Texas A&M AgriLife Extension

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Texas Watershed Steward Handbook

A Water Resource Training Curriculum

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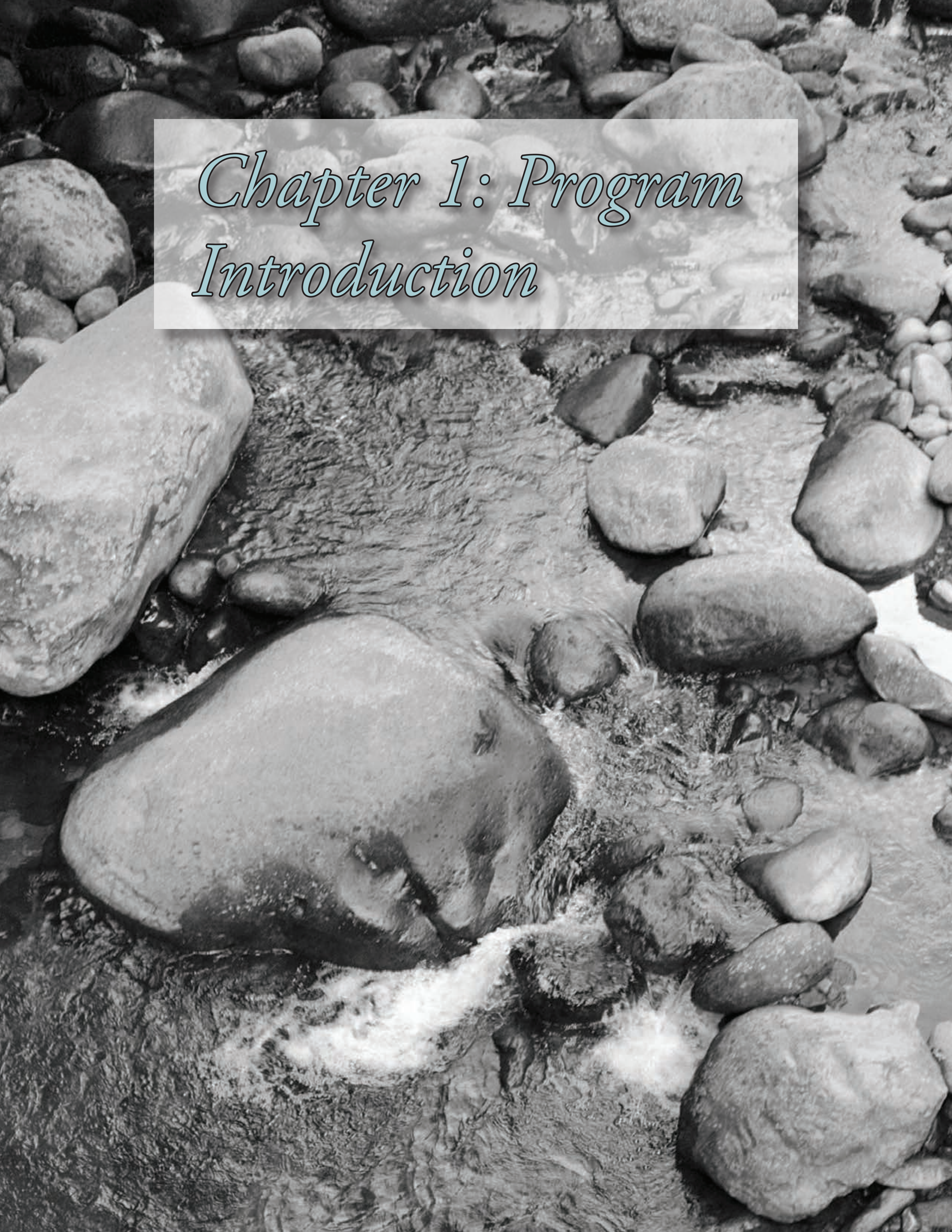


About This Handbook

The *Texas Watershed Steward Handbook: A Water Resource Training Curriculum* was written for participants in the Texas Watershed Steward program (TWS). This handbook will give you the background, principles, and tools you need to become a Texas Watershed Steward. It is designed to be an educational resource and training guide for Watershed Stewards throughout the state.

The information in this handbook is for educational purposes only. Reference to commercial products and/or trade names is made with the understanding that no discrimination is intended and no endorsement by the Texas A&M AgriLife Extension Service is implied.

About the Texas Watershed Steward Program

The Texas Watershed Steward program is an educational training offered by the Texas A&M AgriLife Extension Service in cooperation with the Texas State Soil and Water Conservation Board (TSSWCB) and other partner agencies and organizations. The purpose of the Texas Watershed Steward program is to promote healthy watersheds, increase understanding of the potential causes of water resource degradation and give people the knowledge and tools they need to prevent and/or resolve water quality problems.

The broad goals of the Texas Watershed Steward program are to:

- Make citizens more aware of and knowledgeable about water issues.
- Help individuals become community leaders in dealing with water issues.
- Facilitate local efforts and activities to improve water quality.
- Improve and protect the quality of local water resources.

Who Are Texas Watershed Stewards?

Anyone with a willingness to learn and a desire to improve and protect community water resources can become a Texas Watershed Steward. This includes homeowners, agricultural producers, decision makers and community leaders who all live in a watershed and depend on its valuable resources. The Texas Watershed Steward program is open to people of all ages regardless of socioeconomic status, race, color, sex, handicap, or national origin.

The Importance of Watershed Stewardship

The word stewardship means taking the responsibility to care for the well-being of something that is valued. Watershed stewardship means caring for the water, air and biodiversity in an entire watershed, while acknowledging that all resources are connected and all are affected by natural and human activities. Water is the most critical component of life. Without clean water resources, we cannot survive. The quality and quantity of water within our watersheds are greatly affected by the way we choose to live on the land. And since each and every one of us lives in a watershed, good watershed stewardship is crucial to ensuring the sustainability of our water resources for generations to come.

If we become educated about our watersheds and understand how our activities affect them, we will act more responsibly to preserve, protect and enhance these vital resources.

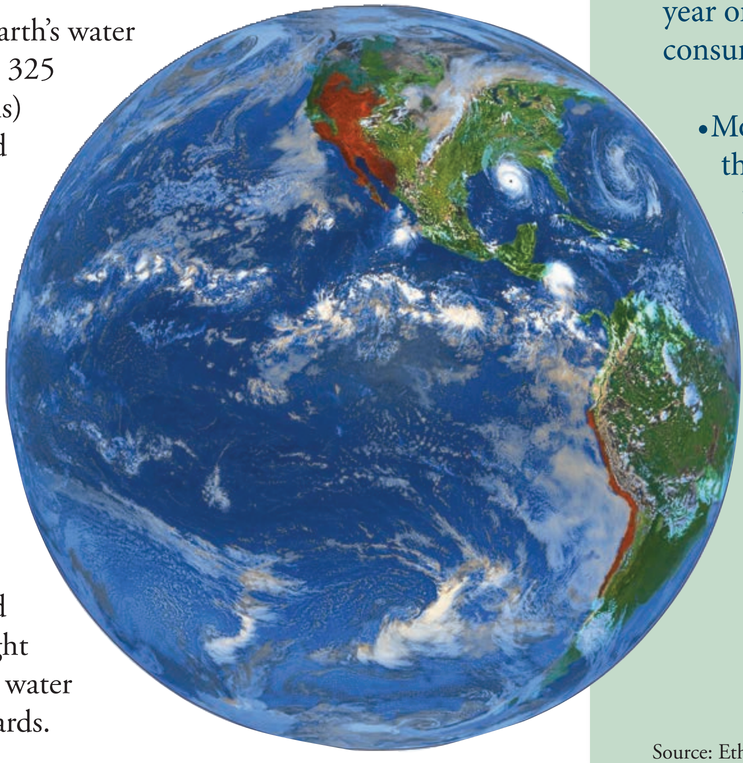
The World's Water

Source: UNESCO

We live on a water planet. In fact, roughly 75 percent of the Earth is covered by water. However, most of the world's water is contained in oceans or seas or is tied up in ice caps and glaciers. Less than 0.65 percent of all the water on Earth today is liquid fresh water, amounting to only 0.01 percent of the Earth's total water resources. For this reason, it is vital that we protect our limited water resources.

You may ask yourself where all of our water is going. About 70 percent of the world's freshwater is being used for agricultural purposes, primarily for irrigated farming. In the past 40 years, the amount of irrigated land in the world has doubled. Roughly 8 percent of the world's freshwater resources are used for human consumption and sanitation, while the remaining 22 percent is used by industry.

If all of the Earth's water (an estimated 325 trillion gallons) were squeezed into a gallon jug and you poured out what was not drinkable (too salty, frozen, or polluted), you'd be left with only one drop, and even that might not pass U.S. water quality standards.



Did You Know?

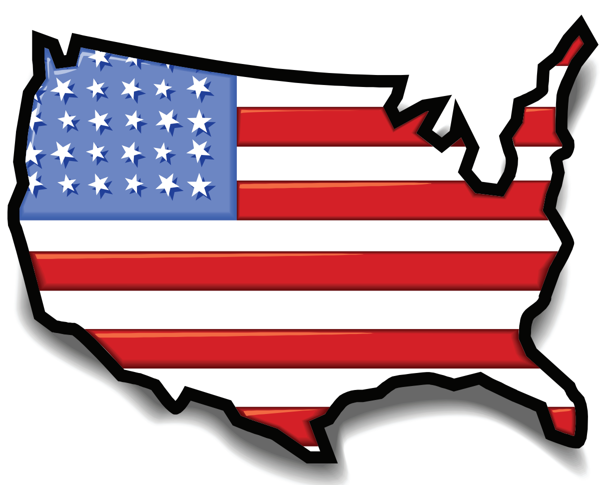
- March 22nd has been celebrated as "world water day" since 1993.
- Seventeen percent of the world's irrigated cropland produces 30 to 40 percent of the world's crops.
- Almost 20 percent of the world population do not have safe drinking water.
- Forty percent of the world population is estimated to not have access to adequate sanitation.
- People spend $366 billion a year on water purification and consumption.
- More than 90 percent of the world's fresh water is located in Antarctica.
- The total amount of water on our planet has remained the same for 2 billion years.
- The average person needs about 2 quarts of water every single day.

Source: Ethos Water.

Water Use in the United States

Source: Central Valley Water Education Center

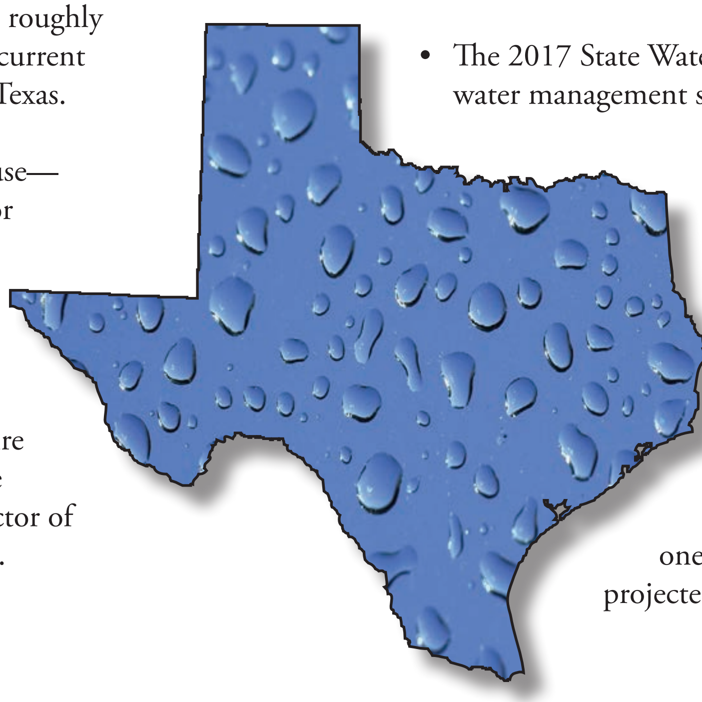
- Of the 4,200 billion gallons of water that will fall on the United States on an average day, only 675 billion gallons can be developed for beneficial purposes.
- The per capita use of fresh water in the U.S. is more than 1,900 gallons per day.
- Approximately 54 million acres of farmland is irrigated in the U.S., and this requires about 160 million acre feet or 166 million gallons per day.
- The 17 western states consume 84 percent of all water used in the U.S.
- California uses more water than any other state (about 25 percent of the total). Texas is number two. Other states that use large amounts of water are New York, Florida, Louisiana, Kansas, Nebraska, Idaho, Ohio, Colorado, Pennsylvania, Arizona and Montana.
- The amount of surface water used in the U.S. is almost twice as much as the amount of ground water used.
- Industry uses 336 billion gallons of water per day, irrigation uses 141 billion gallons, and domestic and rural water needs account for 25 billion gallons per day.
- The amount of water used for the production of electricity in the U.S. increased by almost 500 percent from 1950 to 2000. Irrigation water use increased by about 5 percent.
- Forty percent of people in the U.S. drink well water, which often receives little or no treatment.
- An individual living to the age of 70 will need about 1½ million gallons of water during their lifetime.
- The average person uses 20 to 80 gallons of water each day at home (washing dishes—10 gallons; flushing a toilet—3 gallons; taking a shower or bath—20 to 30 gallons; washing a load of clothes—20 to 30 gallons).
- More than 70 percent of all bottled water is sold in just five states—California, Florida, Illinois, New York and Texas, with California consuming more than all the rest.
- The use of bottled water is increasing by 25 percent each year.
- Approximately two-thirds of the human body is made up of water.



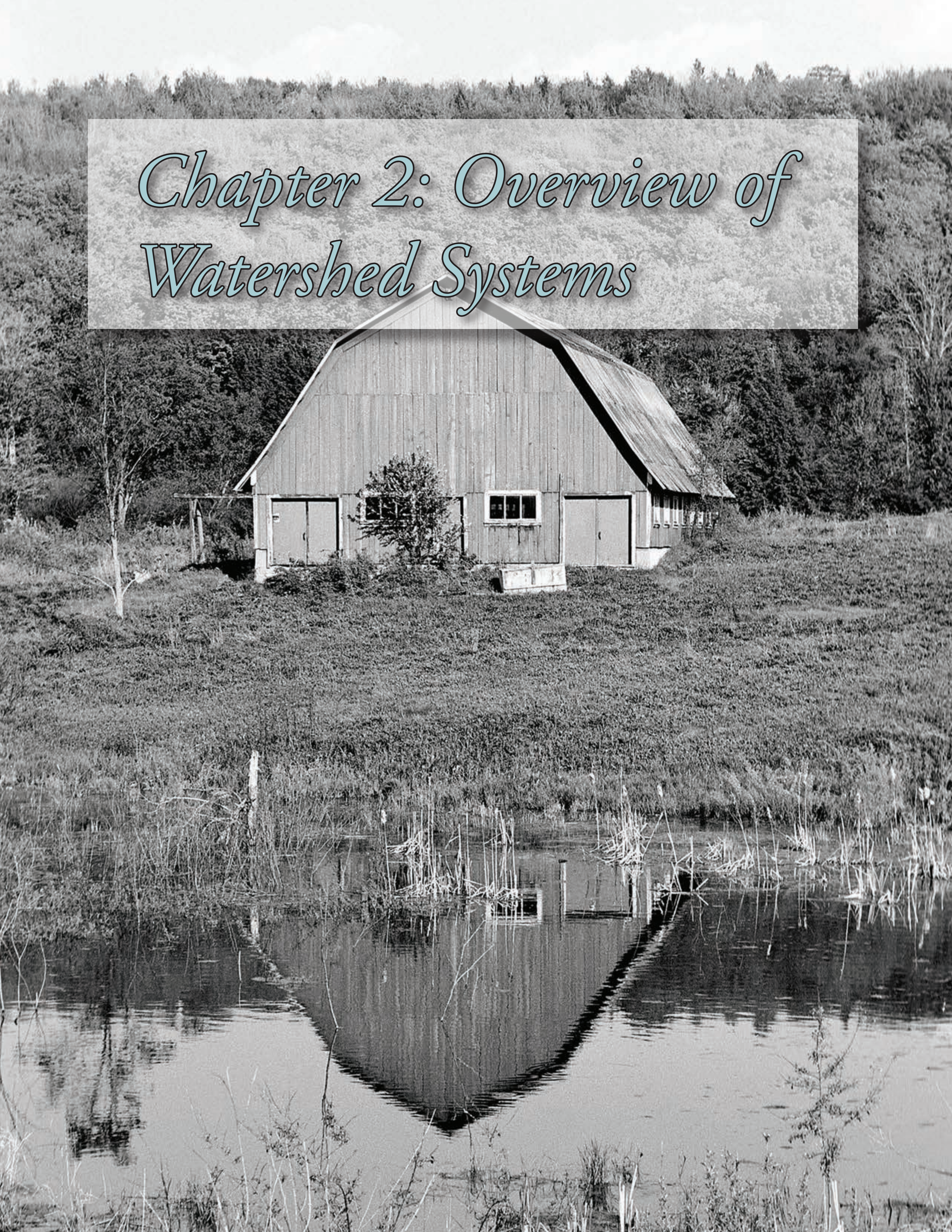
Texas Water Facts

Sources: Texas Water Development Board, Texas Environmental Profiles

- Texas has approximately 191,228 miles of streams and rivers, more than 8 million acres of inland and coastal wetlands, and more than 3 million acres of reservoirs and lakes.
- Texas has only one natural lake—Caddo Lake in East Texas. The other 6,700 lakes in the state are man-made reservoirs.
- The Rio Grande River, which begins in Colorado and flows 1,896 miles to the Gulf of Mexico, is the longest river in Texas.
- Texas has nine major aquifers and 21 minor aquifers. The largest aquifer is the Ogallala, which lies under portions of eight states.
- Of all the water used in Texas, roughly 40 percent iss drawn from surface water sources and 60 percent from groundwater sources.
- The irrigation of agricultural lands accounts for roughly 51 percent of the current water demand in Texas.
- Municipal water use—including water for households, businesses, restaurants, public offices, sanitation, landscaping and fire protection—is the fastest growing sector of water use in Texas.
- By 2070, Texas' population is expected to nearly double from an estimated 29.5 million in 2020 to about 51 million in 2070.
- By 2070, the demand for water in Texas is expected to increase by 17 percent, from about 18.4 million acre-feet in 2020 to about 21.6 million acre-feet in 2070.
- By 2070, the supply of water from existing sources in Texas will be 11 percent smaller than it is today.
- To meet Texas' water needs in 2070, 8.9 million acre-feet of additional water supply must be developed. Therefore, the current water infrastructure does not meet the projected demand in 2070.
- More than 400 communities in Texas have inadequate water service when facing drought conditions.
- The 2017 State Water Plan identified the water management strategies and projects required to meet Texas's future water needs. The estimated cost is $63 billion.
- If Texas does not implement the State Water Plan, about 33 percent of municiple water uses would have less than one-half the water they are projected to need in 2070.



Chapter 2: Overview of Watershed Systems



What is a Watershed?

A **watershed** is an area of land that water flows across, through, or under on its way to a stream, river, lake, or ocean. Each drainage system has its own watershed, and all drainage systems and watersheds are connected across the landscape.

The boundary between any two watersheds is called a **divide** (Fig. 1). Watershed divides are defined by the elevational highpoints (the highest point of an area of land, such as the top of a hill or mountain) that surround a given drainage system or network of drainage systems. Any water that falls outside of a watershed divide will enter another watershed and will flow to another point. All of the land that drains water to a common drainage system is considered to be in the same watershed.

IN THIS CHAPTER, YOU WILL LEARN ABOUT:

- Watersheds and how they function
- The different ways watersheds are used
- Watersheds in Texas
- Watershed hydrology and the water cycle
- Natural features found in watersheds

Watersheds include nested systems of smaller watersheds called **sub-basins** or **sub-watersheds**. Watersheds come in many different shapes and sizes and have many different features. They can have hills or mountains or can be nearly flat. They may include farmland, **rangeland**, small towns or big cities. Watersheds may be as small as the portion of a yard draining into a mud puddle or as large as the Mississippi River Basin, which drains 1.2 million square miles.

Where do we find watersheds? WE FIND THEM EVERYWHERE. All land area is part of a watershed and we all live in a watershed.

Figure 1. Watershed diagram. (Image courtesy of Pollution Probe: The Source Water Protection Primer, *www.pollutionprobe.org/Publications/Primers.html*.)

Watersheds in Texas

Texas has more than 191,000 miles of streams and rivers that drain into 15 major **river basins** and eight **coastal basins** (Fig. 2). Each of these large basin systems is a collection of many smaller watersheds that are organized together based on the river or portion of coastline with which they are associated. For example, a river basin is all of the watershed area that drains into a particular river. It generally will include many smaller watersheds that deliver water to creeks, streams and other water bodies within the river basin.

Five Texas river basins originate outside of Texas: the Rio Grande, Canadian, Red, Brazos and Colorado. The remaining ten river basins all originate within Texas' borders. The coastal basins in Texas are generally poorly drained and are situated between many of the large river basins along the Gulf of Mexico. They contain only small streams, commonly called "bayous."

The major river and coastal basins in Texas are quite unique and vary greatly in size and shape. Each reflects the climate, geology, topography and vegetation of its respective landscape. No Texas river or coastal basin is in its natural state along its entire length. Each has been changed somewhere along its course by dams, levees, engineered channels, and wastewater treatment plants.

What is the difference between a basin and a watershed? Both basins and watersheds are areas of land that drain water to a particular body of water such as a lake, stream, river, **estuary** or ocean. In a river basin, for example, all of the water drains to a large river. The term watershed is generally used to describe a smaller area of land that drains to a smaller stream, lake or **wetland**. There are many smaller watersheds within coastal basins and river basins.

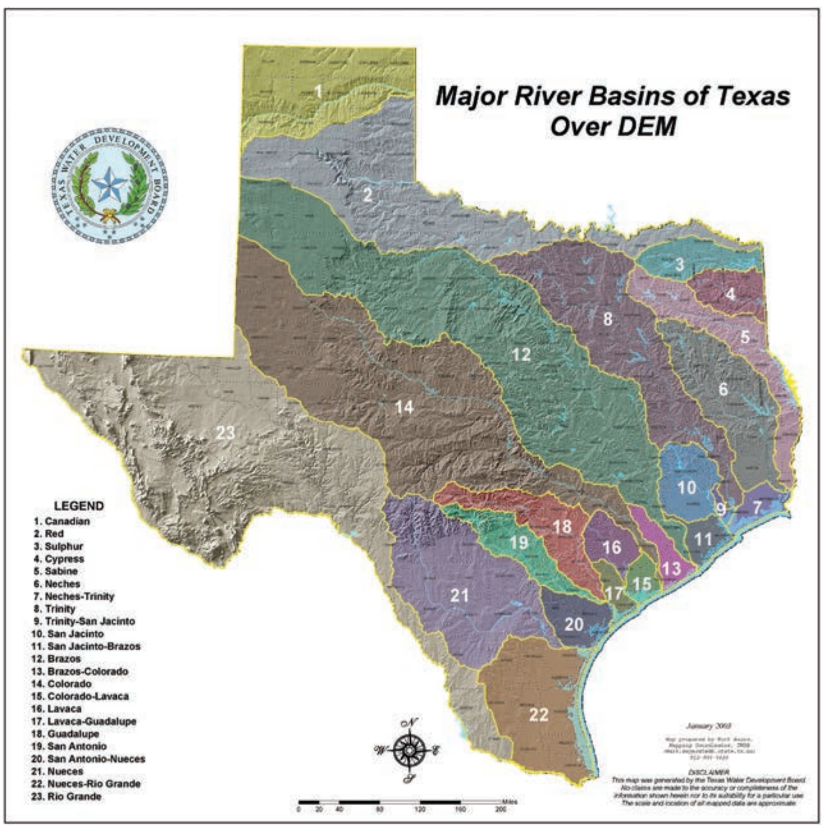


Figure 2. Major river basins of Texas. (Image courtesy of the Texas Water Development Board.)

How Do Texans Use Watersheds?

Texans use their watersheds for a variety of purposes such as recreation, water consumption, transportation, industry, natural resource extraction, agriculture, housing development and commercial development (Table 1).

About 80 percent of the state's groundwater is used for agricultural irrigation, mostly in the Texas Panhandle, the Lower Rio Grande Valley, and

Table 1. Human uses of a watershed.

HUMAN USES OF A WATERSHED	EXAMPLES
Recreation	Boating, fishing, swimming, water skiing, hiking, rock climbing, camping, hunting, etc.
Water consumption	Drinking, irrigation, gardening and lawns, channeling of water
Transportation	Bridges, railroads, roads, etc.
Industrial	Thermal cooling, waste treatment
Extraction of natural resources	Ore and mineral mining, rock quarrying, logging, commercial fishing
Agriculture	Crops, forage production, irrigation, etc.
Housing development	Houses, sidewalks, roads, etc.
Commercial development	Large buildings, retail stores, roads, sidewalks, etc.

areas around San Antonio. The remaining 20 percent of groundwater is used by cities and industry. Roughly 65 percent of the state's surface water is used by cities and industry, while the remaining 35 percent is used for irrigation, steam-electric power generation, mining ,and livestock production. Looking at the big picture, agricultural irrigation, municipal uses, and manufacturing account for 95 percent of all the water used in Texas.

Principles of Watershed Hydrology

The term **hydrology** means the "study of water." **Watershed hydrology** is the study of water as it interacts with various parts of a watershed, including the land, the sea, and the sky.

Nearly 75 percent of the Earth's surface is covered by water, most of which has been around since the Earth was formed several billion years ago. All of the water on the Earth is constantly moving and recycling via an endless process known as the **water cycle**, or the **hydrologic cycle** (Fig. 3).

The water cycle is one of the largest physical processes on Earth. It is driven by energy from the sun and by the force of gravity, and it supplies all of the water needed to support life. There is no beginning or end to the water cycle--it is always happening, no matter what.

As Figure 3 shows, the components of the water cycle include evaporation, condensation, precipitation, transpiration and runoff. **Evaporation** occurs when the water in lakes, oceans, rivers and streams (surface water) is heated by the sun and converted to a gas called **water vapor**. Evaporation also occurs in trees and plants through a process called **transpiration**. In this process, liquid water evaporates from plant leaves and stems and is converted to water vapor. In Texas, it is estimated that 90 percent of all precipitation is lost through evaporation or plant transpiration. On a broader scale, approximately 80 percent of all evaporation on Earth originates in oceans, with the remaining 20 percent occurring from inland water sources (streams, rivers, lakes, etc.) and vegetation.

Condensation is the process by which water vapor returns to its original liquid state. It typically occurs in the atmosphere when warm air rises, cools, and, as a result, loses its capacity to hold water vapor. Excess water vapor then condenses to form clouds. Condensation in the atmosphere may also be visible as fog, mist, dew or frost, depending on the physical conditions of the atmosphere.

