Wonders of Wetlands*, ECI & The Watercourse (1995). Project WET's K–12 wetland activity guide, features more than 70 pages of background material followed by more than 40 activities. Available through http://projectwet.org or the Minnesota Project WET coordinator.

2. MN County Atlas Program, DNR. www.mndnr.gov (search "county atlas") This website offers maps and reports of the characteristics and pollution sensitivity of MN's groundwater.

3. Volunteer Water Monitoring Programs, Minnesota Pollution Control Agency. http://www.pca.state.mn.us/water/volunteer-monitoring.html This website provides information on several volunteer monitoring programs active throughout Minnesota, including lake monitoring, stream monitoring and wetland monitoring.

4. *America's Wetlands: Guide to Plants and Animals* by Marianne D. Wallace (2004). This book includes illustrations and descriptions to help identify wetland types, plants, and animals throughout the USA. The book provides a list of common and scientific names, detailed species information and maps.

5. Groundwater Flow Models, MN DNR and other local government agencies. An interactive classroom tool that is designed to show the flow of water and toxins though differing gradients. This "giant ant farm" can be used in front of the classroom and is easily used by students themselves. Used to demonstrate flowage through confined and unconfined aquifers as well as the effects of pumping on these aquifers. Contact the Project WET Coordinator to check out the model.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

MN DNR

Chapter 4. Life in Water

Key Concepts:

- Life in water has different opportunities and challenges than life on land
- Different bodies of water provide different settings for living things
- Characteristic communities exist for each water habitat type

From microscopic bacteria to fish that weigh as much as some fifth graders, Minnesota waters are home to a wide range of living things. As with things that live on land, the biodiversity—mix of plants, animals, and other living things found in aquatic habitats—varies dramatically from one place to another, depending on variables such as temperature, chemical characteristics of the water, depth, availability of sunlight, season, presence of other living things, and more.

A Different Life

Life in water differs from life on land in many ways. For example:

- Because water is denser than air, plants are able to stand upright with less cell-wall support than plants on land need. Animals, also, can get by with a less rigid infrastructure. Some, like the freshwater jellyfish, have a well-defined shape in water, but collapse into a formless heap when taken out of the water.
- Water is a wonderful transporter. It helps deliver nutrients to plants as well as deliver food to animals. A freshwater mussel, for instance, can stay in one place on the bottom of a river without running out of food. As water flows over its mouth, it filters tiny plankton from the current. Water also helps some animals reproduce. Fish and frogs release sperm and unfertilized eggs into the water. The water provides a medium for bringing the two together to start new life.
- Underwater habitats make it possible for living things to move vertically, as birds do when they fly through the air, rather than just along a surface, as mice and moose do as they walk on land.
- Because water has a high specific heat, plants and animals that live in water enjoy more moderate temperature swings than their terrestrial cousins.

Some Minnesota water plants, such as sago pondweed and coontail, have pockets of air in their tissues that allow them to float at the surface of a lake or pond.

Aquatic Communities

Just as different groupings of plants and animals are found in different habitats on land, various aquatic habitats harbor distinct communities of living things. Which creatures inhabit a particular portion of a lake, stream, or wetland depends on the many physical, chemical, and biological traits of the water body, including its size and three-dimensional shape of the water body; the temperature, acidity, clarity, and other traits of the water; the type of rock or soil underlying it; whether the water is moving or still; and what other things are living there. When you think of the diversity of combinations of these and related characteristics that occur across Minnesota, it's not surprising that aquatic communities are many and varied as well.

Although aquatic communities vary widely, they share one important trait with each other and with land-based communities: Energy flows through them in an eat-and-be-eaten network known as the food web. Roughly speaking, all aquatic life forms can be divided into five groups, depending on how they obtain their energy.

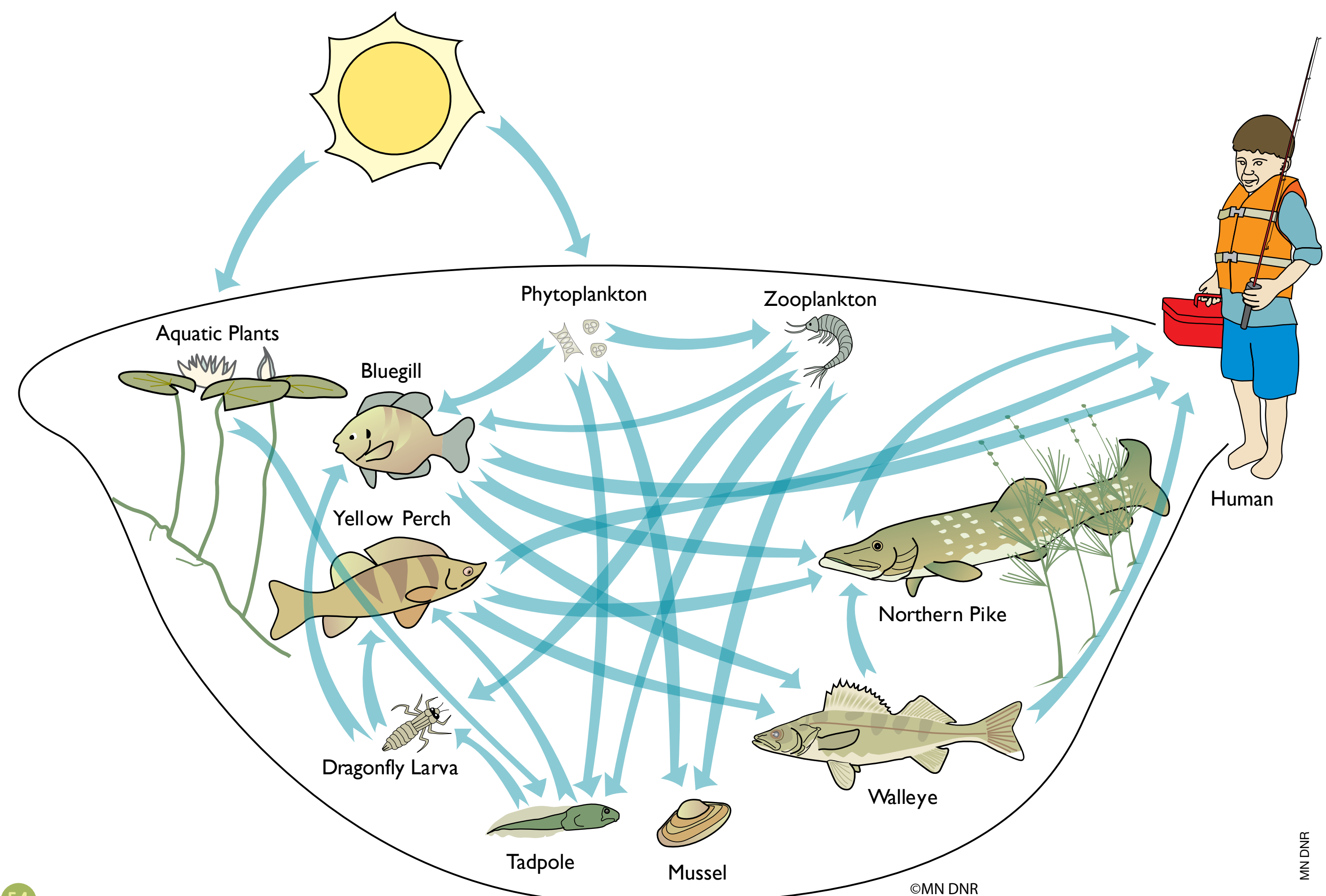
Primary producers are living things that capture energy from the nonliving environment—most often in the form of sunlight. Plants are the best-known primary producers. Other primary producers that provide energy to aquatic ecosystems include protists, such as chlamydomonas, and autotrophic bacteria such as cyanobacteria (blue-green algae).

Primary consumers are organisms that eat primary producers. Primary consumers common to Minnesota waterways include daphnia, fairy shrimp, tadpoles, and mosquito larvae.

Secondary consumers eat primary consumers. Minnesota examples include painted turtles, perch, and crayfish.

Tertiary consumers eat secondary consumers. Northern pike, loons, and otters are among water creatures that are tertiary consumers.

Decomposers are organisms that break down nonliving organic material (e.g., dead plants or feces) back into its constituent molecules. Aquatic fungi and some bacteria belong to this category.

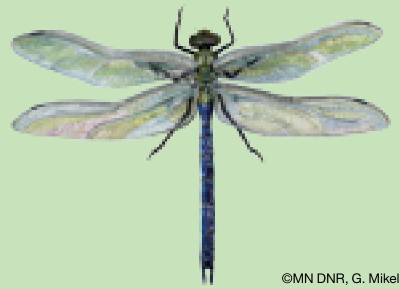


MN DNR

Life in Running Water

Imagine spending your days in front of a very large fan that is continually blowing you in one direction. That's a bit like what life is like for plants and animals that live in running water. As water rushes downstream, they either have to literally "go with the flow," or find a way to hold themselves in place.

Not Fish. When you think of river life, what comes to mind? Many people think of fish as the primary inhabitant of running water. In reality, however, insects are generally more abundant in Minnesota's running waters.



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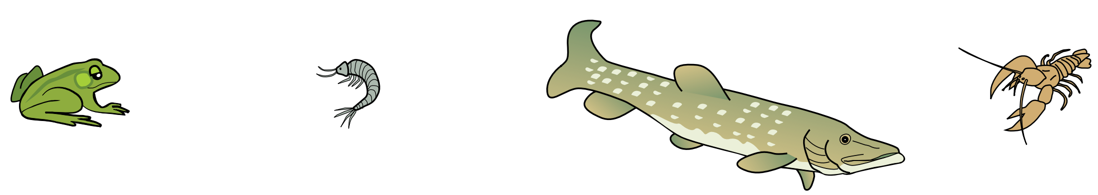
Rich Range

Running water is home to a rich range of living things. Some are tiny: Bacteria, phytoplankton, and zooplankton can be too small to see, or look like specks in a handful of stream water. Larger plants, macroinvertebrates, frogs, turtles, and fish are also part of the picture. All these life forms together can broadly be divided into four groups: floaters, drifters, swimmers, and sedentary life forms. Floaters and swimmers may travel with the water or propel themselves against it. Some, such as fish and tadpoles, have special shapes that make it easier for them to defy the current. Drifters, such as phytoplankton and zooplankton, more or less always go with the flow. Sedentary forms of life use gravity, hooks, and other structural or behavioral adaptations to anchor themselves in place. Some, such as black fly larvae, hold their own against the current by anchoring themselves to rocks. Others, such as crayfish, hide behind obstacles that deflect the flow. Mussels' streamlined shape helps them avoid tumbling downstream. Even suction comes in handy in the case of snails and leeches.

The quantity and specific types of living things in each stream varies with the physical and chemical characteristics of the stream. Particularly important are physical traits such as water speed and temperature, stream shape, water **turbidity,** and nature of the material on the bottom of the streambed. The fast-flowing brooks that arise in the Sawtooth Range along the North Shore of Lake Superior are home to a different mix of species than the sluggish streams flowing through farmland in the south, rich with sediment and nutrients. Large rivers are deep and wide, with plenty of habitat and productivity to support fish as big as the 70-pound flathead catfish that was caught in the St. Croix River in 1970.

Minnesota streams tend to show a gradient of increasing amounts of organic material and increasing biological productivity from the northeastern part of the state to the southwest. Thus, a southwestern waterway is likely to have a denser fish population than a northeastern waterway does.

Floaters Drifters Swimmers Sedentary life forms



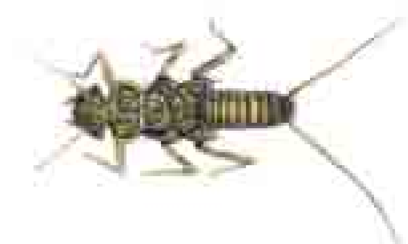
Macro-what? Benthic macroinvertebrates are animals without backbones that are large enough to be seen by the unaided eye and live in or on the sediment at the bottom of lakes, rivers, and wetlands. Many of them live in the bottom of waterways for just a portion of their life cycle.

Researchers pay attention to macroinvertebrates because they are excellent indicators of water quality. Some macroinvertebrates (caddis fly larvae, mayfly larvae, stonefly larvae) are intolerant of poor water quality and either move away or die off when the water isn't clean enough or cool enough. Other macroinvertebrates (midge larvae, giant water bugs, mosquito larvae) are tolerant of poor water quality and can survive well where others cannot. Monitoring how many of which types of macroinvertebrates live in a stream is a relatively simple way to track the stream's health. Researchers and volunteers worldwide collect, categorize and compare which macroinvertebrates they find in their local streams to track the water's health.

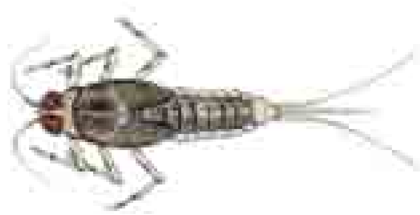
Macroinvertebrates are not only excellent indicators of water quality, but their alien features make them a tremendous hit in the classroom. Whether students are fascinated or squeamish, macroinvertebrates draw them in. A stream or pond study near your school or even just observing macroinvertebrates in the classroom is an excellent way to engage your students.

Caddis Fly Larvae

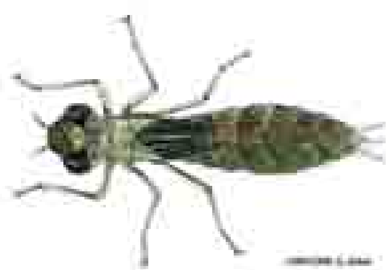
Stonefly Larvae



Mayfly Larvae



Dragonfly Larvae



Bryozoan Balls. If you're big on "ick," you'll be hard pressed to come up with a better creature to get to know than bryozoans. Found attached to rocks or docks in streams around Minnesota, these invertebrates form colonies that resemble lumpy balls of slime-beige jello. Among the oldest forms of life on Earth, bryozoans help clean the water around them by filtering out detritus and algae for food. Check it out on the Internet—or better yet, in a slow-moving stream or pond near you!

Along the Way

Just as physical and chemical characteristics vary from stream to stream, habitat varies along a stream's course, creating different mixes of creatures in different parts of the same stream. This idea of the existence of a gradation in habitat and biotic communities is known as the river continuum concept.

At the headwaters, water tends to move quickly and sediment loads are low. Because the stream is narrow, much of it may be shaded. These conditions make these waters great habitat for fish like trout that like cool water and need a relatively silt-free bottom surface for successful spawning. Nutrients flow in from the surrounding land.

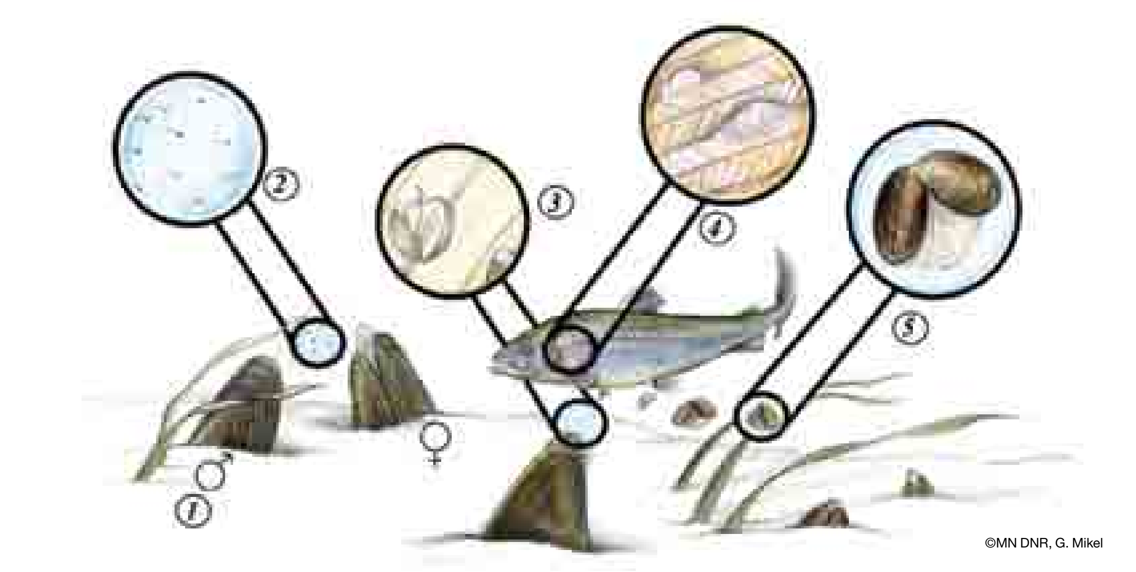
Midcourse, in what's known as the transfer zone, water carries sediment stirred up from upstream. By this point the water has collected a lot of organic material for filter feeders such as mussels to eat. Plant life tends to be rich in this part of a streambed.

In the lower part of a stream, called the depositional zone, water moves more slowly across a broader area. Sediments picked up by the river float along in the water, decreasing the availability of light to rooted plants. Fish in these stretches tend to be plankton eaters, such as carp and catfish.

Even within one part of stream living conditions vary. Fast-flowing waters are interspersed with pools and backwaters of relatively quiet water, each with its own unique habitat characteristics. The variety is valuable to living things; stretches of a river with diversity in structure and materials provide richer habitat than more homogeneous stretches. Riffles (stretches of more turbulent water) provide important habitat for young fish, mussels, insects, and other invertebrates that prefer them over more placid places. Trees along the edges of rivers provide welcoming shade to fish and invertebrates and help keep the water cool.

Mussels are easily harmed by habitat disruption, sediment, and chemical pollutants. Because of human activity, more than half of Minnesota's 48 native species of mussel have been extirpated or are listed as endangered, threatened, or of special concern.

Where Baby Mussels Go to Grow. Bottom-dwelling mussels lack the ability to move very far on their own. So how do they disperse? When it comes time to send their young out into the world, they enlist the aid of organisms with more mobility. A female mussel releases her young, called glochidia, into the water when a fish swims by. Some glochidia attach themselves to the fish's gills. When they metamorphose into juveniles, they fall off—potentially some distance from where their odyssey began.



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Life in Lakes

As is the case with rivers, biotic communities vary both from lake to lake and within a lake. The actual species that make up any one habitat depends on a variety of factors, including climate, **geomorphology,** land use, water depth, hydrologic history, and water chemistry characteristics such as pH and nutrient content.

Minnesota is home to 14 species of frogs and toads.

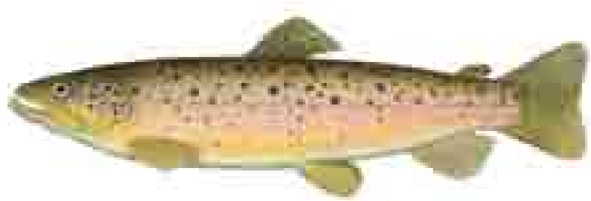
Lake to Lake

We saw in Chapter 2 that each lake has unique physical characteristics. In the same way, each lake has its own biological fingerprint as well.

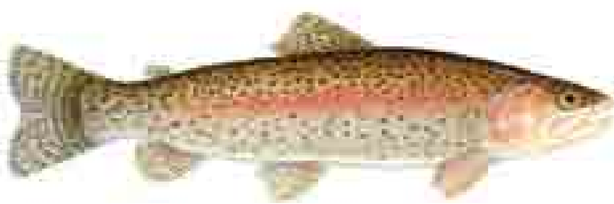
The clear, cool, deep lakes of northern Minnesota with their rocky shores have relatively few nutrients to support plant life and an extensive "dark zone" below which plants can't grow. Because of the coolness (cool water holds more oxygen than warm water) and the lack of demand for oxygen by plants, these lakes can support life forms such as trout that have high oxygen needs.

Because of geomorphology and land use, lakes in southern Minnesota tend to be shallower and more nutrient rich than those in the north. Vegetation is abundant, and fish and other animals are limited to those species that can survive in relatively warm, low-oxygen conditions. Clear Lake in Jackson County, for example, has a maximum depth of 9 feet and is rich with algae. Common fish in this lake include yellow perch, black bullheads, channel catfish, and freshwater drum.

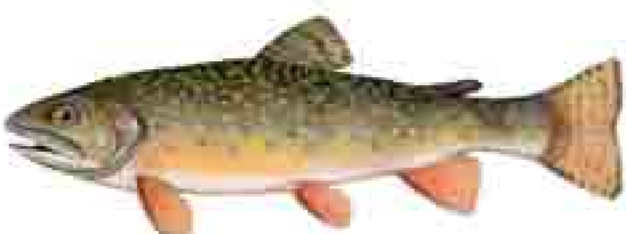
Example Cool Water Fish Species



Brown Trout



Rainbow Trout

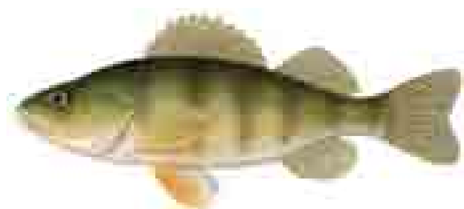


Brook Trout

Lake Trout

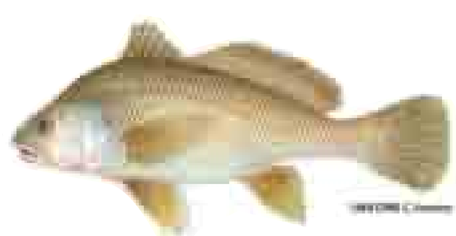
Example Warm Water Fish Species

Channel Catfish



Yellow Perch

Black Bullhead



Freshwater Drum

Littoral Zone

The littoral zone is the part of a lake where light reaches to the bottom. With abundant sunlight, nutrient input from land, and organic debris frequently stirred up by waves, the littoral zone is a riot of biological richness. Near shore, rooted emergent plants such as wild rice and bulrushes stand tall above the water's surface, providing shelter for ducklings, young fish, tadpoles, snails, and other invertebrates. Insects and insect larvae swim at or below the surface or cling to plants, providing abundant food for the larger animals. In some lakes, snapping turtles lurk near submerged objects, waiting for pretty much anything that looks like a meal to float or swim by.

One of Minnesota's more famous lake occupants is the common loon, *Gavia immer.* Some 12,000 loons spend the summer on our lakes, torpedoing beneath the surface in pursuit of perch or bluegills or perched high on a bundle of dried grasses waiting for eggs to hatch. Their solid bones help them dive, and their red eyes help them see underwater. Loons are well known for the haunting sounds they make as they call to one another or announce their territory. They are unusual among birds in that they are better adapted to aquatic life than they are to terrestrial life, with legs so far back on their bodies that the best they can muster on land is an ungainly waddle. The loon was named the state bird of Minnesota in 1961.

Slippery Stuff. If you've ever had to pull a littoral-zone plant off your fishhook, you may have noticed that parts of it seem particularly slimy. The slime is not part of the plant, but a whole world of other plant and even animal species living on it. If you had a microscope, you could find a variety of one-celled and multiple-celled creatures comprising the slime.