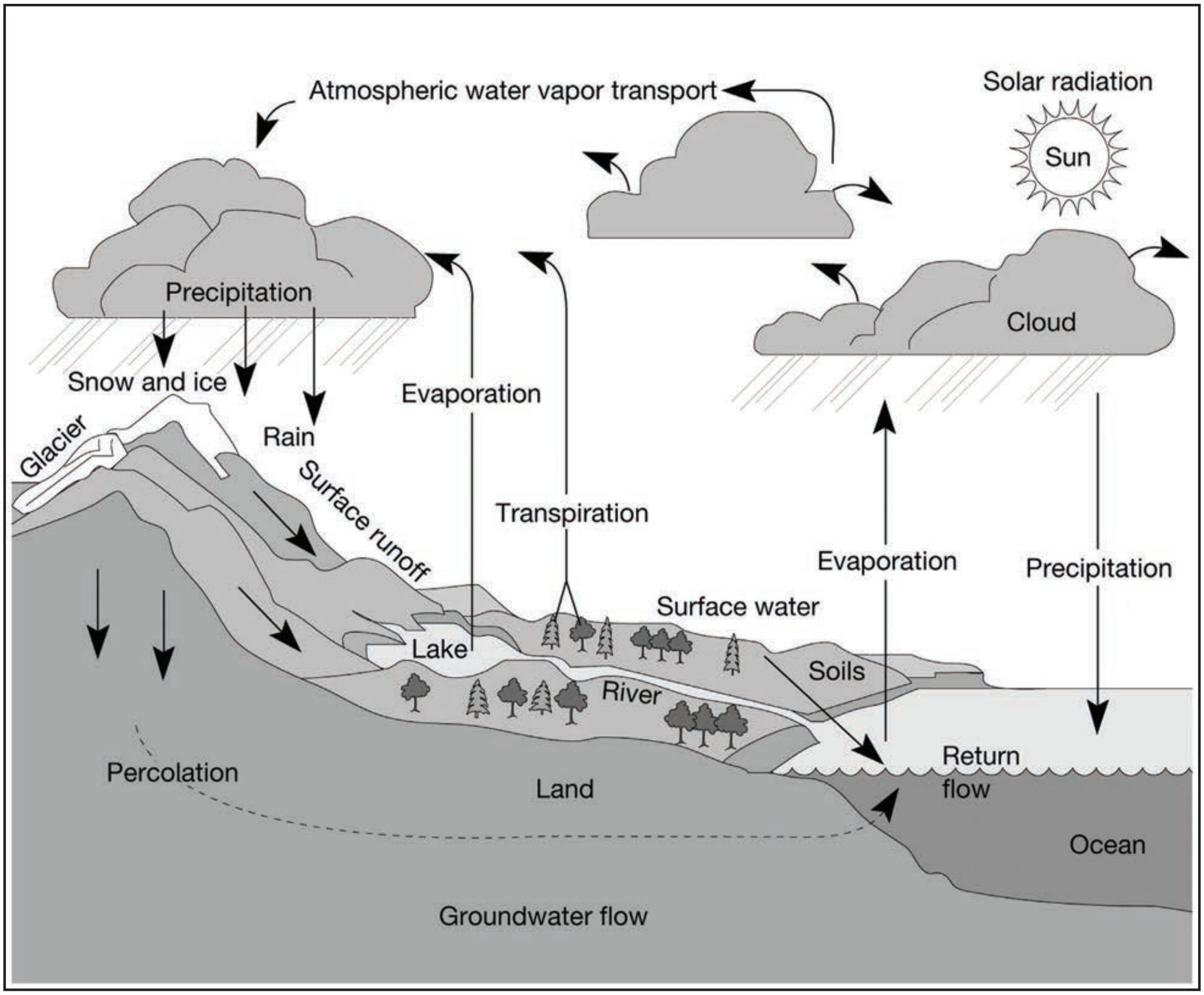


Figure 3. The water cycle. (Diagram courtesy of Dr. Fred Mackenzie, University of Hawai'i at Manoa.)

Precipitation occurs when condensed water in clouds—which is too heavy to remain suspended in the air—falls to the Earth as rain, sleet, hail or snow. Precipitation is a major component of the water cycle and it is the primary source of the fresh water found on the surface of the Earth.

Several factors affect the movement of precipitation once it lands in the watershed. Once precipitation reaches the Earth, it can follow one of five pathways:

1. It can be absorbed by plants and utilized in various biological processes.
2. It can filter through the soil profile and end up as groundwater—water that is stored in underground layers of rock and sand known as aquifers. Groundwater provides 60 percent of the water used in Texas; 97 percent of the groundwater used in the state comes from nine major aquifers, the largest one being the Ogallala Aquifer, which underlies most of the Texas Panhandle.
3. It can evaporate, both from the surface of the Earth or as it falls from the sky.

4. It can be stored in ice caps and glaciers, which can store frozen water for thousands of years.

5. It can **run off** into streams and rivers and become **surface water** that eventually makes its way to the ocean. Runoff occurs when the rate of precipitation exceeds the rate at which the water can be absorbed into the soil. Runoff also occurs when water falls onto an **impermeable** surface, such as a parking lot or a sidewalk, where it can't easily be absorbed into the soil.

No matter which pathway precipitation follows, it will always continue cycling and recycling through the various steps in the hydrologic cycle. This process occurs continuously, in all parts of a watershed, and in all parts of the world.

Natural Watershed Functions

As the water cycle is occurring, a watershed system must be able to balance the influx of water in such a way as to optimize watershed function. A watershed has five primary functions that can be categorized into hydrological and ecological functions. The functions include:

Hydrological functions:
1. Water capture
2. Water storage
3. Water release

Ecological functions:

4. Providing diverse sites for biogeochemical reactions to take place.
5. Providing habitat for plants and animals of various kinds.

Hydrological function 1: Water capture

Water **capture** is the process by which water from the atmosphere is captured or stored in the soil. When water is captured in the soil, it can infiltrate the soil surface and percolate throughout the **soil profile** (Fig. 4). **Infiltration** is the movement of moisture from the atmosphere into and through the surface of the soil. **Percolation** is the downward movement of water through the soil profile. Several factors affect infiltration and percolation rates, including the soil type (primarily texture and depth), **topography** and climate.

Hydrological function 2: Water storage

Once water is captured in the soil, it is stored in the pores (air spaces) between soil particles. The amount of moisture that a soil can hold depends on the soil's depth, texture and structure. For example, much less water can be stored in sandy soils than in clayey soils. This is because sandy soils are made up of large soil particles with large pores in between these particles. Water drains more easily through large pores than through small pores.

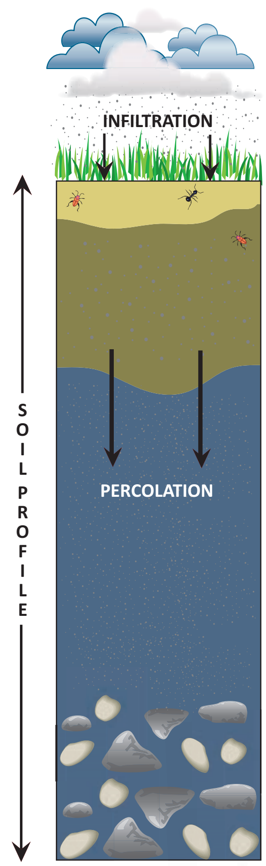


Figure 4. The soil profile.

The kinds, amounts and distribution of vegetation on the ground also greatly affect the amount of water stored in a watershed. For example, a piece of land can be dominated by shallow-rooted **annual** species (cheatgrass), deep-rooted **perennial** species (sturdy grasses, trees and shrubs), or a mixture of these. Different types of plants use water in varying amounts and from varying depths in the soil profile, which affects how much water can be stored in a watershed.

Hydrological function 3: Water release

Water is released from a watershed when it moves through the soil profile to seeps and springs, or across the land surface as runoff, and ultimately into streams and rivers that flow to oceans. Water is safely released when it moves out of the watershed without causing environmental problems. There are two ways water is released:

1. **Subsurface flow**: the flow of water below the land surface that is in excess of the water that can be stored in the soil.
2. **Overland flow**: the flow of water over the ground surface that occurs when precipitation exceeds the soil's infiltration rate.

The kinds and amounts of vegetation in a watershed affect the amounts of water released and the rate at which it flows in a drainage system. Vegetation protects the soil surface from the impact of raindrops, which can damage soil structure and reduce infiltration. Vegetation along streambanks slows the release of water into streams; in heavy rains, that can help prevent the erosion of streambanks, reduce the amount of sediment in the water, and help maintain the water's quality (Fig. 5).

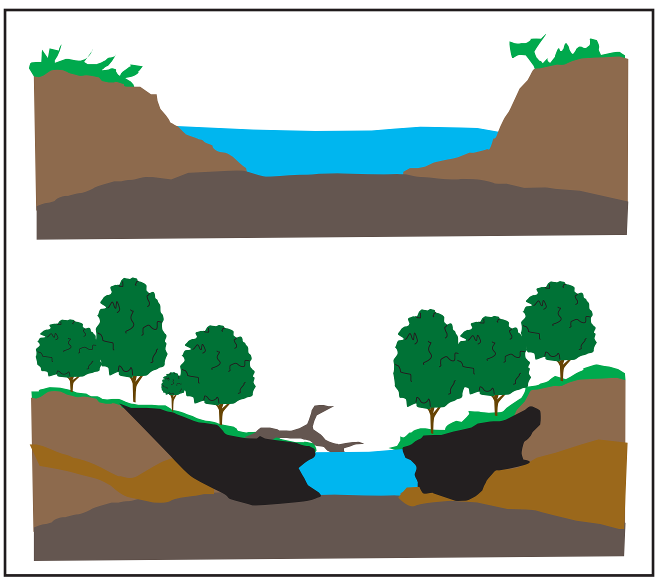


Figure 5. Comparison of stream banks with and without riparian vegetation (adapted from Pritchard 1998.)

Ecological function 1: Provide diverse sites for biogeochemical reactions

Biogeochemical cycling refers to the biological, physical and chemical transformations of elements that are found in soil, water and air. Many of these interactions are quite complex, and very important in maintaining proper watershed function. Nutrient elements such as nitrogen, sulfur, phosphorus, carbon and hydrogen, and organic materials containing these nutrients, are constantly undergoing biological, physical and chemical reactions with the surrounding environment. These processes help maintain the plant and microbial communities found along water bodies in a watershed. Plants and microbes, in turn, fuel additional reactions and biogeochemical cycling. These communities also help maintain the global atmosphere through a complex cycle in which carbon is trapped in plant biomass, preventing its release into the atmosphere as carbon dioxide, a greenhouse gas.

Ecological function 2: Provide habitat for plants and animals

Habitat refers to the natural home of a plant or an animal. A healthy habitat contains everything a species needs to survive—food, water, cover, and a place to raise young. Our human habitat might include our home, our place of work, and the grocery store. The habitats of plants and animals, on the other hand, might include a small puddle in a backyard or a massive rainforest on another continent. Because different living things have different needs for food, water and cover, each kind of plant and animal requires a specific kind of habitat. Healthy and abundant habitat is critical not only to the survival of plants and animals, but also to the overall function of a watershed.

Watersheds provide critical habitat for all kinds of aquatic and terrestrial plant and animal species. The types of habitat found in a watershed depend on the environmental factors that exist there. A watershed that receives very little precipitation might have mostly desert habitat, which would support plants and animals that are adapted to living in dry conditions without a lot of water and dense vegetation (Fig. 6).

Figure 6. Typical desert habitat in a watershed that receives very little precipitation. (Photo courtesy of Jennifer Peterson, Texas AgriLife Extension Service.)

Natural Watershed Features

A healthy watershed contains some natural features that help it carry out its essential functions. These features include uplands, floodplains, riparian zones and water bodies (Fig. 7). These features are intimately connected and work together to ensure that a watershed is functioning properly. In general, watersheds and all of their natural features function to capture, store and release water safely; to filter out sediments, pollutants and other potentially harmful materials; and to provide diverse sites for biogeochemical reactions and habitat for plants and animals.

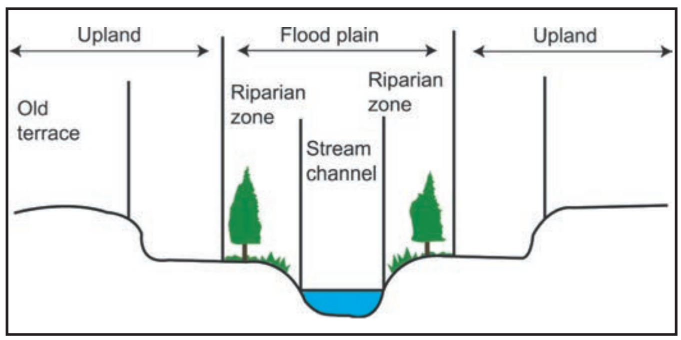


Figure 7. Diagram of the natural features found in healthy, functioning watersheds. (Diagram courtesy of Dictson and White, 2004.)

An **upland** is an area of land located at a higher elevation above a water body. Uplands typically form watershed boundaries, or divides. The upland areas of a watershed are important habitat for mammals, birds, reptiles and amphibians. Upland vegetation stabilizes the soil surface, minimizes surface erosion, and filters and retains dissolved and suspended matter carried by surface water runoff from the surrounding land.

The **floodplain** is the flat area of land surrounding a body of water that is subject to periodic flooding. After heavy rainfalls, the floodplain holds excess water, allowing it to be slowly released into the river system or seep into groundwater aquifers. Floodplains also help to filter out sediment from floodwaters, thereby keeping it out of water bodies. Floodplains often support an abundance of aquatic life and are often used as recreation areas.

The word riparian means "of the river." The **riparian zone** is the **non-cultivated**, vegetated land that touches and immediately surrounds a stream, river, lake or other body of water. This zone often includes wetlands (Fig. 8), which are areas of land that are regularly **saturated** with water for at least part of the year and that contain vegetation adapted to living in saturated conditions. Wetlands and other components of the riparian zone perform vital functions that help maintain the health of the watershed. Riparian zones help to:

- Stabilize watershed slopes and streambanks. The roots of trees and plants hold streambank soil in place so that ground is not lost to erosion.
- Filter pollutants. The vegetation in the riparian area traps sediment and other pollutants, and absorbs nutrients from the watershed before they can reach the water.
- Maintain proper water temperatures within the stream or river. Trees and plants hanging over the water shade it and help keep it cool all summer (this is critical to fish life, as many fish can't live with a rise in temperature of even a few degrees).
- Supplement nutrients. As leaves and insects fall into the water, they provide food for animals living in the stream.
- Provide habitat and food for wildlife. Many birds (Great Blue Herons, Kingfishers, Eagles, Osprey, etc.) and other animals rely on vegetation near water for their homes and resting places.
- Provide a "transitional zone" from bank to floodplain to watershed slope. This is critical for flood mitigation, as it gives floodwater a place to slow down and soak in or enter the stream with less energy.

Figure 8. Wetland full of plants adapted to live in or near water. (Photo courtesy of © 2007 JupiterImages Corporation.)

A water body refers to any stream, river, pond, lake, estuary or ocean. Water bodies can be flowing (**lotic**) systems (streams and rivers) or non-flowing (**lentic**) systems (ponds and lakes).

The flow of water in these systems, particularly in rivers and streams, is greatly affected by the natural features of the watershed (including the topography, slope, soils and vegetation). For example, the natural **meanders**, or curves, in a stream or river help slow down the flow of water and control flash flooding. A severe, rapid release of water will occur in straight channels with little resistance to water movement. As mentioned earlier, vegetation helps protect streambanks by absorbing energy from flowing water.

All parts of a watershed are equally important. The upland and floodplain zones capture and store water, while the riparian zone is the primary release mechanism for the watershed. Proper care of the uplands, floodplains, riparian zones and water bodies keeps the watershed functioning properly. The ideal condition will keep most water where it falls, reduce runoff, and allow for moderate stream flows.

KEY POINTS TO REMEMBER:

- A watershed is an area of land that water flows across or under as it drains to a body of water.
- Watersheds are everywhere!
- Watersheds are used for many different purposes.
- Watersheds are a critical component of the water cycle, which is an endless process that cycles water and distributes it across the Earth.
- Watersheds have hydrological and ecological functions.
- Watersheds have natural features that help them perform these hydrological and ecological functions.

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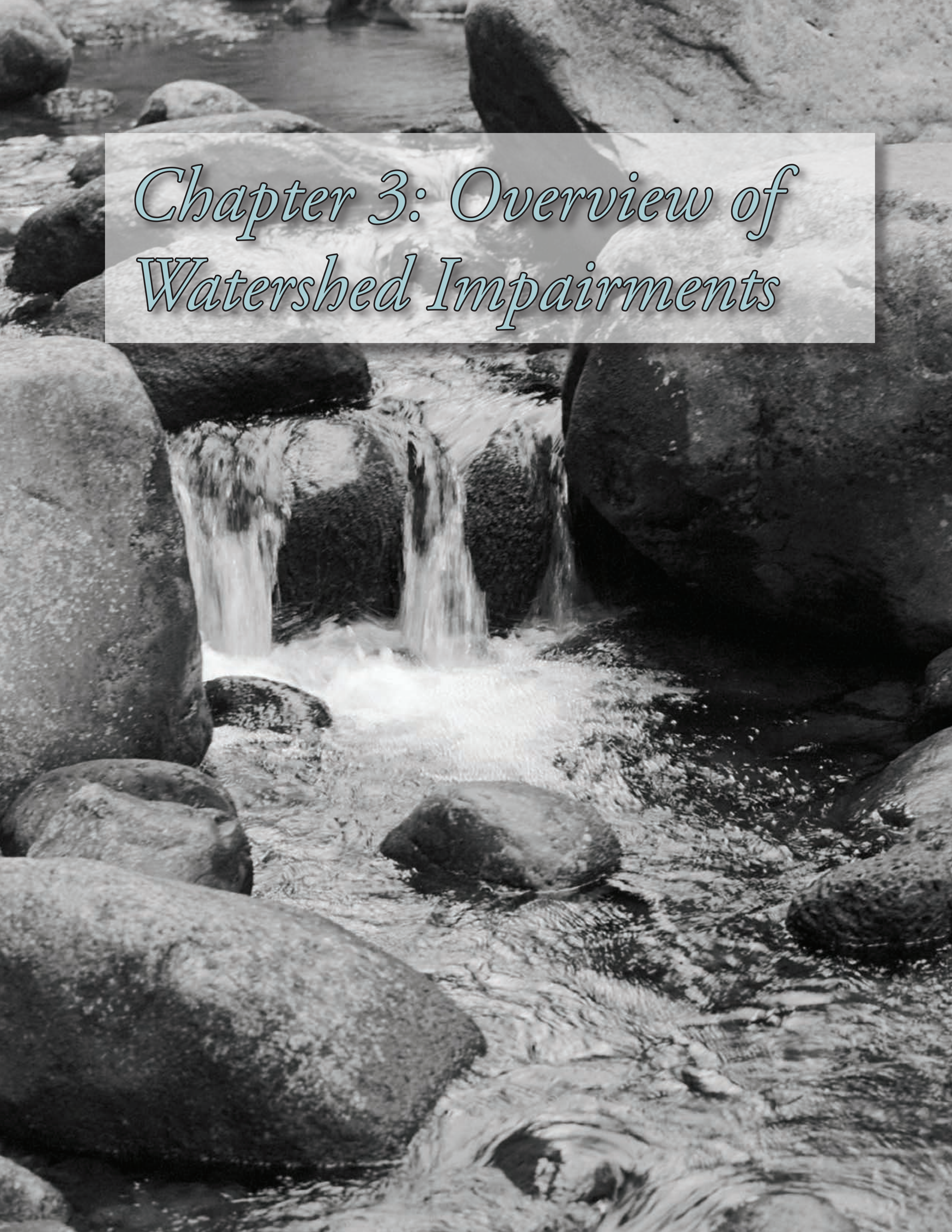
Notes

Chapter 3: Overview of Watershed Impairments



Water Quantity and Quality

> IN THIS CHAPTER, YOU WILL LEARN ABOUT:
> - Water quantity and quality
> - Point and nonpoint sources of pollution
> - Human impacts on water quantity and quality
> - Water law and regulation in Texas
> - Water quality testing and monitoring

We ended the previous chapter by talking about natural watershed features and functions. The kinds of features in a watershed, and the extent to which they are functioning properly, affect the quantity and quality of water in the watershed.

Water Quantity

Water quantity refers to the volume of water that is available. Water comes from groundwater sources such as underground aquifers, and from surface water sources such as lakes, streams and reservoirs.

How do we know how much water is available in surface water and groundwater sources? A different method is used for each kind of water system. The main way to evaluate the quantity of water in streams and rivers is through a **streamflow hydrograph** (Fig. 9). A streamflow hydrograph is a water chart showing flow data collected from river and stream flow gauges. The flow gauges tell us how much water flows past a certain point over a certain period of time. If a lot of water flows past a flow gauge, then the quantity of water in the river is large, and vice versa.

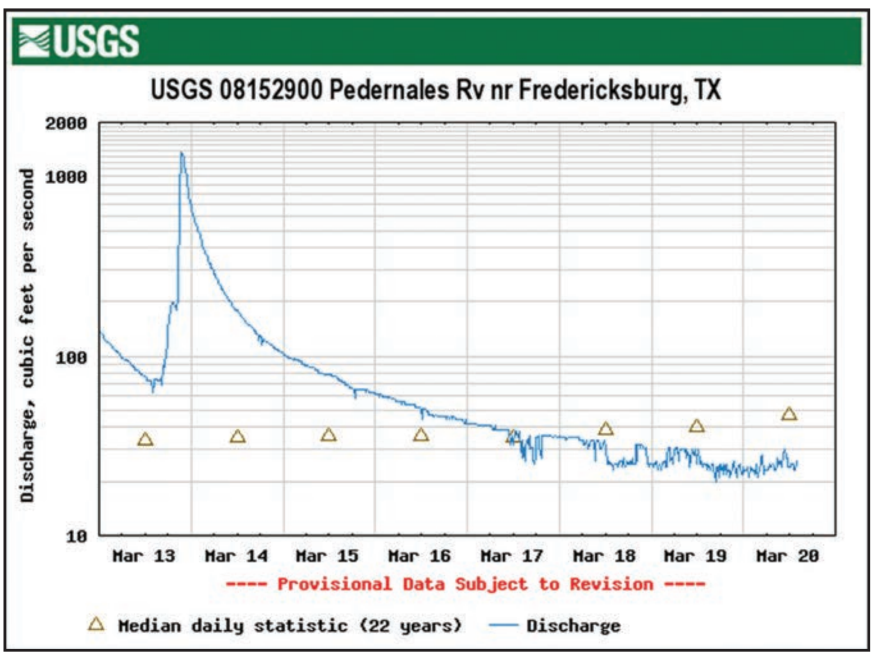


Figure 9. Stream flow hydrograph. (Image courtesy of the United States Geological Survey.)

To determine the quantity of water in lakes, we must know the depth and shape of the lake bottom and how the lake level changes over time. The depth and shape of a lake bottom are determined with **sonar** devices that reveal the variations in lake depth and describe how the surface area and volume of the lake change with lake depth. Lake gauges, much like the flow gauges used in streams and rivers, are used to determine how the lake level changes over time. These data can then be plotted on a hydrograph.

The amount of water in groundwater sources is hard to quantify because there is so much variation in underground geologic properties and the depth of the Earth's surface. Interactions between the various soil layers and aquifers must also be understood, which is very difficult. Complex flow **models**, mapping and other methods are often used to estimate the quantity of water in underground sources.

Two major factors affect the daily, monthly and yearly differences in water quantity levels both above and below ground:

1. Natural variations in climate
2. Changes caused by human activity

Climate can have a huge impact on the amount of water in surface and underground sources. Events such as droughts, ice storms and floods can alter the availability of water on a daily, monthly and yearly basis. One of the most important climatic indicators of water quantity in Texas is rainfall. As rainfall increases, the amount of available water also increases. Rain gauges throughout Texas measure rainfall amounts and distributions and these data are used to evaluate the amount of water available above and below ground. Precipitation maps and charts created from these data graphically represent rainfall ranges and distributions throughout the state (Fig. 10). Average annual rainfall in Texas varies widely from as little as 8 inches in the far west to about 56 inches in the east.

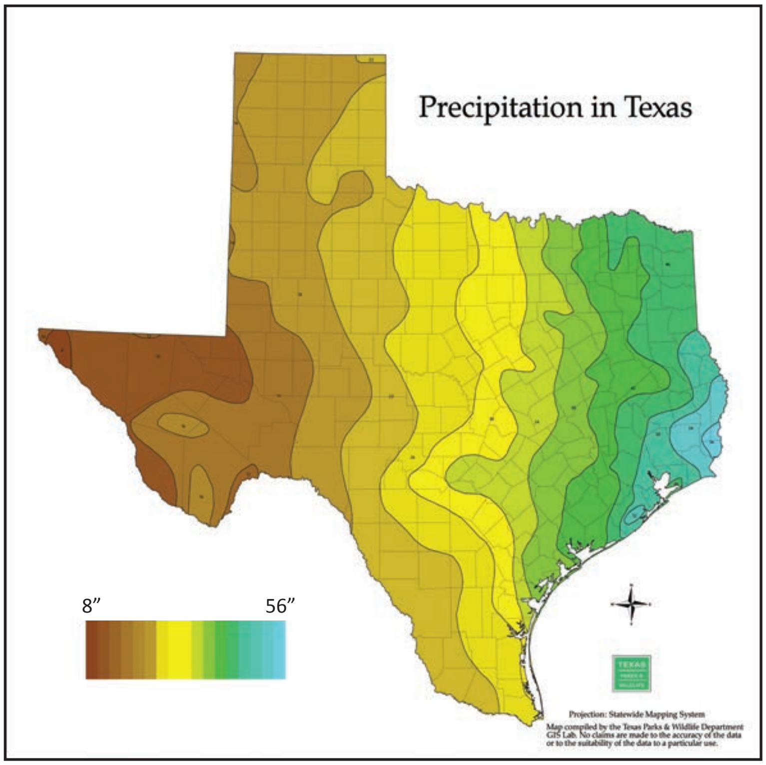


Figure 10. Texas precipitation map. (Image courtesy of Texas Parks and Wildlife Department, 2007.)

Human activity also affects water quantity. Humans alter the flows of streams and rivers by building dams and diverting water for a variety of uses. When people waste water, they are further reducing the quantity of this scarce resource.

So, how much water is actually contained in Texas' surface and groundwater sources? The 2012 State Water Plan estimates that Texas currently has about 13.5 million **acre-feet** of "firm-yield" water, during drought years, in surface water sources such as rivers, lakes and reservoirs. Roughly 40 percent of the water used in Texas comes from surface water. Texas has 188 major reservoirs, 175 of which supply water for municipal, irrigation or industrial use. The Texas Water Development Board (TWDB) estimates that 62 percent, or 8.4 million acre-feet, of this available surface water can actually be used because of restrictions in infrastructure capacity, water permits and contracts. The TWDB estimates that by 2060 almost 9 million acre-feet of surface water will be available for supply, this number may increase with the implementation of management strategies outlined in the 2012 plan.

Texas also has an estimated 3 to 4 billion acre-feet of groundwater that is stored in nine major aquifers and 21 minor aquifers. The largest is the Ogallala Aquifer, which underlies portions of eight different states. Only about 10 percent of groundwater can actually be recovered and used, mainly because of the cost of extracting it. Each year, an estimated 5.3 million acre-feet of rainfall recharges Texas's aquifers. Water drawn from groundwater sources accounts for approximately 60 percent of all the water used in Texas. According to the 2012 State Water Plan, existing groundwater supplies (the amount of groundwater that can be removed with current permits & existing infrastructure) are projected to decrease by 30 percent between 2010 and 2060.