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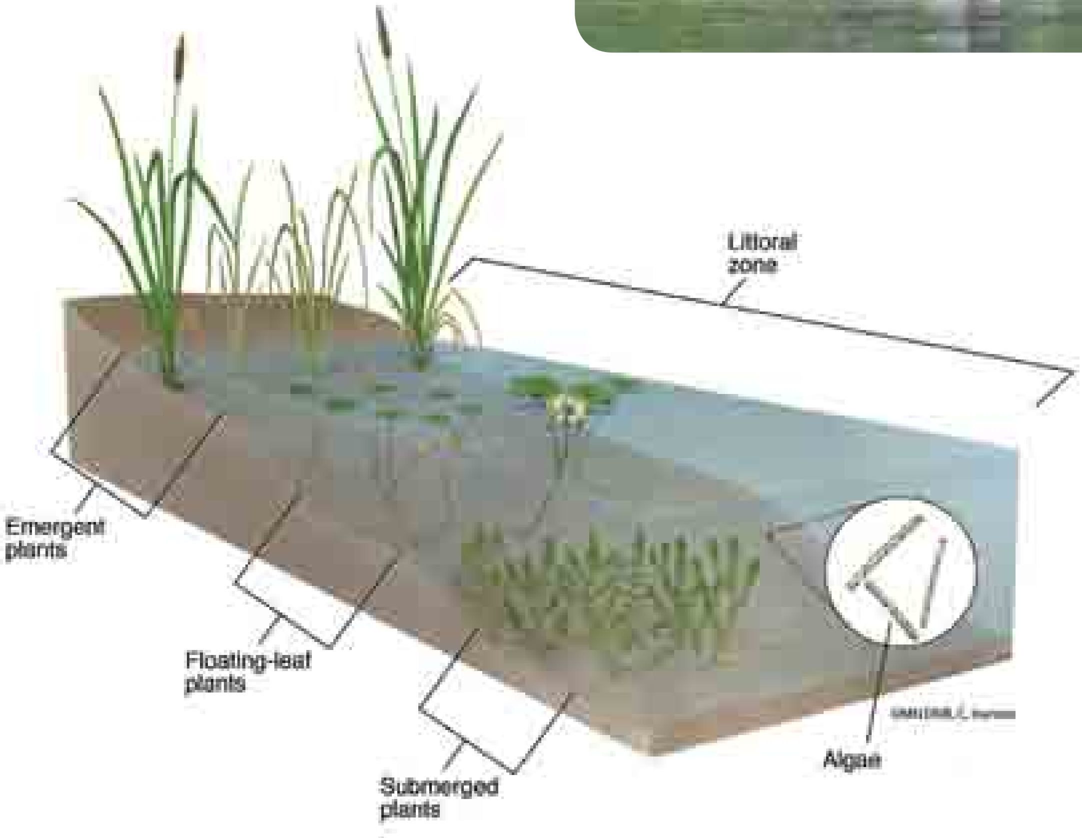


Limnetic Zone

The limnetic, or open-water zone, begins where the water becomes deep enough that light does not reach the bottom. Vegetation found in this zone is floating rather than attached to the bottom of the lake.

Fish are well-known occupants of the limnetic zone. Which fish live in which lakes, and in which parts of lakes, varies dramatically with traits of the fish and traits of the lake. *Oligotrophic* lakes—lakes with clear, cool water—for example, can support trout. Lakes with more nutrients, known as *mesotrophic* lakes, are better suited for walleye, perch, northern pike, and their kin. *Eutrophic* lakes, rich with nutrients, support crappies, large-mouth bass, sunfish, suckers, and carp.

The limnetic zone is also home to plankton, microscopic plants and animals that thrive in a myriad of forms and under a myriad of conditions. Plankton show interesting variations in abundance and location over time. On a daily basis, some undergo a vertical migration, rising upward in the water column during the day and dropping down toward the bottom at night. Over the course of a summer, the types of plankton ebb and flow as well, with diatoms dominant in spring, green algae prevailing in June and July, blue-green algae peaking at the end of the growing season, and diatoms once again emerging in late fall.

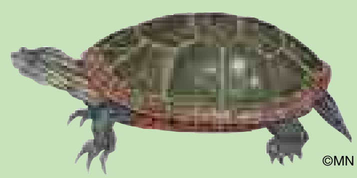
Diatoms

Profundal Zone

The profundal zone is the area of open water below which not enough light penetrates to support photosynthesis. Even though it is by definition a dark place, the profundal zone is not lifeless. Fish and zooplankton thrive here, nourished by nutrients washed into the lake or captured by the algae above.

Benthic Zone

The benthic zone is the bottom of the lake. Invertebrates thrive here, nourished by the rich rain of energy-bearing dead creatures, waste products, vegetation, and other materials carried down through the water column. Examples of animals living at the bottom of Minnesota lakes include mussels, dragonfly nymphs, worms, and bottom-feeding fish.



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Buried Alive. In the fall, painted turtles dig their way into the muck at the bottom of a pond or lake. They remain there, buried alive, until changes in the water above them signal that spring has arrived.

Ducks, Snails, and Itchy Swimmers. Many a Minnesotan who has enjoyed a swim on a warm summer's day has ended up with a close encounter with Schistosome cercariae, one of our less welcome water inhabitants. *S. cercariae* is a tiny flatworm that lives in the digestive tract of waterfowl and other animals that inhabit lakes. The flatworm's eggs are shed in the host animal's feces and hatch in the water into young called miracidia. The miracidia are picked up by snails that inhabit shallow water. Inside the snails, the miracidia morph into another form called cercariae. After several weeks, the cercariae leave the snail in search of a host for their adult phase. If a cercaria happens to be in a water droplet attached to you as you leave the lake, it will try to burrow into your skin to survive as the droplet dries. Your body's immune system will quickly kill it, leaving you with an itchy red spot at the scene.

Swimmer's itch is most common in late June and early July. You can minimize your chances of a close encounter by not attracting waterfowl to your swimming area, not swimming in shallow water when the wind is blowing toward shore, keeping beaches clear of debris that harbors snails, and toweling off briskly when you leave the lake.

Life in Wetlands

Just as there are many kinds of wetlands, there are many kinds of plant and animal communities that inhabit them. In wetlands where there is standing water, the species might be similar to those found in the littoral zone of a lake—small fish, cattails, water lilies, snails, and a variety of plankton. Cold, acidic bogs harbor a unique mix of plant species adapted to thrive under the unique conditions they present, such as sphagnum moss and pitcher plants.


MN DNR

Pitcher plant.

Wetland Plants

Wetland plants have it made when it comes to water and nutrients. Both are found in abundant amounts in these soggy habitats. But wetland plants also face special challenges. The waterlogged soil in which they are rooted has little oxygen, so survival demands adaptations that reduce the oxygen needs of roots or help them obtain it from somewhere other than the pores in the soil. Many wetland plants have special airspaces in their tissue that allow oxygen absorbed above water to travel to submerged tissues, including roots.

Sphagnum moss, of course, is the iconic species in peat bogs. It may be accompanied by tussock cottongrass (a sedge) or by a variety of broad-leaved plants. An interesting type of adaptation that has evolved in several bog plants is the ability to trap and dissolve insects and other tiny animals. Bladderwort, sundew, and pitcher plant all have special structures that allow them to attract and capture prey, then dissolve it and extract needed substances from the remains. This trait is commonly found in habitats low in nitrates and ammonia, nutrients plants need to grow.

A number of Minnesota shrub and tree species have adaptations that allow them to thrive in wet habitats. Willows, with their flexible branches, can stay standing in the face of the ebb and flow of changing water levels. Black ash, black spruce, and tamarack have adaptations that allow them to tolerate substantial moisture in the soil. As in other habitats, what grows where is linked to physical, chemical, and biological traits of the setting. Northern white cedar will grow in a wetland with rich, high-pH (basic) soil for instance, while tamarack is more likely to be found on acidic soils that have a low-pH and lack abundant nutrients.

Black Spruce


MN DNR

Wetland Animals

The abundant vegetation of wetlands is attractive to animals that eat plants—and as a result, to the animals that eat plant-eaters as well.

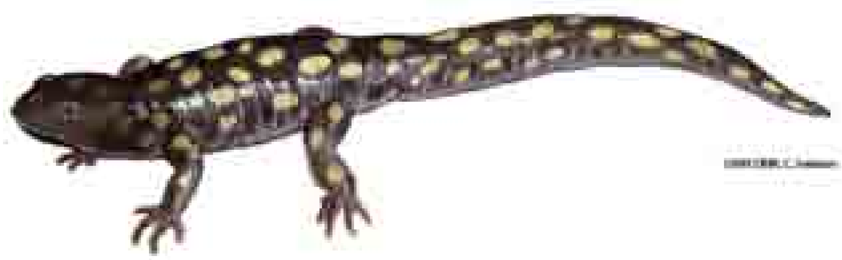
Many kinds of birds spend time in wetlands. Ducks, geese and swans use them for nesting during the summer and for resting on their spring and fall migrations. Grebes, herons, and other long-legged birds spend their days fishing among the vegetation with their long spearlike bills.

Perhaps the most common wetland bird species is the red-winged blackbird. Found in abundance throughout the United States, this bird nests among emergent vegetation. Its distinctive "conk-a-reeee" song is often one of the first signs of spring in Minnesota.

When it comes to mammals, muskrats are probably among the most abundant in Minnesota wetlands. These water lovers not only eat cattails and other wetland plants, they also build their homes out of them. Muskrat lodges have been found up to 9 feet in diameter.

Smaller animals commonly found in Minnesota wetlands include tadpoles, dragonfly larvae, fairy shrimp, snails, clams, salamanders, and snakes.

Tiger Salamander



Red-winged Blackbird

MN DNR

Sandhill crane colt.

WI U of M, Extension Service

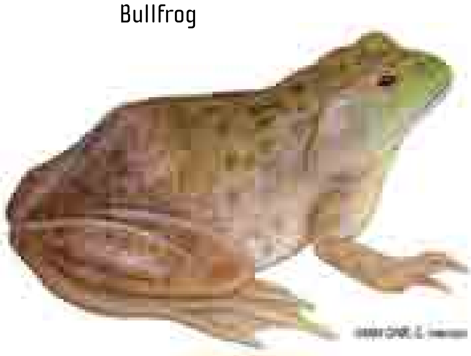
Land Life Meets Water

Plants and animals that spend all their time in the water are most intimately associated with lakes, rivers, streams, and wetlands. But creatures that spend time on land use bodies of water in many ways, too. In fact, riparian areas (the land along rivers and lakes) are among the richest of all habitats. Moose, ducks, osprey, raccoons, otters, loons, herons, and many other birds and mammals forage for food in lakes and rivers. Salamanders, frogs, dragonflies, and other insects use them as breeding grounds. Some turtles and amphibians winter in the mud at the bottom.

Birds use lakes and rivers as navigational aids when migrating. Hawk Ridge in Duluth sees a remarkable concentration of raptors each fall as south-migrating birds encounter Lake Superior and funnel down its shore to the southwestern corner. More than 300 species birds use the Mississippi River as a navigational highway. Four out of every 10 waterfowl in North America migrate south along this river.

Beavers have a particularly interesting relationship with waterways: They not only benefit from them, but dramatically alter them, too. Beavers cut down trees with their teeth and use the logs and branches to build dams across flowing waters, creating ponds on which they build their lodges, also made of cut-down trees. A beaver dam can be 100 feet long. Some dams are taller than a person!

Bullfrog



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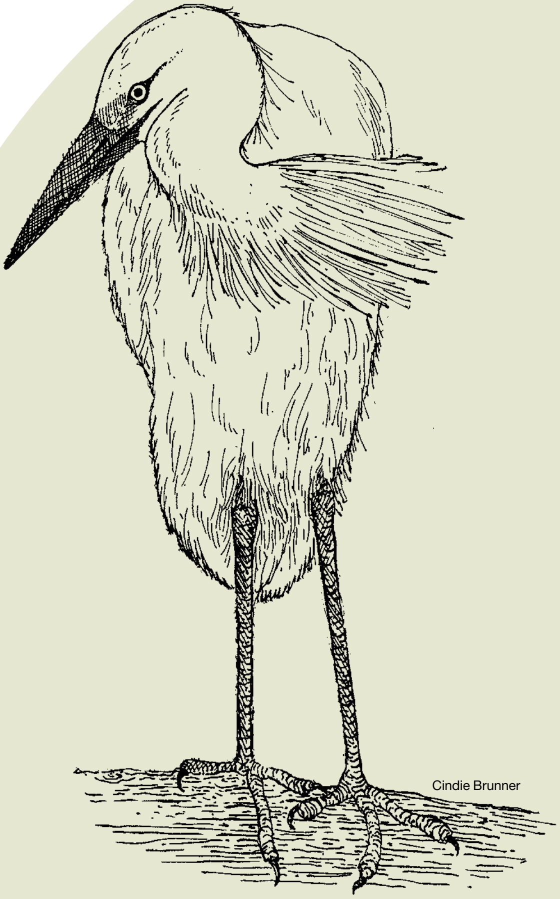
River otter.

Snowy Egret



Cindie Brunner

CAREER PROFILE

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Minnesota DNR
St. Paul

If you think you're immersed in your work, you should see Bernard Sietman. He's often in it over his head—literally. A malacologist (mussel scientist) with the DNR, Sietman spends some of his workdays in scuba gear sampling mussels at the bottom of the Mississippi or St. Croix rivers.

Mussels are among the world's most imperiled animals. Past problems with water quality in the Minnesota eliminated these aquatic invertebrates from many of the state's waters. Sietman studies mussels and habitat to understand where various species of threatened, endangered, and rare mussels live or historically lived, and what they need to survive. He then reintroduces mussels to areas from which they have been eliminated. To do that, he and colleagues survey rivers and lakes. They learn about when female mussels reproduce, and determine suitable host species for larval mussels, which must attach themselves to fish to survive. They then use information from their research and that of other scientists to grow juvenile mussels and reintroduce them to suitable areas within their historic range.

When he's not in scuba gear, Sietman conducts laboratory experiments to learn more about how various fish serve as hosts for microscopic mussel larvae. He also shares the results of his studies with others so they can help save mussels, too.

Sietman became fascinated with the diversity found among mussel species when he was taking an aquatic invertebrates class in college and has been working with mussels ever since. He says a sense of curiosity and experience in the outdoors are valuable attributes for success in his field. "Go fishing, camping, and hiking," Sietman recommends. "Wade around in a stream and get wet and dirty. Observe and appreciate nature." A college degree in biology or environmental science—preferably a graduate degree—is important preparation as well.

Related careers:
fisheries biologist,
ecologist

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water is essential for all life to exist

Aqua Bodies (water in living things) EL

The Life Box (basic needs) EL

Life in the Fast Lane (wetland species needs) EL, MS, HS

Water Address* (adaptations) EL, MS, HS - Activity cards and pictures of Minnesota species.

Water resources are managed

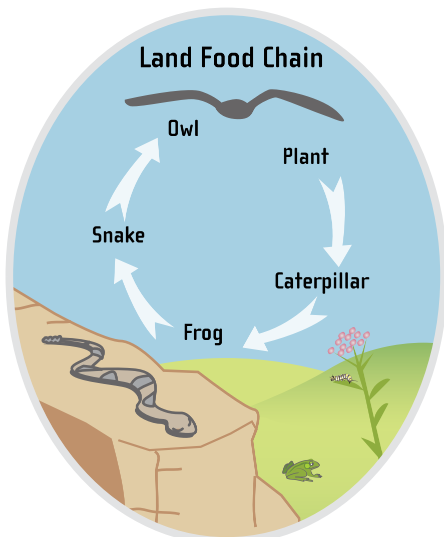
Macroinvertebrate Mayhem* (benthic macroinvertebrates & water quality) EL, MS - Example macroinvertebrate species data for Minnesota's three main watersheds.

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

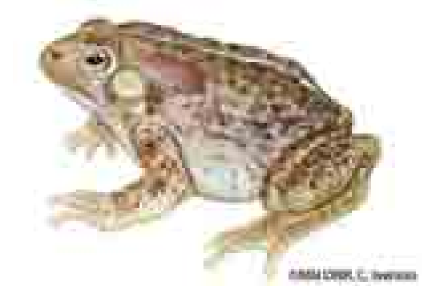
Comparing Aquatic Communities: Compare and contrast plant and animal communities in various bodies of water, including major types of creatures: producers, consumers, decomposers. What are the common ones in each?

Food Chains: Compare land and water food chains. Which are longer and more complex? Why?



Simple Aquatic Plant and Animal Identification: Show very young students large pictures of a variety of well-known Minnesota aquatic animals and plants and ask "Who am I?" types of questions for each. Follow this up by learning more about each animal or plant and its habitat. See "Nature Snapshots" on the DNR website for species background information.

Class Pet: Help very young students appreciate the importance of water to life by keeping a fish, toad, or other animal in your classroom. How does it use water?



Out and About

What's in the Water? Collect a jar full of water from a nearby pond or creek. Take it back to your classroom and pour it into white plastic bins or glass pie tins sitting on white sheets of paper. Have students use magnifying glasses to find and observe the activities of tiny living things in the water. How many different types of organisms do they see? How do the organisms move differently from one another? Where might they live in their natural habitat (on the bottom, floating in the water, under a rock, etc.)?

Windowsill Water Observation: If your circumstances allow, place a large bowlful of water outside your classroom window. Keep a clipboard, paper, and pencil near the window so students can record observations. What animals use the water, and how? Do plants start to grow in it?

Pond Study: Do a local pond study or macroinvertebrate monitoring of a local stream to learn about what lives in the water and help determine the water quality.

A few excellent resources:

1. Keys to life in the pond and stream, University of Wisconsin Extension Service. http://clean-water.uwex.edu/pubs/wav.htm Two 11x17-inch keys to help identify river and pond life for different grade levels.

2. *Wonderful Wacky Water Critters,* University of Wisconsin Extension Service. http://watermonitoring.uwex.edu/pdf/level1/WWWC.pdf A detailed, illustrated guide for young readers that was created in conjunction with the Keys to life in the pond and stream. Describes insects included in pond and river keys.

3. Macroinvertebrate key to life in the pond and stream in color, MN DNR. Available through DNR's MinnAqua Program—see www.mndnr.gov/minnaqua to contact the MinnAqua specialist near you.

4. *Field Guide to the Freshwater Mussels of Minnesota,* MN DNR. http://www.dnr.state.mn.us/eco/nhnrp/mussel_survey/fieldguide.html Contains photographs, shell descriptions, habitat associations, and distribution maps. Also contains general information about mussels, their importance in the ecosystem, threats to their survival, collection methods and collection regulations.

5. aniMap: An interactive mapping tool, MN DNR. http://www.dnr.state.mn.us/maps/animap/index.html Use this website to locate common animal species, view animal lists for your area of interest. Based on data collected by the Minnesota County Biological Survey.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

MN DNR

Chapter 5. Using Water

Key Concepts:

- People use water in many ways
- Water influences where people live
- Most household water supplies in Minnesota come from groundwater
- Water is important for generating electricity
- Water is important in manufacturing
- Agriculture depends on the right amount of water at the right time
- Transportation uses can affect water
- Minnesota's tourism industry depends on water

Pick 10 Minnesota cities—any cities. Find them on the map. What do they have in common? They're all in Minnesota, for one. And chances are, most (if not all) are associated with a body of water. Winona, Red Wing, St. Paul. St. Cloud, Grand Rapids all grew up along the Mississippi. Duluth, Lutsen, and Grand Marais share Lake Superior. Moorhead, Red River of the North. Bemidji, Lake Bemidji. New Ulm and Mankato, the Minnesota River. Stillwater and Taylors Falls, the St. Croix River.

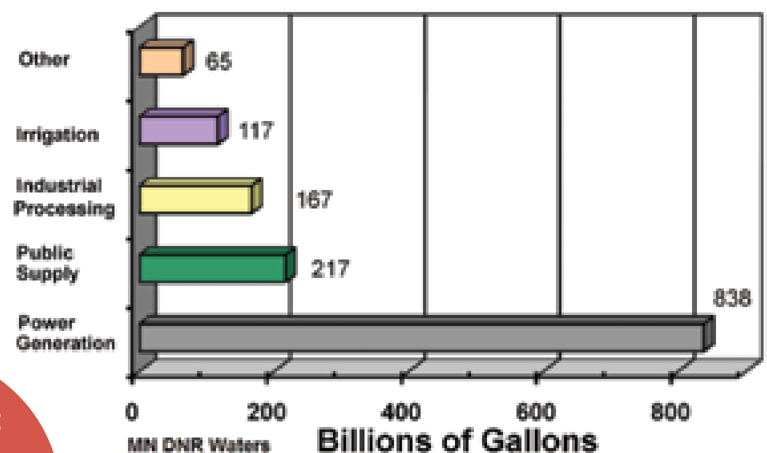
From the earliest times people have been drawn to water. Some of Minnesota's best records of original inhabitants come from the shores of Mille Lacs Lake, where evidence of inhabitation dates back some 9,000 years. Fort Snelling was built as a wilderness outpost at the confluence of the Minnesota and Mississippi Rivers in 1825—making the place the Dakota had called *makoce cokaya kin,* the center of the universe, a hub for settlers as well as Native Americans. As European immigrants settled the state, cities and towns developed along rivers and on the shores of lakes all around the state.

Confluence: the place where two rivers run together.

Why do people so universally seek water? It's probably because we use water in many ways. In fact, we literally can't live without it. If you were stranded without food, you could probably survive for weeks. If you were stranded without water, your fate would be dire within days.

Water use can be divided into two broad categories. **Offstream use** is water use that involves removing water from its source. Examples include diverting water for drinking, irrigating farm fields or cooling power plants. In 2008, Minnesotans used 1.4 trillion gallons of water for power generation, public water supply, industrial processing, irrigation, and other offstream uses.

Minnesota Water Use for 2008: 1.4 trillion gallons



How much is 1.4 trillion gallons?

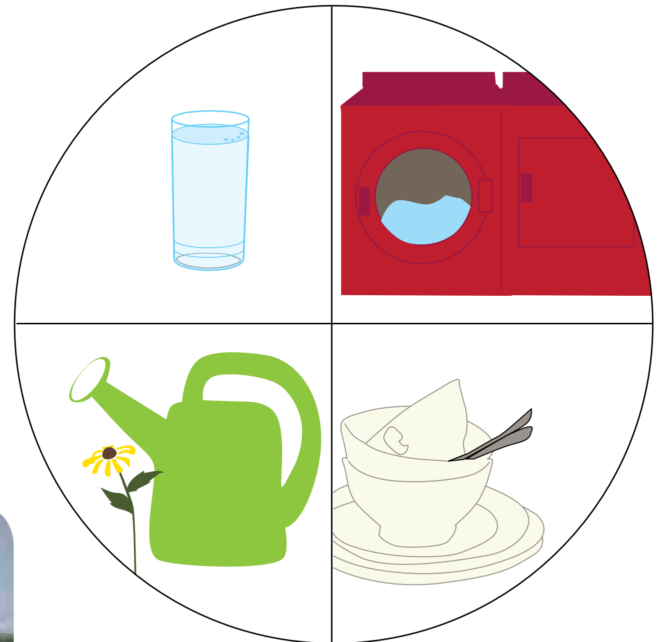
Lake Superior contains 3 quadrillion gallons of water (10% of the worlds fresh water). If Minnesotans used water exclusively from Lake Superior and it was not replenished, how many years until it would run out? Have students figure out how long the water supply would last.

Answer: 2142 years.

Uses in which the water is not removed from the lake, stream, groundwater, or other source are considered **instream uses.** Examples of instream use include fishing, providing habitat for a wide range of living things, hydropower production, and transporting goods.

Offstream and instream uses of water are important to helping people survive and thrive. However, they can have adverse effects on the water cycle, water bodies, and the community of living things that depend on them. Chapter 6 describes some of the negative impacts water use has had in the past and continues to have on waterways, and provides examples of how we can and do work to protect waters from harm as we benefit from them.

The average American uses 80 to 100 gallons of water each day for drinking, washing dishes and laundry, watering lawns and gardens, and other activities. That's the equivalent of 853 cans of pop.



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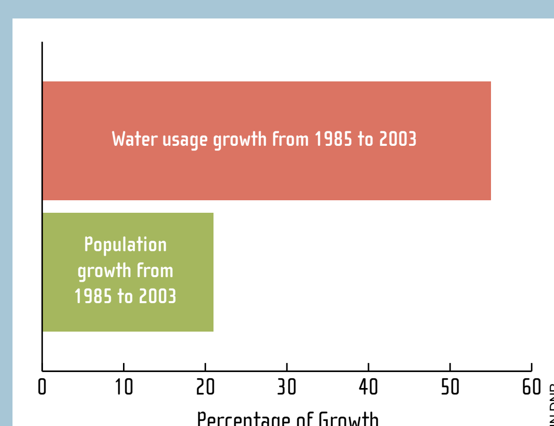
Instream water use.

Adult humans need to take in about 2½ quarts of water per day to stay healthy.

Slicing the Water Pie. All together, Minnesotans used 3.4 billion gallons of water per day in 1995. By volume, the most water use is for cooling power plants, followed by public water supply, mining, irrigation, industrial uses, domestic uses, commercial uses, and livestock.

In recent years in Minnesota, water use has grown faster than population. Between 1985 and 2003, for instance, water use grew 55 percent. During that same time, population grew 21 percent.



Water at Home

The most universal use of water is domestic use. Every day we tap our local water resources for drinking, food preparation, cleaning, and waste disposal in our homes. Some of us get our household water from a municipal water supply, and some of us get it from private wells. Municipal water supplies may come from groundwater or surface waters such as Lake Superior or the Mississippi River. Wherever your household water supply comes from, it's part of Minnesota's water cycle.

Water In …

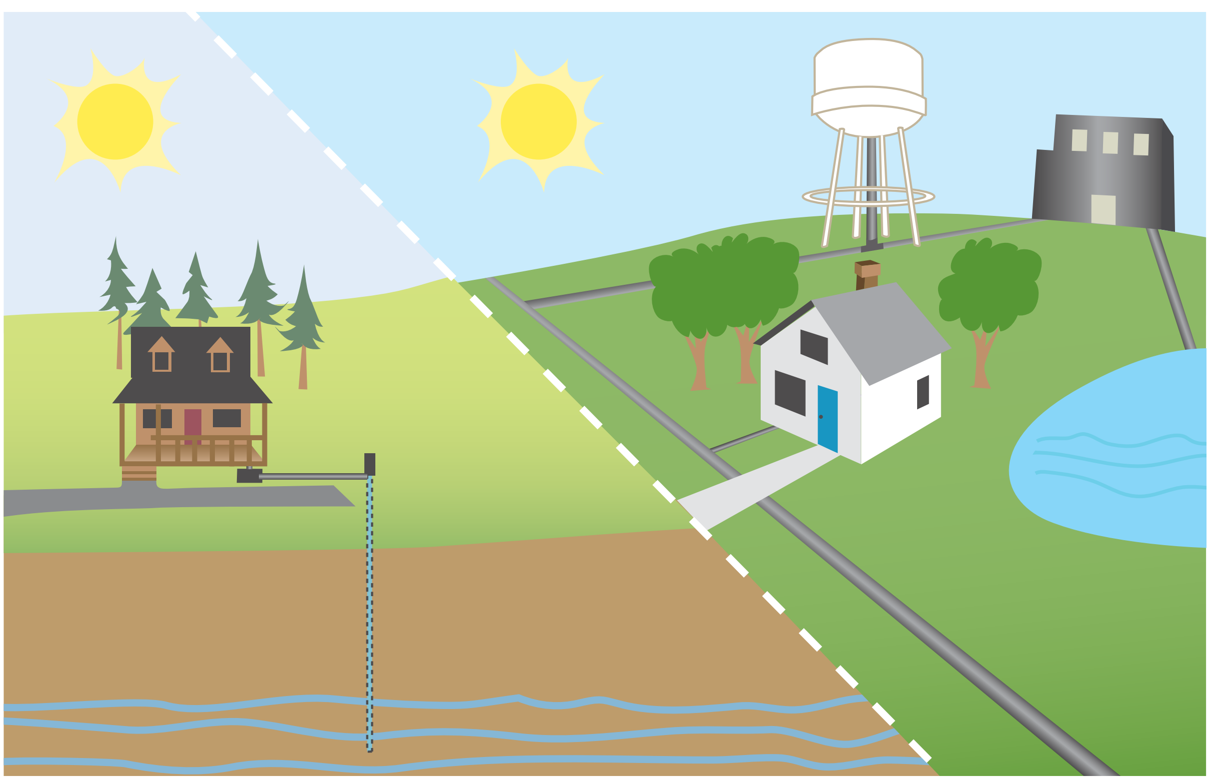
You probably don't think too much about it when you turn a handle in your kitchen or bathroom and water comes out of the faucet. But historically, that's a relatively new notion. For much of history—and in some places, yet today—people have scooped water directly from lakes and streams or drawn it up from beneath the ground to meet the water needs of everyday living. That means using water at its source, or carrying it in containers to where it is needed. When European settlers first began to settle Minnesota, they often settled where they could find water.

Today, most Minnesotans draw their household water from a municipal water supply or have it pumped directly from a well that taps groundwater.

In the case of a private water supply (well), an electric pump pulls water from the aquifer into a pressure tank. The water may be screened for particles and treated to remove minerals that give it an undesirable color or flavor. The pressure tank uses electricity to pressurize the water. When someone turns on a tap or flushes a toilet, the pressurized water flows through pipes to the point of use.

Minnesotans drill an average of 10,000 to 12,000 new wells each year.

In cities and towns, residents share a municipal water supply rather than obtaining their water from individual wells. The local water treatment facility draws water from a river, lake, or large well. A process called flocculation uses chemicals to make the dirt in the water to clump together. Small particles are allowed to settle out, then the water is filtered to remove even smaller particles. The water is treated with chlorine to kill germs, and it may also be fluoridated to reduce dental decay. Other substances may be added to reduce iron staining, hardness, or scaling. Then it is stored in a water tower or other reservoir so enough will be available to meet an average daily demand for emergencies and fire protection. Homes and businesses are hooked up to the water supply via a series of underground pipes known as water mains. Water mains have branches leading to individual houses. When a resident turns on the tap to obtain water for drinking, cooking, cleaning, flushing the toilet, or watering the lawn or garden, water flows from the holding tank or water tower.



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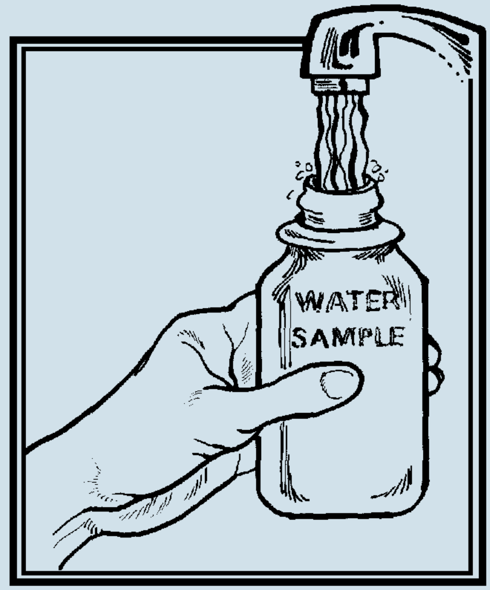
Keeping Drinking Water Safe. The Minnesota Department of Health has a number of requirements to ensure the safety of drinking water throughout the state. Community water suppliers, noncommunity water suppliers (like schools, day cares, and factories that serve the same individuals daily) and noncommunity nontransient water suppliers—those that are independent of the community supply but supply water to a stable population of 25 or more, such as a school or business—must engage a certified water operator and follow a prescribed schedule for testing water to make sure it's safe. Noncommunity transient public suppliers—places like restaurants and churches that supply water to people who come and go—need not engage a certified operator, but they, like nontransient suppliers, are required to undergo a sanitary survey every three years. MDH recommends that people on private wells have their drinking water tested once a year for total coliform, once every two to three years for nitrate (more often if infants or young children are in the home), and at least once for arsenic.



U of WI Extension

More than a million Minnesotans get their water from private wells.

About three-quarters of Minnesota's drinking water is drawn from groundwater. For example, the city of Rochester withdraws about 4 billion gallons per year from the Prairie du Chien–Jordan aquifer. The city of Willmar withdraws 1.6 billion gallons per year from the Quaternary Buried Artesian aquifer. The city of Grand Rapids pumps water from five wells and stores it in a half-million-gallon tank underground. Many Twin Cities suburbs tap groundwater as well.

The other one-quarter of Minnesota's drinking water comes from various sources of surface water. Most of the drinking water in the Twin Cities and St. Cloud comes from the Mississippi River—in fact, about 1.1 million Minnesotans use water from the Mississippi. Duluth and other North Shore communities such as Two Harbors, Silver Bay, and Grand Marais draw their water from Lake Superior. Moorhead and East Grand Forks take water from the Red River. Other communities that use surface water include Thief River Falls, Albert Lea, and Chisholm.

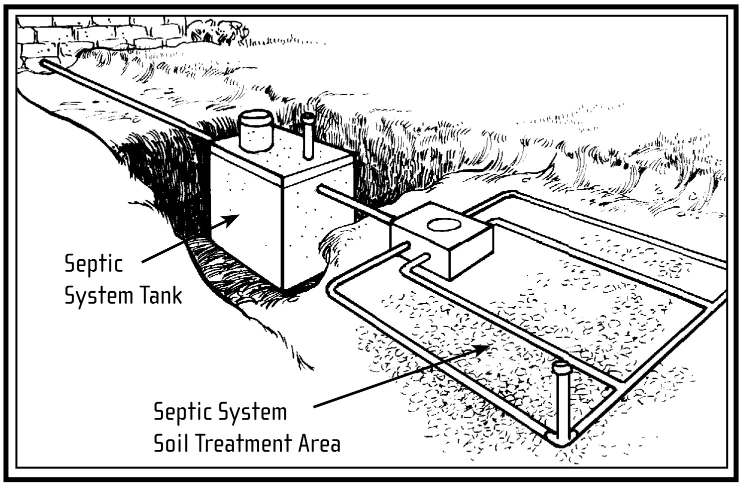
In 2007, domestic water and other "public supply" uses in Minnesota added up to 227 billion gallons.

The city of Minneapolis water distribution system has 1,000 miles of water mains. That's equal to almost half the length of the Mississippi River!

Treatment on Arrival. In addition to the treatment water receives where it is withdrawn from a source, some homes and business places choose to treat water again to remove any remaining undesirable staining substances, chemicals, tastes, and odors. These devices include water softeners, filters, distillation systems, activated carbon, and reverse osmosis.

… And Out Again

What comes in, must go out, and it did not take long for people to realize that water could be used to dispose of waste as well. Today most buildings in Minnesota use water to wash wastewater from sinks, tubs, and toilets through pipes to a place where it is treated and then returned to the environment.



U of WI Extension

Nearly one-third of Minnesotans use individual wastewater treatment systems, also known as septic systems or individual sewage treatment systems for disposal of wastewater. Water flows into a tank, where solids settle out and some of the organic matter in the water starts to degrade. From the tank, water flows into a specially designed soil treatment area, where microorganisms finish the job of breaking down the organic matter.

Wastewater from most Minnesotans is treated in a municipal wastewater treatment facility run by their community. Water flows in pipes to a central facility, where first large objects are screened and solids and grease are removed. Microorganisms then begin to break down the organic material in the water. Finally, the water is disinfected to kill any disease-causing organisms it might contain. It also is treated to remove nutrients that would promote the growth of plants and algae wherever it ends up. Eventually the treated water is released through a pipe to a nearby river or lake, or in some cases sprayed onto land.


tMN DNR

Wastewater treatment plant. St. Cloud, Minnesota.

Food From Water

If you're one of Minnesota's 2.3 million avid recreational anglers, you know that our state's great waters also are a source of food. Each year anglers pull millions of fish from state waters. Many of those end up on dinner plates.

Inhabitants of the land we now call Minnesota have been harvesting food from waters here since long before the advent of bait shops and dip nets. Archaeologists believe fish were part of the Paleoindian diet (along with mastodon!) between 10,000 and 6,000 B.C. During the Archaic period, 6,000 to 800 B.C., people often settled along lakes and rivers. We have strong evidence in the tools they left behind that fishing was among the ways they obtained their food.

Biodiversity: Minnesota waterways are home to 158 species of fish.

In addition to supporting sports anglers, Minnesota waters also support commercial fishing. In the early 2000s, more than 50 commercial fishing businesses harvested about 3 million pounds of fish per year from Lake Superior, the Mississippi River, Canadian border waterways, and some scattered lakes in southwestern Minnesota. Commercial fishing also takes place today on Red Lake in northern Minnesota. Many commercial fishing businesses grow fish in aquaculture systems rather than harvesting them from the wild.

MN DNR

Commercial herring fishing, Lake Superior.

Other foods that grow in Minnesota waters include wild rice, cranberries, and snapping turtles.

Manoomin, Wild Rice. For centuries, late summer has meant wild rice harvest in the place we now call Minnesota. A grass with edible, nutritious seeds, wild rice once grew throughout the state in the shallows of lakes and rivers. In fall, people would canoe through the rice stands, bending and brushing the long stalks with special sticks, called flails, so that the seeds fell into their canoe. After processing, the seeds provided a staple food through the long winter.

Today much of the wild rice we find in stores is grown on wild rice farms rather than in the wild. But each year, about 1,600 people buy licenses so they can harvest Minnesota wild rice from the 60,000-some acres of wild waters that still provide habitat for this valued and valuable food source.

Minnesota Historical Society.

Support for Energy

Did you know that Minneapolis was once known as the flour capital of the world? Why do you think that was? The answer is St. Anthony Falls on the Mississippi River. When wheat harvests were ready to be milled into flour, the falls provided the waterpower to turn the mills that ground it into flour.

In the early days of European settlement, waterfalls around Minnesota were used to run sawmills, flour mills, and other equipment and machinery. Use of water for manufacturing forest products in Minnesota, for example, dates back to 1821, when the U.S. Army built a sawmill at St. Anthony Falls on the Mississippi River to produce boards for building Fort Snelling. Today we continue to capture the kinetic energy of water rushing downhill for work that meets human needs by using hydroelectric dams to direct the flow of water through turbines, causing them to turn. The turning turbines are connected to magnets that spin within wire coils, generating electricity. Minnesota has 32 hydropower facilities with a total capacity of 204 megawatts (MW). (For comparison, the Allen S. King coal-fired power plant near Stillwater has a power production capability of 588 MW.)

Minnesota Historical Society.

By far, the most common use of water in Minnesota is for generating power. In fact, the number one use of water for anything in Minnesota—is in the generation of electricity in both fossil fuel–fired and nuclear-fired power plants. Most electricity in the state is produced by heating water to make steam that is then used to turn turbines and generate electricity. Other water is then used to cool down the heated water. In nuclear power plants, water is also needed to cool equipment.

Water is also used in refining oil to produce transportation fuel, and is an important part of the production equation for renewable fuels such as ethanol and biodiesel from crops and other plant materials. In addition to being used to grow biofuel crops, water is also needed to transform the biomass into a usable fuel. With current technologies, an estimated 4 to 4.8 gallons of water is needed to process each gallon of ethanol produced.

In recent years innovators have been exploring the possibility of generating electricity using small turbines attached to floating barges in flowing water. As with conventional hydropower, such turbines use the energy of flowing water to turn a turbine that in turn turns a generator to produce electricity. The first commercial turbine of this sort in the United States was installed in the Mississippi River near Hastings, Minnesota in 2008. Researchers are studying the turbine's impact on the river and its inhabitants.

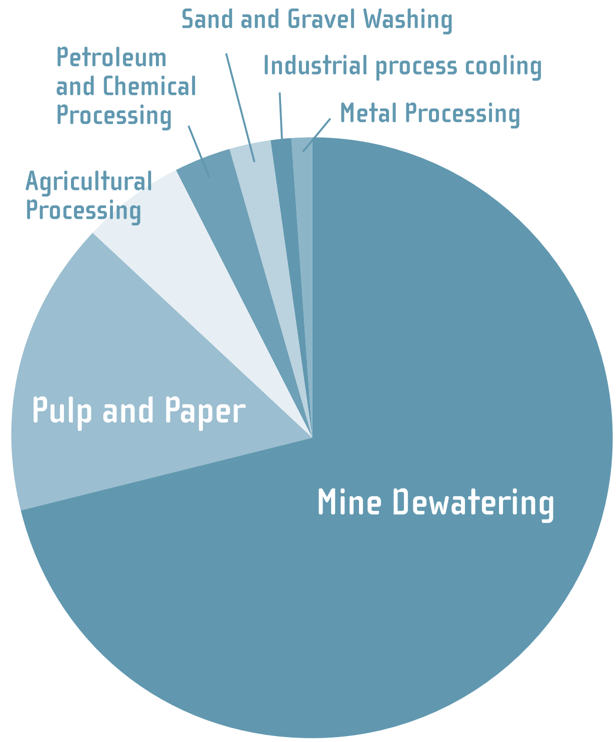
USFWS

Industrial Uses

Water is used in many other industries in addition to electricity generation. In Minnesota, mining processing and pulp and paper manufacturing are the two major industrial uses of water.

Some industrial applications involve adding water to the material being manufactured. When paper is made, for example, tree chips are cooked in water, or recycled paper is soaked in water. Other applications include using water for washing.

Most water used for industrial purposes in Minnesota comes from lakes and rivers. In 2007, some 167 billion gallons of water were withdrawn for industrial purposes in Minnesota. Most of this total—118.3 billion gallons—was for mine dewatering. The second biggest industrial water user was pulp and paper production at 26.2 billion gallons. Other uses included agricultural processing (9.3 billion gallons), petroleum and chemical processing (4.8 billion gallons), sand and gravel washing (3.7 billion gallons), industrial process cooling (2.2 billion gallons), and metal processing (1.4 billion gallons).



MN DNR

MN DNR

Most water used for industrial purposes in Minnesota is for mine dewatering.

In 2007, Minnesotans used some 445 million gallons of water to make artificial snow.

A Lot of Cold Air. In 2007, Minnesota businesses used 338 million gallons of water for air conditioning.

Agriculture and Irrigation

Agriculture is another important use of water in Minnesota and around the world. Both plant agriculture and animal agriculture demand abundant water.

In the early days of modern farming, water for plants came from the sky, and water for animals came from a river or lake, or was drawn up from the ground by a wind-driven pump. Then, in the late 1800s, farmers began to irrigate their crops. Most irrigation water comes from groundwater rather than lakes and streams. In 1995 Minnesota farmers used 62 million gallons of water a day to quench their livestock's thirst and sanitation needs. In 2008, Minnesota agricultural producers and others used 117 billion gallons of water for irrigation.


MN DNR

"The ordinary farmer will pooh, pooh at the desirability of [digging irrigation ditches], and will prefer to do business on the old plan of just looking to Providence for the rain that falls on the just and unjust. You that are engaged in horticultural pursuits, can well afford to look into this matter, remembering that ... each acre upon which you can conduct water means four acres, as its production is increased from two to three fold from irrigation."

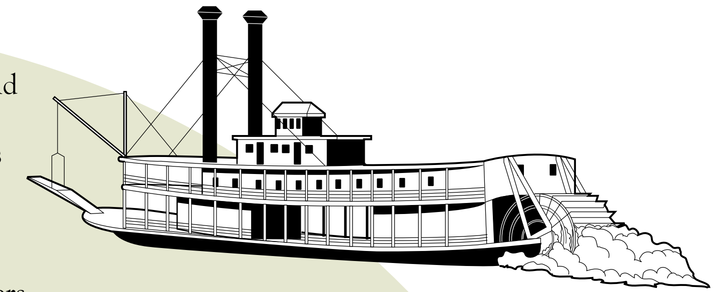
—From *"Irrigation for Minnesota"* by S. M. Emergy, published in the 1894 Annual Report of the Minnesota State Horticultural Society

All Wet. Irrigation is not just for farm crops and front lawns! In 2007, 9.7 billion gallons of water were used to irrigate golf courses in Minnesota, and another 125 million gallons were used to maintain cemetery vegetation.

Water Meal. What's that on the table—a small lake? In a way, yes. From seed to plate, it takes about 1,400 gallons of water to make a hamburger, French fries, and soda. Most items we use daily hide the "virtual water" needed to create them.

Transportation

Before highways and roads, bodies of water served as transportation routes through the land we now know as Minnesota. Native American Indians traveled rivers and lakes in bark canoes and dugouts. They also walked or used sleds to traverse ice: Even when frozen, water bodies offered an easier means of transportation than traveling through forests and over hills. Explorers and voyageurs followed in their wake and their footsteps.



National Park Service, Voyageurs National Park Collection

Map of main fur trade routes in northern Minnesota and Canada.

In 1823, a steamboat made the first trip to Fort Snelling from St. Louis. The limiting factor for using the stretch of the Mississippi River above Fort Snelling for transportation was the presence of shallow spots and rough water in the river gorge (now the area south of the Ford Dam). St. Paul grew up at the upper end of feasible steamboat travel on the Mississippi River. In 1824, the federal government assigned the U.S. Army Corps of Engineers the task of creating and maintaining a navigable waterway along the Mississippi River. The corps created the lock and dam system and began dredging the water.

In the mid- to late1800s, Minnesota's northern rivers were used for transportation of a different sort: shipping logs downstream to markets and mills. Over the course of less than a century, huge numbers of logs were transported in this way.

The Mississippi River continues to be an important water highway today, carrying coal, cement, wheat, and other goods.

Ecosystem Services. As water works its way through the water cycle, it provides a variety of valuable services that would be expensive if not impossible to obtain through technological fixes. The most obvious, of course, is precipitation. Every time it rains, farmers, gardeners, golf course operators, park managers, and lawn caretakers are saved the expense of irrigating or watering their crops and plants. Rain also washes streets and parking lots when it falls. Clouds provide welcome shade in hot weather. Evaporation helps cool everything from our own bodies to entire cities. Water features provide ecosystem services, too. Wetlands cleanse water by filtering nutrients and sediment. Lakes provide food and fun. Rivers carry boats and cargo upstream and downstream, saving fuel.

These functions, known as ecosystem services, are critical to consider when we make decisions that may affect the availability and distribution of water in our lives. Although we may not pay for these services when they are readily available for free, we would likely have to pay some serious money to compensate for their absence if they were not.

Recreation

Water is also a source of fun! Whether swimming, motor boating, fishing, canoeing, kayaking, waterskiing, sailing, ice skating, waterfowl hunting, or any of many other water-related activities, Minnesotans know how to enjoy the world of water. Our state has more boats per capita than any other state in the nation—one boat for every six people! The only outdoor activity that has more participants than recreational boating in Minnesota is walking. Truly this is the place for boaters to be.

Even if we're not motoring or paddling around on it, water can provide us with a source of beauty, comfort, and delight and fill us with a sense of well-being. The sound of running water (as long as it's not a plumbing problem) can be restful and calming. People from all over the United States and beyond flock to Minnesota's North Shore of Lake Superior to take in the striking beauty of foaming waterfalls as rivers tumble over rock to the big lake below.

MN DNR

Grand Portage State Park.

More than 30 of Minnesota's 74 state parks and recreation areas have a water feature as part of their name.

Lake Pepin Prodigy. Getting pulled around a lake by a long rope tied to a motorboat—who ever thought of that?!? With our focus on recreational boating, it's not surprising that the inventor of modern water skiing has a Minnesota connection. The story goes that an 18-year-old Minnesota man, Ralph Samuelson, decided to try skiing on Lake Pepin, a widening of the Mississippi River near Red Wing, on a June day in 1922. After being towed around countless times by his patient brother, he perfected his technique to the point where others wanted to give it a try, too. The rest, as they say, is history.

Minnesota Historical Society.