> *DID YOU KNOW?*
>
> *What is an Acre-Foot?*
> - The amount of water needed to cover 1 acre of land in 1 foot of water.
> - 1 acre-foot equals 325,851 gallons of water
> - It would take 1 million acre-feet of water to cover Rhode Island in 1 foot of water.

Water Quality

Water quality is a term used to describe the chemical, physical and biological characteristics of water (Table 2), usually with respect to its suitability for a particular purpose or designated use. Examples of designated uses of water include:

- Aquatic life use
- Contact recreation (swimming)
- Public water supply
- Fish and shellfish (oyster) consumption
- Other general uses (navigation, water supply for agriculture and industry, seagrass propogation, wetland function, etc.)

The chemical, physical and biological characteristics of water, or **water quality parameters** as they are often called, determine whether the quality of water is good enough for drinking, recreation, irrigation, aquatic life or other designated uses. By examining these parameters, and their interactions with each other and with the surrounding environment, we can assess the overall condition of a body of water. These parameters also tell us about the health of a watershed. And because all watersheds are connected across the landscape, the quality of a body of water is a great indicator not only of how well its watershed is functioning, but also of how well the surrounding watersheds are functioning. Some of the key chemical, physical and biological parameters used to evaluate water quality are discussed below.

Table 2. Common chemical, physical and biological water quality parameters.

CHEMICAL PARAMETERS OF WATER
Electrical conductivity
pH
Dissolved oxygen (DO)
Fecal bacteria
Nutrients (nitrogen, phosphorus)
PHYSICAL WATER QUALITY PARAMETERS
Temperature
Total suspended solids (TSS)
Turbidity
Stream flow (discharge)
BIOLOGICAL WATER QUALITY PARAMETERS
Benthic macroinvertebrates
Biochemical oxygen demand (BOD)
Submerged aquatic vegetation (SAV)

Chemical Water Quality Parameters

The chemical characteristics of water are a measure of the substances (such as nutrients, heavy metals and pesticides) that are dissolved in it or are in **particulate** (solid) form. Following are descriptions of common chemical parameters.

Electrical conductivity is the measure of a solution's ability to conduct an electrical current. It is affected by the amount of **total dissolved solids** (**TDS**) in the water. Both organic and inorganic solids make up the total dissolved solids found in water. Common inorganic solids include potassium, sodium, chloride, carbonate, sulfate, calcium and magnesium. The higher the level of TDS, the higher the electrical conductivity will be. Measuring TDS and electrical conductivity is a way to estimate the salt content of a body of water. This information is useful in determining the suitability of water for irrigation and drinking purposes.

Conductivity is affected by water temperature; the warmer the water, the higher the conductivity. Environmental conditions such as geology, drought, changing seasons, and heavy rainfall also can affect the conductivity of water by altering the concentrations of dissolved salts. Groundwater often has higher levels of dissolved solids than surface water because of the contact it has with rock and soil. When streams and rivers are flowing slowly, TDS and conductivity are usually higher because there is less water to dilute the dissolved materials. When flows are very high, TDS levels are typically lower.

pH is an estimate of the acids and bases in a solution. It is measured on a scale that ranges from 0 (very acidic) to 14 (very basic; Fig. 11). A reading of 7 (neutral) represents the pH of completely pure water. A pH range of 6.0 to 9.0 will generally support freshwater fish and bottom-dwelling aquatic organisms.

pH can have a significant effect on aquatic life. Water that is either too acidic or too basic can kill aquatic plants and animals. In addition, pH can affect the **solubility** and **toxicity** of other substances found in water. Runoff from urban and industrial areas may contain cadmium, chromium, lead and other elements that, under normal conditions, are insoluble; this means they do not dissolve in water and are not toxic to aquatic organisms. But when the pH of water is too low (the water is too acidic), many of these substances become more soluble and may become toxic to aquatic plants and animals.

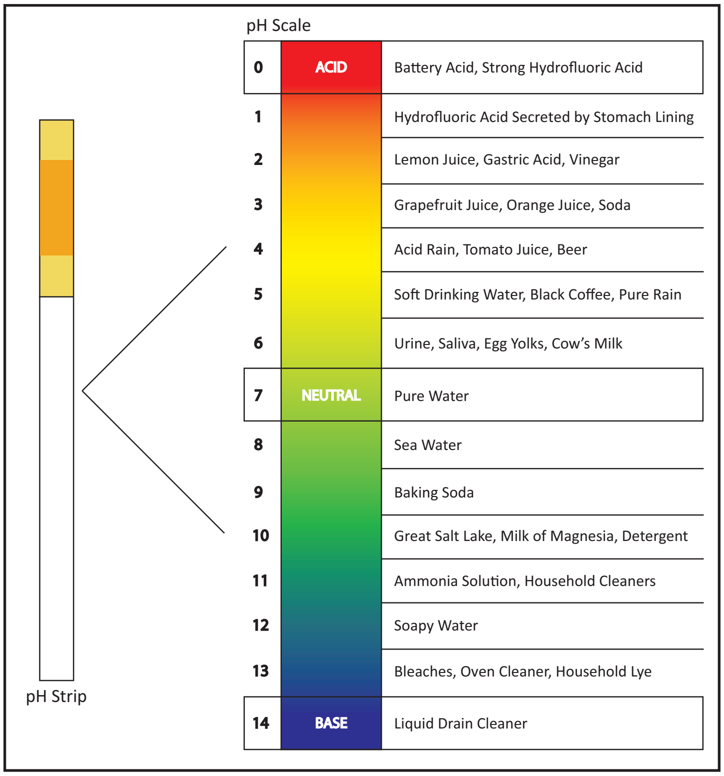


Figure 11. pH strip and pH scale.

Dissolved oxygen (**DO**) is the measure of dissolved gaseous oxygen (O_2) found in water or other liquids. Gaseous oxygen enters water by **diffusing** from the surrounding air, by agitation or rapid movement of the water (aeration), or as a by-product of **photosynthesis**. Oxygen is removed from water through **respiration** and **decomposition** of organic matter.

Adequate DO is necessary for high quality water and is a good indicator of a water body's ability to support aquatic life. Like water, oxygen is a necessary element for all forms of life, including fish and other aquatic organisms. Fish "breathe" by absorbing DO through their gills. Water with too little DO can put stress on aquatic life and even cause large fish kills (Fig. 12).

Many factors can affect the amount of DO in water, including:

- Volume and velocity of water flowing in the water body
- Climate and season
- Type and number of organisms in the water body
- Altitude
- Amounts of nutrients in the water body
- Organic wastes
- Riparian vegetation
- Groundwater inflow
- Dissolved or suspended solids

Fecal bacteria are microscopic organisms found in the feces of humans and other warm-blooded animals. Fecal bacteria by themselves are usually not harmful; in fact, they occur naturally inside of you. They are found in the human digestive tract and aid in the digestion of food.

Fecal bacteria are **indicator** organisms. When found in water, they indicate the potential presence of **pathogenic** organisms such as bacteria, viruses and parasites that can cause disease and illness. When fecal bacteria counts are high in a river or lake, there is a greater chance that pathogenic organisms are also present. If you swim in water with a high level of fecal bacteria, you have a greater chance of developing some type of illness such as typhoid fever, hepatitis, gastroenteritis, dysentery or ear infection.

Fecal bacteria can enter a body of water with the effluents from wastewater treatment plants and septic systems. Other sources include livestock, pets and wildlife. Whether or not fecal bacteria can survive in water depends on the water's temperature and the amounts of nutrients and sediment it contains.

In a water quality context, nutrients refer primarily to nitrogen and phosphorus. **Nitrogen** is one of the most abundant elements on Earth. About 80 percent of the air we breathe is nitrogen. It is found in the cells of all living things and is a major part of proteins. In the environment, nitrogen is found in many forms including **ammonia** (NH_3), **nitrites** (NO_2) and **nitrates** (NO_3). When plants and animals die and decompose, ammonia is produced. Ammonia is converted into nitrate (NO_3) with the help of bacteria and used in plant and animal growth. Nitrogen can eventually be returned to the atmosphere by volatilization.

Figure 12. Fish kills can result from low dissolved oxygen levels. (Photo courtesy of © 2007 JupiterImages Corporation.)

At optimal levels, nitrate is an important nutrient because it helps plants grow. An excessive level of nitrate, however, can be quite harmful to water quality. Too much nitrate in water can result in

Figure 13. Algal bloom resulting from excess nitrogen in the water. (Photo courtesy of © 2007 JupiterImages Corporation.)

a rapid growth of algae and other plant life (Fig. 13). The over-enrichment of water with nutrients is called **eutrophication.** A massive growth of aquatic plant life can make water extremely murky and raise its temperature. When the plants die and start to decompose, bacteria begin to use up all of the oxygen in the water. The oxygen level can become so low (a condition known as **hypoxia**) that many types of fish, insects and other animals can no longer survive. Common sources of nitrates include commercial fertilizers, wastewater treatment plants, animal wastes, septic systems, and decaying plant residues (e.g., compost).

Phosphorus is a nutrient required by all organisms for the basic processes of life. Phosphorus is a natural element found in rocks, soils and organic material. It clings tightly to soil particles and is used by plants, so its concentration in clean waters is typically very low. However, phosphorus can pollute water very quickly when too much of it enters from sources such as:

- Fertilizers
- Animal wastes
- Industrial discharge
- Sewage
- Drinking water treatment

In natural waters, phosphorus is usually in the form of phosphate (PO_4). Like nitrogen, phosphorus is a plant nutrient. Excessive amounts can cause the rapid growth of algae and aquatic plants. When large masses of algae and plants die, the bacteria that decompose them use up the available oxygen, which leads to hypoxia. Extremely low dissolved oxygen concentrations can cause fish kills. In addition, the loss of oxygen in the bottom layers of waters can free phosphates trapped in the sediment, which further increases the phosphorus in the water. A very high level of phosphate in drinking water may cause digestive problems in people and animals, but otherwise is not toxic.

Physical Water Quality Parameters

The physical parameters of water are a measure of its natural attributes, including the following:

Water temperature is a critical factor in determining the rates of biological and chemical processes that occur in and around bodies of water. Temperature affects the oxygen content of water (cold water can hold more oxygen), the rate of photosynthesis by aquatic plants, the metabolic rates of aquatic organisms, and the sensitivity of organisms to toxic wastes, parasites and diseases. Water temperature can be changed by weather, the removal of streambank vegetation that provides shade, the impoundment of water by a barrier such as a dam, the discharge of industrial cooling water, the runoff of urban storm water, and the inflow of groundwater.

Total suspended solids (**TSS**) include solids that float in water or on its surface, and that are large enough to be trapped by a filter (TSS differs from Total Dissolved Solids, or TDS, which was discussed earlier). TSS can include silt, decaying plant and animal matter, industrial wastes and

CHEMICAL PARAMETERS OF WATER
Dissolved oxygen (DO)
Electrical conductivity
Fecal coliform bacteria
Nitrate/nitrite/nitrogen
pH
Total Phosphorus
PHYSICAL WATER QUALITY PARAMETERS
Temperature
Total suspended solids (TSS)
Turbidity
Stream flow (discharge)
BIOLOGICAL WATER QUALITY PARAMETERS
Benthic macroinvertebrates
Biochemical oxygen demand (BOD)
Submerged aquatic vegetation (SAV)

sewage. High levels of TSS can make water murky. We can measure the clarity of water and the levels of TSS by measuring the water's turbidity. The turbidity of water increases as levels of TSS increase.

Why does it matter if water is murky? The effects of high turbidity and TSS are numerous:

- Water becomes warmer as suspended particles absorb heat from sunlight, which causes oxygen levels to fall. Warm water holds less oxygen than cool water.
- Photosynthesis decreases because less light penetrates the water, resulting in even further drops in the oxygen level.
- The combination of warmer water, less light, and oxygen depletion makes it impossible for some forms of aquatic life to survive.

Water with a high level of TSS often has higher concentrations of bacteria, nutrients, pesticides and metals. These pollutants may be attached to particles of sediment that are washed into a body of water after a storm. Once in the water, the pollutants can be released from the sediment or travel farther downstream. Water with a high level of TSS can cause problems for industry, because the solids may clog or scour pipes and machinery.

Stream flow, or discharge, is the volume of water that moves over a point during a fixed period of time. Stream flow affects the concentrations of dissolved oxygen, natural substances, and pollutants in the water, as well as the temperature and turbidity. Thus, stream flow should be considered when measuring water quality.

Stream flow includes both: 1) the volume of water in a water body, and 2) the velocity of the water moving past a given point. It is often expressed as cubic feet per second (cfs). The flow of a stream is directly related to the amount of water moving through the watershed and into the stream or river channel. The discharge rate of a river or stream varies over time. For example, stream flow during the summer time may be much lower than in the spring or after a heavy rain (Fig. 14).

Figure 14. Summer time stream flow in a Texas creek. (Photo courtesy of Nikki Dictson, Texas AgriLife Extension Service.)

CHEMICAL PARAMETERS OF WATER
Dissolved Oxygen (DO)
Electrical Conductivity
Fecal Coliform Bacteria
Nitrate/Nitrite/Nitrogen
pH
Total Phosphorus
PHYSICAL WATER QUALITY PARAMETERS
Temperature
Total Suspended Solids (TSS)
Turbidity
Stream Flow (Discharge)
BIOLOGICAL WATER QUALITY PARAMETERS
Benthic Macroinvertebrates
Biochemical Oxygen Demand (BOD)
Submerged Aquatic Vegetation (SAV)

Biological Water Quality Parameters

The biological characteristics of water, also known as **biocriteria**, are a measure of the water's ability to support aquatic plant and animal life. Some of the common biological parameters are discussed below.

Benthic macroinvertebrates are bottom-dwelling (benthic) organisms that are large enough to be seen with the naked eye (macro) and lack a backbone (invertebrate). Examples are snails, worms, crayfish, and clams (Fig. 15). Most benthic macroinvertebrates complete part or all of their life cycles attached to submerged rocks, logs, or vegetation.

These organisms are important biologically because they play a vital role in the natural flow of energy and nutrients. Many invertebrates also feed on algae and bacteria. Benthic macroinvertebrates are excellent indicators of the health of a water body, because many of them have very specific tolerances to pollutants and react to changes in water quality. Consequently, if a stream is inhabited by macroinvertebrates that have a high tolerance to pollution, while the more sensitive species are missing, there is likely to be a pollution problem.

Biochemical oxygen demand (**BOD**) measures the amount of dissolved oxygen used by microorganisms when they decompose organic matter in water. Sources of organic matter are woody debris, dead plants and animals, animal manure, effluents from industry (such as pulp and paper mills, food-processing plants, wastewater treatment plants, and feedlots), failing septic systems, and urban storm water runoff. As the amount of organic matter in water increases, the number of microorganisms and the amount of oxygen they use increase. The result of excessive BOD is the same as the result of inadequate dissolved oxygen—aquatic organisms become stressed and can suffocate and die.

Figure 15. Benthic macroinvertebrates. (Photos courtesy of Dr. Bart Drees, Texas A&M University and © 2007 JupiterImages Corporation.)

Submerged aquatic vegetation (**SAV**) is a type of plant that grows below the surface of the water. These plants may be rooted or floating. SAV supplies food and shelter to fish and invertebrates, adds oxygen to the water, traps sediment, reduces turbidity, and absorbs nutrients such as nitrogen and phosphorus. When water contains a lot of SAV of varied species, the quality of the water is good. When the number and diversity of SAV species start to decline, chances are that something has happened to degrade the water quality.

Point and Nonpoint Sources of Pollution

Figure 16. Water flows out of a pipe carrying pollutants to nearby waterways. (Photo courtesy of USDA Natural Resources Conservation Service.)

What causes the chemical, physical and biological quality of water to become impaired? The Environmental Protection Agency has defined two major sources of pollution—point and nonpoint.

Point source pollution is pollution that is discharged from a clearly defined, fixed point such as a pipe, ditch, channel, sewer or tunnel (Fig. 16). In Texas, one major type of point source pollution is the millions of gallons of **wastewater** discharged by industrial facilities and municipal sewage plants into the surrounding waters every day. Discharged wastewater, whether treated or not, can contain substances that are harmful both to aquatic and human life. Untreated or partially treated wastewater can also lower the amount of dissolved oxygen in streams and rivers, reducing the quality of the water as habitat for aquatic plants and animals.

DID YOU KNOW??

The combined authorized municipal and industrial discharge of wastewater in Texas — about 61.5 billion gallons per day — is enough to fill Texas Stadium, former home of the Dallas Cowboys, 79 times every day.

Sources: Sanger and Reed, 1997.

Nonpoint source pollution (**NPS**) is pollution that *does not* originate from a clearly defined, fixed location (Fig. 17). NPS pollution originates from many different places across the landscape, most of which cannot be readily identified. For this reason, NPS monitoring is extremely difficult because the contaminants are not easily traceable to an exact source or point of origin. NPS pollutants are generally carried off the land by runoff from storm water or excess irrigation. As the runoff moves over the land, it picks up and carries away natural and man-made pollutants, finally depositing them in surface water and even in underground sources of drinking water.

Both point and nonpoint sources of pollution have, to some degree, affected all of Texas' 15 inland river basins and eight coastal basins,

DID YOU KNOW??

The EPA estimates that each American household generates 20 pounds of chemical waste each year, much of which is improperly disposed of and ends up in rivers, lakes and aquifers. In an effort to control this nonpoint source pollution, many communities have set up chemical waste collection programs to encourage the proper disposal of household chemicals.

Source: EPA.

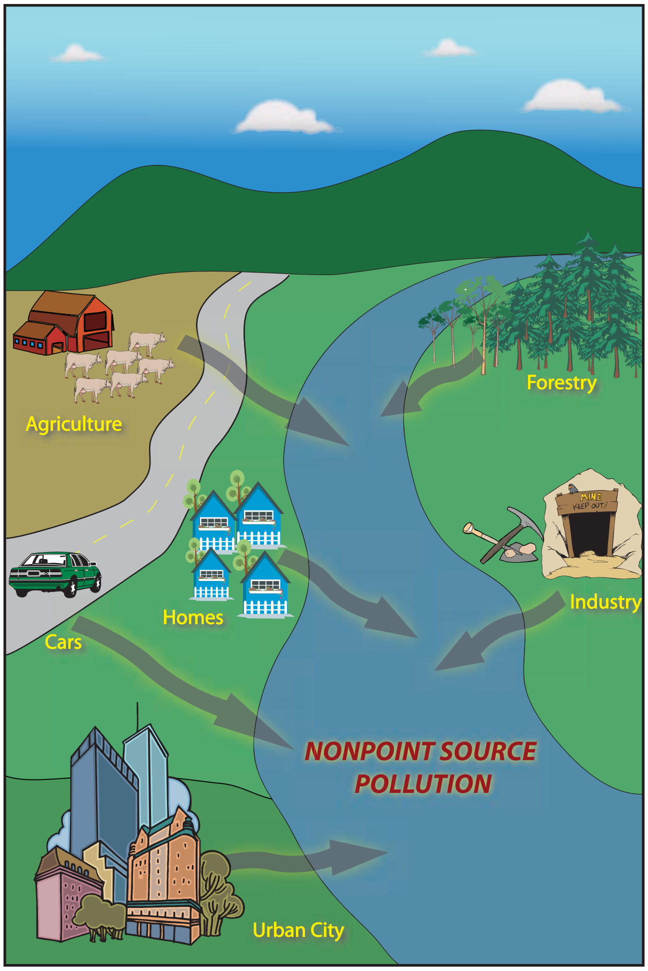


Figure 17. Nonpoint source pollutants originate from many different places and are carried to water bodies by runoff.

several of its reservoirs, and all of its estuaries, coastal wetlands and bays. Nonpoint source pollution, however, is the leading cause of the nation's surface water quality problems. The **U.S. Environmental Protection Agency** (**EPA**) estimates that more than half of all water pollution in the U.S. originates from nonpoint sources! In Texas alone, 92 percent of the state's water bodies are affected by nonpoint sources of pollution (Fig. 18). When we talk about nonpoint source pollutants, there are generally four main categories you need to be aware of (Table 3).

Nonpoint Source Pollutant 1: Bacteria

Most **bacteria** are harmless to healthy people, but some bacteria can be pathogenic, meaning they can cause disease. Disease-causing bacteria and **viruses** can enter bodies of water from many sources, including failed septic systems, boat discharges, livestock, waterfowl, and even the family pet. For example, runoff from agricultural areas where manure is either deposited by livestock or collected and spread on fields can be a source of bacteria and viruses, some of which may be pathogenic. Urban areas also can be a source of pathogenic bacteria and viruses, especially where the concentration of dogs and other family pets is high or where sanitation facilities are inadequate. Bacteria carried in storm water runoff are a major issue because they can pose severe health and environmental risks and can have major economic impacts. In Texas, more than half of the water bodies that have been evaluated are impaired because of excess bacterial levels!

DID YOU KNOW??

A single gram of dog feces contains 23 million fecal coliform, a type of bacteria that can be harmful to humans and can indicate the presence of pathogenic bacteria and viruses.

Source: van der Wel, B. 1995.

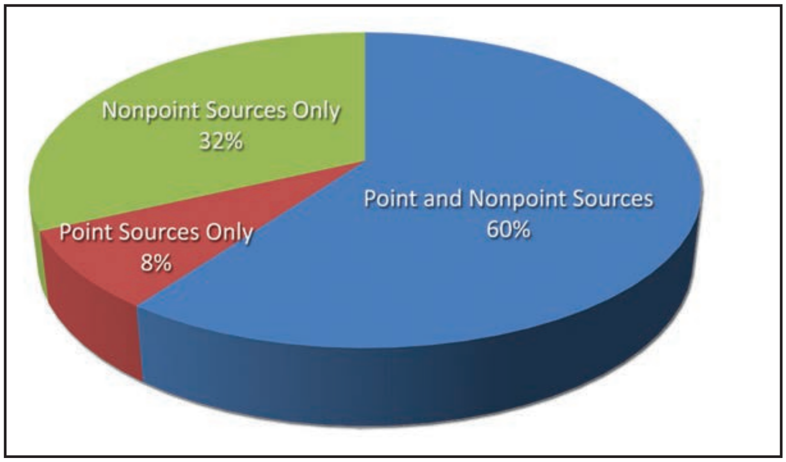


Figure 18. Rivers, streams, reservoirs and bays affected by nonpoint source pollution. (Source: TCEQ, Clean Water for Texas: Working Together for Water Quality, 2003.)

Table 3. Types of nonpoint source pollutants and their effects. (Source: Bureau of Land and Water Quality, State of Maine Department of Environmental Protection.)

POLLUTANT	NONPOINT SOURCE	EFFECTS
Bacteria	Livestock and pet waste, septic systems and boat discharge	Introduces disease-bearing organisms to surface water and ground water, resulting in shellfish bed closures, swimming restrictions, and contaminated drinking water
Nutrients (phosphates and nitrates)	Fertilizers, livestock and pet waste, septic systems, suburban/urban development, soil erosion	Promotes algae blooms and aquatic weed growth, which can deplete oxygen, increase turbidity, and alter habitat conditions
Sediment (soil)	Construction, driveways, ditches, earth removal, dredging, mining, gravel operations, agriculture, road maintenance, forest operations	Increases surface water turbidity, which reduces plant growth and alters food supplies for aquatic organisms, decreases spawning habitat and cover for fish, interferes with navigation, and increases flooding
Toxic and hazardous substances	Landfills, junkyards, underground storage tanks, hazardous waste disposal, mining, pesticides/herbicides, auto maintenance, runoff from highways and parking lots, boats, marinas	Accumulates in sediment, posing risks to bottom-feeding organisms and their predators; contaminates ground and surface drinking water supplies; some contaminants may be carcinogenic, mutagenic and/or teratogenic, and can bioaccumulate in tissues of fish and other organisms, including humans

As they decompose organic matter, bacteria compete with other aquatic life for limited dissolved oxygen. As bacteria levels rise, their oxygen consumption increases and the concentration of dissolved oxygen in the water drops. In addition, elevated levels of bacteria indicate that water quality is impaired and the water is probably unsuitable for drinking and other domestic uses. Its suitability for recreation and its ability to sustain aquatic life also may be impaired. Waterborne diseases such as hepatitis, cholera and salmonella can result from elevated bacteria levels and can pose severe risks to human health. Because bacteria can come from many sources, identifying the sources and controlling their levels can be extremely difficult and expensive.

Nonpoint Source Pollutant 2: Nutrients

Nutrients themselves are not pollutants–they are vital to plants and animals and are necessary to sustain life in general. However, when the levels of nutrients in water become too high, they are considered pollutants and can threaten the surrounding ecosystem.

Two main nutrients of concern are nitrogen and phosphorus. Nitrogen is highly soluble; it dissolves and moves easily into surface water. **Leaching** of nitrogen through the soil profile and into groundwater is also a concern. Phosphorus is less soluble and mobile than nitrogen, but can attach to soil particles and be transported via runoff. Nitrogen and phosphorus are components of manure and other animal wastes, and of the fertilizers used in urban, suburban, rural and agricultural areas. When excess nitrogen and phosphorus run off the land into streams and lakes after a storm, these nutrients stimulate plant growth, but not necessarily the kind of plant growth that is beneficial. An overabundance of aquatic plant life can lead to eutrophication and make water unsuitable for habitat, recreation, fishing and other important uses.

DID YOU KNOW??

On average, an open feedlot generates about 300 tons of manure containing 11,000 pounds of nitrogen per year. By contrast, animals on open rangeland deposit about 1/10 of a ton of manure containing 8 pounds of nitrogen per acre per year.

Source: Sweeten, Baird, and Manning, 1991.

It is estimated that about 12 million tons of nitrogen and 4 million tons of phosphorus are applied each year as inorganic fertilizer in the United States. Another 7 million tons of nitrogen and 2 million tons of phosphorus are applied as manure. If not applied properly and in the correct amounts, these important plant nutrients can become pollutants.

Nitrogen and phosphorus also can originate from the atmosphere. Scientists believe that the combustion of fossil fuels such as oil and coal by power plants, large industries, and automobiles is a major source of nutrients in the atmosphere.

Nonpoint Source Pollutant 3: Sediments

One of the most important nonpoint source pollutants is sediment (Fig. 19). Sediment is the loose particles of clay, silt, and sand found in soil that is carried off the land by wind and water erosion. Most sediment comes from agricultural fields, surface-mined lands, and construction sites. These areas are at especially high risk of increased erosion because they generally lack sturdy vegetation to help keep soil in place and to block wind and water moving across the surface. Eventually, sediment finds its way to bodies of water and settles to the bottom.

Sediment is always present in water bodies, but in excessive amounts it can create harmful conditions for plants and animals living in or near the water. Sediment can cloud the water, preventing light from penetrating to the leaves and stems of aquatic vegetation. Excessive sediment can also smother benthic macroinvertebrates and can clog waterways and ports.

Nonpoint Source Pollutant 4: Hazardous Substances

Hazardous substances include any material that can be harmful to humans and/or the environment. Pesticides and toxic chemicals are common examples.