CAREER PROFILE

Bill Hansen
President,
Sawbill Canoe Outfitters, Inc.
Tofte

Bill Hansen's parents started Sawbill Canoe Outfitters near Tofte, Minnesota, when he was 3 years old. Ever since, he's been helping people enjoy Minnesota's bountiful lakes by providing the equipment they need to travel in the Boundary Waters Canoe Area Wilderness.

"We enable people to visit one of the world's most unique water-based wilderness areas," Hansen says. "I love introducing people to the wilderness and watching them discover the joys of wilderness canoe camping."

Hanson's business depends on clean, healthy waterways that can provide recreational opportunities for people who visit northern Minnesota. A typical summer day might include renting canoes and giving visitors advice on choosing a route, as well as sweeping the floor and maintaining equipment. A typical winter day would include answering email, answering phone questions, shoveling snow, placing orders for equipment, fixing equipment, and enjoying some cross country skiing. Hansen loves living and working right on the edge of a big lake. His only wish is that he could go on more canoe trips himself.

How would a person prepare for a career like his? Hansen recommends spending as much time as you can in the wilderness. Business skills like accounting and human resources management are also important, as is the ability to fix just about anything.

Related careers:
fishing guide,
resort owner

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water is essential for all life to exist

Aqua Bodies (water in living things) EL

Poison Pump (waterborne disease/drinking water) EL, MS

Water connects all Earth systems

Wet Vacation (climate, tourism) MS

Water is a natural resource

Common Water (water users) EL, MS

A Drop in the Bucket (global water distribution) EL, MS, HS

Energetic Water (water for energy) EL, MS

Irrigation Interpretation (agriculture) EL, MS

The Long Haul (historical and current water use) EL, MS, HS

Water Works (interdependence of water users) EL, MS

Water resources are managed

Back to the Future (analyzing streamflow data & floodplain planning) EL, MS, HS

The Price is Right (community planning) HS

Sparkling Water (wastewater treatment) EL, MS, HS

Superbowl Surge (wastewater planning) MS, HS

Wet Work Shuffle* (water careers) EL, MS, HS - Career profiles from professionals around MN.

Water resources exist within social constructs

Choices Preferences Water Index (water users) MS, HS

Dilemma Derby* (water issues, problem solving) MS, HS - MN case studies of historical water issues.)

Easy Street (historic and current water use) EL, MS, HS

Hot Water (debate water issues) HS

Water Concentration (historic and current water use) EL, MS

Water Crossings* (rivers & history) EL, MS, HS - MN water crossings stories, maps.

Water resources exist within cultural constructs

Wish Book (recreation) MS, HS

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Community Roots: Invite students to research the history of water in your community or another community with significance to them. How were local lakes and rivers used in the past? What body or bodies of water sustain people and businesses there today? How do they do so?

What are Ecosystem Services? Have older students identify and explore an ecosystem service provided by water that moves through the water cycle in your community. If water were not available to perform that service, how would the service be provided, and what would it cost? Some ideas: irrigating farm fields, washing streets, filtering sediments and nutrients from runoff before it gets to lakes or rivers, providing cooling water for power plants, cooling the air through evaporation, providing shade (in the form of clouds), transporting cargo up and downstream, providing recreational opportunities.

Calculate Your Water Footprint: Students can get a sense for their own water footprint. Help them identify the source of the water they use at school and at home. Then have them keep track of how much water they use for a week. Do a web search for "personal water use" and "water footprint calculator" for some guidelines on numbers to use for brushing teeth, flushing the toilet, washing dishes, etc.

School Water Use: Talk to your school's facilities management staff to determine how much water is used at school each day—inside and out. What are the biggest users of water: restrooms, swimming pool, sprinkler systems? How much money does you school spend on water each year? How could you help reduce water use?

Sharing Water Stories: Invite very young students to share stories of fun they've had with water—playing in a puddle, swimming in a pool, washing dishes, watering the garden, riding in a boat, walking in the rain, splashing in the tub.

Out and About

Neighborhood Water Use: How is water used in the vicinity of your school? Go for a hike in the neighborhood and look for different ways water is being used. If you encounter a business, ask how water is used there. Take a clipboard and pencil to record your discoveries. If your circumstances allow, split into several groups and head out in different directions, then compare notes when you return.

School Water Use: For very young children, arrange for a tour around the school to see all the different places and ways water is used.

A few excellent resources:

1. Local Drinking Water Information website, US EPA. http://www.epa.gov/safewater/dwinfo/index.html Students can see if their local annual drinking water quality report is posted online.

2. *Water A Natural History* by Alice Outwater (1997). Covering the history of the United States waterways, this book moves from the reservoir to the modern toilet, from the grasslands of the Midwest to the Everglades of Florida, through the guts of a wastewater treatment plant and out to the waterways again. It shows how human-engineered dams, canals and farms replaces nature's beaver dams, prairie dog tunnels, and buffalo wallows.

3. Wastewater Treatment Plant Tours (Twin Cities area), Metropolitan Council. http://www.metrocouncil.org/Environment/Education/mcesTours.htm Find information about scheduling tours for your class.

4. Minnesota Water Use Statistics, MN DNR. http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html This site shows how and where Minnesota's water is used and permitted.

5. Water Use in the United States, United States Geological Survey. http://ga.water.usgs.gov/edu/wateruse.html This section of the USGS Water Science site is includes information for students about how the USA uses water on an everyday basis.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET Activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

MN DNR

Chapter 6: Harm and Hope

Key Concepts:

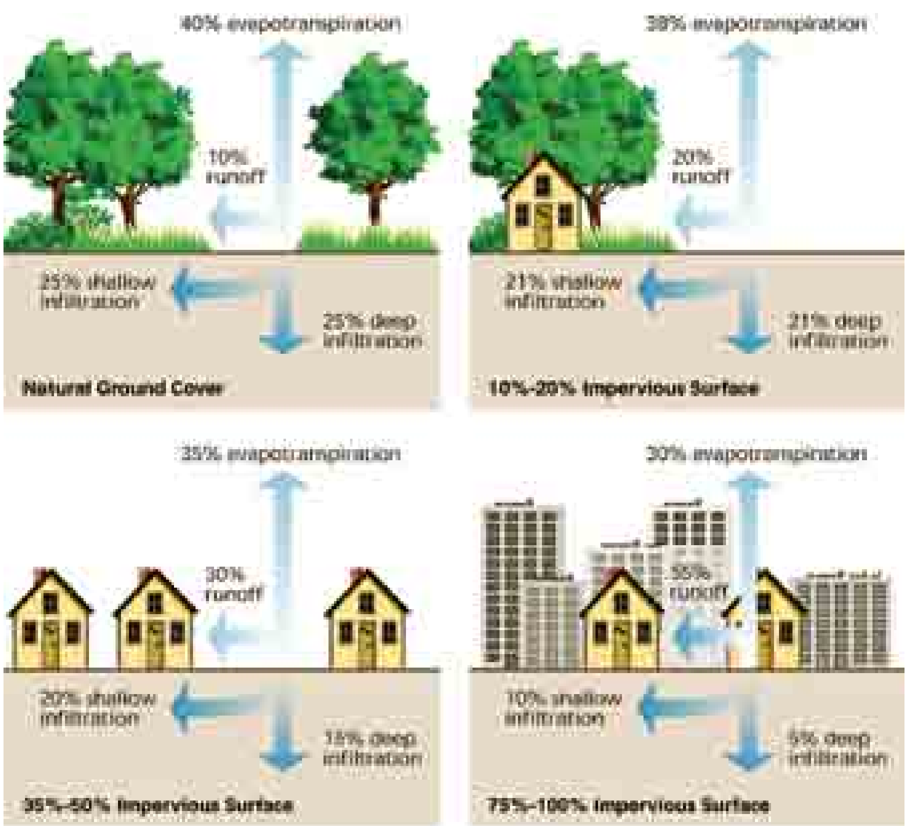
- Human activities can harm or help water quality, the water cycle, and the biological characteristics of water bodies in many ways
- It's up to each of us to help keep water healthy

CATS AND CATERPILLARS, TURTLES AND TREES... Water affects every living thing, and every living thing affects water. But no species has a greater impact on water in the environment than humans. Our actions can harm or help lakes, streams, wetlands, groundwater, and oceans. We can make it harder or easier for water to meet the needs of other living things. We can affect how well it meets our own needs, too.

In the past, water often seemed so abundant and ubiquitous that people did things like drain wetlands, dam rivers, and pollute lakes without much worry about long-term impacts. Today we realize that water and waterways can be harmed, and water supplies can be degraded or used up altogether. As a result, we have taken actions to reverse harm caused in the past. We also have established limits on the kinds and magnitude of changes we make.

Most human-caused changes in water and waterways fall into three main categories. First, we alter levels of *pollutants* in waterways. Second, we create *water cycle changes* by influencing location and movement of water. Third, we produce *biological changes* by introducing species into water bodies that were not there before, or removing or changing proportions of existing inhabitants.

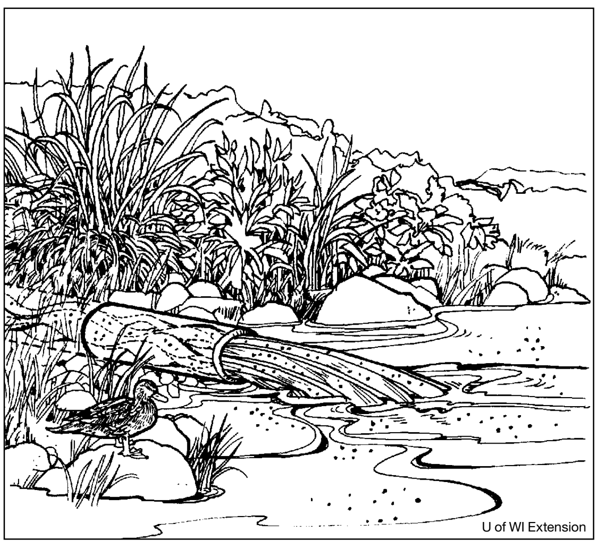
Changes to the Water Cycle as the Built Landscape Changes



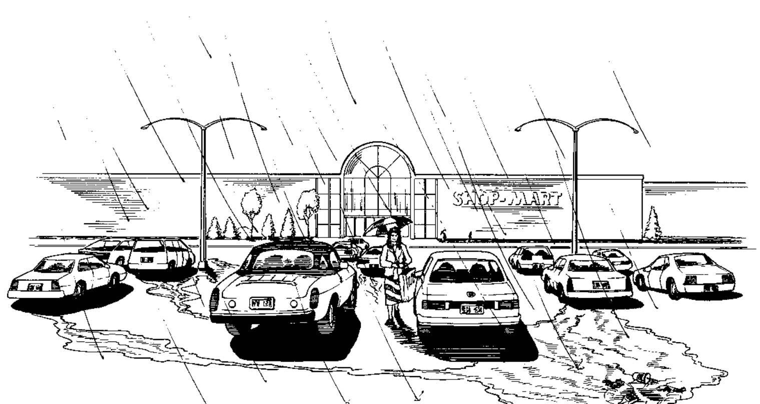
In *Stream Corridor Restoration: Principles, Processes, and Practices* (10/98). By the Federal Interagency Stream Restoration Working Group (FISRWG). ©Used with permission.

Pollutants

Many of the most obvious impacts we have on Minnesota's waters have to do with pollutants humans introduce into waterways and watersheds. These include pathogens, nutrients (alone, or as part of organic matter), acids, salts, other chemicals, and thermal pollution (heat). Pollutants introduced to waters through a specific outlet, such as a pipe from an industrial plant, are known as **point source pollution.** Those that enter waters in more dispersed way, such as runoff from a parking lot or farm field or pollutants carried by rain, are called **nonpoint source pollution.** We may tend to notice point source pollution more, because it's concentrated. But most water pollution in Minnesota today is nonpoint source pollution. This runoff can have a huge impact on waterways by carrying sediment, nutrients, toxic chemicals, and other pollutants into them, dramatically altering their chemical, physical, and biological properties.



Point source pollution.



Nonpoint source pollution.

Pathogens

Waterborne diseases are a leading cause of disease and death in many countries. With modern water treatment facilities and wastewater disposal, Minnesota is fortunate to have relatively few problems with pathogens in water. Periodically, problems will occur, however. When septic systems malfunction, adequate wastewater treatment systems are not in place, or other sources of contamination exist, pathogenic bacteria, viruses, and protozoa can pollute lakes and streams and sicken people who ingest the water.

Nutrients

If you've ever fertilized your lawn, garden, or houseplants, you know that plants need three primary nutrients to grow: nitrogen (N), phosphorus (P), and potassium (K)—the N-P-K numbers on the fertilizer label. Plants in lakes and rivers need these nutrients, too. But if lakes and rivers get too much of these nutrients, plants and algae, including particularly troublesome cyanobacteria (blue-green algae), start to proliferate. When the overly abundant plants and microorganisms die, oxygen-using decomposing organisms in the water end up working overtime, and the amount of oxygen dissolved in the water drops. Fish and other animals that depend on oxygen in the water are likely to suffocate. An overabundance of aquatic plants interferes with uses such as swimming, boating, and fishing.

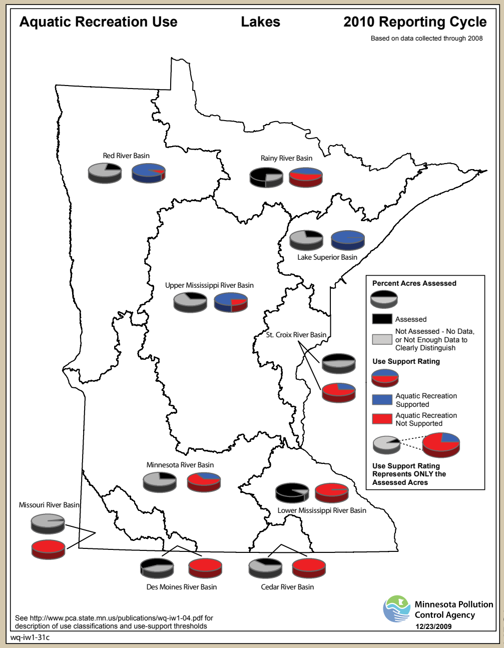
Blue Babies. Nitrate-contaminated groundwater can cause serious health problems in humans. If infants drink it, the nitrate can affect the ability of their blood to transport oxygen. The resulting condition, called methemoglobinemia, or blue baby syndrome, can cause vomiting and diarrhea, inadequate oxygen supply to tissues, and even death. Nitrate in groundwater can also be dangerous for pregnant women and people with compromised immune systems.

How do nutrients end up in Minnesota's lakes and streams? Often, they are carried along with runoff. Runoff occurs when precipitation falls on land and, rather than soaking into the ground where it falls, travels along the surface of the ground to a stream or lake, picking up dissolved nutrients or nutrient-laden materials such as leaves, fertilizer, pet waste, or livestock manure along the way. Another major source of nutrients to waterways has been sewage wastewater. Before cities and towns had wastewater treatment plants, human waste often ended up in waterways. Poorly functioning septic systems or septic systems too close to a lake or river can also release nutrients that contaminate surface water.

When cities began installing wastewater treatment facilities to remove pollutants from wastewater before they could foul surface waters, water conditions improved (see appendix 2 for Minneapolis water treatment case study). Laws regulating the use of phosphorus in cleaning products have also helped to reduce excess plant growth due to the overuse or misuse of fertilizers. One of the hopeful changes in Minnesota's struggle to keep its waters clean is the passage of a law restricting the use of phosphorus in lawn fertilizer. In 2005, Minnesota became one of the first states in the nation to require property owners and managers to test their soil to determine if phosphorus is needed before it can be applied. This law, which also prohibits spilling or spreading fertilizer on impervious surfaces, is helping to prevent nutrients from reaching lakes and streams.

One source of nutrient pollutants in ground and surface water is improper wastewater treatment. According to the Freshwater Society, some 40 percent of septic systems in the state don't meet state standards. Despite laws to the contrary, in some places, raw sewage still flows directly into surface waters. A 2004 report to the Minnesota Legislature estimated that an estimated 60,000 so-called "straight pipe" systems were discharging some 6.75 million gallons of untreated wastewater each day into the state's waterways.

This Is a Test. Scientists characterize the nature and health of a body of water by performing various tests that give insights into its chemical, physical, and biological characteristics. Parameters commonly measured when testing waterways include alkalinity, bacteria, conductivity, dissolved oxygen or biochemical oxygen demand, hardness, nitrate content, pH, phosphate content, temperature, total dissolved solids, and turbidity or transparency.

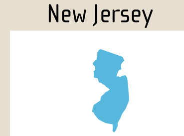


MPCA


Chisago County Staff Photo

Dead Zone

New Jersey



Dead Zone. The ramifications of polluting waters with oxygen-depleting nutrients don't end at the Minnesota border. Nitrogen traveling down the Mississippi River eventually ends up in the Gulf of Mexico, where it stimulate algal blooms that deplete the oxygen bottom-dwelling organisms need to live. Due to nonpoint source pollution from the Mississippi watershed, the plants and animals living in the Gulf of Mexico, such as lobsters, oysters, and fish, have been dying off or have had their reproductive systems altered. The size of the Gulf of Mexico dead zone varies from year to year, with the average being around 6,000 square miles. That's 30 times the size of Mille Lacs Lake, or almost the size of the state of New Jersey—and is visible from space!

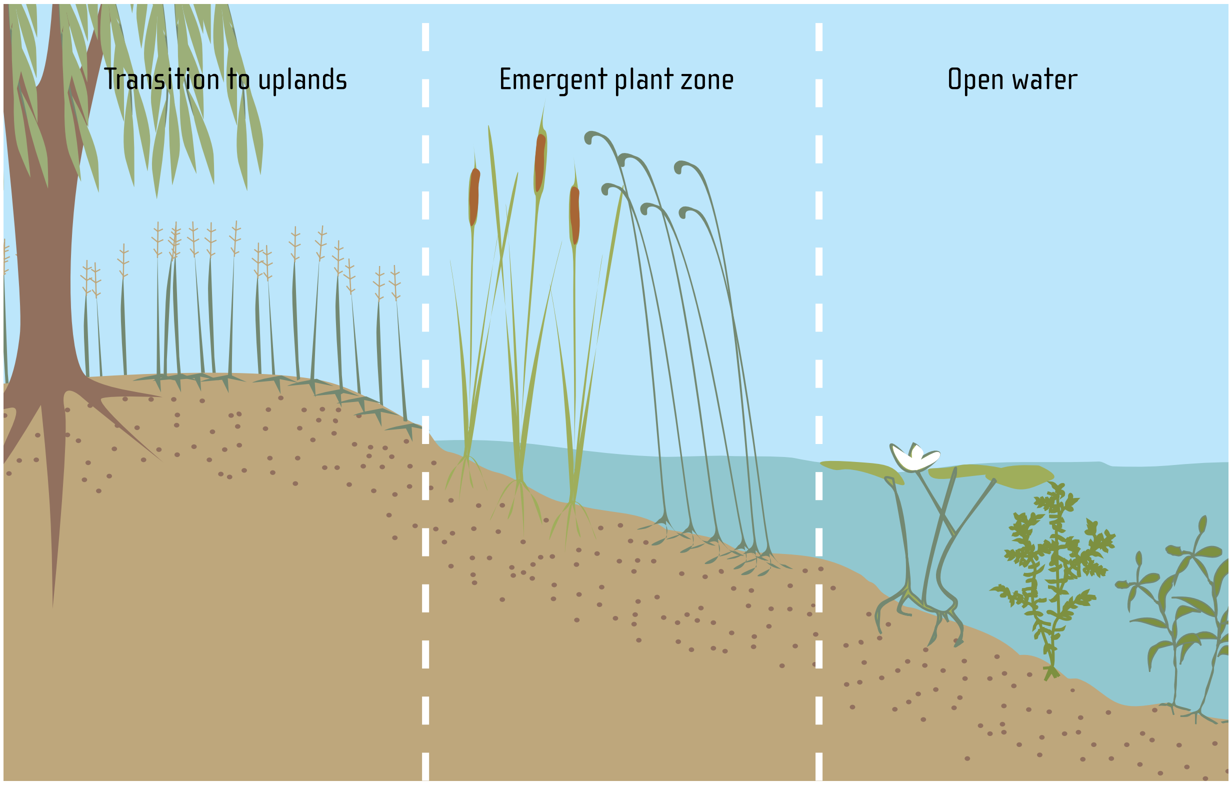
Acid

Natural rain is only mildly acidic due to carbon dioxide in the air, which makes a weak acid. When sulfur dioxide and nitrogen oxides produced by burning of coal and other fossil fuels mix with other substances in the air, they can form sulfuric acid and nitric acid, which are strong acids. Rain and snow can then carry the extra acidity into waterways, lowering the pH in the aquatic habitat in a way that makes it hard for fish and other living things to reproduce properly and in some cases even to survive.

Acidification of lakes became a big issue in the United States in the 1980s. Minnesota was not as susceptible as East Coast states, in part because there were fewer acidifying emissions here, and in part due to geological conditions that help neutralize acids that fall from the sky. In addition, sulfuric acid is consumed in wetlands by natural bacteria that "breathe" sulfate after all oxygen is depleted in the sediment. Nevertheless, Minnesota was the first state in the nation to pass a law protecting waterways from acid deposition and to set an acid deposition standard to protect aquatic life.

These actions and others at the federal level have reduced the threat of acidification. However, scientists are still concerned about the link between acid precipitation and mercury in the food chain. Bacteria in wetlands that consume sulfuric acid also convert mercury pollution into the form that readily enters the food chain. By promoting proliferation of these bacteria, acid deposition may increase the likelihood that the fish we like to catch and eat are contaminated with unsafe levels of mercury.

Freshwater Marsh Cross Section



Chlorides and Road Salt

In the old days, drivers who wanted to travel in wintery conditions would use tactics like installing tire chains and road authorities would add sand to icy roads to give tires more traction and make driving a little safer. As roads and cars have improved, so has the demand to drive faster in the winter and to do so safely. Road salt (most often, sodium chloride) is an inexpensive way for road authorities to melt ice and snow. When the ice melts, the water that runs off of the roadway may look relatively clean, but dissolved in the water is the salt that helped melt the ice in the first place. Modern Minnesota winters mean plenty of salt on the roads, and therefore in the ditches and waterways.

Shingle Creek on the west side of Minneapolis is the first Minnesota stream to be classified as impaired on the basis of its concentrations of chloride. This means that the creek contains a level of chlorides higher than the state and federal chronic standard of 230 milligrams per liter (about 1 teaspoon of salt in 5 gallons of water). Considered a toxic substance, chloride can harm aquatic organisms by disrupting natural processes that help regulate their metabolisms. Once it enters our waters, it's very persistent. It settles to the bottoms of lakes and changes their chemistry, preventing the bottom part of the lake to mix, or turnover, and changing the way the lake supports all of the life found in it. There are also signs of chloride in Shingle Creek watershed's groundwater—during low flow times in August, high levels of chloride show up in Shingle Creek as the groundwater flows into the creek.

Fortunately, we are starting to pay attention to chloride by studying its effects and ways to reduce it in our waters. The Minnesota Pollution Control Agency is now sponsoring voluntary certification courses to train snow removal staff from around the state on the steps they can take to reduce the amount of salt getting into our waters (and save their employers money at the same time.) The suggested changes focus around "anti-icing" instead of deicing. Melting ice with rock salt from the top down is inefficient, but by applying a liquid deicer to roads prior to a storm, it creates a thin layer of melting between the road and ice and allows for better plowing. When traditional rock salt is applied to the road about a third of it bounces of the street into the ditches automatically, wasting the salt and increasing unwanted chlorides in our waters. Switching to a wet salt mix reduces the amount that bounces off the road, melts the ice faster and reduced the overall amount of salt needed to provide a safe traveling surface. Because rock salt only works on warm pavement (over 150° F), another solution is to use different deicers when the road is colder. In the future we may look at other non-chemical solutions like heated roads. Even if we don't install heated roads, simple changes to our current actions can make a huge difference!