Pesticides. Pesticides include insecticides, fungicides, herbicides, and other materials designed to eliminate or control pests. They are used extensively by farmers, homeowners, commercial exterminators, golf course managers, parks departments, schools, highway departments, utility companies, and others to control insects, weeds, and other unwanted pests.

Figure 19. Sediment runs off an agricultural field and into nearby waterways after a heavy rain. (Photo courtesy of USDA Natural Resources Conservation Service.)

Pesticides can enter a body of water through surface water runoff, wind and water erosion, leaching, and "spray drift," which occurs when wind blows a pesticide into a body of water as it is being sprayed over an area of land. Once in a body of water, pesticides often decompose into more toxic compounds, increasing the threat to the surrounding environment. Although pesticides are used to control only certain target species, they often unintentionally harm surrounding organisms. Furthermore, some pesticides decompose rather slowly. Because of this, they can build up in the food chain and can have a cascading effect throughout the system.

Over 1 billion pounds of pesticides are used in the U.S. each year at a cost of about $12 billion. Currently, the agricultural sector accounts for 60 to 70 percent of total pesticide use. In Texas alone, the Texas Agricultural Statistics Service estimated that farm and ranch operators spent $345 million on pesticides in 2002. The exact cost and amount of pesticides used in Texas for non-agricultural purposes, including use by homeowners, parks departments, golf course managers and others, has not been compiled by any government agency.

DID YOU KNOW??

Effects of Pesticides in Texas

- In 1961, Austin's Town Lake experienced one of the worst fish kills in history. Fish were killed through the 140 mile corridor from Austin to the Gulf of Mexico. It was later determined that a chemical company had washed pesticide containing DDT down a storm drain in downtown Austin. In 1999, the fish consumption advisory was finally removed.
- A 2005 research study conducted at Texas Tech University linked the development of breast cancer in women to their exposure to volatilized chlordane, a common home pesticide used to prevent termite infestation.
- In July 2006, 27 horses died on a ranch in College Station as a result of eating feed contaminated with a pesticide used to kill weevils.
- In 2017, the Texas Department of State Health Services issued several fish consumption advisories and warnings for surface waters in Texas. Such advisories and warnings may result from pesticide contamination in fish and commonly include the chemicals: chlordane, organochlorine, dioxin, and others.

Source: City of Austin, USGS, Texas Tech University Health Science Center, Equisearch, Texas Department of State Health Services.

<u>Toxic chemicals</u>. Toxic chemicals, such as spilled oils and fuels found on city streets (Fig. 20), are examples of harmful substances that can run off the land surface and be washed into surrounding bodies of water. **Combustion** of fuel from automobiles and factories can introduce **hydrocarbons** and metals into the atmosphere. These can eventually end up in water through **atmospheric deposition** or runoff. Industrial facilities without the proper means to control runoff also can contribute toxic chemicals to the environment. Various businesses and even homeowners may use chemicals such as solvents, paints, and cleaning solutions that can harm aquatic environments. The effects of toxic chemicals are usually greatest near urban areas where there is lots of business, industry, and increased transportation activity.

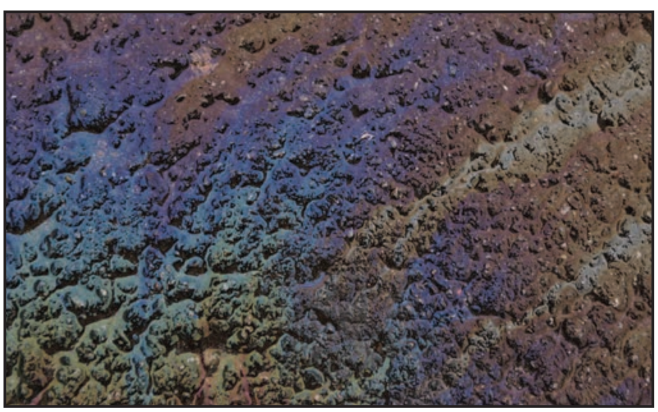


Figure 20. Spilled fuel on a street. (Photo courtesy of © 2007 JupiterImages Corporation.)

Toxic chemicals can have detrimental effects on drinking water quality, water used for recreation, aquatic plant and animal life, and the pipes and pumps associated with industrial and other facilities. Cleaning up water contaminated by toxic chemicals can be very difficult and quite expensive.

Consequences of Impaired Water Quality

Water pollution is a serious problem that can have staggering consequences for the economy, biodiversity, and human health. According to the EPA, more than 50 percent of the waters that have been assessed do not meet the water quality standards states, territories, and authorized tribes have set for them. This includes more than 40,000 individual river segments, lakes and estuaries, approximately 500,000 miles of rivers and shorelines, and about 13 million acres of lakes. These waters are polluted mostly by sediments, excess nutrients, and harmful microorganisms. An overwhelming majority of the U.S. population-308 million people-live within 10 miles of these polluted waters.

Millions of dollars are spent annually to control point and nonpoint source pollution and to reverse the harmful effects of poor water quality on the environment. Over the past century, the U.S. has established a vast and complex system to provide clean water for drinking, agriculture, and industry to dispose of wastewater; facilitate transportation; generate electricity; irrigate crops; and reduce the risks of floods and droughts. Although this infrastructure has brought tremendous benefits, it also has come with major economic and environmental costs.

Degraded water quality can seriously limit the **biodiversity** of aquatic and terrestrial species and their habitats. Harmful conditions such as hypoxia, eutrophication, and algal blooms can destroy aquatic life. Increased sediment can clog the gills of aquatic organisms and cloud the water. Populations of benthic macroinvertebrates and other aquatic species that have low tolerances to contaminants can be reduced or eliminated from a system. Native shoreline vegetation that shades the water and prevents soil erosion can be replaced by invasive weeds and plants that do not protect the water body and its functions.

Perhaps the most important consequence of impaired water quality is the tremendous risk it poses to human health. In 2010, all 30 coastal states with beaches monitored by the EPA's BEACH Program were forced to issue health advisories or closures because of high levels of bacteria and other contaminants in the water. Contact with contaminated water can cause rashes, ear aches, pink eye, respiratory infections, hepatitis, encephalitis, gastroenteritis, diarrhea, vomiting, and stomach aches. Even more serious are the consequences of contact with toxic chemicals, which include human birth defects, cancer, neurological disorders, and kidney ailments.

DID YOU KNOW??

- Forty percent of the rivers in the U.S. are too polluted for fishing, swimming, or aquatic life.
- The Mississippi River—which drains nearly 40 percent of the continental U.S., including its central farm lands—carries about 65 million tons of nitrogen pollution into the Gulf of Mexico each year. The resulting hypoxic coastal dead zone in the Gulf each summer is about the size of Massachusetts.
- About 1.2 trillion gallons of untreated sewage, storm water, and industrial waste are discharged into U.S. waters annually. The EPA has warned that sewage levels in rivers could be return to the super-polluted levels of the 1970s.

Source: NOAA Year of the Ocean, Grinning Planet Water Pollution Facts.

How Land Use Affects Water Quantity and Quality

The quality and quantity of our water resources are determined by natural environmental influences and the activities of humans. In this section, you will learn about the ways human actions can impair water quality and quantity. In later sections, we will focus on ways people can benefit the land by implementing various watershed management and protection strategies.

Figure 21. Overhead view of Austin, Texas showing different land use and land cover characteristics. (Photo courtesy of © 2007 JupiterImages Corporation.)

Water quality and quantity are closely linked to the way land is used and the type of land cover (Fig. 21). Specific **land use** categories include agriculture, industry, recreation, residential, and urban. Most of the ways people use land have the potential to generate pollutants that can impair water quality and/or reduce water quantity.

Land cover refers to the biological or physical features of the land surface. Types of land cover include forests, agricultural fields, lakes, rivers, and even parking lots. When people change the way land is used in a watershed, they usually alter the land cover at the same time. For example, when a new housing development is built, forests and fields are largely replaced by new types of land cover, such as roofs and pavement.

Here are some activities that can impact both water quantity and water quality (Fig. 22):

- Urban and agricultural irrigation
- Using fertilizers and pesticides
- Mining and resource extraction
- Construction of roads and buildings
- Disposing of municipal and industrial wastes and wastewater

Unless done carefully, the effects of these land use activities can be severe. Such activities can alter the natural hydrology of a system, alter the land cover, create pollution, increase erosion and sedimentation, allow exotic species to invade at the expense of native vegetation, and harm biodiversity.

Adequate supplies of good quality water are vital to the health and social and economic well-being of all Texans. Yet water quality and quantity are at risk in many areas of the state because our population is growing and our use of the land is changing so rapidly (Table 4). We must ensure the safety of our water resources for generations to come.

Table 4. Population trends for Texas projected through 2040. (Source: Texas State Data Center and Office of the State Demographer.)

YEAR	POPULATION ESTIMATE
2010	26,058,565
2015	29,213,801
2020	32,736,693
2025	36,682,163
2030	41,117,624
2035	46,105,933
2040	51,707,500

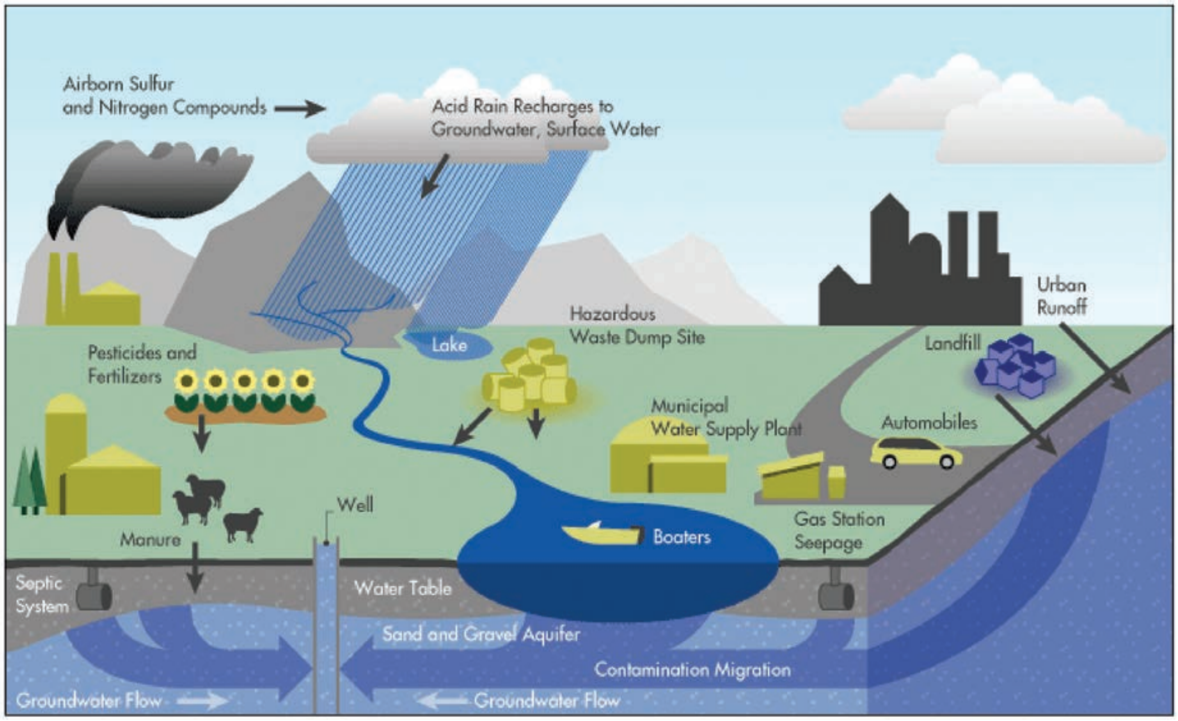


Figure 22. The effect of human activity on watersheds. (Image courtesy of Pollution Probe: Source Water Protection Primer, *www.pollutionprobe.org/Publications/Primers.html.*)

Urbanization has enormous effects on water quality and quantity, because the amounts of wastewater, industrial contaminants, and solid waste per unit area generated in urban areas is dramatically greater than in rural areas.

Urbanization also changes the hydrology of an area because of increases in **impermeable** surfaces like houses, parking lots, and roads. Impermeable surfaces prevent water from soaking into the soil. The conversion of permeable soil to impermeable surfaces reduces the amount of infiltration and increases the amount of runoff and sedimentation. Excess sediments and pollutants become concentrated in streams and rivers, altering the quality of the water. When storm water can't soak into the soil, the amount of storm water runoff and peak flows increase. Stream channels widen as banks erode to accommodate the large volumes of water. To control increased peak flows and runoff, streams and rivers are often **channelized** (straightening a section of a stream, building retention walls along the streambanks, and sometimes making the streambanks and bottoms concrete), which alters stream composition and flow.

The decrease in water infiltration caused by urbanization also reduces the amount of **groundwater recharge**—the downward replenishing flow of rainfall through the soil profile to an underground aquifer. This is a concern since 60 percent of the water used in Texas comes from groundwater aquifers. The extraction of water for growing populations also puts increased demands on local water resources, both above and below ground, and can leave streams, rivers and wetlands with insufficient water to function properly.

Construction sites usually remove habitat for native plants and animals and expose the soil surface to wind and rain. This increases erosion and sedimentation and makes it possible for invasive species to out-compete native vegetation for resources. The loss of native vegetation further reduces wildlife habitat and valuable shading along shorelines.

We often focus on the effects of pollution rather than the causes of pollution. People can cause serious impairment to water quality and quantity when they change the land use or land cover type in a watershed. The effects of these changes can indirectly alter the whole ecological system.

Water Quality Law and Policy in Texas

There was no comprehensive water law in the United States until the 1960s when several federal laws related to water quality were passed (Table 5). Perhaps the most important legislation of this era was the Clean Water Act (CWA) of 1972, which today is the foundation of surface water quality protection in the United States. The CWA was prompted by the serious degradation of many of the nation's streams and rivers, growing concern over disease epidemics caused by waterborne bacteria, and several high-profile oil spills.

The CWA was established to restore and maintain the chemical, physical, and biological condition of the nation's waters. Currently, the CWA sets surface water quality standards for major rivers and lakes in the nation and requires that public and private facilities acquire permits for discharging wastewater. The CWA also protects wetlands by requiring the U.S. Army Corps of Engineers to issue permits (Section 404 permits) for all dredging and filling projects. Lastly, the CWA funds the construction of sewage treatment plants under the construction grants program. In 1987, the CWA was amended to address nonpoint source pollution by requiring that states develop nonpoint source management plans. It is important to note that while the CWA protects the quality of surface waters, it does not address water quantity issues or the quality of groundwater resources (except groundwater that is used as a public drinking water supply).

The quality of surface water in Texas is regulated by the water quality standards established in the CWA. There are three types of water quality standards:

1. Surface water quality standards (also referred to as stream standards)

Table 5. Federal environmental laws related to water quality. (Source: Texas Environmental Profiles.)

FEDERAL LAW	DATE	PURPOSE
National Environmental Policy Act (NEPA)	1969	Required an Environmental Impact Statement (EIS) for federally funded projects.
Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)	1972	Required registration and regulation of pesticides and other agricultural chemicals.
Endangered Species Act (ESA)	1973, 1988	Protected animal and plant species that the U.S. Fish and Wildlife Service designates as threatened or endangered.
Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)	1980	Created a $1.6 billion Superfund to clean up abandoned hazardous waste sites and required major industries to report annual releases of toxic wastes into the air and water, or onto land.
Coastal Zone Act Reauthorization Amendments	1990	Focused efforts on reducing polluted runoff in 29 coastal states.

2. Effluent standards (for wastewaters)
3. Drinking water standards (also cover groundwater used as a public water supply)

Surface Water Quality Standards

Under the CWA and Chapter 26 of the **Texas Water Code**, the **Texas Commission on Environmental Quality** (**TCEQ**) has sole authority to develop and amend surface water quality standards for the state. Under the CWA, Texas must define how water bodies will be used and must develop and enforce a comprehensive set of water quality standards for each specific use. Every 3 years, Texas is required to evaluate its water quality standards and, if necessary, revise them to keep in accordance with federal laws and guidelines. The EPA is required to review state water quality standards to ensure that they meet the goals outlined in the CWA.

There are three parts to the Texas Surface Water Quality Standards: (1) **designated uses**; (2) chemical, physical and biological criteria to protect those uses; and (3) an **antidegradation policy** designed to prevent the deterioration of existing levels of good water quality.

Several designated uses of water are defined in the Texas Surface Water Quality Standards and are listed below. A water body may be assigned one or more of these designated uses:

- Aquatic life use
- Contact recreation
- Public water supply
- Fish and shellfish consumption
- General use (Navigation, water supply for agriculture and industry, seagrass propogation, wetland functions, etc.)

For each body of water where these designated uses are attainable, upper and lower limits for common biological, chemical, and physical water quality parameters are established. These include standards for dissolved oxygen, temperature, pH, total dissolved solids, fecal bacteria, and toxic limits. Any water body that exceeds the accepted limits of any of these parameters is considered an **impaired** water body that cannot support some or all of its designated uses.

The third part of the state water quality standards is antidegradation. Under the CWA, Texas is responsible for developing an antidegradation policy for maintaining the quality of the state's water bodies. In essence, this policy protects clean waters from becoming impaired and prohibits impaired water bodies from becoming more impaired.

Texas must regularly monitor its water bodies to determine whether they meet state and federal water quality standards. Water quality testing and monitoring are the responsibility of the TCEQ. The results obtained from testing and monitoring provide the basis for effective policies that promote the protection, restoration, and wise use of surface waters in Texas.

Every 2 years, the TCEQ must develop and submit a report to the EPA that describes the status of all the surface water bodies in the state that were monitored and evaluated during the most recent seven year period. This report is called the **Texas Integrated Report for Clean Water Act, Sections 305(b) and 303(d),** formerly known as the TWQI. Each water body is assigned uses and criteria consistent with the Texas Surface Water Quality Standards that are evaluated against water quality data to determine attainment or support of the use. Water bodies that do not meet their designated use(s) are identified as "impaired" and are placed on the 303(d) List. Impaired water bodies must be restored through various watershed management and protection activities, which will be discussed in later sections. The Integrated Report is an important management tool because it identifies the bodies of water that are a priority for restoration and those for which preventive measures (e.g., limits on discharges of wastewater and nonpoint source controls) are necessary to prevent current impairments.

Wastewater Effluent Standards

According to the CWA, all municipal and industrial facilities that discharge wastewater must obtain discharge permits from the EPA. These permits are known as **National Pollutant Discharge Elimination System** (**NPDES**) permits. Contrary to its name, the NPDES permit doesn't actually eliminate pollution. Instead, it controls point source pollution by setting limits on the quality and quantity of wastewater that can be discharged from a facility.

The TCEQ is responsible for issuing, enforcing, and renewing these discharge permits on a 5-year basis. The TCEQ issues three types of wastewater permits:

1. Municipal
2. Industrial
3. **Confined Animal Feeding Operations** (**CAFOs**) such as feedlots, dairies, and poultry operations (Fig. 23)

Figure 23. Texas feedlot. (Photo courtesy of © 2007 JupiterImages Corporation.)

As of March 2009, Texas had issued 751 industrial, 2,602 municipal and 796 CAFO permits. Besides obtaining wastewater discharge permits, facilities must also submit monthly effluent reports to the TCEQ that show whether they are within their permit limits. Enforcement actions can be taken against facilities that fail to meet their monthly effluent limits.

Drinking Water Standards

Most Texans receive their drinking water from municipal water systems. Texans also obtain drinking water from private water suppliers and private wells.

The **Federal Safe Drinking Water Act** (**SDWA**) of 1974 established standards to ensure the safety of both surface water and groundwater sources used for public drinking water. Under the SDWA, the EPA sets standards for drinking water quality and oversees the states, localities, and water suppliers that implement those standards.

The EPA sets drinking water standards based on three criteria:

1. Whether the contaminant harms human health
2. Whether the contaminant can be detected in drinking water
3. Whether the contaminant is known to occur in drinking water

In Texas, the TCEQ is responsible for implementing and regulating the drinking water standards set by the EPA and does so by making sure that public water systems regularly monitor their water supplies, assess their results, and comply with the standards. Drinking water supplied by public water supply systems is routinely tested for about 90 different contaminants to ensure compliance with state and federal standards (*http://www.epa.gov/safewater/contaminants/index.html)*.

There are two categories of drinking water standards:

1. Primary standards
2. Secondary standards

Primary standards protect against contaminants that are harmful to human health, including pathogens, radioactive elements, and toxic chemicals. Primary standards set the maximum amount of each pollutant that can be in the drinking water supplied by a public water system. These limits are known as **maximum contaminant levels** (**MCL**).

Secondary standards protect against contaminants that are not harmful to human health, but pose a nuisance because they can cause unacceptable odor, taste, color, corrosion, foaming ,or staining. Maximum limits are also set for these contaminants and are known as **secondary maximum contaminant levels** (**SMCL**).

Despite strict rules and standards protecting the quality of drinking water, a water supply system may still become contaminated and violate certain drinking water standards. When a violation occurs, the public water supply system must notify its customers about what the violation means to them and what steps are being taken to correct the situation. If consumption of the water poses a threat to human health, the water supply system is required to use mass media to reach the public as quickly as possible.

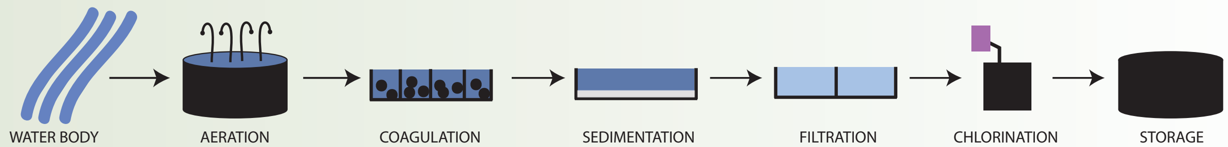
The quality of water in private wells is not regulated by the state. Regularly testing and monitoring of the water quality in private wells is up to the well owner.

Water Quality Testing, Monitoring and Regulation

Water Quality Testing and Monitoring

How can we ensure that the state's surface waters, wastewater effluents, and drinking water sources are meeting federal and state water quality standards? The answer is through water quality testing and monitoring. When the quality of

How does drinking water get to your home? Water is delivered from a groundwater or surface water source to a treatment plant, where it is first aerated to allow volatile gases to escape. Next, small particles are clumped together through the use of coagulating agents and allowed to settle out of the water. Particles that do not settle out through coagulation slowly filter out to the bottom of a maze-like settling tank in a process known as sedimentation. The material at the bottom, called sludge, must be removed and disposed of because it may contain some toxic elements. Next, water flows through long, horizontal tanks with filters made of gravel, sand or granulated activated carbon and is collected at the bottom. Filtration removes additional particles and bacteria. Finally, chlorination or other disinfectants kill any remaining microbes. But remember, this type of treatment happens only to water provided by a public water supply - not a private home well.



Source: Texas Environmental Profiles.

water is tested, the biological, chemical, and physical characteristics of water are analyzed and the results determine the overall quality of a body of water related to its suitability for a specific use. Testing for water quality over a period of time (water quality monitoring) helps us understand the dynamics of a particular body of water and whether the water quality is improving or declining.

Scientists, regulatory agencies, industries, and municipalities use many different instruments to test the quality of surface water, groundwater, and drinking water, including **Secchi disks**, probes, nets, **sondes**, gauges and meters (Fig. 24). Basic surface water quality assessment packages include tests for *E. coli* and *Enterococcus spp*. bacteria, nitrates, phosphorus, pH, sodium, chloride, fluoride, sulfate, iron, manganese, total dissolved solids, and dissolved oxygen. Other tests may be appropriate if a particular contaminant is suspected. For example, some groundwater sources are tested for arsenic, selenium, and uranium and both surface water and groundwater sources used for drinking are often tested for harmful pesticides. Regular testing will show whether the water quality is changing and can

Figure 24. Water quality testing. (Photo courtesy of USDA Natural Resources Conservation Service.)

help detect when some sort of activity is degrading water quality.

Water quality monitoring is a fundamental tool in the management of Texas' freshwater resources. Water quality is monitored to:

- Identify particular pollutants of concern
- Identify whether the quality of the water is appropriate for a particular use
- Determine the quality of a particular water body
- Detect trends in water quality
- Determine the effectiveness of watershed restoration and enhancement projects

Regular water quality testing and monitoring of both surface water and drinking water are required by the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). In Texas, surface water quality monitoring falls under the TCEQ's Surface Water Quality Monitoring Program (SWQM). This program encompasses the full range of activities required to obtain, manage, store, assess, share, and report water quality information to other TCEQ teams, agency management, other agencies and institutions, local governments, and the public.

Under the SWQM Program, there are several state-based monitoring efforts that help ensure the safety of the surface waters in Texas. The Texas **Clean Rivers Program** (**CRP**) is a state-fee funded water quality monitoring, assessment, and public outreach program created in 1991 by the Texas Legislature as a result of the Texas Clean Rivers Act. This legislation requires that water quality assessments be conducted for each of the 23 major river and coastal basins and their sub-watersheds. The CRP is a collaboration of 15 partner agencies (Table 6) and the TCEQ. The CRP provides the opportunity to approach water quality issues within a watershed or river basin at the local and regional level through coordinated efforts among diverse organizations. For more

Table 6. Texas Clean Rivers Program partner agencies. (Source: TCEQ.)

CRP PARTNER AGENCIES
Angelina and Neches River Authority
Brazos River Authority
Guadalupe-Blanco River Authority
Houston-Galveston Area Council
International Boundary and Water Commission
Lavaca-Navidad River Authority
Lower Colorado River Authority
Lower Neches Valley Authority
Northeast Texas Municipal Water District
Nueces River Authority
Red River Authority of Texas
Sabine River Authority
San Antonio River Authority
Sulphur River Basin Authority of Texas
Trinity River Authority of Texas

information on the Texas Clean Rivers Program visit *https://www.tceq.texas.gov/waterquality/clean-rivers.*

The Texas **Coastal Management Program** (**CMP**) is a water quality monitoring and management program implemented by the Texas **General Land Office** (**GLO**) to ensure the long-term ecological and economic productivity of Texas' coastlines. Under the CMP, the GLO administers a number of monitoring programs, including the Texas Beach Watch Program. The Texas Beach Watch Program is a non-regulatory program that monitors water for *Enterococcus spp*., potentially harmful bacteria that are normally found in the feces of people and many animals. Water samples are collected from 167 stations in Aransas, Brazoria, Cameron, Galveston, Jefferson, Kleberg, Matagorda, Nueces, and San Patricio counties. Samples are collected weekly during the peak beach season (May through September) and every other week from October through April. For more information on the CMP and Beach Watch Program visit *http://www.glo.state.tx.us/coastal.html.*

Another program stemming from the GLO's responsibility to protect Texas' coastline is the Adopt-A-Beach program, which is dedicated to preserving and protecting Texas beaches. Through this program, volunteers sponsor beach cleanups, raise public awareness, generate public support, and educate citizens about the importance of clean coastal waters. For more information on this program visit *http://www.glo.texas.gov/adopt-a-beach/.*

In surface waters where fish consumption is a designated use, the Texas **Department of State Health Services** (**DSHS**) conducts chemical testing and monitoring of fish tissue to determine whether consuming the fish is a risk to human health. Many types of contaminants can be found in fish, but some of the most common are mercury, arsenic, **PCBs**, **VOCs,** and **dioxins**. Of particular concern are those pollutants that **bioaccumulate** in the food chain. When a pollutant bioaccumulates in each level of a food chain, an organism at the top of the food chain (humans, predators) will ingest a much greater concentration of the pollutant than was originally present at the bottom of the food chain. Pollutants can accumulate in living things any time they are ingested and stored at a faster rate than they are broken down or excreted. For more information on DSHS fish tissue sampling visit *http://www.dshs.state.tx.us/seafood/.*

Surface water quality data from local and state monitoring programs are compiled in EPA's largest computerized environmental data system, known as STORET (short for STOrage and RETrieval).This database is a repository for biological and physical water quality data and is used by state environmental agencies, EPA, and other federal agencies, universities, private citizens, and many others.