Other Chemical Pollutants

Many chemicals from many sources can pollute water bodies. Gasoline and oil from streets, parking lots, and boat motors wash into and contaminate lakes and rivers. Runoff from storm water can carry herbicides and insecticides from lawns and chemicals from cars down storm drains. Heavy metals such as mercury found in power plant air emissions can wash or fall into surface waters and bioaccumulate in fish and other living things. Sodium from road salt can upset the chemical balance of surface waters. Lead fishing tackle and ammunition that end up in lakes, streams, and wetlands can poison wildlife that accidentally eat them. Organic chemicals such as pesticides and herbicides can harm water life, too.

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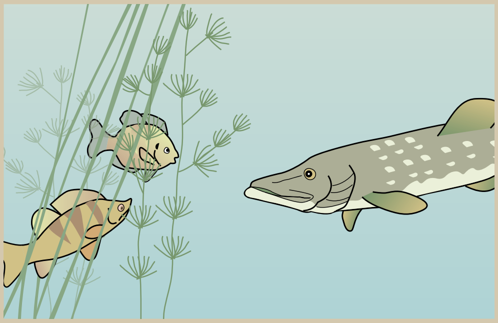
Toxic chemicals found in groundwater include a class of chemicals known as volatile organic compounds, or VOCs. These are chemicals that are manufactured as part of common products such as cleaners, paints, and fuel. The Minnesota Pollution Control Agency monitors groundwater for the presence of VOCs. Other chemicals of concern in groundwater include pesticides and perfluorinated chemicals (PFCs).

Some chemical pollutants, rather than poisoning living things that ingest them, will alter their internal control systems instead. These compounds, known as *endocrine disruptors,* can cause changes in an animal's anatomy or make it hard for animals to reproduce or properly carry on other functions controlled by hormones. For example, male fish begin to show female traits. Endocrine disruptors come from a variety of sources. Some cleaning compounds, plasticizers, pesticides, and other chemicals used in commerce and manufacturing function as endocrine disruptors. Pharmaceuticals also get into the water systems when they are excreted by people, or when unused medications are washed down sinks or toilets. Since most are not removed from the water by wastewater treatment plants, they are released into waterways, where they have the potential to have endocrine-disrupting impacts on fish and other wildlife. Most of the soaps, shampoos, cleaners, supplements and other personal care products we choose to use can also have serious, but largely unstudied, effects on the environment.

The good news about chemical pollution is that we recognize that it is a problem and are doing something about it. Years ago, people didn't think twice about pouring pollutants into waters, figuring they would get diluted or wash away and not be a problem. Now we know better. Since the 1970s, the amount of contamination entering lakes and rivers has been dramatically reduced. As scientists learn about risks from new pollutants, policy makers and regulators are working hard to protect our waters from them as well.

Half of Minnesota's wetland areas have been drained since 1850.



Bioaccumulation. Some pollutants, including mercury and organic pesticides, tend to collect inside the bodies of living things after they are ingested. When other creatures eat plants and animals that have taken up such contaminants from the environment, the pollutants accumulate in even higher concentrations inside them. Animals toward the top of the food chain, such as fish-eating fish, eagles, and mink, can bioaccumulate pollutants at levels high enough to cause health problems. Many lakes in Minnesota have fish consumption advisories—recommendations about how much fish and what types of fish people should eat—because of pollutants that bioaccumulate. Unfortunately, animals cannot avoid consuming mercury as we are able to do.

Matthew Lindon, MPCA

What's THAT? In Minnesota lakes, some things that look like contaminants may simply be the result of natural processes. In late spring, the yellow dust that gathers along shorelines is more likely pine tree pollen than pollution. The dark, "root beer" stain of some northern Minnesota lakes is due to natural chemicals called *tannins* that the water picks up as it travels through wetlands. The oily sheen that shows up on some waters is not human-caused pollution but natural organic materials. The "suds" that sometimes pile up along the shores of fast-flowing streams or on the downwind side of lakes are often composed of naturally occurring organic compounds that have been whipped up by wind or waves.

Thermal Pollution

Water withdrawn from lakes and streams is often used to cool equipment used to generate electricity or manufacture products. If the cooling water is returned directly to the lake or stream it can increase the temperature there. This thermal pollution can have several impacts on waterways. Warm water holds less dissolved gas than cold water does, making it more difficult for fish and other aquatic life forms to obtain the oxygen they need. Heat can speed the growth of bacteria and plants, which also reduces dissolved oxygen and makes it hard for some animals to survive. Heat can also stress animals that have little tolerance for changes in temperature. The added stress can make them more susceptible to disease and predation, or make it harder for them to reproduce. All of Minnesota's fish species are susceptible to harm from thermal pollution, but trout are especially sensitive.

One way we control thermal pollution is to use cooling towers or ponds to allow water used for electrical generation or manufacturing to cool before returning it to the source. In Minnesota, some communities, including downtown St. Paul, use the warm water to help heat buildings in the winter.

Pavement can also create a risk for thermal pollution by heating runoff. Think about how hot a paved parking lot gets in July, then imagine being a rain drop hitting that pavement. This heated runoff water has the greatest effect on spring-fed streams and for waterways near intensely paved areas (areas where much of the ground is covered with pavement or is otherwise impervious). Loss of shading trees along stream banks can also contribute to thermal pollution. In recent years people have worked hard to reduce thermal pollution from these sources by reducing the flow of storm water into rivers and lakes and keeping or planting trees along streams for shade.

Particulates and Solids

Two thousand, seven hundred tons. That's how much of Minnesota soil is lost each day. It washes down the Minnesota River past Mankato as wind and water erode soil and sand from farms, construction sites, roads, and other areas where they are not held in place by vegetation or barriers. Though the Minnesota River bears a larger load than most Minnesota waterways, it's not alone. Many other rivers receive a greater sediment load due to humans, too, leading to a variety of water quality problems. Soil carries with it nutrients and chemicals that pollute the water. Turbid water (water with a lot of sediment in it) makes it difficult for aquatic plants and animals to live and breathe. Sediment plugs fish gills, covers up mussels, impairs drainage systems, and limits transportation.

The problem used to be much worse. As people became aware of the problems caused by erosion and sedimentation, practices changed. Farmers began using measures such as contour plowing, conservation tillage, and buffer strips to hold the soil in place. Cities began requiring erosion control measures such as sediment control fencing, mulching, and catch basin protection to reduce the washing of particulates into surface water. Loggers now use a variety of "best practices," such as strategic stream crossing, to protect water quality. Lakeshore owners are helping by growing native plants, which hold soil in place, at the water's edge. Some city residents are helping out by building rain gardens, special low-lying areas incorporated into landscaping that catch water and allow it to soak into the ground rather than to rush, pollutant-laden, into the storm drain.

Particulates and Lake Pepin. Everything has to go somewhere. For phosphorus and sediment carried downstream by the Minnesota and Mississippi rivers from croplands and cities, that somewhere includes Lake Pepin, a widening in the river near Red Wing. A 2000 sediment-core study by Science Museum of Minnesota researchers showed that Lake Pepin is taking on sediment 10 times faster than in 1830. At current rates, the lake is predicted to be completely filled within 300 years.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Water Cycle Changes

For billions of years water has cycled from sky to earth and back again across the landscape of what is now Minnesota. The cycle has never been constant in space or time. Both location and distribution have shifted through the eons. Minnesota has seen volcanoes and glaciers, up-thrusting and erosion, and water has shaped each resultant landscape.

In recent times, humans have joined the forces altering water's progress through the water cycle and across the landscape by activities such as damming rivers, draining wetlands, and withdrawing groundwater from aquifers that would otherwise provide groundwater to streams, springs, and lakes. We have dramatically altered how water moves across the landscape. Some of those changes have had adverse consequences for the land and the living things it sustains. As a result, within the past few decades, we have reversed some previous modifications made to the water cycle, removing dams and reestablishing wetlands to restore habitat and ecosystem services provided by waterways.

Ditching and Draining

Wetlands were once seen as dangerous, unhealthy places, and a waste of what could be good, productive land. Much effort was put into draining them so they could be used for cropland, houses, schools, and business places. In the late 1800s and early 1900s, thousands of miles of ditches were dug around the state. Well-meaning farmers, struggling to provide food for a growing population, worked hard to drain the water from what many saw as wasted land. In the Twin Cities and other communities, many low-lying areas were drained and filled to make solid ground for homes, schools, roads, and businesses. All told, it has been estimated that half of Minnesota's wetlands were drained or filled in the process of settling this state.

We have dramatically altered how water moves across the landscape.

As is so often true, a change in one part of the environment caused problems in other parts. Lakes and rivers, robbed of the filters that formerly filtered runoff before it reached them, were

Wetlands in Minnesota Prior to European Settlement

Source: Anderson & Craig, 1984

Wetlands in Minnesota Today

Source: Anderson & Craig, 1984

Used with permission. Anderson, J. P., & Craig, W. J. 1984. *Growing Energy Crops on Minnesota's Wetlands: The Land Use Perspective.* p. 1-95. University of Minnesota, Center for Urban and Regional Affairs, Minneapolis. Publication No. CURA 84-3.

inundated with nutrients and sediments. Valuable habitat for ducks and other wildlife disappeared, and waterfowl began looking elsewhere for places to rest and feed on their migratory journey.

In his book *Streams and Rivers of Minnesota,* Thomas Waters gives the example of Ten-Mile Creek in southwestern Minnesota. In the late 1960s nearly 300 miles of ditches and drain tiles (network of pipes below ground) were installed in the creek's 100-square-mile watershed. The result was not only a gain of good farmland, but also a loss of almost 5,000 acres of wetlands. Wildlife experts estimate that the loss translates into the annual loss of production of some 12,000 ducks and 9,000 muskrats—not to mention the countless other plants and animals that would have made their homes there.

In addition to draining wetlands, ditching also reduces groundwater recharge and causes water to run into rivers more quickly by carving for them a relatively uninhibited path of travel. The result is that rivers are "flashier"—they fill faster in rainstorms—and more sediment is scoured from the riverbanks, increasing erosion and dirtying waters downstream.

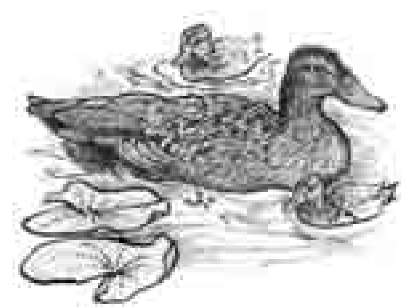
As we became more aware of the importance of wetlands, more emphasis was placed on preserving rather than draining them. In the 1950s a "Save the Wetlands" program set aside wetlands as wildlife habitat. Today people are working around the state to protect and restore wetlands and in some cases filling or plugging drainage ditches.

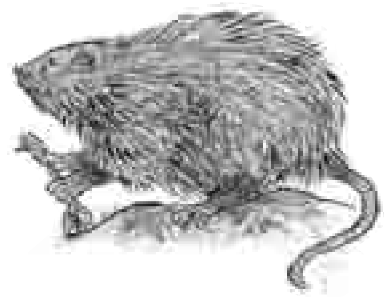
East Side Neighborhood Development Company

Lake Phalen Shopping Center paved over wetland (prior to demolition and restoration).

RWMWD

Lake Phalen Shopping Center site after demolition and wetland restoration.





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Minnesota has more than 21,000 miles of drainage ditches. Ditching and draining is responsible for the loss of hundreds of thousands of acres of small lakes in the state.

Dams, Channels, and Levees

Minnesota has also dramatically altered the natural trajectory of water through the water cycle by damming rivers. Over the years, some 2,500 dams have been installed on Minnesota's lakes and streams.

Dams change rivers by altering the flow of water and causing sediments to collect in the slowed water upstream from the dam. They also affect the free movement of fish and other animals living in the river. In recent years, the Minnesota DNR has been working to remove dams that are no longer needed from rivers around the state. Today Minnesota has approximately 1,300 dams remaining.

Another way people have altered the path Minnesota waters take on their way from cloud to sea is to **channelize** streams—straighten, deepen, and widen them. Close to 22,000 miles of Minnesota streams have been channelized.

Levees are used to protect riverside communities from floodwater and provide public safety. However, they also raise the water level and speed elsewhere, and take away the ecologically important interaction between river and floodplain.

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More than 90 percent of the Minnesota River watershed is being farmed. Much farmland is ditched to deliver water quickly from the surface. Many streams have been straightened, deepened and widened to speed water downstream—a process called channelization. Water is no longer allowed to follow its more meandering, historic course.

Minnesota is home to 69,200 miles of natural streams. It's also home to some 70,000 miles of artificial waterways—ditches that have been carved into the land to dry out soggy areas and make them more suitable for farms, roads, homes, and other uses.

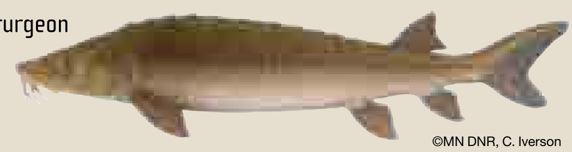
Better Than a Dam Site. In 1908 the Kettle River Power Company built a hydroelectric dam across the Kettle River to power its quarrying operations. As good as the dam may have been for that purpose, it was not very good for the river ecosystem. Fish and mussels couldn't travel upstream. Valuable spawning habitat was destroyed.

By the 1990s the hydropower plant was no longer operational, the Kettle River had been designated a Wild and Scenic River, and the dam had been donated to the Minnesota DNR and declared structurally unsound. In 1995, after a study confirmed the environmental benefits of removing it, the DNR used a wrecking ball and backhoe to remove it. Lake sturgeon and other fish began migrating upstream. Spawning habitat was restored and sediment stopped accumulating behind the dam. Today, a waterfall and rapids uncovered in the process provide beauty and recreational opportunities to residents and visitors alike.


MN DNR

Kettle River with dam and without.

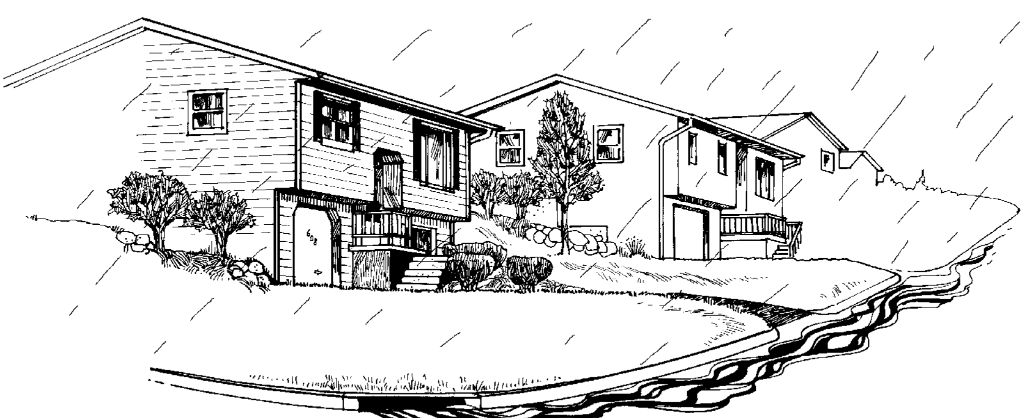
Lake sturgeon


©MN DNR, C. Iverson

Impervious Surfaces

What happens when rain hits the roof of your house, or the street in front of it? Before your house was built and the lot was developed, much of the rain that fell would soak into the ground. With a surface too dense to permeate, it now runs off, often untreated through a storm sewer, into a lake or river.

The problem with impervious surfaces is that water carries sediments, heat, and other pollutants into lakes and streams when it runs off. Runoff water that runs off is also prevented from replenishing aquifers. Less water is available then for municipal wells and household wells, as well as natural processes like gradually feeding stream flow and providing water to springs.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Slowing the Flow. Some people install features such as rain gardens and rain barrels around homes and businesses to keep a handy supply of water available for various purposes and to keep it from rushing so fast to a stream or lake. On lakeshore property, there is a growing trend toward leaving lakeshores natural rather than growing lawn to the water's edge. This is helping to protect lakes from runoff and nutrients that cloud the water, cause algal blooms, and generally disrupt the balance of nature within them. New engineering techniques have created porous pavement that looks like regular asphalt, but allows water to seep through to the ground. When whole neighborhoods join forces and do these projects together, a significant amount of progress can be made.

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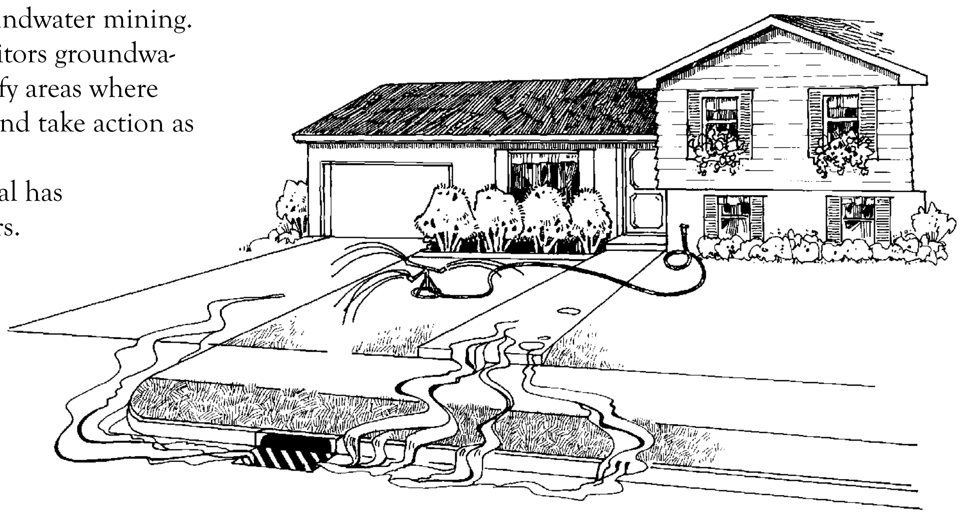
Today, planners and developers are beginning to take into consideration the value of keeping water in its place as they add roads, buildings, and parking lots to undeveloped land. Low-impact development options such as green roofs, rain barrels, pervious pavement, and rain gardens are techniques that are being used more often to prevent water from running quickly into lakes and streams. It all adds up to helping keep both surface and groundwater healthy.

Groundwater Mining

Extensive use of groundwater can result in a long-term lowering of the water table. This phenomenon is known as groundwater mining. The Minnesota DNR monitors groundwater supplies so it can identify areas where overuse may be occurring and take action as needed.

Groundwater withdrawal has grown greatly in recent years. Between 1991 and 2005, groundwater use in Minnesota increased 26% while population increased 18%. Currently, the population is growing quickly in a corridor stretching from St. Cloud through the Twin Cities. With more people comes more demand for water.

Farms and industries around the state are also using more groundwater: During the 1991 to 2005 period, for example, use of groundwater for crop irrigation in the state increased by 65 percent. Water planners are watching carefully to make sure demand for groundwater does not result in overuse. This is important because groundwater is replenished by surface water, and vice versa. In some cases it is better to use water from several sources to lessen impacts on each.



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Lakeshore Development

Lakes throughout Minnesota are experiencing hefty development pressure today. In the Brainerd Lakes area, for example, small fishing cabins and resorts have been replaced by huge homes with expansive lawns. Changing land ownership is making possible the development of more and more lakes to multiple developments as paper companies and other industrial forest landowners sell off their property. These changes can impact water quality and aquatic habitat.

Many lake associations are learning about how their property affects the water. To help protect the lake and the natural beauty that attracted them in the first place, landowners are learning how they can help improve the water quality, and changing their landscaping and other practices correspondingly.

Programs like NEMO (Nonpoint source Education for Municipal Officials) help local decision makers understand how the decisions they make in planning their communities affects their water and how they have many simple, cost-effective options available as they plan and improve their communities.

MN DNR

Global Climate Change

As climate changes, scientists predict we will see dramatic changes in the water cycle in Minnesota. Storms are expected to become more severe. Extended periods of drought and more frequent floods will be more likely. Warming temperatures will speed evaporation, potentially lowering the level of surface waters. Lakes will be more susceptible to oxygen depletion in winter, increasing the chances of fish die-offs. Wetlands may be lost as droughts increase in frequency and/or severity. Some species will be unable to survive in the new conditions.

Some experts think that we are already seeing impacts of global climate change on Minnesota's waters. For example, annual precipitation at Brainerd has increased from 23.03 inches during the period 1921–1950 to 27.62 inches in 1978–2007. And according to the Minnesota Pollution Control Agency, precipitation has increased 20% in some parts of southern Minnesota as well.

MN DNR

Biological Changes

In many instances these actions have been harmful to native species. In other instances they have been beneficial as we work to restore populations formerly depleted by pollution or other human action.

Minnesota's lakes, streams, wetlands, and other bodies of water have long played host to an amazing diversity of, in Charles Darwin's words "endless forms most beautiful and most wonderful"—living things that crawl, swim, float, photosynthesize, eat, die, and give rise to new life. Before humans began to rapidly change the environment, populations of various living things grew and declined in balance with each other, occasionally interrupted by cataclysms and other sudden events. In recent years, human impacts have added new, balance-disrupting forces to the picture, resulting in shifts in the amounts and variety of life in our waters.

More than 20 aquatic invasive species are found in Minnesota waters.


USFWS

A USFWS employee in Missouri holds an Asian carp. The DNR is trying to limit the introduction of Asian Carp to Minnesota.

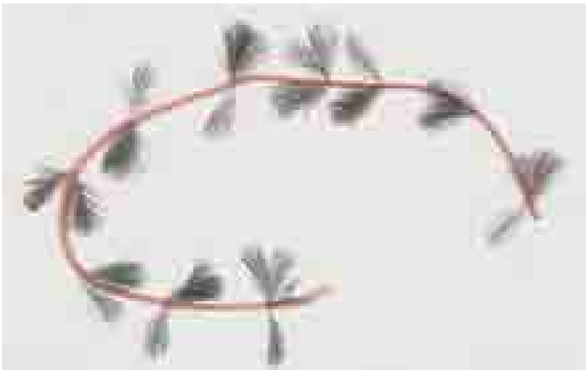
Invasive Species

Imagine getting up one day and finding someone you don't know sitting in your kitchen, eating your cornflakes and drinking your orange juice. You go to use the bathroom, and find it occupied by another mystery guest. Later, when you come home from work or school, the entire house is filled with strangers. During the day they have managed to eat all the food from your refrigerator, take over your bedroom, and break three windows.

Many Minnesota aquatic plants and animals have days—sometimes entire lives—like that. Their native habitat has been invaded by nonnative species, plants or animals that people have intentionally or accidentally brought from other places and displaced the native plants and animals. These species are often from Europe or Asia. Some nonnative species live fairly compatibly with the ones that are already here. Others, called invasives disrupt the balance of nature and reduce native species' ability to thrive. The result in some cases has been a loss of balance in aquatic ecosystems, crowding out of native species, and economic impacts ranging from loss of desirable species to fouling of underwater equipment such as water intake pipes. Minnesota spends millions of dollars each year trying to slow the spread of and reduce the impacts of aquatic invasive species.

Lake Superior alone is home to at least 27 kinds of invasive plants, animals, and other organisms.

Many aquatic species have been intentionally or unintentionally introduced into Minnesota waterways. Some aquatic invasive species affecting Minnesota's waters today include:


MN DNR

Eurasian watermilfoil


MN DNR

common carp


MN DNR

zebra mussel


MN DNR

curly-leaf pondweed


MN DNR

rusty crayfish


MN DNR

purple loosestrife


Jeff Gunderson

spiny water flea


M. Gaden and R. Bergstedt

sea lamprey

MN DNR

bighead carp

Peter Dziuk

flowering rush

David Jude, School of Natural Resources and Environment, University of Michigan

round goby

MN DNR

ruffe

MN DNR

faucet snail

Minnesota Sea Grant

New Zealand mud snail

Public education programs, monitoring programs, and enforcement efforts are working to reduce spread of Eurasian watermilfoil and zebra mussels by encouraging anglers and boaters to remove aquatic plants, animals, and water from watercraft before moving from one body of water to another. Chemical control and physical barriers are attempting to keep the lid on sea lamprey populations.

For more information on the many invasive species found in Minnesota, see www.mndnr.gov

Wild Waters, Troubled Waters.
Even the Boundary Waters Canoe Area Wilderness is not safe from invasive species. Spiny water fleas, tiny crustaceans native to Europe and Asia that were inadvertently brought to Minnesota by ships traveling the Great Lakes, have invaded some waters in the wilderness. The water fleas, which look like a cross between a mosquito and a sewing needle, eat the plankton that form the basis of a lake's food web. They likely invaded the wilderness with the inadvertent assistance of anglers as they clung to fishing lines or other equipment.

Lost or Depleted Species

The many changes we've made in waterways affect their ability to sustain native life forms. As a result, a number of species have been reduced in number or have disappeared altogether from Minnesota's waters, including:

- *skipjack herring*—migrates from the sea, but dams now obstruct
- *ebony shell mussel*—depend on skipjack as host
- *paddlefish*—spawn in gravelly rapids that are altered by dams
- *sturgeon*—spawn in gravelly rapids that are altered by dams
- *blackfin cisco*—crescent stripetail stonefly
- *Blanding's turtles*

In many cases, conservation activities have helped reverse or mitigate the impact of some of the trends that have negatively affected native species in the past. Removal of dams has helped restore sturgeon along stretches of the Red River. A 1999 moratorium on walleye fishing in the Red Lakes helped increase the number of walleye after many years of overfishing. Sea lamprey control efforts have contributed to the recovery of lake trout in Lake Superior after the species nearly disappeared in the 1950s. Improved wastewater treatment in the Twin Cities has allowed mussels to return to formerly uninhabitable parts of the Mississippi River.

A dozen things you can do to care for Minnesota waters:

1. **Dispose of unwanted household chemicals and pharmaceuticals properly.** Don't flush drugs down the toilet! Most counties have household hazardous waste disposal sites. Information on proper pharmaceutical disposal can be found on the Minnesota Pollution Control Agency website.
2. **Examine your boat and remove any plant material clinging to it before moving it from one body of water to another.**
3. **Use rain barrels and rain gardens to capture runoff and reduce impacts to lakes and rivers.** For suggestions on how to create a rain garden using native plants, contact your city or county office.
4. **Check your toilet and sinks for leaks and repair if needed.**
5. **Volunteer to help monitor lakes and rivers** (see online resources listed at the end of this chapter).
6. **Keep lakeshores natural!** If your shoreline is planted in turf grass, consider replanting it with native species. Contact the DNR, the University of Minnesota Extension Service, your soil and water conservation district office, or bluethumb.org for suggestions on what to plant and where to obtain plants.
7. **Don't dump anything into lakes or rivers, onto streets, or down storm drains.** Wash your car on your lawn instead of in your driveway.
8. **Volunteer to start or join a lake or river cleanup in your community.** For more information contact your local lake or river association or the DNR Information Center, 651-296-6157 or 888-646-6367.
9. **Recycle!** Recycling paper uses less water to process than virgin pulp from trees.
10. **Don't water your lawn unless it really needs it.** If you have an automatic sprinkler system, use a rain sensor and adjust settings monthly according to the recommendations of your county soil and water conservation district. Especially make sure you're not watering the sidewalk or street!
11. **Support river-friendly farming.**
12. **Conserve water by using low-flow showerheads and toilets.**

C A R E E R P R O F I L E

Dennis Lindeke
Assistant Plant Manager,
Metro Council Environmental Services
Cottage Grove

Each day, millions of gallons of wastewater go down the drain in Twin Cities homes and workplaces. Dennis Lindeke is one of the people who makes sure that water is clean when it is released to the area's beautiful river systems.

Before modern wastewater treatment facilities like the one Lindeke manages were built, people were sickened by waterborne diseases, and few game fish swam in this stretch of the Mississippi River. Thanks to modern facilities, waterborne disease is now rare, and you can catch trophy walleye and bass in the corridor between Minneapolis and Hastings.

Lindeke is responsible for maintaining the function of the biological processes that cleanse wastewater. He also works with his staff to keep mechanical equipment in good shape and monitors effluent to make sure it meets strict water quality standards. He says the favorite part of his job is working with people who are dedicated to keeping Minnesota's waterways healthy and clean.

"We are very proud of what we do, day-to-day," he says. "It is really an amazing thing—in a period of about eight hours, we take the pollutants out of the wastewater and discharge very clean water back in to the rivers."

The job gets more challenging every year, however, as wastewater experts learn more about hard-to-remove pollutants such as pharmaceuticals, nutrients, and heavy metals and try to figure out ways to deal with them.

Why would a person choose a career in wastewater treatment? Lindeke does what he does because he cares about the environment. He likes the challenge, too, of needing to know a lot about a lot of different things. People in his position often have engineering or science degrees and use chemistry, biology, math, mechanical and electrical systems, personnel management, writing, and public speaking skills every day.

Related careers:
water treatment plant operator,
chemical engineer

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water education involves a variety of teaching strategies

Water Actions (personal action) MS, HS

Water connects all Earth systems

Just Passing Through (erosion) EL, MS

Rainy Day Hike (stormwater pollution) EL, MS

Water is a natural resource

A-maze-ing Water (stormwater pollution) EL, MS

Color Me a Watershed* (watersheds, mapping) HS - Aerial photos of MN major watersheds over time.

Common Water (water users) EL, MS

A Drop in the Bucket (global water distribution) EL, MS, HS

Sum of the Parts (nonpoint source pollution) EL, MS

Water Meter (water conservation) EL, MS

Where are the Frogs? (acid rain) MS

Water resources are managed

Every Drop Counts (water conservation) MS

A Grave Mistake* (groundwater) MS, HS - case studies of Minnesota groundwater contamination.

Humpty Dumpty (ecosystems, parts) EL, MS

Macroinvertebrate* Mayhem (benthic macroinvertebrates & water quality) EL, MS - Example macroinvertebrate species data for Minnesota's three main watersheds.

Money Down the Drain (water conservation) EL, MS

The Pucker Effect (groundwater) MS, HS

Reaching your Limits (water quality) EL, MS

Sparkling Water (wastewater treatment) EL, MS, HS

Water resources exist within social constructs

Dilemma Derby* (water issues, problem solving) MS, HS - MN case studies of historical water issues.)

Hot Water (debate water issues) HS

Whose Problem is it? (water issues, problem solving) MS, HS

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Research and Protect: Choose a body of water near you. Research past, present, and anticipated future threats. Explore what people have done/are doing to protect it. If there is a need, consider taking it on as a class project. Write an article for the school or local newspaper about the project. Younger students could collect trash around the school grounds to keep it from collecting in local water bodies.

Local Scene? Have students contact city or county environmental staff, soil and water conservation district staff, or watershed district staff to learn what each office is working on and find ways the class or any citizen can become involved in the needs of the community.

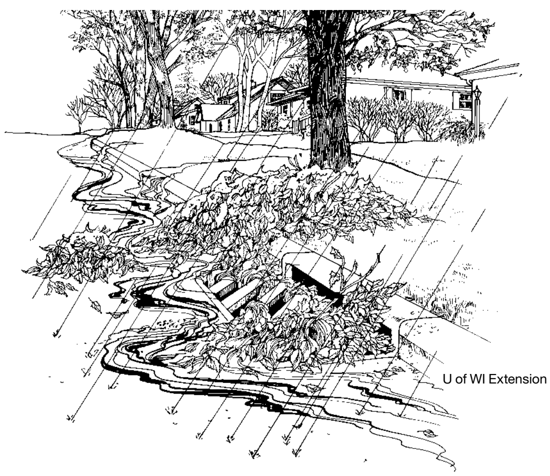
How big of a problem is urban runoff? Practice math skills by calculating the amount of water prevented from soaking in by some familiar impervious spaces—your school building, a typical city street, or the parking lot at the mall. A house with a 1,000-square-foot footprint, for example, sheds more than 600 gallons of water during a one-inch rainstorm.

Drinking Water Reports: Water suppliers that serve the same people year-round must prepare annual water quality reports (consumer confidence reports) for their customers. The reports tell where drinking water comes from, what's in it, and how you can help protect it. Water suppliers send out CCRs to homes and some post them online, however, citizens can request a copy from their local water utility. Have your students contact your local water supplier to get a copy of the local Consumer Confidence Report and learn about their tap water.

Observing Water Samples: For younger students, brainstorm a list of six places you can find water in your community (including running out of the faucet). On your own, reuse plastic peanut butter jars to collect samples of water for each and put the jars on display in your classroom. How do the samples differ? Are some cleaner than others? If so, why?

Out and About

Investigating Storm Sewers: Many storm sewers empty directly into rivers and lakes. After researching where the drains in the vicinity of your school drain, get permission to stencil messages near the drains reminding people not to dump harmful chemicals down them where they can wash into drains. Write an article for your local newspaper explaining the importance of keeping pollutants out of storm sewers.



Rain Garden: With students in the lead, design and install a rain garden at your school. Talk to your local watershed district or county environmental services staff to see if they can help you with planning or planting costs (many offices have cost-share programs and free raingarden planning advice.) Invite local media to tell your story so others can learn what you did and why you did it.

Stewardship and Service: Look at the list of things you can do to care for Minnesota waters. Choose one of these practices as the focus of a service-learning project. Develop and carry out a plan to encourage residents of your community to adopt the practice.

Visit with Local Water Officials: Visit a nearby soil and water conservation district or watershed district project with a staff member from the organization who can tell you what happened/is happening and why.

How much is Impervious? Map and calculate impervious surfaces on school grounds. Where does the runoff water go? What would be the advantage of slowing it down? What could you do to make that happen? (e.g., rain barrels, rain gardens)

Save Water = Save Money: Help your school save water and money while learning lots about measurement and calculation by doing a school water audit. Search “school water audit” online for example audits.

A few excellent resources:

1. Water Footprint Calculator, Water Footprint Network. http://www.waterfootprint.org/?page=files/WaterFootprintCalculator. The water footprint is an indicator of direct and indirect water use of a consumer or producer. The water footprint of an individual, community or business is defined as the total volume of freshwater that is used to produce the goods and services consumed by the individual or community or produced by the business.

2. Water Data for the Nation, United States Geological Survey. http://waterdata.usgs.gov. This website allows you to look up real-time data on streamflow, groundwater table levels, precipitation, etc. for specific points in MN.

3. Water on the Web http://www.waterontheweb.org/. Water on the Web helps college and high school students understand and solve real-world environmental problems using advanced technology. The program includes two sets of curricula, data from many lakes and rivers nationwide, extensive online primers, data interpretation and Geographic Information System Tools, and additional supporting materials.

4. Storm drain stenciling guide, University of MN Extension Service. http://www.cleanwatermn.org/app_themes/cleanwater/pdfs/GetInvolved_InNeighborhood/StormDrainStencilingGuide.pdf A simple guide on how to storm drain stencil with your students.

5. Minnesota Water, Let's Keep it Clean website, Metro WaterShed Partners. http://cleanwatermn.org/ This website provides public stormwater pollution prevention education materials and products.

6. Find your local watershed district at http:///www.mnwatershed.org, your soil and water conservation district at http://www.maswcd.org, or a list of who to contact at all levels of government, local, state and federal at http://shorelandmanagement.org/contact/index.html. See appendix 3 for a summary of Minnesota local and state water contacts.

7. Minnesota Pollution Control Agency water website, MPCA. http://www.pca.state.mn.us/water/index.html Find out more about the MPCA's programs to help protect our water by monitoring its quality, setting standards and controlling what may go into it.

8. MN Water Conservation Resources Website, MN DNR. http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/conservation.html This website contains links to water conservation resources and information like water conservation toolboxes for water suppliers and citizens, summary of residential water use, and water efficiency tools.

9. Minnesota Shoreland Management Resource Guide, MN Sea Grant and University of MN's Water Resources Center. http://shorelandmanagement.org/index.html. This website provides easy access to information about sustainable shoreland practices to improve management of Minnesota's lakes and rivers. The Website contains scientific and technical background, camera-ready quick and easy answers (FAQs), highlights of citizen action, and contact information for Minnesota counties.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET activities
Educational materials/classroom resources for Project WET teachers
Out and About—field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

Lyndon Torstenson

Chapter 7: Governing Water

Key Concepts:

- Laws, rules, and regulations help keep water clean and available for a variety of uses, from providing life-giving drinking water for people, to providing support for our economy, to providing habitat for other living things, to providing beauty and recreational opportunities for all.
- Federal, state, and local governments work together to care for Minnesota's waters.

Water is a public resource that all have a right to use.

WHO OWNS THE WATERS OF MINNESOTA? Who is responsible for taking care of them?

We all do, and we all are.

Water is a public resource that all have a right to use. There are different laws and regulations governing that right, but the basic idea in Minnesota is that no one owns the water—we all have rights to it.

We all can take care of water by using it wisely, not polluting or wasting it, and encouraging others to do the same. In addition to these activities, it's important to pay attention to water issues at the local, state, and national levels, providing input to elected officials as they shape laws affecting water, and providing input to those who are appointed to carry them out.

In Minnesota, the rights and responsibilities related to water are determined by federal laws, state statute, local ordinances, and the rules, regulations, and permits that result from them.

Why Govern Water? If we didn't have government controls, some people would use water to meet their own needs without adequately considering the cumulative impact of many users on the resource. This phenomenon. known as the "tragedy of the commons," leads to unsustainable use. Laws, rules, and regulations provide a framework that allows us to all share and care for water resources.

Who Governs Water?

A 2009 report by the Citizens League lists two-dozen entities involved in governing water in Minnesota. They include:

Federal
Bureau of Indian Affairs
Farm Service Agency
Natural Resources Conservation Service
U.S. Army Corps of Engineers
U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
U.S. Geological Survey
Minnesota
Board of Water and Soil Resources
Clean Water Council
Environmental Quality Board
Legislative-Citizen Commission on Minnesota Resources
Minnesota Department of Agriculture
Minnesota Department of Health
Minnesota Department of Natural Resources
Minnesota Department of Transportation
Minnesota Geological Survey
Minnesota Pollution Control Agency
Local and Regional
Cities and Towns
Counties
Lake Improvement Districts
Metropolitan Council
Sanitary Districts
Soil and Water Conservation Districts
Watershed Districts
Watershed Management Organizations

Federal Laws

A number of federal acts influence the fate of waters in the United States. The Boundary Waters Treaty of 1909 between the United States and Great Britain established an international body known as the International Joint Commission with the power to resolve disputes regarding waterways shared by the United States and Canada. Various federal laws were enacted over the years related to improving navigation on the Mississippi River. The Federal Water Pollution Control Act of 1948 laid the groundwork for subsequent legislation. Amended in 1972, it became known as the Clean Water Act with further amendments in 1977. This law set the ground rules for how water should be protected with a goal of making all waterways in the United States fishable and swimmable.

The federal Safe Drinking Water Act, passed in 1974, helps protect the quality of the water we drink. Other federal level mandates that impact Minnesota's waterways include the Wild and Scenic Rivers Act of 1968, the Coastal Zone Management Act of 1972, PL 101-233 (relating to habitat for migratory birds), and executive orders related to floodplain management and wetland protection.

The federal laws are enforced and reinforced through the efforts of multiple agencies, each with its own unique role. The U.S. Environmental Protection Agency (USEPA), U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service (USFWS), U.S. Geological Survey (USGS), Natural Resources Conservation Service (NRCS), National Park Service (NPS), National Oceanic and Atmospheric Administration (NOAA), and Federal Emergency Management Agency (FEMA) are among those involved in protecting our nation's waters according to the laws Congress passes.

Protecting Public Water Supply.
Federal regulations and state statutes and rules specify limits to contaminants in public water supplies. They require that public water suppliers notify members of the public served by a water supply if it exceeds the standards. In Minnesota, public water supplies are monitored for more than 140 kinds of microbes, radioactive minerals, inorganic contaminants, volatile organic chemicals, disinfection byproducts, and synthetic organic chemicals.

MN DNR

St. Croix River.

Saving Wetlands. In 1991 the Minnesota Legislature passed the Wetland Conservation Act, one of the most stringent wetland protection laws in the nation. Its goal is to ensure no net loss of wetlands in the state. Amended a number of times, the act requires individuals to, if possible, avoid draining or otherwise altering wetlands. If that is not possible, the law requires that the impact be minimized and any losses of function, value or acreage be compensated with the creation of a replacement wetland.

State Laws

In addition to the limits established by federal law, the fate of Minnesota's waters is also influenced by state legislation affecting the quality, distribution, and use of water. Minnesota has long been a leader in protecting its lakes, rivers, and wetlands with strong water laws.

State statutes relate to a wide range of water-related issues, from acid rain to zebra mussels, and include such diverse topics as the recovery of sunken logs and endangered species protection. Among the earliest was the Water Conservation Act of 1937. Passed partly in response to years of drought and difficulty managing Minnesota's waters, this law was the beginning of the state's public waters permit program and water appropriation permit program. Other specific acts affecting Minnesota's waters and how we use them include the Shoreland Management Act of 1969, the Floodplain Management Act of 1969, the Minnesota Wild and Scenic Rivers Act of 1973, the State Water Pollution Control Act, the Acid Deposition Control Act of 1982, the Ground Water Protection Act of 1989, and the Wetland Conservation Act of 1991.

State agencies involved in conserving, protecting, and allocating the use of water in Minnesota include the Minnesota Pollution Control Agency (MPCA), the Minnesota Department of Natural Resources (DNR), the Board of Water and Soil Resources (BWSR), the Minnesota Department of Agriculture (MDA), and the Minnesota Department of Health (MDH). Statutes or rules give these and other agencies and government entities responsibility for various aspects of water management.

Included in state agency responsibilities are carrying out mandates of federal laws and staying within boundaries drawn by federal agencies. The Minnesota Pollution Control Agency, for example, is responsible for administering the federal Clean Water Act. The Minnesota Department of Health, which regulates drinking water quality, must adopt standards at least as strict as those of the EPA. Minnesota's standards can be and sometimes are more rigorous than federal standards. The Environmental Quality Board, made up of the heads of key state agencies, citizens, and a representative of the governor's office, also coordinates water planning and influences water policy.

The basic principle underlying who gets to use water and how in Minnesota is a blend of what's called **riparian (waterside) rights** and **reasonable use.** In the western half of the United States, rights to use a water source belong to whoever started using it first. In Minnesota, water belongs to all of us. Anyone who owns property on the shore of a body of water has the right to access it, as long as they do so in a way that doesn't unreasonably inhibit the ability of others to exercise their same right. The Minnesota DNR is responsible for issuing permits for withdrawing groundwater and surface water. Permits are required for appropriating more than 10,000 gallons per day or 1 million gallons per year. The MPCA regulates discharges to surface water bodies.

Minnesota's 2006 Clean Water Legacy Act provided nearly $25 million for cleaning up Minnesota's waters. It also established a Clean Water Council to help make it happen.

In Minnesota, water belongs to all of us.

The Clean Water, Land and Legacy constitutional amendment, approved by voters in 2008, raised the state sales tax to provide dedicated dollars funding to, among other things, projects to protect and improve the state's waterways. The amendment, which resulted in creation of the Clean Water Fund, explicitly calls for protecting drinking water sources; protecting, enhancing, and restoring wetlands; and protecting, enhancing, and restoring lakes, rivers, streams, and groundwater. Of the funds raised, 33 percent will go to the Clean Water Fund to be spent to protect, enhance, and restore water quality in lakes, rivers, streams, and groundwater, with at least 5 percent of the fund spent to protect drinking water resources. The Clean Water Fund is overseen by the Lessard-Sams Conservation Outdoor Heritage Council, a citizen council that decides how the money will be allocated.

Local Government

Minnesota waters are also affected by action at the local level. County, township, and city governing bodies, through their authority to regulate private lands in their jurisdiction (planning and zoning) also regulate land activities that affect water resources. Because lakes and streams don't start or stop at city, township, or county boundaries, Minnesota also has local management groups organized by entire watershed areas. These are most often referred to as watershed districts. Minnesota also has 91 soil and water conservation districts. These local units of government provide funds, education, and technology to help landowners care for their land and water. Sometimes the units managing a particular water resource do overlap.

Research suggests the greatest impact to water resources is from local land use and management. As a result, federal, state, and local regulations are often implemented and managed at the smallest local governmental level.

City of Plymouth

Water quality monitoring.

You and Me

MN DNR

Of course, the smallest, and ultimately most influential, unit of government is each of us. We alone are responsible for deciding whether our personal actions will help or harm Minnesota's waters. We get to choose for ourselves every day between behaving in a way that takes water for granted, or in a way that protects its ability to sustain us and other living things. We have the power to lead by example (see page 102 for a short list of things you can do to care for Minnesota's waters).

What will Minnesota's waters be like 10—or 50—years from now? Will they meet the needs of future generations, as they so ably have ours?

At the end of the day, it's up to you and me.

At the end of the day, it's up to you and me.

Your Opinion Counts! Can people who aren't lawmakers or lawyers get involved in setting and enforcing laws, rules, and regulations that protect water? Absolutely!

Share your opinions with those who are running for or already in office. Each Minnesotan is represented in U.S. Congress by two senators and one representative. At the state level, we each have one senator and one representative. Other political entities that influence water policy in Minnesota include county government, city or township government, the Metropolitan Council, and watershed boards. The president of the United States and the governor of Minnesota also provide input that affects waterways. You can find contact information for your state and federal representatives by going to http://www.gis.leg.mn/mapserver/districts/index.html or contacting your school or local library information center. You can learn how to connect with decision makers at the county, watershed district, and local level by contacting the pertinent offices (use a phone book or do an Internet search using the name of your county or community). You can also learn more about your watershed district at http://www.mnwatershed.org.

A very significant way you can help protect water through government processes is to provide testimony through public hearings. You can find out when and where public hearings will be held by watching city, county, and watershed district websites for information on planning commission meetings.

A fourth way to help establish and enforce water-protecting laws is to get involved in nongovernmental groups that work to influence water policy and legislation. Wherever you are, and whatever age you are, there is a group for you—ranging from local lake associations and sporting clubs, to statewide organizations (in Minnesota, groups like Minnesota Waters, Minnesota Center for Environmental Advocacy, Minnesota Environmental Partnership, and Clean Water Action) to national organizations such as the Izaak Walton League of America and National Audubon Society. Do an Internet search for the organization name or contact your library information center to learn more.

C A R E E R P R O F I L E

Career Profile
Kevin Reuther
Legal Director, Minnesota Center for Environmental Advocacy
St. Paul

It's important to have laws that protect water. It's also important to make sure those laws accomplish what they are intended to accomplish. Environmental lawyer Kevin Reuther is one person who helps do just that.

Reuther acts as a legal advocate for Minnesota's water resources when state agencies make rules related to water and decide how to enforce them. He also takes water resources' side in court. When all else fails, he may file a lawsuit against a government agency that his organization thinks is not working hard enough to protect water. By getting the judicial branch of government involved, he helps ensure that laws designed to protect water are effective.