Monitoring for drinking water contaminants is mandated by the federal SDWA. The data collected focus on toxic chemicals for which

Table 7. Water quality testing frequency for public water systems. (Source: Texas Environmental Profiles.)

CONTAMINANT	MINIMUM TESTING FREQUENCY
Bacteria	Monthly or quarterly, depending on system size and type
Protozoa and viruses	Continuous testing and monitoring for turbidity; monthly for total and fecal coliforms, as indicators
Volatile organics (e.g., benzene)	Groundwater systems: annually for two consecutive years; surface water systems: annually
Synthetic organics (e.g., pesticides)	Larger systems: twice in three years; smaller systems: once in three years
Inorganic/metals and nitrites	Groundwater systems: once every three years; surface water systems: annually
Lead and copper	Annually
Radionuclides	Once every four years

maximum contaminant levels have been established. Federal regulation requires that all public water suppliers routinely test and monitor the quality of their water to ensure that it is safe to drink. Table 7 outlines the testing frequency for each category of contaminants.

You will find data on the quality of local drinking water at the EPA's "Local Drinking Water Information" Web site at *http://www.epa.gov/safewater/dwinfo.htm*. In addition, EPA has developed a Safe Drinking Water Information System (SDWIS) at *http://water.epa.gov/scitech/datait/databases/drink/sdwisfed/index.cfm*. It tracks public water systems and their violations of EPA's drinking water regulations. The EPA has also recently developed a new National Drinking Water Contaminant Occurrence Database found at *http://water.epa.gov/scitech/datait/databases/drink/ncod/databases-index.cfm.* It is a repository of drinking water quality data. The United States Geological Survey (USGS) makes its water quality data available to the public through its National Water Information System (NWIS) at *http://waterdata.usgs.gov/nwis/%20.*

There are no federal regulations for private water supplies and water quality testing is the responsibility of the individual owner of the water supply. About 6 percent of Texans rely on private wells and other sources for their drinking water. Private domestic water supplies should be tested at least once a year. More frequent seasonal testing should be done in areas where drinking water supplies are obtained from shallow wells or surface water sources because these are more prone to contamination. The quality of water in a private well can change over time if the land use changes either in the immediate area or farther away where recharge of the aquifer occurs. Drinking water should be tested at the source (at or near the wellhead) and at the tap (kitchen or common use area).

The TCEQ maintains a list of laboratories certified by the state to analyze drinking water samples. The list can be found at *http://www.tceq.state.tx.us/assets/public/compliance/compliance_support/qa/txnelap_lab_list.pdf.* The cost of testing a private well depends on the particular parameters that are analyzed.

Regular water quality monitoring is often difficult to accomplish because of the time and resources required and the cost of continual water testing. It is also difficult to establish an adequate water quality monitoring plan that accurately characterizes the quality of water over time. More and more, volunteers at the local and regional levels are being relied upon to perform regular monitoring of Texas's water resources.

Water Quality Regulation

Who is in charge of regulating, testing, and monitoring our state's water bodies? Many federal, state, and local entities work together to monitor and protect water quality.

At the federal level, the EPA is primarily responsible for administering the water quality standards outlined in the CWA. At the state level, the EPA delegates water quality management authority to the Texas Commission on Environmental Quality (TCEQ).

The TCEQ is the primary water quality agency in Texas. It has chief responsibility for establishing water quality standards in the state, for planning how water quality will be managed, for issuing permits for point source dischargers, and for abating all types of nonpoint source pollution except those from agricultural and silvicultural (forestry) sources. The TCEQ also is responsible for completing the CWA §305(b) assessment and the §303(d) list of impaired waters, together known as the *Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)*, every 2 years. The Integrated Report is available at *http://www.tceq.texas.gov/waterquality/assessment.*

The Texas Legislature has delegated some water quality authority to the **Texas State Soil and Water Conservation Board** (**TSSWCB**). The TSSWCB is responsible for administering Texas' soil and water conservation laws and for managing programs for the prevention and abatement of agricultural and silvicultural nonpoint source pollution. Together, the TCEQ and the TSSWCB share responsibility for monitoring and managing surface water quality in Texas.

In addition to the TCEQ and TSSWCB, many other state agencies and organizations play a role in water quality management and regulation. The **Texas Legislature** makes and revises state water law, provides financial resources to state water agencies, and sets the legal framework for water entities. The **Texas Water Development Board** (**TWDB**) provides leadership, planning, and financial assistance, information, and education for the conservation and responsible development of water resources in Texas. The Groundwater Resources Division of the TWDB is responsible for monitoring the water levels and quality of the state's aquifers, for conducting regional aquifer modeling, and for maintaining water well records.

The **Texas Parks and Wildlife Department** (**TPWD**) plays an important role in protecting, maintaining, and restoring water quality for aquatic life and for recreational activities such as fishing and swimming. The Texas General Land Office (GLO) is primarily responsible for managing the 367 miles of Texas coastline and is the lead agency for the Texas Coastal Management Program, which focuses on the protection of Texas' coastal resources. Through its many programs, the GLO strives to support access to outdoor recreation and protect natural coastal habitats and wildlife.

Several regional and local entities also play a role in protecting and managing the state's water resources. On the regional scale, **groundwater conservation districts** (**GCDs**) implement groundwater management and conservation practices in the state. In Texas, GCDs are created by the Texas Legislature or by the TCEQ through a local petition process. Each district is required to develop and adopt a groundwater management plan for the efficient use of groundwater and to address various issues such as drought, waste, and conservation. The TWDB is charged with approving these management plans, providing assistance to GCDs, and providing groundwater information to citizens and legislators.

Groundwater conservation districts are important, because nearly 60 percent of the state's water demand is supplied by groundwater resources. Currently, there are 96 GCDs in Texas. The first district (High Plains Underground Water Conservation District No. 1) was created in 1951; it also happens to be the largest district in Texas, covering more than 10,000 square miles. For more information on GCDs visit *https://www.twdb.texas.gov/groundwater/conservation_districts/.*

River authorities protect and monitor Texas' rivers. They are essentially multi-county water districts, created by the Texas Legislature, whose governing members are either elected or appointed by the governor. There are 17 river authorities in Texas, the first of which was the Brazos River Authority created in 1929. River authorities vary in terms of their structure and function. Most river authorities are involved in water supply and distribution (primarily for irrigation), flood control, and water quality management. Some river authorities generate and sell electric power, regulate navigation, and handle sewage treatment and solid waste disposal.

At the local level, municipal water suppliers, municipal utility districts, private water suppliers, and many other entities all have a hand in the management and protection of Texas' water resources.

KEY POINTS TO REMEMBER:

- Water quantity is affected by climate and human activity.
- Water quality describes the chemical, physical, and biological characteristics of water.
- Water quality can become impaired as a result of point and nonpoint sources of pollution.
- Nonpoint source pollution is the leading cause of the nation's water quality problems.
- Bacteria, nutrients, sediment, and hazardous substances are the four main nonpoint source pollutants.
- Impaired water quality is a serious issue! It can cause serious illness and even death.
- The TCEQ and the TSSWCB are primarily responsible for water quality management and regulation in Texas.

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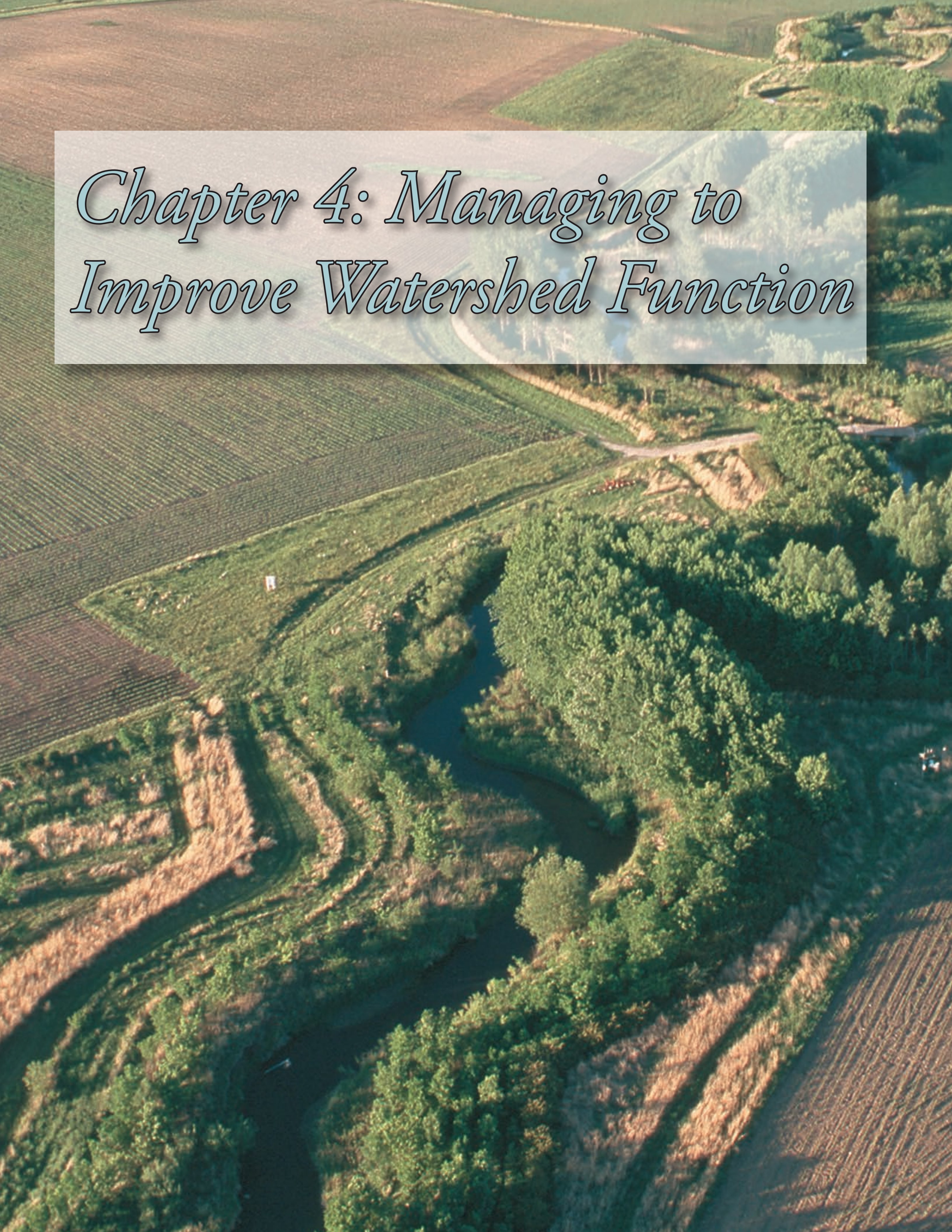
Notes

Chapter 4: Managing to Improve Watershed Function



Using a Watershed Approach

When it comes to managing things like population, voting, crime, unemployment, business, and other human issues, political jurisdictions are often used to coordinate the process and make management more efficient. But most of these things are neatly contained within city, county or state boundaries that are well-defined and do not overlap.

Managing surface and groundwater resources, on the other hand, is a much different story. Water resources don't have neatly defined boundaries that parallel political jurisdictions. Streams, rivers, lakes, and underground aquifers almost always cross city, county, or state lines and may even overlap with one another.

Therefore, the only way to effectively manage and protect surface and groundwater resources is to use a **watershed approach**. The watershed approach is a flexible framework for managing the quantity and quality of water found within specified watershed boundaries.

The goals of the watershed management approach are to:

1. Identify and prioritize water quality/ quantity problems in the watershed
2. Develop increased public awareness and involvement
3. Coordinate efforts with other agencies/ organizations in the watershed
4. Measure success through monitoring and other data collection

Watersheds are appropriate management units because they are defined by the geographic and hydrologic features of the area and include the terrestrial and aquatic components within the watershed's boundaries. This makes it possible to address water quality problems in a holistic manner (rather than focusing on the individual problems of each water body), while at the same time taking into account the interconnectedness of all watersheds across the landscape. A watershed approach tends to be community-based and uses the expertise of both the public and private sectors. According to the EPA, a watershed approach is the most effective means of addressing today's water resource challenges.

IN THIS CHAPTER, YOU WILL LEARN ABOUT:

- Using a watershed approach
- Watershed Protection Plans (WPPs) and Total Maximum Daily Loads (TMDLs)
- Best Management Practices (BMPs) in agricultural, urban, small-acreage, and residential settings

Water Quality Improvement Projects

A watershed approach is often used to design and implement water quality improvement projects at the watershed scale. This makes it possible to consider all major issues in the watershed during the planning process. Water quality improvement projects are usually implemented to improve water bodies that have been placed on the 303(d) list (as a reminder, a water body on the 303(d) list is one that does not meet the chemical, physical, and/or biological criteria necessary to support its designated use(s)). All impaired water bodies in Texas are on the state's 303(d) list.

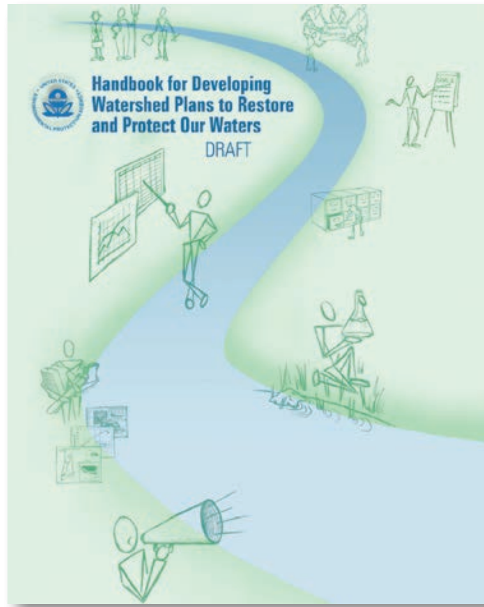
Water quality improvement projects are separated into two major categories: 1) Watershed Protection Plans (WPP) and 2) Total Maximum

Daily Loads (TMDL). Both are designed to improve and protect water quality and the overall health of a watershed. Later in this section, we will discuss various Best Management Practices that may be part of these projects.

A **Watershed Protection Plan** (**WPP**) is a community-driven management framework that uses the watershed approach to solve complex water quality problems within a watershed. The purpose of a WPP is to protect healthy bodies of water and restore impaired ones. WPPs are developed and managed through partnerships among federal and states agencies and local groups and organizations. They rely heavily on **stakeholder** involvement at the local level.

The EPA has guidelines for WPPs. See the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters," available online at *http://water.epa.gov/polwaste/nps/handbook_index.cfm*. According to the EPA's guidelines, each WPP should contain the following elements:

1. Identification of the causes of impairment and pollutant sources that need to be controlled
2. Estimation of the pollutant load reductions that need to be achieved through management



3. Description of the point/nonpoint source management actions needed to achieve the load reductions
4. Estimation of the technical/financial assistance required to implement these management actions
5. Information/education component to increase public understanding and awareness
6. Schedule for implementing the management actions
7. Measurable milestones for tracking the implementation of management actions
8. Criteria for determining whether load reductions are being achieved
9. Water quality monitoring component to evaluate the effectiveness of the plan

In Texas, the TCEQ and the TSSWCB both have roles in developing and implementing WPPs because these agencies share responsibility for managing nonpoint source pollution in the state. An important part of their role is providing technical and financial assistance to local groups developing and implementing WPPs. Other agencies and organizations in the state, including the USDA Natural Resources Conservation Service (NRCS), the Texas A&M AgriLife

Extension Service, and Texas river authorities, also provide educational and/or technical assistance for developing WPPs.

Most WPPs in Texas are funded through the **Clean Water Act Section 319(h)** Nonpoint Source Pollution Grant Program. Through this program, the EPA allocates 319 funding to the TSSWCB and TCEQ to carry out their nonpoint source management programs. The TSSWCB and TCEQ direct these funds to various projects throughout the state, including WPP development projects. However, a variety of state and/or local groups or organizations can initiate, develop, and implement a WPP.

In most cases, a watershed is selected for WPP development because it has been placed on the state's 303(d) list. When this occurs, state and federal agencies (TSSWCB, TCEQ) often facilitate the process by helping local and regional stakeholders form a steering committee and other work groups. Representatives of the agencies will meet with these groups to help them develop a plan that includes the nine elements outlined by EPA. Once the WPP is written and approved by the stakeholders, implementation can begin. The plan also can be submitted for approval by state agencies and the EPA as part of a request for funding to implement the proposed management actions.

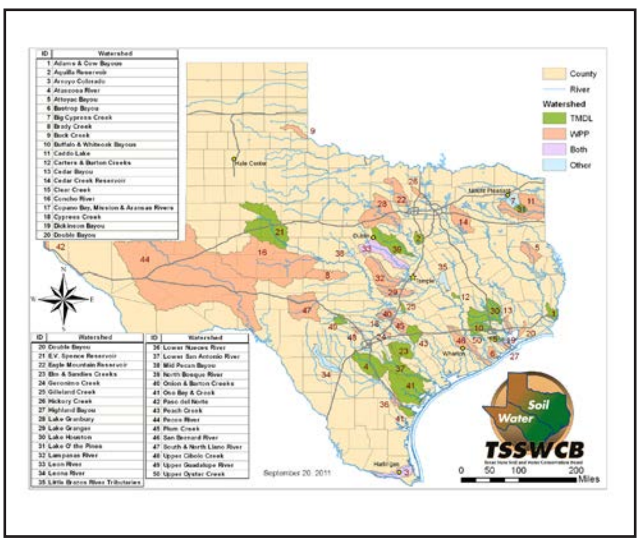


Figure 25. Ongoing and future WPPs planned in Texas. (Source: TSSWCB.)

From start to finish, the development and implementation of a WPP can take several years. WPPs are vital to improving the water quality in watersheds across Texas. Visit the TSSWCB's web site at *http://www.tsswcb.state.tx.us/wpp* or the TCEQ's web site at *http://www.tceq.texas.gov/compliance/monitoring/nps/mgmt-plan/index.html#protection* to find out about WPPs being developed in Texas and how you can get involved (Fig. 25).

The second major type of water quality improvement project is a **Total Maximum Daily Load** or **TMDL**. As the name implies, a TMDL refers to "the amount, or load, of a specific pollutant that a water body can receive on a daily basis and still meet the water quality standards" (EPA, 2005). The maximum pollutant load for a particular body of water is established by conducting a detailed water quality assessment. During this assessment, pollutant loads are allocated among the various point and nonpoint pollutant sources that may be affecting the water body. A margin of safety and the effects of seasonal variations are figured into the maximum load calculation.

The TMDL program and associated regulations are outlined in **Section 303(d)** of the Clean Water Act. The law calls for each state to give EPA a list of its impaired bodies of water and prioritize that list for TMDL development based on five categories of classification.

- *Category 1*: Attaining the water quality standard and no use is threatened.
- *Category 2*: Attaining some of the designated uses; no use is threatened; and insufficient (or no data) are available to determine if the remaining uses are attained or threatened.

- *Category 3*: Insufficient data (or no data) to determine if any designated use is attained.
- *Category 4*: The standard is not met or is threatened for one or more designated uses but the development of a Total Maximum Daily Load (TMDL) is not required.
  - *Category 4a*: A TMDL has been completed and approved by the EPA.
  - *Category 4b*: Other pollution control requirements are reasonably expected to result in the attainment of the water quality standard in the near future.
  - *Category 4c*: Pollution is not the cause of the water quality standard not being met.
- *Category 5*: The water body does not meet applicable water quality standards or is threatened for one or more designated uses by one or more pollutants.
  - *Category 5a*: A TMDL is under way or scheduled, or will be scheduled.
  - *Category 5b*: A review of the water quality standards will be conducted before a TMDL is scheduled.
  - *Category 5c*: Additional information will be collected before a TMDL is scheduled.

Like WPPs, TMDLs also undergo various phases of approval, ending with a final approval from the EPA. Once completed, an Implementation Plan (**I-Plan**) is developed based on the load reduction estimates established in the TMDL. The I-Plan specifies limits for point source dischargers and recommends best management practices for nonpoint sources. It also lays out a schedule for implementation. Together, the TMDL and the I-Plan serve as the mechanism to reduce the pollutant, restore the full use of the water body, and remove it from the 303(d) list (TSSWCB, 2007). Unlike the actual TMDL, however, I-Plans require approval only at the state level (the state agency involved in TMDL development will have final approval for the I-Plan). In Texas, the TSSWCB and the TCEQ are both responsible for TMDL development and implementation since both agencies are responsible for managing nonpoint source pollution in the state. Visit the TSSWCB's web site at *http://www.tsswcb.state.tx.us/tmdl* or the TCEQ's web site at *http://www.tceq.texas.gov/waterquality/tmdl* to learn about TMDLs being developed in Texas and how you can get involved.

The main difference between a WPP and a TMDL is that TMDLs are regulatory in nature, meaning they are required by federal law. WPPs are voluntary programs and are not mandated by federal law. In general, WPPs are a way of restoring water quality that can result in removing a body of water from the 303(d) list, therefore avoiding regulatory action in a watershed. WPPs are often a better fit for watersheds that have few or no permitted dischargers, where the probable cause is loading from nonpoint, unregulated sources. In some cases, however, TMDL development is unavoidable, especially if the body of water has been placed in impairment Category 5a and the impairment is seen as an emergency situation. TMDLs can often be completed more quickly than a WPP because they focus only on a single pollutant rather than all potential pollutants. In certain situations, WPPs and TMDLs can be developed for the same body of water, depending on the impairment issue. In these cases, a WPP can be used to implement a completed TMDL or vice versa (Fig. 26).

Best Management Practices

When a body of water is impaired and placed on the 303(d) list, it is the responsibility of the state environmental agencies and concerned stakeholders to resolve the water quality problem(s) so that the water body can ultimately be removed from the list. The implementation phases of both a WPP and a TMDL outline specific activities that will be completed in the watershed to improve water quality. These activities may include a wide range of efforts requiring the involvement of federal and state agencies, city and county governments, local businesses and industry, and individual citizens.

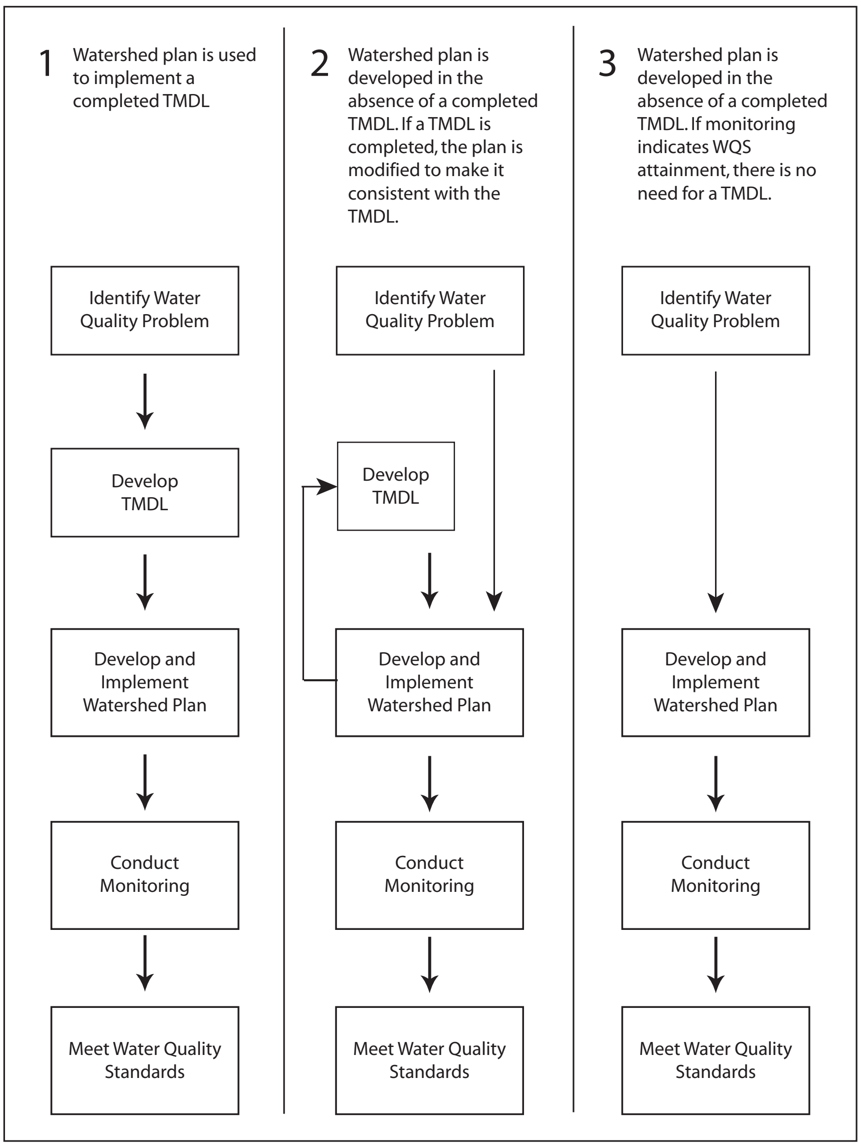


Figure 26. Potential relationships between TMDLs and watershed plans (WPPs). (Adapted from Figure 2-2 in Handbook for Developing Watershed Plans to Restore and Protect Our Waters, EPA, 2005.)

Most point sources of pollution are regulated by federal and/or state agencies. Pollution controls for these sources are governed by federal and state laws that place specific requirements on the types and amounts of pollutants that can be released in a watershed. As a result, recommendations outlined in the WPP for point sources must consider these requirements and work in concert with existing regulatory programs.

While nonpoint sources of pollution also are addressed through federal and state regulatory programs, control of these sources is often a much greater challenge. Remember, nonpoint source pollution is diffuse and does not originate from a fixed location as point source pollution does. One approach to controlling nonpoint source pollution is the adoption of **Best Management Practices**, or **BMPs**.

The EPA defines BMPs as "methods that have been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources." BMPs can be implemented by anyone, anywhere in a watershed; however, the types of BMPs implemented depend on the specific sources and types of pollutants that are causing the problem. For example, there are specific BMPs for both agricultural and urban areas. The following sections discuss specific types of BMPs.

Agricultural BMPs

The United States has approximately 330 million acres of cropland, pasture, and rangeland (Fig. 27) that produce an abundant supply of food and food-based products. Agriculture is vital to the economic and social well-being of all Americans. If not properly managed, however, agricultural activities can degrade the quality of nearby bodies of water.

According to the EPA, agriculture is listed as a source of pollution for 24 percent of the impaired river miles and 14 percent of the lake acres that have been assessed in the United States. Agricultural activities such as over-irrigation, inappropriate fertilizer and pesticide application, overgrazing, removal of riparian vegetation, and improper livestock manure and wastewater management all generate nonpoint source pollutants that can enter the water supply by seeping into groundwater or running off into surface waters. The primary agricultural nonpoint source pollutants are nutrients, sediment, animal wastes, salts, and pesticides. Sedimentation is the most common source of agricultural water pollution. The effects of agriculture on water quality are summarized in Table 8.

Figure 27. Cattle grazing on pasture in Texas. (Photo courtesy of Matt Berg, Texas A&M AgriLife Extension Service.)

Using agricultural BMPs can help prevent and/or minimize the effects of nonpoint source pollution. Most agricultural BMPs strive to control sediment carried off of agricultural lands, encourage sound pest and nutrient management techniques, and prevent or minimize potential runoff to ensure economic, environmental, and agronomic sustainability. Adopting agricultural BMPs can ultimately increase efficiency and profits, increase property values, improve water quality, and benefit the local community.

Agricultural BMPs can be structural or nonstructural in nature. Structural practices, such as fences and buffer strips, often involve some sort of construction, installation, and maintenance. Structures can be vegetative (buffers) or non-vegetative (fencing). Nonstructural practices, on the other hand, are activities or behaviors that reflect better planning and management, and increased education and awareness. Table 9 lists the effectiveness of selected agricultural BMPs in controlling sediment, nutrients, pesticides, and pathogens. For more information on agricultural BMPs for controlling nonpoint source pollution, visit the NRCS Farm Conservation Solutions web site at *http://www.nrcs.usda.gov/wps/portal/nrcs/detail/wi/technical/cp/?cid=nrcs142p2_020779*.

Management Practices

Nutrient management involves reducing the amount of fertilizer used by applying only the amount a crop needs. It includes

Table 8. Agricultural impacts on water quality. (Adapted from Ongley, 1996.)

AGRICULTURAL ACTIVITY	EFFECTS	
	SURFACE WATER	GROUNDWATER
Tillage/Plowing	Sediments carry phosphorus and pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.	
Fertilizers	Runoff of nutrients, especially phosphorus, leading to eutrophication; taste and odor problems in public water supplies; excess algae growth leading to hypoxia and fish kills	Leaching of nitrate to groundwater; excessive levels are a threat to public health
Manure spreading	Spreading on frozen ground or near surface water results in high levels of contamination by pathogens, metals, phosphorus, and nitrogen leading to eutrophication and potential contamination	Contamination, especially by nitrogen
Pesticides	Runoff of pesticides contaminates surface water, inhibits growth and reproduction in wildlife; public health affected when people eat contaminated fish. Pesticides can be carried by wind over very long distances and contaminate aquatic systems miles away	Some pesticides may leach into groundwater, causing human health problems from contaminated wells
Feedlots/Animal corrals	Contamination of surface water with pathogens (bacteria, viruses, etc.), leading to chronic public health problems. Contamination by nutrients and metals contained in urine and/or feces	Potential leaching of nitrogen, metals, etc. to groundwater
Irrigation	Runoff of salts causes salinization of surface waters; runoff of fertilizers and pesticides causes ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can cause serious ecological damage and potential human health problems	Enrichment of groundwater with salts, nutrients (especially nitrate)
Forestry practices	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; pesticide run-off and contamination of surface water and fish; public health problems caused by loss of potable water	Disruption of hydrologic regime, often with increased surface runoff and decreased groundwater recharge; affects surface water by decreasing flow in dry periods and concentrating nutrients and contaminants in surface water

managing the amount, form, methods, and timing of nutrient application (either animal waste, commercial fertilizers, or other forms of nutrients) (Fig. 28). Nutrient management is cost-effective, because it limits the amounts of nutrients lost. Furthermore, it is one of the best ways to reduce nonpoint source nutrient pollution.

Integrated Pest Management, or **IPM**, is an ecologically based strategy designed to keep pest populations below economically injurious levels using a variety of control tactics (Fig. 29). IPM is not a single pest control method, but rather a series of pest management evaluations, decisions, and controls aimed at reducing the amount of pesticide used and the amount that moves into the environment. The first phase of IPM uses monitoring, pest forecasting, scouting, and economic thresholds to determine when pest control is warranted. If pests must be controlled, there may be several options:

- Biological control (such as releasing natural

Table 9. Structural and nonstructural agricultural BMPs. (Adapted from USDA Agriculture Information Bulletin 598.)

BEST MANAGEMENT PRACTICE	EFFECTIVENESS IN CONTROLLING NONPOINT SOURCE POLLUTANTS			
	Sediment	Nutrients	Pesticides	Pathogens
Management practices				
Nutrient management	-	+	-	-
Integrated pest management	-	-	+	-
Irrigation system, tailwater recovery	+	+	+	-
Irrigation water management	+	+	+	+
Regulating water in drainage systems	-	+	+	-
Soil salinity management	/	/	/	-
Structure for water control	+	+	/	-
Water table control	-	+	+	-
Waste management system	+	+	-	+
Runoff management system	+	+	-	+
Vegetative and tillage practices				
Conservation tillage	+	+	+	-
Contour farming	+	+	+	/
Contour stripcropping	+	+	+	/
Buffer or filter strips	/	/	/	/
Cover and green manure crop	/	/	/	-
Conservation cropping sequence	+	+	+	-
Field windbreaks	/	/	/	-
Pasture and hayland management	/	/	-	/
Structural practices				
Terrace	+	+	+	-
Water and sediment control basin	+	+	+	-
Grade stabilization structure	/	/	-	-
Grassed waterway	+	+	-	-
Streambank and shoreline protection	+	+	-	-
Wetland development and restoration	+	+	+	/
KEY *+ Medium to high effectiveness* */ Low to medium effectiveness* *- No control to low effectiveness*	***NOTE*** *These practices may not perform as indicated at all sites and in all situations.*			

insect enemies)
- Mechanical control (plowing, cultivating, etc.)
- Cultural control (planting insect-resistant varieties, crop rotation, destroying pest refuge sites, etc.)
- Chemical control

When pesticides must be used, the objective is to select the least-toxic product possible and strictly follow all application guidelines on the product label. For more information on IPM, visit *http://ipm.tamu.edu/*.

Irrigation water management promotes the efficient use of irrigation water to produce profitable yields, conserve water, and minimize the leaching of nutrients into groundwater. The timing and amount of irrigation water applied to agricultural lands are critical decisions for each operator because they affect profits and crop yields (Fig. 30). Applying too much water increases pumping costs, reduces water efficiency, and increases the potential for nitrates and pesticides to leach into groundwater. On the other hand, delaying irrigation until plants are water-stressed can reduce yield and make fertilizers and pesticides less effective. An irrigation water management plan should use soil moisture monitoring techniques to determine when irrigation is necessary. Irrigating only when a crop needs it is an effective BMP for reducing nonpoint source pollutants.

Figure 29. Crop consultant scouts field for pests as part of an integrated pest control strategy. (Photo courtesy of USDA Natural Resources Conservation Service.)

Figure 28. Application of ammonia fertilizer at planting time. (Photo courtesy of USDA Natural Resources Conservation Service.)

Vegetative and Tillage Practices

Conservation tillage is a way to reduce the amounts of sediment and nutrients that move into water from agricultural lands (Fig. 31). Two types of conservation tillage are minimum tillage and no-tillage. Minimum till leaves at least 30 percent of the soil surface covered with plant residue after the tillage or planting operation. No-tillage is the practice of leaving the soil undisturbed from harvest to planting, except for nutrient injection. Crop seeds are planted by a device that opens a trench or slot through the sod or pervious crop residue. Conservation tillage can reduce soil loss by 50 percent or more as compared to conventional tillage.

Contour farming is the alignment of all farm tillage, planting, and harvesting practices with the contour of the land (Fig. 32). The goal is to reduce erosion and surface runoff and, thus, the transport of nutrients and pesticides from the field. Contoured rows retain rainwater, which

Figure 30. Center pivot irrigation system. (Photo courtesy of USDA Natural Resources Conservation Service.)

increases infiltration and reduces runoff.

Cover and **green manure crops** are crops of close-growing grasses, legumes, or small grains grown primarily for temporary, seasonal soil protection and improvement, except where there is permanent cover as in orchards or vineyards (Fig. 33). Green manure crops are plowed under and incorporated into the soil to control erosion, add organic matter and nutrients, suppress weeds, and reduce the need for nitrogen fertilizers.

Vegetative buffer strips or **filter strips** are strips of grasses or other vegetation placed along streams or drainage areas to trap sediment, filter nutrients and other pollutants, and promote the infiltration of water into the soil. The width of a filter strip depends on the slope and amount of land area delivering water to the strip and the type of vegetation used.

Structural Practices

Water and **sediment control basins** are erosion control structures commonly installed across the bottoms of drainage ways to prevent bank and gully erosion on farmland and to minimize sedimentation of nearby water bodies (Fig. 34). Basins help improve water quality downstream by trapping sediment, by controlling water flow within a drainage area, and by storing runoff water and allowing it to slowly infiltrate into the soil profile.

Terraces are level soil embankments that are usually constructed on the contour of the land. They help control runoff and soil erosion. Because they tend to promote water infiltration into the soil, these structures also are effective in reducing both nutrient and pesticide losses.

Grassed waterways are natural drainages that are planted with sod-forming grasses to help control runoff water from agricultural lands (Fig. 35). Covering the drainage way with grass helps

Figure 31. Conservation tillage. Farmers leave crop residue on the soil surface to reduce erosion by wind. (Photo courtesy of USDA Natural Resources Conservation Service.)

Figure 32. Contour farming. (Photo courtesy of USDA Natural Resources Conservation Service.)


Figure 33. Cover crops. (Photo courtesy of USDA Natural Resources Conservation Service.)


Figure 34. Water and sediment control basins hold runoff water to prevent flooding and sedimentation. (Photo courtesy of USDA Natural Resources Conservation Service.)

prevent gullies from forming in the fields, traps sediment, absorbs chemicals and nutrients in runoff water, and provides cover for small birds and mammals.

Streambank and shoreline protection involves the use of vegetation, structures, **bioengineering** or management techniques to stabilize and protect streambanks, riparian areas, and shorelines (Fig. 36). The goal is to reduce the sediment and nutrients entering water from eroding streambanks and shorelines. Healthy riparian and shoreline areas can provide abundant wildlife habitat and cover. Mature woody vegetation along streambanks can lower stream temperature and improve fish habitat.

There are many government programs to help farmers and ranchers design and pay for agricultural BMPs to control nonpoint source pollution. The EPA, NRCS, and many state agencies offer cost-share programs, technical assistance, and economic incentives. Many individuals use their own resources to adopt technologies and management practices that protect and improve water quality.


Figure 35. Grassed waterways prevent erosion as they carry runoff from fields. (Photo courtesy of USDA Natural Resources Conservation Service.)

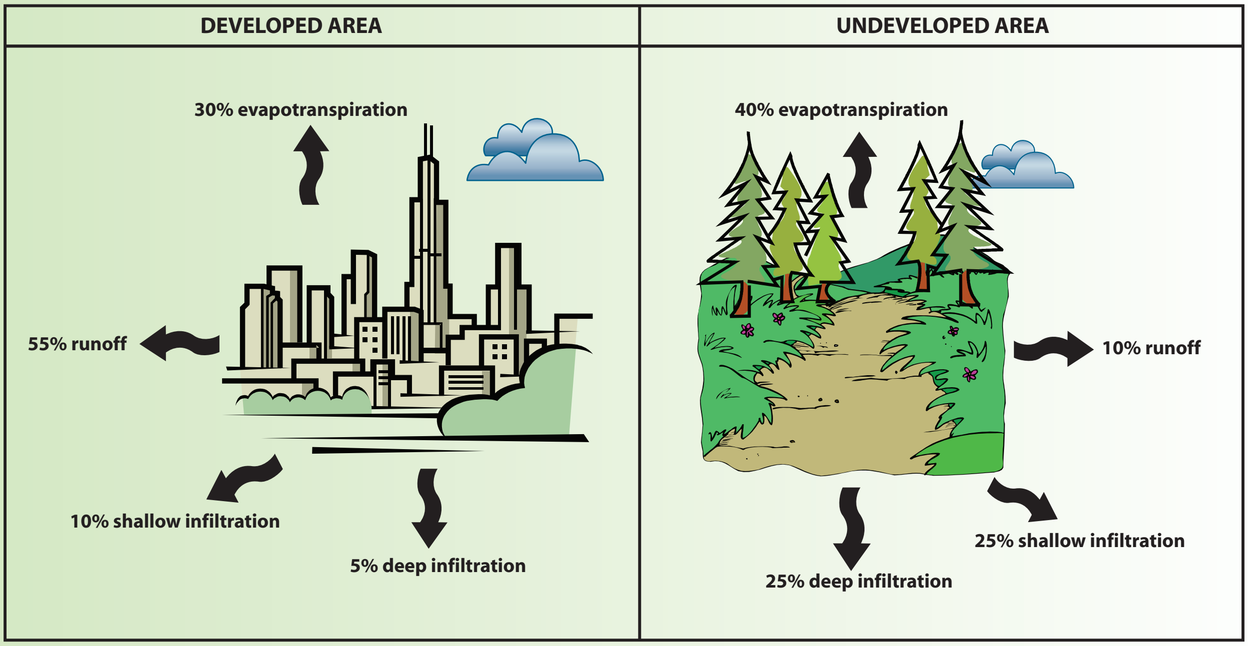
Figure 36. Trees, shrubs, and grasses form effective riparian buffers. (Photo courtesy of USDA Natural Resources Conservation Service.)

AGRICULTURAL BMP SUCCESS STORY: ***Aquilla Reservoir – Hillsboro, Texas***

Aquilla Reservoir was built in 1983 for water supply, flood control, and recreation purposes. Located approximately 10 miles southwest of the city of Hillsboro in east-central Texas, it controls drainage from a 255-square mile watershed. Corn and sorghum production comprise 40 percent of land use in the watershed. The reservoir is the sole source of water for the Aquilla Water Supply District's treatment plant. In 1997, the reservoir was placed on Texas' 303(d) list of impaired waters for excessive levels of the herbicide atrazine. Project partners initiated a TMDL effort to reduce agricultural atrazine sources as well as urban pollution sources in the watershed. As a result of technical assistance provided to corn and sorghum producers, the use of agricultural BMPs, and educational efforts targeted towards urban residents, atrazine concentrations in Aquilla Reservoir declined by 60 percent. The waterbody now meets atrazine concentration standards, and in 2004 the Texas Commission on Environmental Quality (TCEQ) recommended that Aquilla Reservoir be removed from the state's 303(d) list of impaired waters.

Photo courtesy of US Army Corps of Engineers.

COMPARING HYDROLOGY IN URBAN AND NATURAL SETTINGS



Impervious cover in a watershed results in increased surface runoff. As little as 10 percent impervious cover in a watershed can result in stream degradation. Heavily urbanized places like cities and downtown areas can have as much as 90% impervious surface cover.

Urban BMPs

The Census Bureau estimates that the amount of land in the United States covered by urban areas has increased from roughly 15 million acres in 1945 to over 98 million acres in 2007. During this same period, the population of the U.S. more than doubled. According to the annual USDA National Resources Inventory (NRI) report, the amount of developed land increased by 36 percent between 1982 and 2007.

Urbanization means that more and more land is being covered by impervious surfaces such as parking lots, roads, and buildings (Fig. 37). These types of surfaces increase rainfall runoff, because water cannot infiltrate into the soil. Instead, water is channeled into storm drains and emptied into neighboring creeks and streams. This can cause flooding, erosion, stream channel alteration,

Figure 37. Suburban area of Goforth, Texas. (Photo courtesy of Matt Berg, Texas AgriLife Extension Service.)

Table 10. How impervious surfaces in urban areas affect the environment. (Source: Urbanization of Streams: Studies of Hydrologic Impacts, EPA 841-R-97-009, 1997.)

IMPERVIOUS SURFACES LEAD TO:	EFFECTS				
	Flooding	Habitat loss	Erosion	Channel widening	Streambed alteration
Increased volume	x	x	x	x	x
Increased peak flow	x	x	x	x	x
Increased peak flow duration	x	x	x	x	x
Increased stream temperature		x			
Decreased base flow		x			
Changes in sediment loadings	x	x	x	x	x

and ecological damage, all of which pose serious threats to watersheds (Table 10) and can be very costly to reverse. The EPA acknowledges that urban runoff is one of the leading causes of poor quality surface water across the U.S.

Urban BMPs generally focus on controlling water flow and reducing the amounts of pollutants–primarily nonpoint source pollutants–that enter bodies of water. Pollutant loads can be especially high in urban areas. Major nonpoint source pollutants in urban areas include pathogens (from the fecal matter of dogs and cats and failed centralized waste collection systems), toxic substances (from spilled oil, grease, and toxic chemicals from cars), nutrients (from excess fertilizer applied to lawns, sports fields, and landscaped areas), and sediment (from construction sites and development) (Table 11).

As with agricultural BMPs, urban BMPs can be structural or nonstructural in nature. Table 12 lists BMPs for urban settings. For a more complete list of urban BMPs, visit the Texas A&M AgriLife Extension Service Environmental Horticulture web site at *http://earthkind.tamu.edu/* and the EPA "National Menu of Stormwater Best Management Practices" web site at *http://water.epa.gov/polwaste/npdes/swbmp/.*

Table 11. Potential pollutants from urban activities and land uses. (Source: The Urban Environment and NPS Pollution, Alabama Cooperative Extension.)

URBAN ACTIVITY OR LAND USE	POTENTIAL POLLUTANTS
Paved areas	Asphalt and concrete particles, road marking paints, crack fillers and joint compounds, anti-skid compounds (salts, sand, and ash), dirt, and other spills
Motor vehicles	Leaked fuel, battery acid, anti-freeze, car-care products, and lubricants; tire, clutch, and brake lining parts; larger pieces of metal and glass; bulk materials spilled from open trucks (sand, dirt, and chemicals)
Industrial/Commercial	Smoke stack emissions; oil and grease from parking lots, salvage yards, service stations, and roadways; overflowing trash and seepage from dumpsters and temporary waste storage areas
Lawns and gardens	Organics like leaves, bark, seeds, twigs, and grass clippings; pesticides; fertilizers; domestic animal wastes
Construction and demolition areas	Sediment; petroleum products and construction materials; solid wastes from construction materials and workers; wash water from concrete mixers
Litter disposal	Waste items disposed of in streets, along water courses, and in other areas

DID YOU KNOW??

Because of impervious surfaces such as pavement and rooftops, a typical city block generates 5 times more runoff than a woodland area of the same size.

Source: EPA.

Table 12. Structural and non-structural BMPs for urban areas (Continued on Page 62). (Adapted from the Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA, 1999.)

BEST MANAGEMENT PRACTICE	EFFECT ON URBAN NONPOINT SOURCE POLLUTANTS			
	Sediment	Nutrients	Toxic Chemicals	Pathogens
STRUCTURAL				
Infiltration systems				
Infiltration basins	+	+	\	\
Porous pavement systems	+	+	\	\
Infiltration trenches and wells	+	+	\	\
Detention systems				
Detention basins	\	-	-	-
Underground vaults, pipes and tanks	\	-	-	-
Retention systems				
Retention ponds	+	-	-	-
Retention tanks, tunnels, vaults, and pipes	+	-	-	-
Constructed wetland systems				
Wetland basins and wetland channels	+	+	-	-
Filtration systems				
Surface sand filter	+	+	-	\
Underground vault sand filter	+	+	-	\
Biofiltration/bioretention systems	+	+	-	\
Vegetation systems (biofilters)				
Grass filter strips	+	+	-	-
Vegetated swales	+	+	-	-
NON-STRUCTURAL				
Education, recycling, source controls				
Automotive product disposal	-	+	+	-
Commercial and retail space good housekeeping	-	+	+	-
General community outreach	+	+	+	+
Industrial good housekeeping	-	+	+	-
Storm drain inlet stenciling	-	+	+	+
Pesticide/herbicide use	-	+	+	-
Fertilizer use	-	+	-	-
Household hazardous material disposal	-	-	+	-
Lawn debris management	+	+	-	-
Pet waste disposal	-	+	-	+
Illicit discharge detection and elimination	+	+	+	+

Table 12. Continued from previous page. Best Management Practices for urban areas. (Adapted from the Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA, 1999.)

BEST MANAGEMENT PRACTICE	IMPACT ON URBAN NONPOINT SOURCE POLLUTANTS			
	Sediment	Nutrients	Toxic Chemicals	Pathogens
Maintenance practices				
Catch basin cleaning	+	-	-	-
Street and parking lot cleaning	+	+	+	+
Road and ditch maintenance	+	+	+	+
Road salting and sanding	+	-	+	-
Vegetation maintenance	+	+	-	-
Low-Impact development practices				
Minimizing impervious areas	+	+	+	+
Directed growth	+	+	+	+
Sensitive area protection	+	+	+	+
Open space preservation	+	+	+	+
Minimizing soil and vegetation disturbance	+	+	+	+
KEY *+ Medium to high effectiveness* */ Low to medium effectiveness* *- No control to low effectiveness*	***NOTE*** *These practices may not perform as indicated at all sites and in all situations.*			

Structural Practices

Infiltration systems are designed to capture and store stormwater runoff so that it can infiltrate into the soil profile. Infiltration components may include infiltration basins, porous pavement systems (Fig. 38), and infiltration trenches and wells. Infiltration systems have numerous benefits. By capturing surface runoff, they reduce the volume of water entering streams and rivers and lessen the effects of excessive flows and urban pollutant concentrations. They increase the rates at which aquifers are recharged and increase base flow levels in nearby streams. Infiltration BMPs can also improve water quality by filtering out pollutants and giving microorganisms in the soil time to break down organic pollutants.

Figure 38. A porous pavement system in a shopping mall parking lot. (Photo courtesy of USDA Natural Resources Conservation Service.)

Detention systems intercept and temporarily store stormwater runoff for gradual release into a receiving water body or storm sewer system. Their main function is to control the flow of stormwater, rather than improve water quality. As a result, downstream flooding is minimized

Figure 39. Retention pond in an urban area of the Plum Creek Watershed in central Texas. (Photo courtesy of Matt Berg, Texas A&M AgriLife Extension Service.)

and stream channels are protected from erosion. Detention systems include detention basins and a variety of underground vaults, pipes, and tanks that direct water flow, store excess water, and empty out between storms.

Retention systems include retention ponds (also called wet ponds or stormwater ponds) and a variety of underground vaults, pipes, and tanks that intercept, store and treat urban stormwater runoff (Fig. 39). In retention systems, water is held indefinitely. Properly designed and maintained retention systems can be extremely effective because they control both water quantity and water quality. Diverting water to a retention system decreases peak discharge and flow rates and reduces stream channel erosion and downstream flooding. Retention systems filter out sediment and suspended solids, improve infiltration and the biological uptake of nutrients by aquatic plants and algae, increase the volatilization of organic compounds, and promote plant uptake of metals and the biological conversion of organic compounds. Retention systems, specifically wet ponds, also have aesthetic appeal and can be used for recreation and wildlife habitat.

Constructed wetland systems are designed to mimic the functions of natural wetlands by removing pollutants from urban stormwater (Fig. 40). In a constructed wetland system, the water, plants, animals, microorganisms, and environment (sun, soil, and air) work together to improve water quality. These systems are particularly efficient in removing contaminants such as nitrogen, suspended solids, hydrocarbons, and even some metals. Constructed wetlands also control the quantity of stormwater runoff for a period of time. Wetlands make excellent wildlife habitat and are aesthetic areas in a community. Constructed wetlands are particularly successful in areas where the groundwater level is shallow so that there is a constant supply of water to sustain the wetland system.

Filtration systems use sand, gravel, peat, compost, or other media to remove contaminants from urban stormwater runoff. Filtration systems help mainly with water quality, although when combined with detention or retention basins they may also help control the quantity of runoff. Filtration systems such as surface sand filters, underground vault sand filters, and biofiltration/bioretention systems (Fig. 41) are often used to treat stormwater in small areas such as parking lots and small developments, in areas with high pollution potential such as industrial areas, or in highly urbanized areas. The system components can be placed under parking lots and buildings, so little land is required.

Figure 40. Constructed wetland in Texas. (Photo courtesy of the South Texas Environmental Institute, Texas A&M University-Kingsville.)

Vegetated systems or **biofilters** use the natural vegetation growing in grass filter strips and vegetated swales to filter stormwater as it flows across the land surface. Thus, water is treated before it is discharged into a storm sewer system. Vegetated systems reduce the overall volume of stormwater, reduce flow velocity, promote infiltration, and trap sediment and other contaminants contained in the water.

Non-Structural Practices

Education is one of the most important non-structural BMPs. The general public is usually unaware of the hazards of nonpoint source pollutants and the ways in which their individual actions may be contributing to problems in their watershed. And most people don't know what steps they and their communities can take to minimize nonpoint source pollution. Educational programs take many forms.

- Using television, newspaper, radio, and other media to present information.
- Enlisting homeowner associations and other groups to encourage good stewardship and the adoption of BMPs by individuals and families.
- Youth education in schools and clubs (scouts, 4-H, FFA, etc.).
- Training public employees, particularly planning and parks and recreation staff, about nonpoint source pollution and BMPs to use in park and open space maintenance, fleet and building maintenance, new construction ordinances, and storm sewer maintenance.
- Training employees of business and industry to incorporate pollution prevention and good housekeeping techniques into their operations.

Figure 41. This green roof constructed on top of a building acts as a bioretention system. (Photo courtesy of Joan Kelsch, Arlington County Government.)

Maintenance programs are very important in reducing urban pollution and ensuring that measures adopted to deal with stormwater are functioning as designed. Important maintenance activities include sweeping streets and parking lots, maintaining roads and ditches, and maintaining vegetation. More than 50 percent of the runoff in residential areas and nearly 80 percent of the runoff in commercial areas comes directly from streets and parking lots, so keeping them clean is vital (Fig. 42). Vegetated systems such as swales, constructed wetlands, and grass filter strips also require regular maintenance to function properly and efficiently. It may be necessary to re-seed disturbed areas several times before they become fully vegetated and perform at an optimum level.

Low-Impact development practices (**LID**) are being adopted in many communities to balance urban growth with environmental integrity through good land use planning. Aquatic resources, water quality, and natural watershed hydrology should be maintained and enhanced during the development process. Some of the most common low-impact development practices include using pervious rather than impervious surfaces, placing restrictions on land use through directed growth, protecting sensitive areas, preserving open space, and minimizing disturbance to soil and vegetation. Other LID techniques include the use of green roofs, grassed swales, rain barrels, rain gardens, and alternative landscaping. Together, these practices help reduce the amount of stormwater runoff that is generated, thereby improving water quality and maintaining the natural hydrology of the watershed.

Not only does LID benefit the environment, it also benefits the municipality, the developer, and the general public. With LID practices, there is less need to build expensive infrastructure such as drainage systems and other utilities. This can save developers a lot of money. With less burden on the existing drainage infrastructure, municipalities have lower costs for repair and replacement. Moreover, communities that preserve the quality of their water resources will not face the need for expensive restoration activities in the future.