Feeling good about making the world a better place is Reuther's favorite part about being a legal director for nonprofit environmental agency. On the other side of the coin, changes in policies and laws rarely happen quickly, so sometimes it's hard not to get discouraged. But even little successes make it worthwhile.

"Working for a nonprofit comes with lots of sacrifices—no big-money salary, no fancy offices," Reuther says. "Nearly all of our cases are truly like David vs. Goliath. And we often lose. But I would never trade the feeling I have as I bike home from a long day's work—the benefit of doing a job you love and feeling good about it."

Students interested in a career in environmental law should be active and involved in school and community activities. Hard work and good grades will help, too. Even though Reuther and others in his profession have been doing their job for a long time, there will always be a need for more.

Related careers:
nonprofit director,
lobbyist

Suggested Project WET Activities and Minnesota Connections

EL = elementary	MS= middle school	HS=high school

Water resources exist within social constructs.

Pass the Jug (water rights) EL, MS, HS

Perspectives (problem solving) MS, HS

Water Bill of Rights (water rights) EL, MS, HS

Water Court (water issues, problem solving) HS

* Some Project WET Activities have Minnesota adaptations posted online for Minnesota Project WET Educators in the trained teacher page at www.mndnr.gov/projectwet. Additional adaptations will be added when possible.

Classroom Connections

Local Laws: Choose a body of water near your school. Find out what laws protect it, and in what way. Find out what public agencies are responsible for caring for it.

Tragedy of the Commons: Why are water laws necessary? Read Garrett Hardin's classic article The Tragedy of the Commons (Science 162 (3859): 1243-48, readily accessible online). Present the concept to your students and discuss it with them in an age-appropriate way.

Create a Law: Invite students to propose a law they would like to see put in place to protect Minnesota's waters. Introduce the basic principles of debate, then allow students to participate in a formal debate of the proposed law.

Officer in the Classroom: Invite a conservation officer to your classroom to talk about laws that protect water and hear some amazing stories of how people break them.

Local Water Issues: Have students identify a water issue that is important in your community. After researching the issue, have them contact the appropriate elected representatives to express their opinion about it.

Water Law Lineup: Make a human timeline of water laws and milestones in class to get the group moving on a difficult and abstract subject.

How Can You Protect it? Ask young students if they were in charge of a lake or river, how would they protect it from harm? Students of any age can help brainstorm a set of rules to help keep a body of water in or near your community healthy.

Out and About

Attend a Government Meeting: Attend a local government meeting that involves discussion of a water-related issue.

Attend a Citizen Meeting: Attend a meeting of a citizen group involved in influencing policy that protects Minnesota's water resources.

A few excellent resources:

1. Water Laws in Minnesota fact sheet, MN DNR. http://files.dnr.state.mn.us/waters/watermgmt_section/pwpermits/water_law_questions_and_answers.pdf. This 4-page publication includes basic questions and answers about Minnesota water laws.

2. Water Laws: Water Resources Law, Policy and Commentary, Smith Partners. http://www.waterlaws.com/court_cases/court_cases.html. A digest of recent Minnesota state and federal court decisions on water law and watershed management.

3. MN State Water Rules, MPCA. (mainly related to water quality) http://www.pca.state.mn.us/water/water_mnrules.html

4. Minnesota Water Statues and Rules, DNR. http://www.dnr.state.mn.us/waters/law.html Lists rules and statutes relating to DNR water programs.

5. Wetland Regulation in Minnesota, MN Board of Water and Soil Resources. http://www.bwsr.state.mn.us/wetlands/publications/wetlandregulation2.html Short description of wetland regulation in MN.

Want More? See www.mndnr.gov/projectwet for resources and information:

Academic standards correlations to Project WET activities
Educational materials/classroom resources for Project WET teachers
Out and About - field trip ideas
Citizen science/service learning opportunities
Useful websites
Suggested books

A Minnesota

10,000 Years Before Present
Lake Pepin formed as the Chippewa River partially blocked the flow of the Mississippi River

Minnesota River Valley

MN DNR

12,000 Years Before Present
Minnesota River Valley formed by glacial meltwater

Background image: Red Lake, MN DNR

Water Timeline

1823
Steamboat completes the trip from St. Louis to Fort Snelling for the first time

1825
Fort Snelling is established at the confluence of the Minnesota and Mississippi rivers

1821
Sawmill constructed at St. Anthony Falls to use power from the waterfall to cut wood into boards

1824
U.S. Army Corps of Engineers takes on the job of making and keeping the Mississippi River navigable

1832
Explorers Henry Schoolcraft and Ozawindib arrive at Lake Itasca, the "true head" of the Mississippi River

St. Anthony Falls

Minnesota Historical Society

1880
Minnesota Fish Commission begins stocking carp in Minnesota lakes and rivers

1872
Minnesota Board of Health established, in part in response to outbreaks of waterborne disease

1891
Itasca State Park becomes Minnesota's first state park

1872
Minneapolis Water Works begins providing drinking water to city residents

1873
A three-day-long blizzard sweeps the state, killing 70

1886
Massive logjam clogs the St. Croix River at Taylors Falls

Minnesota Historical Society

Logjam of 1886, Taylors Falls, St. Croix River

1909
First sewage treatment plant in Minnesota constructed at Baudette

1910
Minneapolis begins treating its drinking water supply to kill bacteria in response to a deadly typhoid fever outbreak

1912
Duluth begins chlorinating its drinking water supply

1920
St. Paul begins chlorinating its drinking water supply

1937
Minnesota Water Conservation Act becomes law

1938
Sea lamprey first found in Lake Superior

1940
Surprise Armistice Day blizzard dumps nearly 17 inches of snow on parts of Minnesota, killing 49

1948
Federal Water Pollution Control Act becomes law

Minnesota Historical Society

Digging out after the Armistice Day blizzard

1959
The St. Lawrence Seaway opens, connecting Duluth to the Atlantic Ocean via the Great Lakes

1967
Minnesota Fluoridation Law passed, setting the stage for required fluoridation of drinking water

1968
Wild and Scenic Rivers Act becomes law; the lower St. Croix is one of the first eight rivers designated

1969
Minnesota Shoreland Management Act enacted

1969
Minnesota Floodplain Management Act enacted

1972
Federal Water Pollution Control Act amended

1972
Coastal Zone Management Act becomes law

1974
Safe Drinking Water Act passed

1975
Voyageurs National Park, the nation's only lake-based park, established in northern Minnesota

Voyageurs National Park

Lyndon Torstenson

1977
Further Water Pollution Control Act amendments result in creation of Clean Water Act

1978
Boundary Waters Canoe Area Wilderness established by act of Congress

1982
Nearly 3 feet of snow fall in the Twin Cities over a period of three days in January

1982
Minnesota Acid Deposition Control Act enacted

1985
Minnesota bans use of lead in plumbing solder, pipes, and fittings

1988
Mississippi National River and Recreation Area established

1988
Minnesota suffers record drought

1989
Minnesota Ground Water Protection Act enacted

1990
Minnesota Wild and Scenic Rivers Act enacted

1991
Wetland Conservation Act enacted

1991
Record snowfall dumps 24 inches of snow in 24 hours on parts of Minnesota

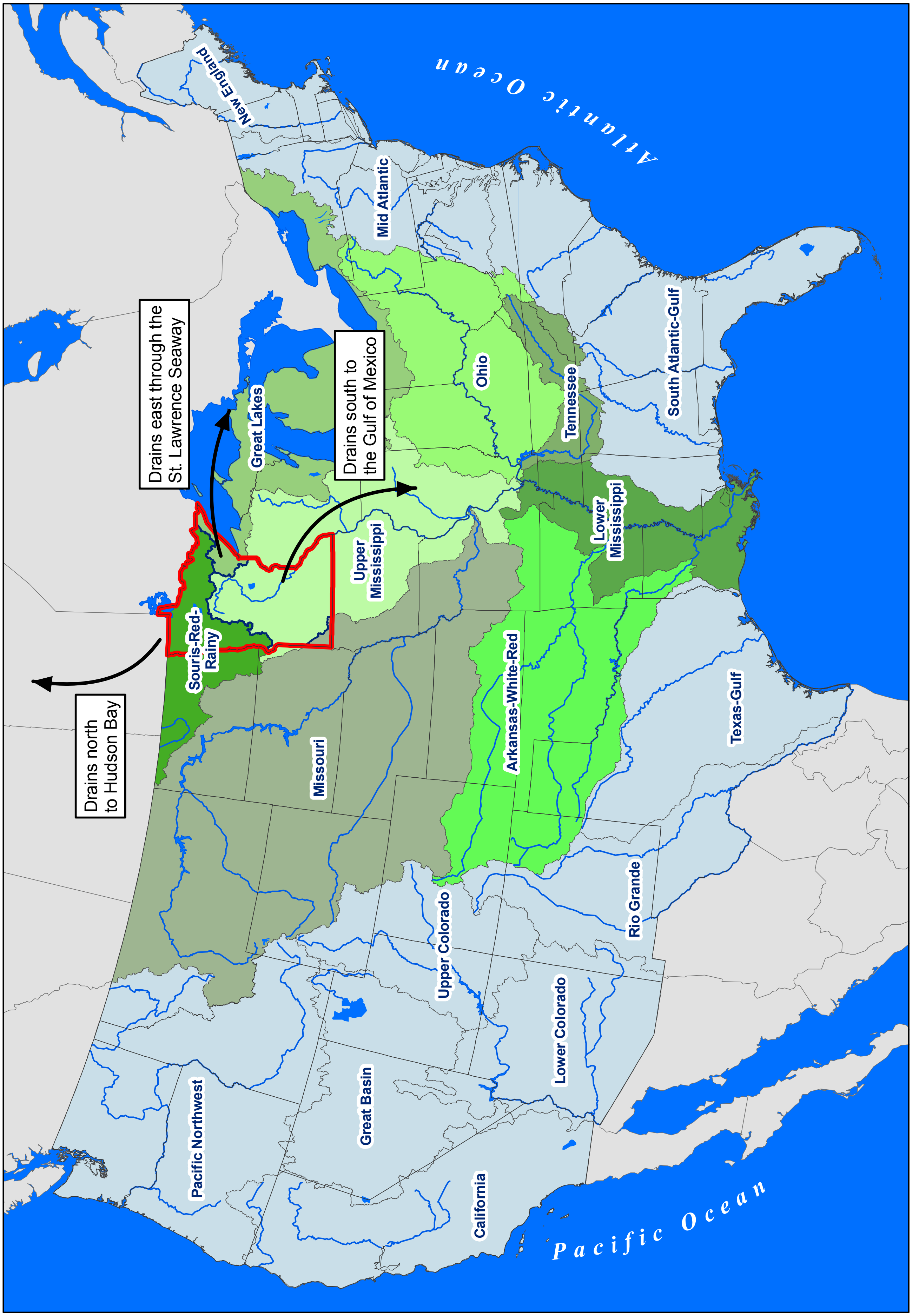
1997
Red River flood devastates East Grand Forks, Moorhead, causing billions of dollars in damage

2007
Southeastern Minnesota struck by a devastating flood as the northeastern part of the state suffers drought

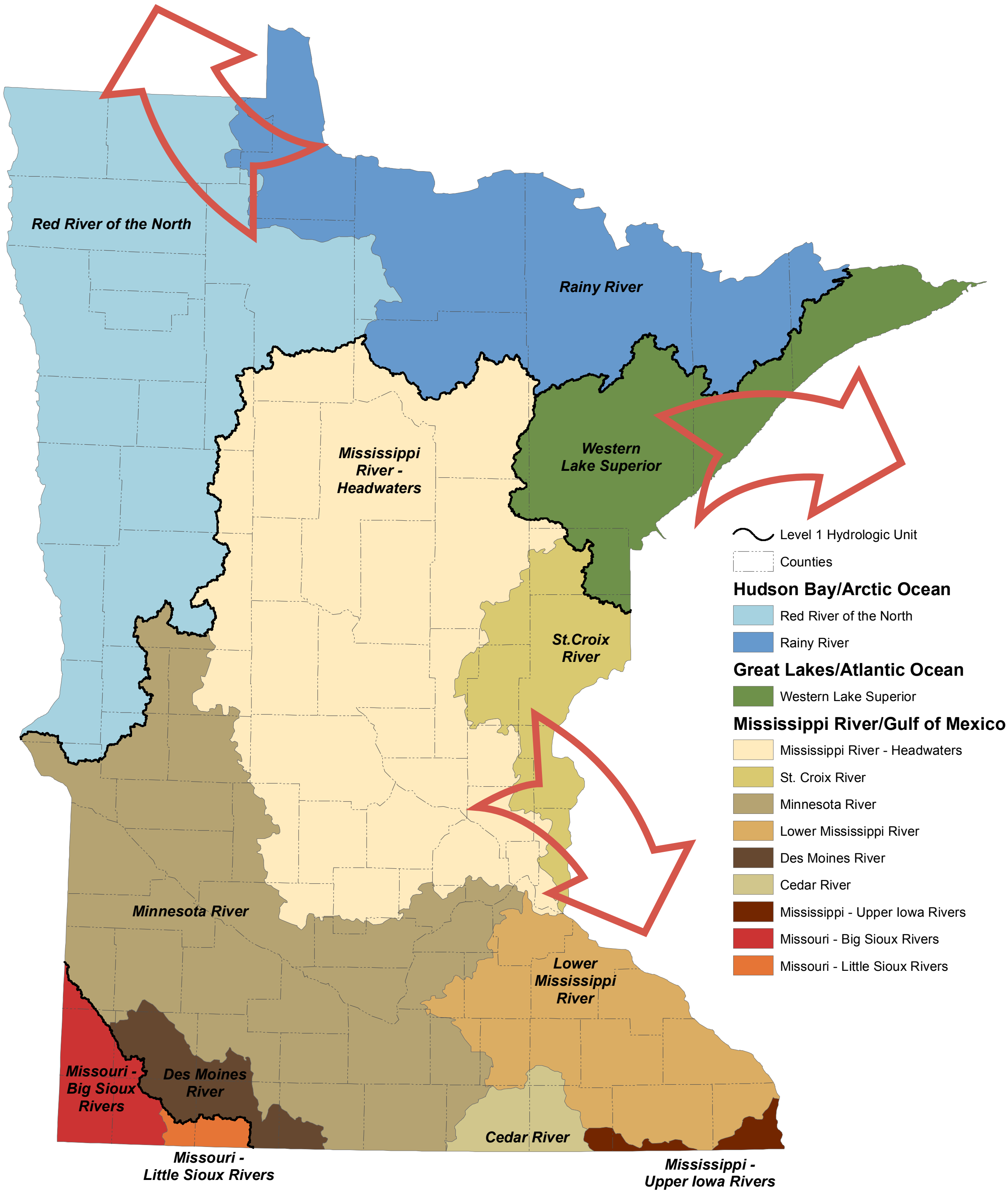
1997 Red River flood

MN DNR

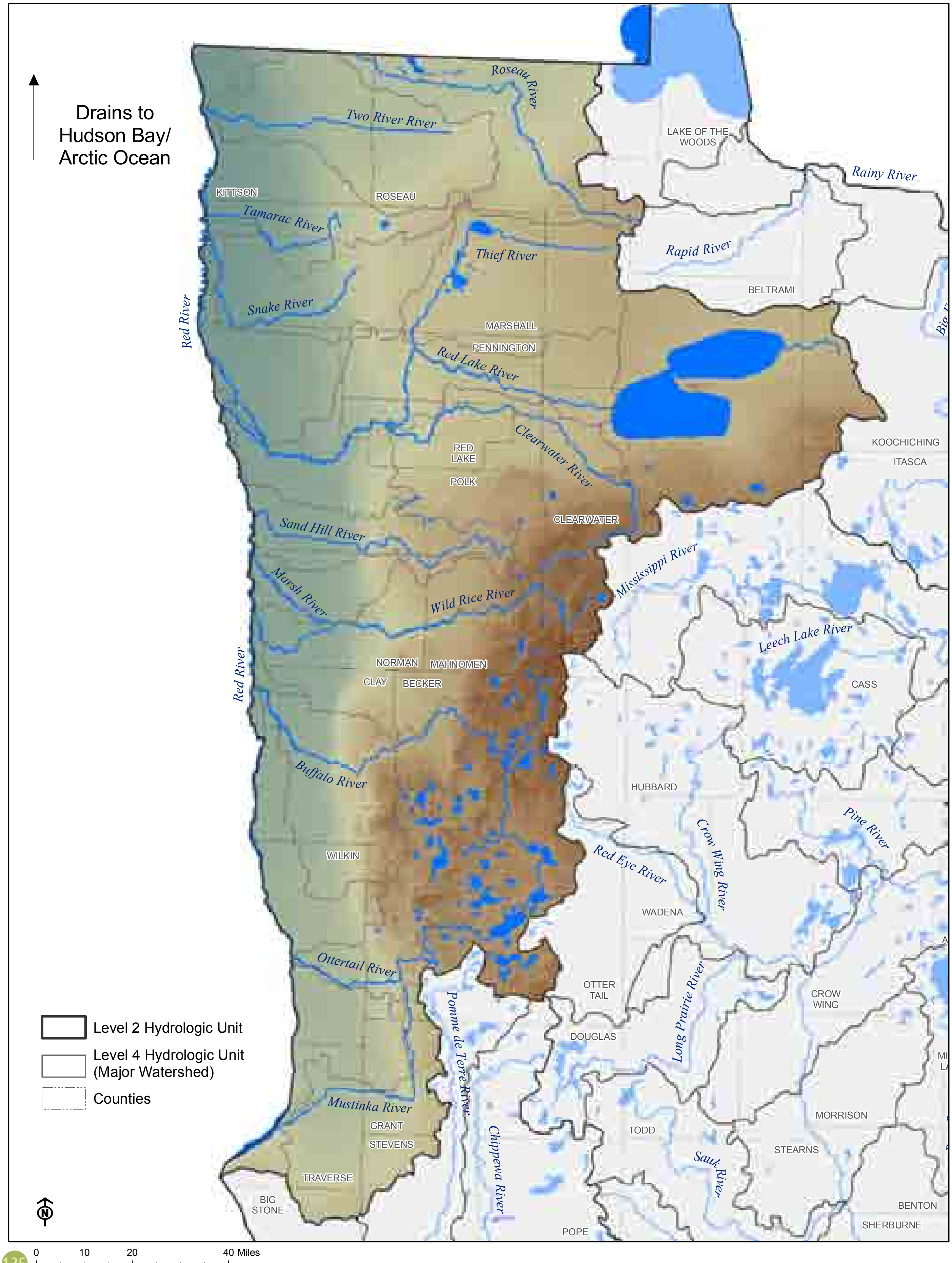
Minnesota's Continental Level Watersheds