Figure 42. Regular cleaning and maintenance of streets can help minimize pollutants that enter storm drains in urban areas. (Photo courtesy of Nikki Dictson, Texas A&M AgriLife Extension Service.)

Forestry BMPs

An estimated 80 percent of our nation's freshwater resources originate from forests that cover about one-third of the United States. Forests provide a number of essential economic, social, and environmental functions in addition to supplying us with clean water. They absorb rainfall, refill groundwater aquifers, slow and filter stormwater runoff, reduce floods, and maintain watershed stability and resilience.

Non-Structural Practices

Pre-harvest planning involves ensuring that forestry activities, including timber harvesting, site preparation, regeneration, and associated road construction, are planned with water quality considerations in mind and conducted without significant nonpoint source pollutant delivery to streams or other surface waters. Road system planning is an essential element because forest roads and stream crossings are one of the largest potential sources of forestry-produced sedimentation. Careful planning can aid in recognizing sensitive areas to avoid, help limit stream crossings by identifying practical alternatives, and minimize the overall area disturbed by the operation. Topographic maps, aerial photographs, and soil surveys are helpful tools commonly used in conjunction with site reconnaissance to plan forestry activities (Fig. 43). It is also a good idea to work with a professional forester before starting any forestry activity, establish a site-specific management plan, and select a contractor that has been trained in BMPs.

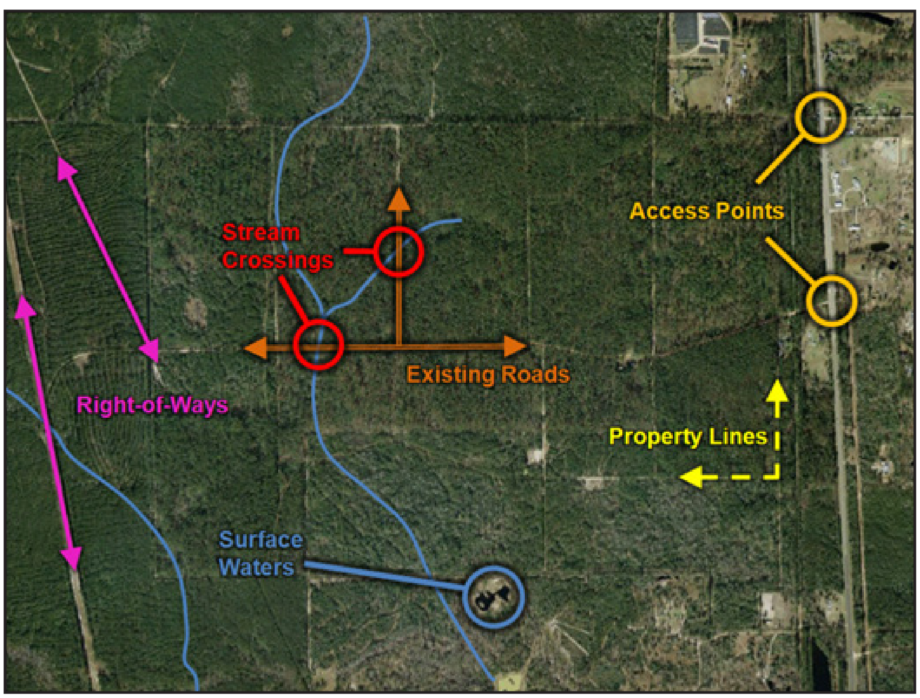


Figure 43. Aerial photographs are helpful tools for planning forest activities to protect water quality. (Photo courtesy of the Texas Forest Service.)

Timber harvesting BMPs include practices such as locating log decks, roads, and skid trails away from streams and on firm ground; capturing and properly disposing equipment fluids and trash; and preventing logging debris from entering stream channels. The goal of these practices is to conduct harvesting in a way that prevents nonpoint source pollution and minimizes the impact to water quality.

Together, **contour planting** and **site preparation** are similar to the agricultural practice of contour farming in that forest regeneration operations are conducted on the contour of the land (Fig. 44). This practice minimizes soil erosion and slows surface runoff, especially on steep slopes with highly erodible soils. Roads and skid trails are also located along the contour for the same reasons.

In order to protect forested wetlands from any potential adverse effects of typical forest management regimes, Section 404 of the Clean Water Act requires the use of mandatory BMPs for forest road construction and maintenance in wetlands. These BMPs ensure that the flow and circulation patterns and chemical and biological characteristics of the wetland are not impaired, that its size is not reduced, and that any adverse effect on the aquatic environment will be minimized.

Practices that protect water resources during and after prescribed burning and wildfires include minimizing or excluding constructed fire breaks from riparian areas to reduce the potential for soil movement and maintain the filtering capacity of the forest floor; refraining from prescribed burning on steep terrain with erodible soils; and ensuring that exposed fire breaks are stabilized, well drainined, and only as wide and deep as needed to prevent erosion. The goal of these practices is to minimize nonpoint source pollution and erosion resulting from prescribed fire and other activities associated with wildfire control or suppression.

Ensuring that application equipment is in good working order, applying chemicals away from surface water bodies and riparian areas, following written guidelines on the manufacturers label, and disposing residues and containers in accordance with state and federal laws are all practices that prevent the direct or indirect application of forestry chemicals, such as pesticides and fertilizers, to open water sources.

Figure 44. Mechanical planting on the contour. (Photo courtesy of the Texas Forest Service.)

Figure 45. Streamside management zones protect streams from nonpoint source pollution originating from adjacent forestry operations. (Photo courtesy of the Texas Forest Service.)

Structural Practices

Streamside management zones, or SMZs, are forested riparian buffers purposefully maintained along streams that receive special management attention because of their value in protecting water quality and other beneficial uses (Fig. 45). SMZs reduce runoff velocity, trap sediment from upslope areas, promote infiltration, ensure bank stability, shade and cool surface waters, and provide important habitat for aquatic organisms and terrestrial species. Site disturbing activities are generally limited within the SMZs in order to maintain the shading, soil stabilization, and water filtering effects of the area.

Stream crossings enable equipment to traverse streams, drains, and ditches, when necessary, while protecting water quality. Typical crossings include bridges, culverts, and fords (Fig. 46). Selecting the most appropriate type of crossing for the site and properly installing it in the best location can prevent excessive sedimentation and unnecessary site disturbance while maintaining natural stream flow.

Revegetation by natural regeneration, hand planting, or direct seeding is used to stabilize exposed or disturbed soils, especially on steep slopes with erodible soils (Fig. 47). Vegetation restabilizes the soil with roots, dissipates the impact force of raindrops, reduces the velocity of surface runoff, contributes organic matter to the soil, which increases soil infiltration rates, and helps to prevent sediment and other pollutants from entering into nearby surface waters.

Figure 46. Bridges, culverts, and fords are among the most common types of stream crossings. (Photo courtesy of the Texas Forest Service.)

Road Construction and Maintenance Practices

Crowning and **outsloping** are road surface shaping techniques that enable quick and effective drainage to prevent erosion of the road surface (Fig. 48). These practices also prevent water from accumulating on the road surface which can lead to rutting and erosion from vehicle traffic. Armoring road surfaces with rock or other forms of aggregate also protects against degradation from traffic (Fig. 49). Road surfaces are constructed to drain into roadside ditches that move water alongside a road to a point where it can safely be diverted into areas away from lakes, wetlands, and streams. This prevents runoff, which might be polluted with soil and other pollutants, from directly entering water bodies.

Waterbars are speed bump-like berms of compacted soil constructed at an angle across the surface of a road to intercept, divert, and drain runoff water. Constructing a series of waterbars at regular intervals along a steep road helps to prevent erosion by reducing the volume of water carried down the road and decreasing the erosive velocity of that water by limiting the distance it can travel. The spacing of waterbars depends on

Figure 47. Revegetation stabilizes disturbed soil and prevents erosion. (Photo courtesy of the Texas Forest Service.)

the type of soils present and the slope of the road. Waterbars are typically constructed in conjunction with **wing ditches** that collect the runoff and disperse it into areas of stable vegetation away from water bodies (Fig. 50). **Cross drains** help to minimize erosion of road surfaces and roadside ditches while also maintaining the natural drainage patterns of the landscape by providing a stable means of transferring water across roads. Culverts transfer water under the road (Fig. 51) while broad based dips and rolling dips transfer water over the road surface.

Figure 50. Waterbars and wing ditches help to safely drain road surface runoff water to prevent erosion. (Photo courtesy of the Texas Forest Service.)

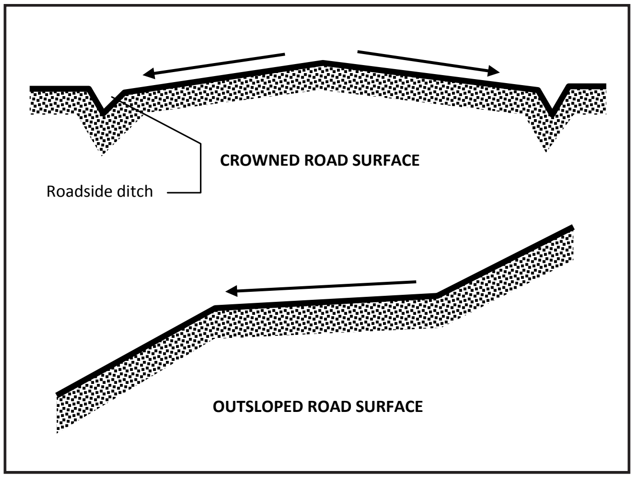


Figure 48. Cross sectional profiles of crowned and outsloped road surfaces for effective drainage. (Diagram courtesy of the Texas Forest Service.)

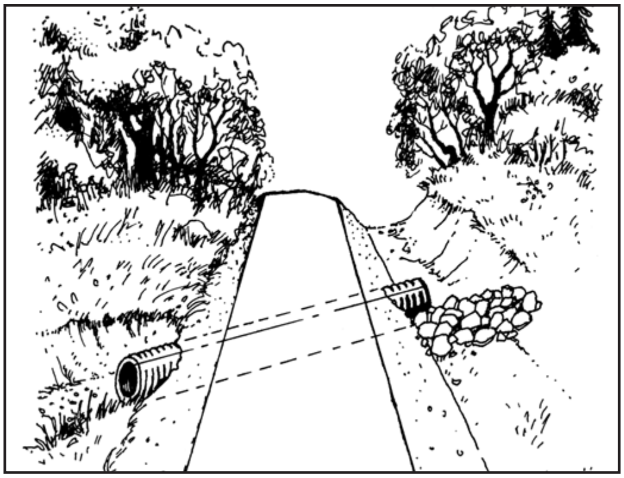


Figure 51. Cross drain culverts reduce erosion by controlling road surface runoff and maintaining natural drainage patterns. (Source: Texas Forestry Best Management Practice Handbook.)

Figure 49. Armoring road surfaces can prevent erosion and improve accessibility. (Photo courtesy of the Texas Forest Service.)

Water Quality Stewardship on Small Acreages

Although more than half of the people in Texas live in cities, many citizens own small-acreage properties in rural and semi-rural areas of the state. These properties range from 2 to 100 acres. Protecting watershed health is just as important in these areas as it is in large agricultural and urban areas. No matter what size property you own or live on, it is part of a watershed system and has an important role in many watershed processes. Small acreages, like agricultural and urban areas, can contribute nonpoint source pollutants to surface water and groundwater. Fortunately, there are many things property owners can do to prevent this.

Managing Your Landscape and Garden

Nonpoint source pollutants such as soil sediment, organic matter, plant nutrients, and pesticides can come from home landscapes and gardens. These potential pollutants can impair water quality, degrade aquatic wildlife habitat, and contaminate drinking water sources. While the quantities of pollutants from a single property might be small, similar amounts coming from many different properties, when added together, can have a very harmful effect. It is easy to control pollutants from home landscapes and gardens by minimizing the amount of contaminated water allowed to run off the property.

URBAN BMP SUCCESS STORY: *Central Park Wet Ponds – Austin, Texas*

The Central Park wet ponds were constructed in 1998 as part of a 38-acre mixed-use development project to help control urban runoff, remove pollutants, and provide aesthetic and economic benefits. A series of three stormwater ponds were built to capture urban runoff flowing from surrounding storm drains in the pond's 164-acre urban watershed. The wet ponds use plants, microbes, and the process of gravity to naturally remove solids and dissolved pollutants from the water before it is released into a neighboring creek. The total cost of the project was $584,000.

It is estimated that the Central Park wet ponds naturally capture the following amounts of pollutants every year:

- 36,400 to 50,000 pounds of total suspended solids
- 55 to 275 pounds of total nitrogen
- 55 to 2,000 pounds of total phosphorus
- 5 to 50 pounds of lead
- 10 to 150 pounds of zinc

Using the natural functions of wet ponds to filter stormwater has saved the City of Austin a great deal of time and money. Signs placed near the ponds have also served as a wonderful tool for teaching citizens about watersheds and the role of the ponds in protecting water quality. In addition to these water quality functions, the wet ponds have provided wildlife habitat for a variety of birds and animals as well as increased the aesthetic value for residents.

Source: City of Austin

Home Landscape Design. The design of your landscape and the materials you use can significantly affect the potential for runoff. Water that runs off is much more likely to contain pollutants than water that has been allowed to infiltrate through the soil. Therefore, it is best to reduce the amount of impervious surface in a landscape and increase the area planted to grasses, trees, and/or natural landscaping features (Fig. 52). Plants selected for your home landscape or garden should be well-adapted to your region and climate. Native plants require less supplemental water, fertilizer, and pesticide to remain healthy. Using native plants reduces both the cost of maintaining the landscape and the potential for water contamination. Bare soil should be mulched or planted with vegetation to reduce wind and water erosion, add organic matter to the soil, and ultimately protect water quality.

Figure 52. Backyard landscaping with native plants and a pond. (Photo courtesy of USDA Natural Resources Conservation Service.)

Use Fertilizers Correctly

The over application of nutrients contained in compost, manure, or synthetic fertilizers can pose serious threats to nearby bodies of water. If more fertilizer is applied than plants can use, the excess nutrients can leach into groundwater or be carried into surface water by stormwater runoff. To avoid this problem, have your soil tested each year to determine how much fertilizer you need. Lawns, gardens, and flower beds all have different nutrient requirements and should be tested separately. Contact your county Extension office for information on soil testing. Once you have the results of the test, apply only the amount of fertilizer recommended.

Fertilizer should be applied when plants are actively growing and can use the nutrients efficiently. Fertilizing when plants are dormant just increases the potential for water contamination. Fertilize trees and shrubs just before or as new growth begins in the spring. Fertilize grasses and flowers when they're in the active growth stage. Minimize leaching by using slow-release fertilizers (they release small amounts of nutrients into the soil over a longer period of time) and being careful not to water too much right after fertilizers have been applied.

Fertilizer spreaders should be calibrated to apply the proper rate based on an annual soil test and the type of fertilizer used. Make sure fertilizer doesn't fall onto sidewalks or streets where it will be washed into storm drains. If it does, be sure to sweep it up.

Manage Weeds

Weeds are invasive plants that can make landscapes unattractive (Fig. 53). Some even cause safety problems for people, livestock, and wildlife. Many states mandate that noxious weeds be controlled on public and private property. Weed control works best when weeds are seedlings. Cut and remove weeds before they go to seed to keep them from spreading, and/or prevent them from establishing by minimizing areas of disturbed land, areas where weeds tend to thrive.

Figure 53. Texas purple thistle (*Cirsium texanum*) is a common weed in Texas. (Photo courtesy of Dr. Billy Warrick, Texas AgriLife Extension Service.)

Use Pesticides Correctly.
Pesticides for controlling weeds, insects, and diseases in gardens and landscapes can be major sources of pollution. They must be applied carefully and only when needed (Fig. 54). If you suspect you have a pest problem but are unable to diagnose it, get help from a qualified professional. Then, try using the least toxic methods first. When using any pesticide, always carefully follow label directions. Never discard pesticides by dumping them down household drains, storm drains, or on the ground. Instead, save left-over pesticides until your community has a free hazardous materials collection event.

Figure 54. Spot spraying, rather than spraying herbicide over the entire yard, is the preferred way to control problem weeds. Spot spraying is also used on farms. (Photo courtesy of USDA Natural Resources Conservation Service.)

Managing Your Well

Most rural homes get their drinking water or irrigation water from a well. Properly managing your well water system is critical to protect groundwater. You should inspect and maintain all wells on your property and avoid any activities that might contaminate groundwater. The wellhead should be inspected to ensure that it was properly constructed and should be re-inspected every 6 to 12 months to make certain it is functioning properly. The well casing should extend at least 12 inches above the ground surface, and there should be a concrete or soil pad surrounding and sloping away from the casing. Inspect the sanitary well cap to make sure the bolts are tight and that no cracks or gaps are visible in the cap or casing. For more information on improving wellhead management and conditions, read Texas A&M AgriLife Extension Service publication SC-029 at *http://agrilifebookstore.org.*

It is especially important to locate your well away from any pollutant-generating activities that occur on your property. Activities and structures such as septic systems, animal waste holding ponds, pesticide and fertilizer storage, and fuel storage should be kept as far away from wellheads as possible. If your well is located in a pasture, fence the wellhead to keep livestock away and prevent urine and manure deposits nearby. Install anti-backflow devices on all outdoor faucets to prevent contaminants from being siphoned into the well or household water system.

It is a good idea to find and record the locations of all wells on your property. Wells that are no longer in use, or abandoned wells, pose a high risk for groundwater contamination because they provide a direct conduit for pollutants to reach groundwater. Larger diameter wells are also safety risks for children, animals, and even adults who can unintentionally fall into them. Texas law makes the landowner responsible for sealing abandoned wells and for any contamination or injury that result from unsealed or improperly sealed wells. Record the locations of all abandoned wells and pass this information on to any future owners of the property. For more information on abandoned wells, read the TCEQ's "Landowner's Guide to Plugging Abandoned Water Wells" at *http://www.tceq.texas.gov/comm_exec/forms_pubs/pubs/rg/rg-347.html* and the Texas A&M AgriLife Extension Service's "Plugging Abandoned Water Wells" at *http://agrilifebookstore.org*. Also visit *http://abandonedwell.tamu.edu/*.

Managing Your Septic System

Properly functioning septic systems safely process household wastewater and sewage. Failing septic systems are serious hazards to groundwater and surface water and are sources of unpleasant odors and bacteria. Through routine inspection and maintenance, you can protect your household water supply and the quality of the surface and groundwater resources in your watershed.

In a properly operating septic system, liquids and solids from the household are separated in the septic tank. Liquids are passed from the tank into the drain field, where they are leached into the soil. Solids are partially digested by microorganisms and the remaining solids settle and slowly fill the tank. Excessive accumulation of solids can cause septic systems to fail. Solids that don't easily decompose, or that might clog the system or interfere with the decomposition process, should not be flushed into a septic system. Some examples include diapers, fats, grease, solvents, oils, paints, and pesticides. A properly sized tank should be pumped out every 3 to 5 years to remove accumulated solids and to prevent a system failure. It is also important to maintain the drain field by keeping away runoff from roofs or pavement, planting and maintaining a good grass cover over the area, and avoiding compaction of the overlying soil so that waste liquids will leach properly.

Managing Small Pastures

Owning some form of livestock is often an important benefit of living in a rural community (Fig 55). In areas with sufficient rainfall and soil fertility, pastures can supply large quantities of high-quality feed for animals. Maintaining the quantity and quality of feed in a pasture saves money, promotes healthy animals, and promotes healthy, functioning landscapes. Some basic pasture management principles include the following:

- Use a proper stocking rate. The size and productivity of your land will determine the number of animals you may have.
- Do not overgraze your pastures.
- Cross-fence pastures to create several paddocks and use rotational grazing.
- Keep animals off water-saturated pastures.

Managing Compost and Manure Piles

Composting waste materials from the household, barn, and garden is a popular and effective way to generate fertilizer and organic matter to add to

Figure 55. Goats grazing on a small pasture in Texas. (Photo courtesy of Matt Berg, Texas A&M AgriLife Extension Service.)

soil. Although composting is a good method of recycling nutrients, it can be a source of organic matter, excess nutrients, and bacteria in streams if managed incorrectly.

Organic residues, particularly those containing animal manures, can contain both nutrients and potential disease-causing organisms. Some organic residues may also be a source of pesticides. To help protect water quality, it is important to site waste piles properly to prevent water from flowing through them. Covering piles is an effective way to accomplish this. Also, use buffer strips along streams to trap contaminants originating from compost or manure piles. If manure and compost are to be used as fertilizer, it is important to apply them at proper rates and times so that plants will be able to use the nutrients efficiently. If significant amounts of compost or manure are to be used, a chemical analysis of the material should be obtained, along with a soil test, to determine the correct application rate.

In summary, while a single home or small acreage property may have a limited effect on water quality, the combined effects of many such properties can be a significant potential source of pollution. The way these areas will affect a watershed depends largely on how the land is managed. Landowners should take the necessary steps to manage their properties in a way that promotes and enhances watershed function and improves water quality.

Non-Domestic Animals and Wildlife

Wildlife such as deer, geese, beavers, and raccoons, and non-domestic animals such as feral hogs, dogs, and cats can contaminate water bodies with bacteria and nutrients. These pollutants can enter the water through direct contact with the animal or in runoff from surrounding land where animal waste is present. Perhaps the greatest concern associated with animal waste is pathogens such as *Cryptosporidium* and *Giardia*, which can pose severe risks to human health. However, animals can also affect watershed health and function by damaging valuable riparian zones and shoreline habitat. This often occurs where humans have introduced new species or where human activity has reduced the amount of natural habitat, forcing animals to be concentrated into limited territories and spaces.

In general, wildlife are not managed to address water quality issues except under special circumstances. However, it can be important to use Best Management Practices to prevent the degradation of riparian habitat and the contamination of water resources by wildlife and non-domestic animals.

Feral hogs, dogs, and cats

Feral hogs are a growing concern in Texas and much of the southern U.S. (Fig. 56). Because hogs have a high rate of reproduction, and prefer secluded habitats along streams, there will often be large numbers of hogs concentrated in small riparian areas. This is a potential threat to water quality, because their rooting can cause severe erosion and soil loss. Large numbers of hogs can also destroy crops.

Feral hogs are usually managed by reducing their numbers through hunting or trapping. There are no birth control products, toxicants, or repellants registered for the control of feral hogs. More information about feral hog management can be found at *http://feralhogs.tamu.edu/*.

Figure 56. Feral hog. (Photo courtesy of Mark McFarland, Texas A&M AgriLife Extension Service.)

Although feral hogs are not classified as game animals, a hunting license is required to hunt them in Texas. However, under state regulations, a landowner does not need a hunting license to take a hog that is causing depredation on his or her property. Rifles, bows, muzzleloaders, and handguns are the most effective tools for hunting feral hogs. In some areas of the state, hunting from a helicopter is an efficient technique.

Trapping is another common method of controlling hog populations. Live traps and snares are the two most popular types of traps. Live traps are usually large, heavy-duty cages with springs or drop doors. Many hogs can be captured in a live trap at the same time without harming the animals. Trapped hogs can be harvested for their meat or sold. Snares are also effective when placed under fences in areas with lots of hog activity. However, snares may unintentionally capture other species. Therefore, snares should be properly maintained and checked regularly.

The number of feral dogs and cats in Texas is increasing. Dogs, especially, can be significant sources of water contamination, but both dog and cat feces may contain bacteria, roundworms, and other parasites that degrade water quality and threaten human health. Feral dogs and cats breed prolifically, so one of the best ways to control them is to spay and neuter these wild animals. This helps protect water quality and reduces the amount of tax money spent to capture, shelter, and/or euthanize the animals. Many cities and towns offer some type of animal population control program and will often spay and neuter cats and dogs at no or low cost.

Wildlife

Under special circumstances, it might be appropriate to control wildlife populations to protect water quality. Lethal methods include hunting, trapping, and the use of pesticides. There are also non-lethal methods such as removing habitat features that attract animals and harassing nuisance species. No animal control measure should be used without the guidance and approval of the appropriate state and federal wildlife agencies. Most animal control activities require a special permit or license. There are often specific federal and/or state guidelines associated with harassment techniques. Some nuisance species (such as Canada geese) may even be protected by federal and/or state law; harming the species or its eggs can result in severe penalties.

Harassment programs can help keep birds and wildlife away from valuable surface waters. Devices used include decoys, eagle kites, noisemakers, scarecrows, and plastic owls. Installing trails or foot paths next to water bodies may increase the presence of people, which can keep birds and other wild species away.

In urban areas and around the home, reducing the attractiveness of yards and landscapes to wildlife can encourage animals to live elsewhere. Many species can be diverted from sensitive areas by fencing, mowing, habitat modification, tree pruning (to reduce bird roosting), or the installation of drainage devices (to keep beavers and muskrats from building dams and dens). Cities may prohibit people from feeding wildlife. Homeowners can remove trash, secure pet feed, and reduce the number of palatable plant species in the landscape to help keep nuisance species away.

Protecting Water Quality Around The Home

Perhaps the easiest place to start protecting surface and groundwater from nonpoint source pollution is right at your own home. Take a close look around your house to find activities and practices that might be contributing to polluted runoff. Quite often, some simple changes can really make a difference. The following tips will help you become part of the solution rather than part of the problem.

Household Chemicals

- Buy nontoxic chemicals and cleaners whenever possible, and use only the amount that you need. When it comes to chemicals, more is NOT necessarily better.
- Properly store all household toxic products such as cleaners, pesticides, solvents, and paints.
- Properly dispose of all unwanted household chemicals at a hazardous material collection center. DO NOT pour any unwanted chemicals down the drain–this could seriously disrupt your septic system or contaminate treated sludge. DO NOT pour any unwanted chemicals on the ground–they can leach into groundwater and contaminate runoff.
- If your car leaks oil onto your driveway, use kitty litter to soak up the oil. Properly package this waste and dispose of it with the household trash.
- Whenever possible, use water-based products and low-phosphate or phosphate-free detergents.

Lawn and Garden

- Select native plants that are well adapted to your region/climate and need little water, fertilizer, and pesticide.
- Cover bare areas with trees, shrubs, mulch, and other vegetative cover to help reduce erosion and promote water infiltration into the soil.
- Use landscaping techniques such as filter strips, porous walkways, and grass swales

to reduce erosion and promote water infiltration into the soil.

- Keep lawn clippings on your lawn so that nutrients in the plant material can be recycled.
- Compost your yard and garden trimmings.
- Test your soil before applying fertilizers to prevent over-fertilization and potential leaching and water contamination.
- Clean storm gutters and drains of leaves and other debris to prevent clogging and flooding.
- Clean up after your pets. Pet waste is a significant source of excess nutrients and pathogens, which can seriously impair water quality.

Septic Systems

- Inspect your septic system annually.
- Pump out your septic system every 3 to 5 years (recommended frequency for a three-bedroom house with a 1,000-gallon tank; smaller tanks should be pumped more frequently).
- Do not use septic system additives.
- Avoid or reduce the use of your garbage disposal, since it can put extra solids into the septic system.
- Do not dump solids down the toilet as they can clog the septic system.