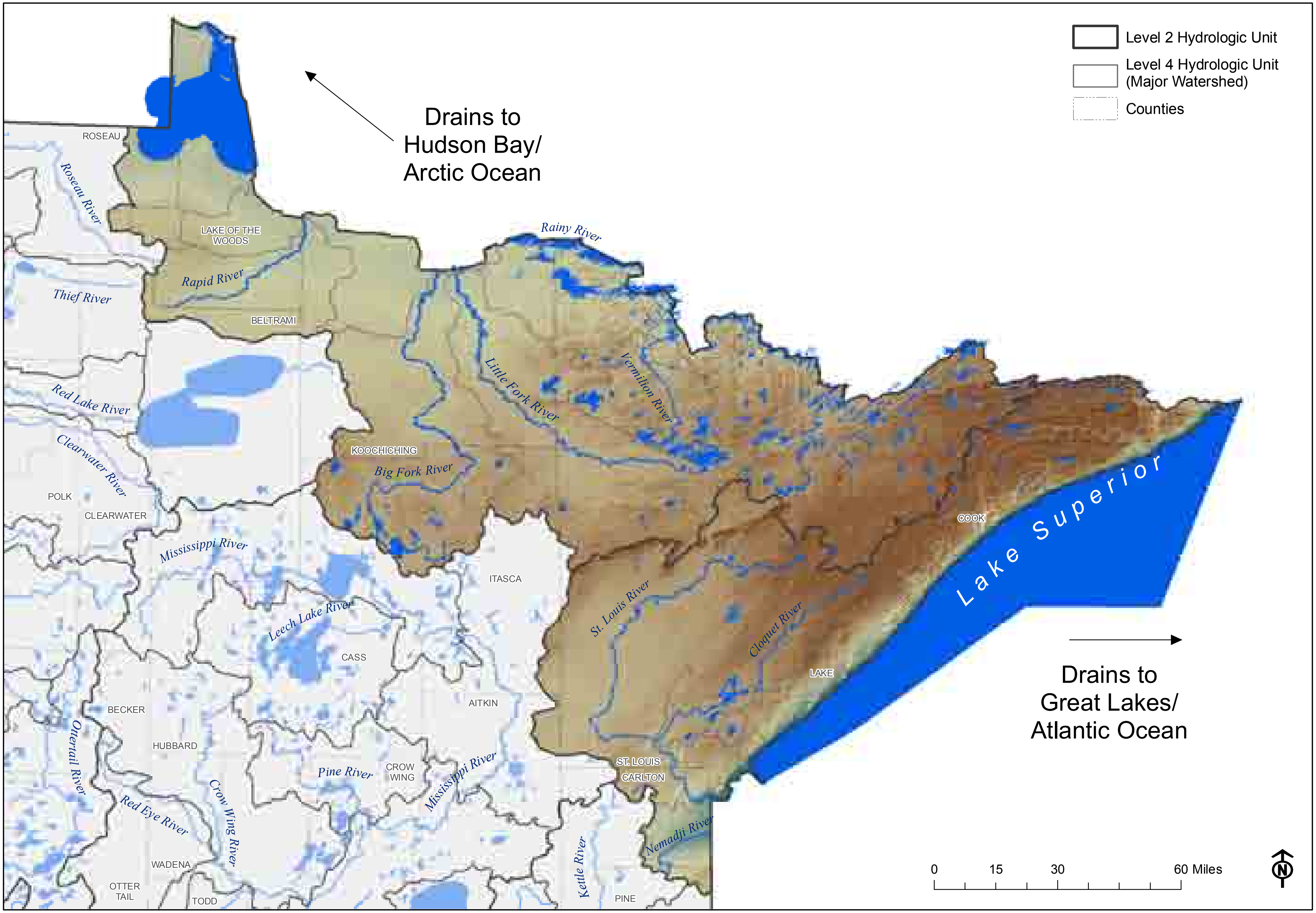
Twelve DNR Level 2 Hydrologic Units



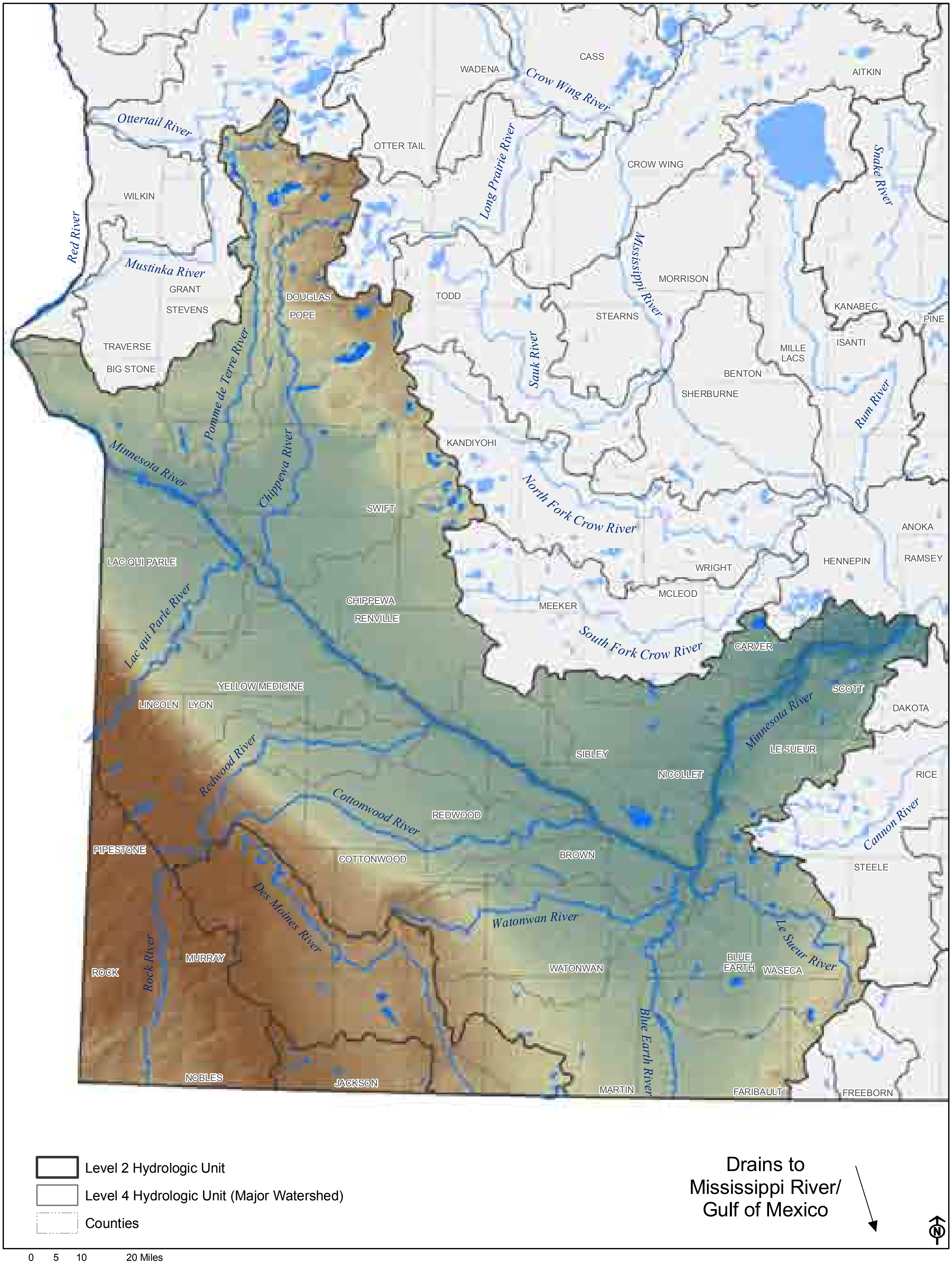
Red River of the North Watershed



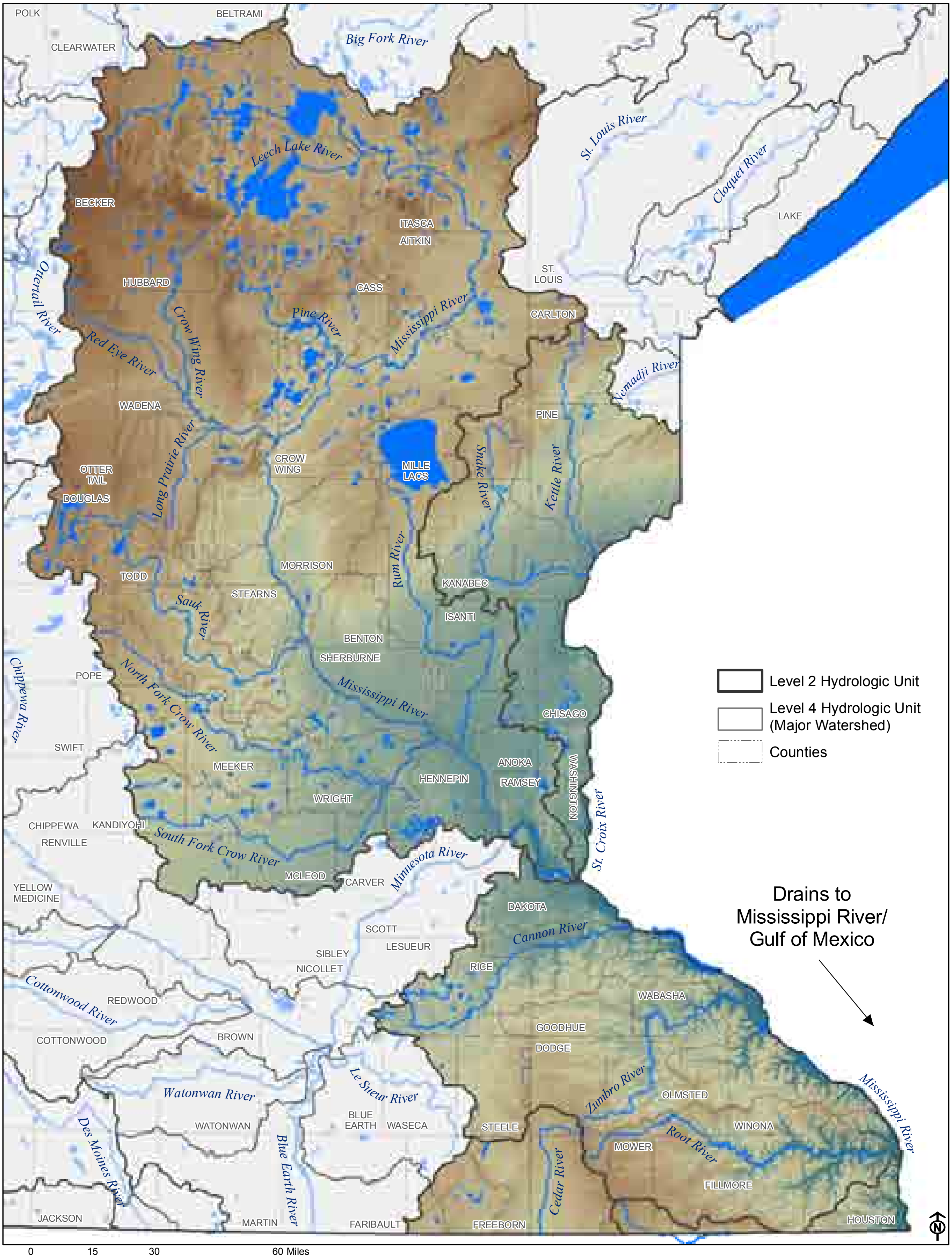
Great Lakes and Rainy River Watershed



Minnesota, Sioux and Des Moines River Watersheds



Mississippi-Headwaters and St. Croix River Watersheds



Sample Minnesota Water Case Study

100th Anniversary of Safe Drinking Water for Minneapolis

February 25, 2010, marks the 100th anniversary of a clean, safe drinking water supply for Minneapolis. Today, we take the quality of water flowing from our taps for granted. Only 100 years ago, the citizens of Minneapolis could not. From 1871 to early 1910, Minneapolis drew its water from the Mississippi River untreated and funneled it directly into homes and businesses. As a result, the city suffered an average of 950 cases of typhoid fever each year and about 10% or 95 people died from the disease every year.

Other metropolitan areas had begun filtering and chlorinating their water supplies before 1910. But starting in 1904, the citizens of Minneapolis became locked in a debate over the source and treatment of their water. The winter of 1909 came and the new year, with no resolution to the debate. There were hints, however, of an emerging typhoid fever epidemic.

On January 31, 1910, Richard Beard replied to a Minneapolis Morning Tribune editorial that declared anyone who carelessly used Minneapolis water was suicidal. Berg went further. He insisted such people were homicidal, for they unwittingly or carelessly transmitted the disease to others, like Typhoid Mary. While critical of individuals, Beard blamed cities that did not filter their water even more. Only filtration, he said, purified the water, and he called for the citizens to demand action from the city council.

By February 1910, the epidemic was spreading, and the city's hospitals were full, and on February 27, the Minneapolis Morning Tribune published an editorial with the headline: "Can Cities Dispense Poison With Impunity?" The editorial suggested legal action against the city. By March 10, over 400 people had contracted typhoid and 45 had died, and four days later, the state health board placed the number of infected at between 800 and 1,200.

On March 16, the Tribune no longer hinted at suing the city. Its editorial that day carried the headline: "Will Somebody Please Sue the City." The suit did not come. Minneapolis had acted. In mid February, the city began building a temporary sterilization plant at Pumping Station No. 4 in Fridley, and on February 25 started adding hyperchloride of lime (chlorine) to its water supply. Almost immediately, the treatment destroyed the typhoid bacilli.

This success (and maybe the talk of law suits) ended the debate and the delays. On March 17, 1910, water supply expert Rudolph Herring submitted a report to the city recommending use of the Mississippi River with proper treatment methods. By the summer of 1910, Minneapolis began work on a purification plant, and on January 10, 1913, the Columbia Heights purification plant opened, using rapid mechanical filtration with coagulation and chlorination. Minneapolis may have been the first city in the Minnesota to chlorinate its water supply. In 1997 Life magazine stated that, "The filtration of drinking water plus the use of chlorine is probably the most significant public health advance of the millennium."

Today, the threats to our drinking water are not as evident or dramatic as typhoid fever, but we cannot take clean water for granted. Once the citizens of Minneapolis believed the water they consumed was safe, they cared less about what they put into the river, and pollution intensified. We have come a long way since then. Completion of the Pigs Eye Sewage Treatment Plant in 1938 and passage of the Clean Water Act in 1972 represent just two key watersheds in how we treat the Mississippi River. But new pollutants are entering the river that could threaten the water we drink. Marking the 100th anniversary of a clean and safe water supply for Minneapolis should help us think about how we treat the river, its creatures and ourselves.

John O. Anfinson
Historian
Mississippi National River and Recreation Area
National Park Service

Contacts for Local and State Water Information

Based on http://www.cleanwatermn.org/Resources/Directory-of-Contacts.aspx

There are many federal, state and local units of government and organizations that you can contact for more information on water resource management, monitoring, regulation, and education. Since all levels of government—local, state, and federal—are involved in managing different aspects of water resources, knowing who to contact can be confusing. If you are uncertain, a good first call is your Soil and Water Conservation District (sometimes simply called "Conservation District"). They will be able to tell you what watershed you live in and what level of government is responsible for your issue of concern. Several online directories exist to help you track down contacts in your area.

Minnesota Shoreland Management Resource Guide's "Who to Contact" http://shorelandmanagement.org/contact/index.html

DNR's Water-related Permit Contacts Directory http://www.dnr.state.mn.us/permits/water/water_permit_contacts.html

Minnesota Water Let's Keep it Clean website's Directory of Contacts http://www.cleanwatermn.org/Resources/Directory-of-Contacts.aspx

Who's Who?

Local Water Managers

City Water Managers (stormwater pollution prevention programs): City departments involved in water management vary from city to city. Try Public Works, Planning and Zoning or Environmental Services. Some cities have taken on watershed management responsibilities through joint-power agreements with neighboring cities.

County Water Managers: Every county has a Local Water Manager, who coordinates water management on the county level and oversees sources of state water program funding.

Conservation Districts (MN Association of Soil and Water Conservation Districts) http://www.maswcd.org/: These local units of government are based on county lines, but are separate from county government. They assist landowners, townships, cities and counties in carrying out projects to reduce soil erosion, stabilize stream banks, establish natural habitats, protect wetlands, monitor water, and reduce runoff pollution.

Watershed Districts (MN Association of Watershed Districts) http://www.mnwatershed.org/: Watershed districts are local units of government based on watershed lines. They often involve more than one county and several cities. Watershed districts are responsible for comprehensive water management and are able to create rules, levy taxes, purchase property and carry out projects to get their work done. Watershed districts exist in some communities throughout Minnesota.

Joint Powers Watershed Management Organizations (In the Twin Cities Metro Area only) http://www.bwsr.state.mn.us/directories/wmolist.pdf: These organizations are similar to watershed districts, but are governed differently. They do not have their own government, but rather are cooperative organizations of cities located in a watershed. The best way to contact a Joint Power Watershed Management Organization is through the public works department of a member city (see City Water Management section above).

State Water Managers

Five state agencies are most heavily involved in different aspects of water management.

Board of Water and Soil Resources http://www.bwsr.state.mn.us/index.html (651-296-3767) BWSR is the state soil and water conservation agency, and it administers programs that prevent sediment and nutrients from entering our lakes, rivers, and streams; enhance fish and wildlife habitat; and protect wetlands. The 20-member board consists of representatives of local and state government agencies and citizens.

Minnesota Department of Agriculture http://www.mda.state.mn.us/en/protecting/waterprotection.aspx (1-800-967-AGRI) The Minnesota Department of Agriculture (MDA) is responsible for or involved in many agriculturally-related water quality programs. Examples include: Agricultural Best Management Practices Loan Program that helps finance water quality practices, research aimed at making cleanup efforts more effective, and regulation of most matters relating to pesticides and fertilizers.

Minnesota Department of Health http://www.health.state.mn.us/divs/eh/water/index.html (651-215-0770 or 888-345-0823) The Minnesota Department of Health protects public health by ensuring a safe and adequate supply of drinking water at all public water systems, which are those that serve water to the public. This includes municipalities, manufactured housing developments, businesses, schools, and other facilities that serve water to more than 25 people on a regular basis.

Minnesota Department of Natural Resources http://www.dnr.state.mn.us/water/index.html (651-296-6157 or 888-646-6367) The Minnesota Department of Natural Resources has the unique role of water quantity management for the state. The DNR strives to help citizens ensure the future of our water resources through programs that manage water resources, watersheds, ecological resources, Wild and Scenic Rivers, shorelands, floodplains, aquatic and terrestrial plants, public waters inventory, and by providing statewide water education and climate, stream, lake, wetland and groundwater information to local and state level decision-makers.

Minnesota Pollution Control Agency http://www.pca.state.mn.us/water/index.html(651-296-6300 or 800-657-3864) Water is one of Minnesota's most abundant and precious resources. The Minnesota Pollution Control Agency (MPCA) helps protect our water by monitoring its quality, setting standards and controlling what may go into it.

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Clean Water Initiative http://cwc.state.mn.us

Climate http://www.epa.gov/climatechange/kids/climateweather.html

Freshwater Society http://www.freshwater.org/water-facts.html

Great Lakes Information Network http://www.great-lakes.net/lakes/ref/supfact.html

Lakes Q&A http://dnr.wi.gov/org/water/fhp/lakes/LakeQuestions.htm

Metropolitan Council http://www.metrocouncil.org

Minnesota Board of Water and Soil Resources http://www.bwsr.state.mn.us/wetlands/wca/index.html

Minnesota Department of Agriculture http://www.mda.state.mn.us

Minnesota Department of Natural Resources Strategic Conservation Agenda files.dnr.state.mn.us/publications/waters/mn_water_supply.pdf

Minnesota habitat descriptions www.dnr.state.mn.us/cwcs/habitat_descriptions.html

Minnesota maps http://geology.com/state-map/minnesota.shtml

Minnesota mussels http://www.dnr.state.mn.us/mussels/index.html

Mississippi River facts http://www.nps.gov/miss/forteachers/brjrrivefact.htm

Minnesota water use http://www.dnr.state.mn.us/waters/watermgmt_section/appropriations/wateruse.html

Snow http://www.or.nrcs.usda.gov/snow/about/swe.html

Snow crystals http://www.its.caltech.edu/~atomic/snowcrystals/primer/primer.htm

Urban water cycle http://www.health.state.mn.us/divs/eh/water/urbancycle/index.html

Water http://ga.water.usgs.gov/edu/

Water cycle http://ga.water.usgs.gov/edu/watercyclesummarytext.html

Water laws http://www.dnr.state.mn.us/waters/law.html

Water on the Web www.waterontheweb.org

Wetlands http://www.dnr.state.mn.us/wetlands/index.html [and links]

Wetlands http://www.fws.gov/r5mnwr/lotw/wetlands.html#list

Wetlands http://www.nwrc.usgs.gov/wetlands.htm

Wetlands in Minnesota http://www.bwsr.state.mn.us/wetlands/index.html

Wild rice http://www.dnr.state.mn.us/snapshots/plants/wildrice.html

Glossary

Definitions are excerpted from and credited to:

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Minnesota DNR website: http://www.dnr.state.mn.us/index.html

Adhesion: The attraction of water molecules to other materials as a result of hydrogen bonding.

Aquifer: An underground formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Aquitard: Underground formations like clay that do not permit water to flow through them and prevent upward and downward movement of ground water.

Benthic Zone: The bottom of the lake where invertebrates live.

Bioaccumulation: The accumulation of a substance (e.g. toxic chemicals such as methylmercury or PCBs) in an organism or part of an organism.

Buoyancy: the upward force a liquid exerts on an object that is immersed in it, counteracting the downward force of gravity.

Capillary Action: The means by which water is drawn through tiny spaces in a material, such as soil, through the processes of adhesion and cohesion.

Channelize: To straighten, deepen and widen streams.

Climate: The meteorological elements, including temperature, precipitation, and wind, that characterize the general conditions of the atmosphere over a period of time at any one place or region of Earth's surface. Earth has three climate zones: Polar, Temperate, and Tropical. Climate zones are further classified into ecosystems and biomes.

Cohesion: The attraction of water molecules to each other as a result of hydrogen bonding.

Condensation Nuclei: Small particles of dust or matter floating in the air that water molecules condense around to form clouds.

Condensation: The process by which a vapor becomes a liquid; the opposite of evaporation.

Confined Aquifer: A water-saturated layer of soil or rock that is bounded above and below by impermeable layers.

Confluence: The place where two rivers come together.

Dams: Any artificial barrier which does or can impound water.

Decomposers: Organisms that break down nonliving organic material (e.g. dead plants or feces) back into its constituent molecules.

Deposition: The transition of a substance from a vapor phase directly to the solid phase without passing through intermediate liquid phase.

Diatoms: Single cell algae—one of the most common types of phytoplankton.

Dimictic Lakes: Lakes that turn over twice per year.

Eutrophic Lakes: Lakes with large amounts of nutrients, murky, shallow water, with silty bottoms and a mix of game fish and carp. They are typically found in southern Minnesota.

Floodplain: lowland areas adjoining lakes, wetlands, and rivers that are susceptible to inundation of water during a flood. For regulatory purposes, the floodplain is the area covered by the 100-year flood or the area that has a 1 percent chance of flooding every year. It is usually divided into districts called the floodway and flood fringe. Areas where the floodway and flood fringe have not been determined are called approximate study areas or general floodplain. Local units of government administer ordinances that guide development in floodplains.

Gas: The state of water in which individual molecules are highly energized and move about freely; also known as vapor.

Geomorphology: The study of landforms; from their origin and evolution to the processes that continue to shape them. Geomorphologists seek to understand landform history and dynamics, and predict future changes through a combination of field observation, physical experiments, and modeling.

Groundwater: The water beneath the land surface that fills the spaces in rock and sediment. It is replenished by precipitation. Under natural conditions much of that recharge returns to the atmosphere by evapotranspiration from plants and trees or discharges to surface waters. Ground water discharge to surface waters allows streams to flow beyond rain and snowmelt periods and sustains lake levels during dry spells.

Heat of Fusion: The amount of heat energy needed to turn a substance from solid to liquid.

Heat of Vaporization: The amount of heat energy needed to turn a substance from liquid to gas.

Hydrogen Bond: A type of chemical bond caused by electromagnetic forces, occurring when the positive pole of one molecule (e.g., water) is attracted to and forms a bond with the negative pole of another molecule (e.g., another water molecule).

Hydrology: the study of water. Hydrology generally focuses on the distribution of water and interaction with the land surface and underlying soils and rocks.

Instream Use: Uses in which the water is not removed from the lake, stream, groundwater, or other source. Examples include fishing, providing habitat for a wide range of living things, hydropower production, and transporting goods.

Levees: Embankments or raised areas that prevent water from moving from one place to another.

Limnetic Zone: The open-water part of a lake where water becomes deep enough that light does not reach the bottom and vegetation is floating rather than attached to the bottom.

Limnology: The science of lakes, rivers, wetlands and other freshwater bodies.

Liquid: The state of water in which molecules move freely among themselves but do not separate like those in a gaseous state.

Littoral Zone: The part of a lake where light reaches the bottom and vegetation grows from the bottom.

Meromictic Lakes: Lakes that never mix or turn over completely.

Mesotrophic Lakes: Lakes with a moderate amount of nutrients, clear water with some algae blooms in summer and support many game fish. They are typically found in central Minnesota.

Monomictic Lakes: Lakes that turn over once per year.

Nonpoint Source Pollution: Pollutants that enter waters from dispersed and difficult to identify sources, such as runoff from a parking lot or farm field or pollutants carried by rain.

Offstream Use: water use that involves removing water from its source. Examples include diverting water for drinking, irrigating farm fields or cooling power plants.

Oligotrophic Lakes: Lakes with few nutrients, clear water, rocky or sandy bottoms, and support species that need clear, cold, oxygenated waters to survive. They are typically found in north east Minnesota.

Point Source Pollution: Pollutants introduced to waters through a specific outlet,such as a pipe from an industrial plant.

Polymictic Lakes: Lakes that turn over many times per year.

Primary Consumers: Organisms that eat primary producers.

Primary Producers: Living things that capture energy from the nonliving environment—most often in the form of sunlight, such as plants, protists and autotrophic bacteria.

Profundal Zone: The open water part of a lake below which not enough light penetrates to support photosynthesis.

Reasonable Use: Anyone who owns property on the shore of a body of water has the right to access it, as long as they do so in a way that doesn't unreasonably inhibit the ability of others to exercise their same right.

Riparian Rights: The right—as to fishing or the use of water—of one who owns land situated along the bank of a stream or other body of water.

Runoff: Precipitation that flows overland to surface streams, rivers, and lakes.

Secondary Consumers: Organisms that eat primary consumers.

Solid: The state of water in which molecules have limited movement.

Solvent: A material such as water that dissolves another substance (the solute) to form a solution.

Specific Heat Capacity: a measurable physical quantity that characterizes the amount of heat that is required to change a body's temperature by a given amount.

Stream: A natural watercourse of any size containing flowing water, at least part of the year, supporting a community of plants and animals within the stream channel and the riparian vegetative zone. A brook or a creek is a small stream. A river is a large stream. Other names for streams around the USA include kills, rills, cricks and sloughs.

Sublimation: The transition of a substance from a solid phase directly to the vapor phase without passing through intermediate liquid phase.

Surface Tension: The attraction among water molecules at the surface of a liquid; creates a skin like barrier between air and underlying water molecules.

Tertiary Consumer: Organisms that eat secondary consumers.

Transpiration: The process by which water absorbed by plants (usually through the roots) is evaporated into the atmosphere from the plant surface (principally from the leaves).

Tributary: A stream feeding, joining, or flowing into a larger stream (at any point along its course or into a lake). Synonyms: feeder stream, side stream.

Turbidity: A measure of the extent to which light passing through water is reduced due to suspended materials.

Unconfined Aquifer: An aquifer in which the upper boundary is the water table.

Water Cycle: The paths water takes through its various states—vapor, liquid and solid—as it moves throughout Earth's systems (oceans, atmosphere, groundwater, streams, etc.). Also known as the hydrologic cycle.

Water Table: The top of an unconfined aquifer; indicates the level below which soil and rock are saturated with water.

Watershed: The total land area that drains water to a river, stream or lake. Also called catchment area, drainage area, or basin.

Weather: The composite condition of the near-Earth atmosphere, including temperature, barometric pressure, wind, humidity, clouds, and precipitation. Weather variations in a given area over a long period of time create climate.

Wetland: An area of land that has mostly wet soil at least part of the year, is saturated with water either above or just below the surface and is covered with plants that have adapted to wet conditions.

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