Water Use and Conservation

- Use low-flow shower heads and faucets, reduced-flow toilet flushing equipment,

RANCH MANAGEMENT UNIVERSITY and THE URBAN RANCHER PROGRAM

Many cities in Texas are facing rapid population growth and development, which is changing the face of Texas agriculture. As a result of this expansion, large tracts of farmland are being subdivided into smaller parcels of land that are being sold to traditional urban dwellers who want to escape city life; hence the term, “urban rancher.” Similarly, individuals who may be inexperienced in regards to having a working knowledge of technical know-how appropriate for managing both small-acerage properties and large ranches may come into ownership of such lands.

Ranch Management University and the Urban Rancher Program are educational programs offered by the Texas A&M AgriLife Extension Service to strengthen the technical knowledge of individuals operating such properties. The programs are proven to be quite beneficial for both novice and beginning ranchers in Texas.

As part of these educational programs, participants can learn about various topics such as wildlife management, fencing, composting methods, vegetable IPM, proper landscape design and fertilization, collecting soil and water samples, agricultural economics for small businesses, pasture management, on-site wastewater treatment systems, farm pond management, and more.

For more information, visit the following web sites: *http://forages.tamu.edu/workshop.html* and *http://theurban-rancher.tamu.edu/*

Photo courtesy of Matt Berg, Texas A&M AgriLife Extension Service.

and water saving dishwashers, washing machines, and other appliances.

- Inspect your house for leaky faucets, toilets, and pumps. If leaks are found, repair them immediately.
- Do not let faucets run when the water is not being used.
- When watering your garden or lawn, use trickle irrigation or soaker hoses to reduce runoff and increase watering efficiency. If using sprinklers, position them so that water falls only on the lawn or garden, not on the sidewalk, driveway, or street.

Automotive Care

- Regularly maintain your vehicle to prevent oil, antifreeze, and other fluid leaks.
- Properly dispose of used motor oil and antifreeze at facilities that accept recyclable automotive fluids (most auto parts retail stores, gas stations, auto repair shops, and hazardous materials collection centers will accept these items). One quart of oil can contaminate up to 2 million gallons of drinking water!
- Wash your car at a commercial car wash rather than in your own driveway to prevent soaps and other chemicals from running off the pavement into the storm drain.

Community Action

- Participate in neighborhood clean-up activities.
- Get involved in local planning and zoning decisions.
- Encourage your municipal officials to develop and follow erosion and sediment control ordinances.
- Write or call your elected local representatives to make sure they are aware of water quality issues and the importance of protecting water quality.
- Participate in community education activities to inform citizens about ways they can help protect water quality.

KEY POINTS TO REMEMBER:

- The watershed approach is a flexible framework for managing the quantity and quality of water resources found within specified watershed boundaries.
- Watershed Protection Plans (WPPs) and Total Maximum Daily Loads (TMDLs) are two major types of water quality improvement projects. BOTH depend on stakeholder involvement at the local level!
- Best Management Practices (BMPs) are methods that have been determined to be the most effective and practical means of preventing or reducing pollution from nonpoint sources.
- BMPs can be implemented to control many types of nonpoint source pollutants on agricultural, urban, small-acreage, and residential lands.

Portions of this chapter were adapted, with permission, from the National Coastal Ecosystem Restoration Manual, Oregon Sea Grant, 2002.

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Notes

Chapter 5: Community-Driven Watershed Protection and Management

Importance of Local Watershed Involvement

IN THIS CHAPTER, YOU WILL LEARN ABOUT:

- The importance of being involved in your watershed
- How to form a successful watershed partnership or organization
- Activities that you can participate in or organize in your watershed

Water pollution can affect the quality of life of everyone in Texas. However, with water being a common resource, often no one takes responsibility for protecting it. Unfortunately, all of the regulations in the world won't solve or prevent water quality problems in Texas. Only local watershed residents and landowners, through their personal actions, can ensure that their watershed, and the water resources it contains, are protected.

Citizen involvement is vitally important.

So, how do we get there? Community-driven watershed management is an approach that encourages citizens to get involved in identifying and addressing key issues within a watershed. Local stakeholders are critical because they actually live in the watershed, use the watersheds' resources, and have the biggest stake in the future of that watershed.

Stakeholders at the watershed level include any individual or group of individuals that could be affected by water quality impairment or by activities implemented to protect water quality. These include regulatory management programs like TMDLs and voluntary programs like WPPs (Fig. 57). Local stakeholders include:

- Watershed residents
- Landowners and managers
- City/county officials
- Citizen groups
- Soil and water conservation districts
- Groundwater conservation districts
- River authorities
- Business and industry representatives
- Community service organizations
- Universities, colleges, and schools
- Environmental and conservation groups
- Religious organizations

Figure 57. Stakeholder meeting for the Plum Creek Watershed Partnership. Stakeholders can be anyone who lives in a watershed and has a direct or indirect stake in the outcomes of watershed protection and management activities. (Photo courtesy of Nikki Dictson, Texas A&M AgriLife Extension Service.)

Stakeholders can also include individuals, groups, and organizations who are not directly affected by management activities, but who are interested in the watershed and/or the particular management activity that is being proposed or implemented in the watershed. Some individuals and organizations may even be located outside of the watershed (Table 13). Remember, watersheds are connected across landscapes, so the management decisions and activities occurring in one watershed also may positively - or negatively - affect conditions in neighboring watersheds.

With the commitment and engagement of all types of stakeholders, trust and support for the management processes and outcomes can be established, responsibility for decisions and actions can be shared, and communication and the coordination of resources can be enhanced. Locally developed solutions allow citizens to take into account unique social, economic, and environmental circumstances in their community. When citizens are involved, they feel a sense of ownership of the problems in the watershed and the solutions being applied to resolve those problems. This better prepares the community and ensures long-term support for future watershed management plans and activities.

Table 13. Potential stakeholders, partners, and collaborators who might reside outside of the watershed but still have a stake in the outcomes of watershed management activities. (Source: Conservation Technology Information Center.)

STAKEHOLDER GROUP	POTENTIAL ROLE
State and federal agencies	• Financial and technical resources • Credibility and visibility for management decisions and programs
Mass media	• Coverage of watershed events • Human interest stories • Understanding of local information needs • Ability to get information out quickly
Absentee (nonresident) landowners	• Leasee support • Practice implementation • Peer pressure
Financial institutions	• Grant management • Linkage with landowners • Prestige for partnerships • Funding for programs
Agribusiness and industries	• Distribute information and influence decisions • Sponsor field days and demonstrations • Donate equipment and services • Funding for programs
Farm organizations	• Distribute information and influence decisions • Sponsor field days and demonstrations • Donate equipment and services • Funding for programs
Environmental and conservation groups	• Knowledge of environmental constituencies • Awareness of problems and issues • Committed and knowledgeable members
Adjacent or downstream watershed stakeholders	• Information sources • Role models • Peer pressure

DID YOU KNOW??

Significant improvement in a watershed can only take place when local citizens realize that the local environment being at risk matters to them and they believe that doing something will improve their own lives and strengthen the community.

Forming and Sustaining Community Watershed Organizations and Partnerships

One of the most effective ways for stakeholders to become actively involved and truly make a difference in their watershed is to form a community watershed group. And, Texas Watershed Stewards can serve as the foundation for that process.

Watershed groups, also called watershed councils, action groups, associations, coalitions, and partnerships, are voluntary organizations made up of all types of stakeholders who share a common interest in protecting and helping their watershed. Consequently, a community watershed group helps the entire community create a common vision for their watershed and works to keep the community focused on the most important issues.

Watershed partnerships often begin when a water quality impairment in a local stream, lake, or other body of water results in the state-mandated development of a TMDL or the need for a WPP. In these situations, state and federal agencies are typically involved and lead the formation of the partnership. But in other cases, partnerships develop simply because local citizens recognize the need to be proactive in protecting their watershed. The driving force may be the desire to identify new threats to the watershed caused by changes in land use (such as increased development) or to address existing problems that have not been resolved. Sometimes, reports of problems in other watersheds stimulate local citizens to be proactive to protect their resources.

A watershed partnership may begin simply as a small gathering of citizens who share a common interest or concern, and recognize the need to involve other citizens and take action to get something done. These small groups can be very effective working within their communities. With time, small watershed groups can evolve into independent watershed organizations with their own budgets, staff and board of directors, and with a common goal of improving water quality and overall watershed health.

Working together in an organized partnership has its advantages, especially when dealing with something as large and complex as an entire watershed. Watersheds sustain many different types of people, land uses, activities, and interests. Successful and effective watershed partnerships help merge these differences into a common vision and increase a community's sense of responsibility, involvement, and commitment to protecting the watershed. Watershed partnerships can also lead to more efficient use of financial resources, an increase in sharing and cooperation, and more creative and socially acceptable approaches to protecting and managing the natural resources in the watershed.

How Do Watershed Partnerships Actually Start?

The formation and growth of successful watershed partnerships usually follow this sequence:

1. One or more individuals who are passionate about the watershed, and are willing to talk to others about it, act as a catalyst. The actions of just one person (who could be a Texas Watershed Steward,

a school teacher, a natural resource professional, a student, etc.) can connect people and motivate others who care about local water issues.

2. As a result, a core planning group develops to organize a community-wide information meeting. Such meetings are not just called in “crisis” situations, but can occur whenever citizens want to get together to improve their watershed or when they see symptoms that could lead to water quality or quantity problems.
3. A community-wide meeting is held so that people can exchange information and ideas about their watershed and what might be done to improve things.
4. A group of volunteer citizens meets regularly around a growing vision for their watershed. This vision is created as they improve their knowledge of the watershed and reflect about its past, present, and future.
5. Experts, including state and federal agency personnel, can be invited to discuss the science of the ecological system and provide technical information and advice so the watershed group, and community at large, can better evaluate problems and propose solutions to those problems.
6. The watershed group develops a clear mission statement with objectives to guide action and puts in place a leadership structure for guiding group activities.
7. Citizens in the watershed group undertake activities that support the intent and mission of the group.
8. The group communicates often with the whole watershed community about what is being learned, planned, and done. It continually invites others to participate.
9. The group regularly reassesses its plan and works to strengthen relationships and knowledge about social, political, and environmental issues that affect the watershed and the community as a whole. The group negotiates, leverages, and cooperates with others to achieve the community watershed vision.

Stages of Group Development

It takes many watershed groups a long time to progress to step 9, and some groups may never quite get there. Any successful group, including a watershed partnership, needs time to develop. In the development process, groups generally experience five different stages, each characterized by high points and low points. Mixed feelings and experiences are normal in the group development process. While each of the stages is unique, they are not mutually exclusive. Rather, the stages blend into one another as the group dynamic takes shape and as time progresses (Fig. 58).

1. **Forming stage**: When a watershed partnership first forms, there are often feelings of excitement and optimism, mixed with skepticism and anxiety. Group members are like hesitant swimmers, afraid to jump in the water with both feet. Despite these initial fears and hesitations, this particular stage is a critical one with regard to the group’s formation and distinctiveness. It is during this stage that the group begins to form and realize its identity and begins laying the groundwork for its future goals and expectations. In addition, the partnership also begins establishing ground rules and working on group communication skills. The expected outcome of this first stage is commitment to the group. Trust and communication among group members, and agreement to the basic rules of group participation, are essential for establishing and sustaining this commitment.

2. **Storming stage**: This is often viewed as the most difficult stage for new watershed partnerships. Reasons are the possible lack of familiarity among group members, confusion over individual roles, group transformation, and the lack of a unified direction. What started out as polite conversations and meetings may degenerate into conflict as group members become more comfortable with each other and begin to feel the need to exert more control or dominance over group decisions. Members might also begin rethinking previously agreed upon objectives and activities for achieving the group's goals. To get past this stage, and to minimize group tension, it is important to recognize and address the conflict right away–ignoring it will lead to distrust and possibly cause the group to collapse. How a group overcomes this particular stage will dictate its future success and progress. The expected outcome of the "Storming" stage is clarification. Conflict and power issues must be resolved for the group to move forward.

3. **Norming stage**: Groups that progress to this stage have made significant strides in the development process. At this point, group cohesion and action are prominent and help set the stage for the development of a solid

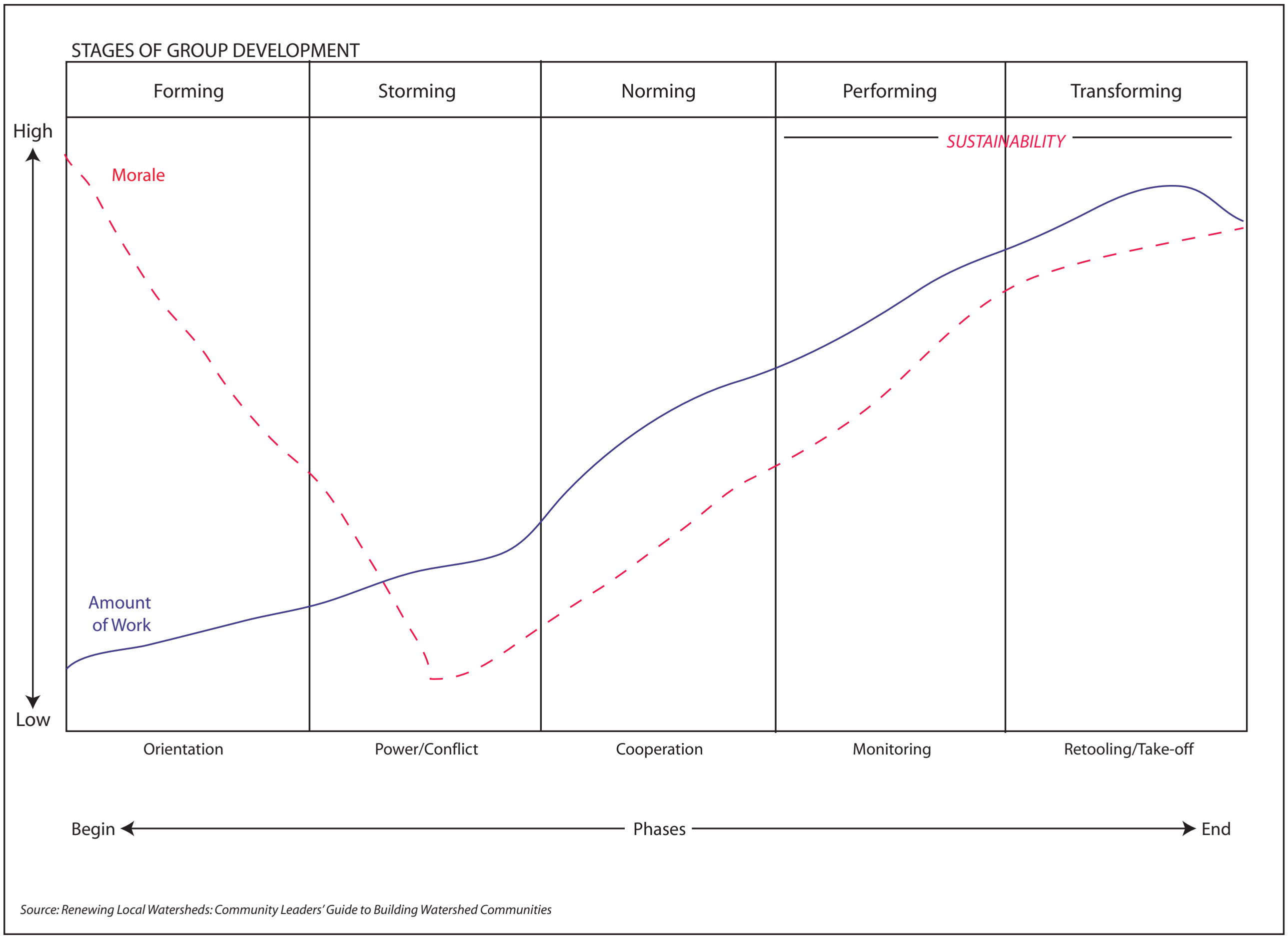

Figure 58. Stages of group development. (Adapted from Morton, L.R., et al. 2006, Renewing Local Watersheds: Community Leaders' Guide to Building Watershed Communities.)

group structure and a sense of community. Group identity is based upon the positive interpersonal relationships between members. Members are able to share their ideas and feelings, recognize each other's strengths, and give and receive feedback in a positive and constructive manner. The expected outcome for the "Norming" stage is clear commitment and cooperation. In achieving this, members begin to identify the overall responsibilities and roles of the group and establish agreement on the group's purpose and function in the community.

4. **Performing stage**: This is the optimal stage of group development and performance. Members feel comfortable with each other and with the group's direction. They are aligned toward achieving goals and producing results, and a strong trust has been established among group members who share the decision-making responsibilities with less anxiety. At this point, group members have learned to effectively listen to one another, engage in dialogue, challenge their own assumptions, and change their opinions. The expected outcome for the "Performing" stage is high productivity, which is accomplished through collective decision-making and effective problem-solving.

5. **Transforming stage**: This particular stage is often the celebration stage for groups that have accomplished many tasks, both internally and in the community. At this point, groups take time to consider their next steps, either deciding to re-organize themselves and move in a different direction, or renew their commitment to their original goals and keep pressing onward. Some groups may change members or develop new relationships with other groups. Still other groups may transform into a network, coalition, or collaboration in order to tackle new challenges in the community. The expected outcome for the "Transforming" stage is sustained interest for renewal and/or redirection.

Each watershed group proceeds through the development stages at a different speed, and sometimes in a different order. Some groups may start at the first stage and progress consecutively all the way through to the last stage. Other groups may progress initially, but later find themselves back in one of the earlier stages. Some groups begin with a history of working together and may already have a well-defined task list and organizational structure. This will help them move through the initial stages much more quickly. It is important to remember that each group will develop and progress at its own pace. A group should not be discouraged if they take a few steps back, especially if this helps them refocus and sustain themselves in the long-term.

The basic foundation for sustaining local interest in a watershed group is a clearly defined vision, mission, and list of objectives. For a new group to successfully form, members must view the group as doing meaningful work and want to be a part of that effort. Once the intent and objectives of the group are evident, other organizational practices can be applied to support development and sustainability.

FOOD FOR THOUGHT

As a watershed group progresses, members should continue asking themselves:

- What stage is our group currently in?
- Which tasks and processes can we focus on to progress to the next stage?
- What tasks do we need to complete in order to achieve goals?
- What tasks are we not focusing on that we need to?
- What group processes are occurring that are blocking us?

Making Your Watershed Group Successful

There are key strategies for forming and sustaining a watershed partnership or organization. Using these strategies during the group development process will pave the way for the group's success, visibility, and respect in the community. Successful watershed organizations usually have certain characteristics that make them effective. Perhaps the most important are collective involvement/broad membership, a common vision, and measurable and attainable goals. It is important to remember, however, that each watershed group is different and certainly does not have to exhibit these characteristics to be successful and effective. Some of the most important characteristics of successful watershed partnerships are discussed below.

<u>Collective involvement/broad membership</u>. A good mix of stakeholders, including individuals and community organizations, is very important to successful watershed partnerships. Watersheds can be very large and undoubtedly include a wide variety of stakeholders, all with individual interests, experiences, backgrounds, and concerns. Including a broad array of members in a watershed partnership is the best way to ensure that all views and concerns are included in planning and management efforts. Each member of the partnership will play a different role in the group, which might include leadership, technical, communication, educational, political, or policy roles. Broad group membership and collective involvement will ensure that each of these roles is filled with appropriate and knowledgeable individuals. While all watershed stakeholders should be welcome, soliciting individuals with specific skills that will be beneficial to the group can be important. Typical partners in a watershed organization include state and local agency representatives, local governmental officials, nonprofit organizations, local businesses, landowners, and local citizens.

<u>Common mission</u>. Watershed partnerships are more likely to be successful if all the members share in one common mission for the entire group. It is very difficult to make progress if group members do not all agree with the group's purpose, goals, and future directions. To help unite group members towards a common mission, it is important to establish a need and direction for the group and making sure that all members know what is expected of them and the group from the very beginning. The group should ask itself key questions, such as:

- What characteristics of this watershed do we want our children and future generations to be able to enjoy?
- How do we envision this watershed in the next 5, 10, or 20 years?

<u>Organizational structure</u>. A well-defined organizational structure is critical for watershed groups, because it forms the basis for group leadership, management, and decision-making. With that said, there is no one structure that fits every watershed group or ensures group success. Each watershed group will be unique in the way it chooses to organize and manage itself.

General leadership responsibility is one of the first things to consider. Some groups choose to follow a leader/co-leader type of structure. In this case, the leader and co-leader (or chair/co-chair; president/vice-president) are elected or appointed by group members. Persons serving in these roles have primary leadership responsibility for the group, including setting up and leading regular meetings and facilitating group decisions. In other cases, groups may choose to share leadership responsibility among a larger portion of their members. Here, a steering committee comprised of several members shares leadership roles and responsibilities. In both cases, sub-committees or work groups can also be formed to focus on specific projects and/or to give recommendations to the steering committee.

In addition to a general leadership structure, it is important for groups to establish a set of ground rules or bylaws. These rules can be used to formalize the mission and goals of the group, and to define various desires or expectations the group has, such as meeting attendance requirements, voting guidelines, and other important items.

Measurable/attainable goals. Establishing realistic goals and objectives makes it easier to measure the group's progress toward them. Articulating a common mission sets the stage for developing the group's goals and objectives. While there is one mission for the group, there can be several different goals and objectives. Likewise, there are many tasks necessary to complete before achieving those goals and objectives. Goals should be both measurable and attainable to keep the

MISSION, GOALS, AND OBJECTIVES

Mission Statement. The mission statement defines the intent of the group and its reasons for existing. The mission statement should offer a clear message that can keep the watershed group focused and be used to gather public support for watershed activities.

Parts of your group's mission may already be defined by city and county planning, Soil and Water Conservation Districts, and regional Resource Conservation & Development agencies. The general public, however, may not be aware of, or committed to, this mission. One role of the watershed community group could be to encourage discussions and help develop a common mission that incorporates the thinking of citizens, business and industry, not-for-profit organizations, natural resource agencies, elected officials, and regulatory agencies.

Goals. To accomplish the mission statement, your group will need to establish short- and long-term goals. Goals are measurable, attainable, and focused statements about what the group wants to accomplish. Goals should be established for general strategies (e.g., increase support and awareness of watershed protection) and for more specific activities (e.g.,make it a requirement that all city officials attend a Texas Watershed Steward training during their term in office). Focus on the future in setting clear and attainable goals. Watershed group members should assume specific responsibilities to accomplish the set goals within a definite time frame.

Tasks. To achieve the group's goals, specific tasks will need to be outlined by group members. Tasks are specific actions that are planned to accomplish the stated goals of the group. Tasks can range from very simple (e.g., buy a projector for group meetings) to more difficult (e.g., write and submit a grant proposal to support the development of a watershed protection plan).

EXAMPLES

Mission Statement: "The Peach Creek Watershed Partnership is dedicated to improving and protecting the quality of Peach Creek, its tributaries, and the surrounding watershed."

Goals: 1) Build an awareness of the watershed and its natural systems; 2) Provide channels of communication that integrate the plans and efforts of people and organizations working to benefit the watershed; 3) Sponsor projects and events that bring positive attention to the watershed and river; 4) Advocate for and review official policies and ordinances that affect the natural systems of the creek and watershed; and 5) Enhance the recreational uses of Peach Creek.

Tasks: 1) Develop a monthly watershed newsletter to send out to community residents; 2) write weekly articles to go into the local newspaper; 3) make at least 4 presentations a month to schools, local community groups, and others about the watershed and current projects; 4) organize a stream cleanup for Peach Creek...

group focused, on task, and in a positive frame of mind. While failure to achieve some goals might actually make a group stronger, too many failures can lower morale and produce negativity among group members.

Local knowledge. The expertise of individual citizens residing within communities and watersheds is critical to effective watershed partnerships. Local citizens usually have in-depth knowledge of the resource base and the local economy. Additionally, locals often share a desire to protect their watershed. Drawing on this localized knowledge of the community will strengthen a watershed partnership and add vital insight to various watershed processes.

Effective communication. Because a watershed partnership is made up of many types of members, the potential for conflict and discord can be rather high. Many watershed partnerships fail because they are unable to overcome differences among members and unite with a common purpose. Using effective communication skills can help prevent conflict.

Established ground rules. Ground rules can be established for anything related to your watershed partnership, including meeting participation, discussion, confidentiality, constructive feedback, decision-making, and more. Having well-established guidelines and adhering to those guidelines will minimize any controversy within the group and help it function more effectively.

Collaborative decision making. Decision making is an important function of group members. Decisions can be as simple as setting a future meeting date or as complicated as establishing budgets for various projects. With every decision, an effort should be made to use a collaborative process so that difficulties caused by different ideas and opinions can be avoided. Collaborative decision making uses **consensus** to ensure that each member's needs and concerns are addressed before a final decision is agreed upon. Collaborative decision making involves the following five steps (Hacker, Willard, Couturier, 2002):

1. Determine the parameters and constraints of the decision. When does the decision have to be made? How much time is needed to make the decision? Are there budget constraints, legal requirements, or other things that need to be considered?
2. Identify the needs of stakeholders and the potential effects of the decision on stakeholders. What does each party need out of the decision? Who will be affected negatively and positively? What must be satisfied in order to achieve an effective decision?
3. Gather information. What information is needed to make an informed decision? Have all the needs of the stakeholders been determined?
4. Identify alternative options. Are there additional options, beyond the most favored ones, that should be considered? How well does each alternative meet the needs of the stakeholders?
5. Make decision and follow through. How will the decision be implemented? Do you need to let other parties know about the final decision? How will you determine if the decision was a good one?

Steady progress. Some groups can fall victim to periods of inactivity during which members' motivation and energy levels are not as high as when the group first formed. To overcome this, it is a good idea to constantly challenge the group with new information, facts, and ideas to spur involvement and action among the group. Begin by planning small projects or outlining a few small tasks (e.g., write a series of newspaper articles, organize a stream walk/cleanup, etc.) that have a good chance for success. Recognize and reward group members for their participation and ideas, and use the power of positive feedback to motivate and encourage. This might help the group realize its potential and stimulate additional tasks, projects and action in the watershed. Ways to encourage and maintain participation in a watershed partnership are discussed later in this section.

Shared resources. Pooling resources from industries, organizations, individuals, and other stakeholders within a watershed can significantly increase the efficiency, effectiveness, and visibility of a watershed organization. Examples of available resources might include an existing educational display created for a local school, water testing kits from an environmental nonprofit, or access to an individual who specializes in grant writing.

Finding and using all available resources within the watershed will help avoid unnecessary duplication of effort and expenditures of time and money while improving the actual on-the-ground progress made by the partnership. Group members should learn about the mission and activities of other local and regional groups, organizations, and agencies that might be able to help with different tasks and projects.

Team building. This is particularly important in the "Forming" stage when group members are just getting to know one another and might be hesitant to initiate communication with members they don't know. Team building can be accomplished in several different ways. Encourage group members to discuss their interest(s) in the watershed and why they want to be involved in the partnership. Also, work together on common activities and small projects that can be easily accomplished. A quick victory in a group just starting out will help build trust and commitment among group members.

Mutual respect. We've already established that watersheds are comprised of many diverse interests and groups of people. As a result, controversy is likely, and overt conflicts may break out from time to time. While some conflict can be healthy for a watershed group to experience, conflict that stems from a lack of mutual respect, and involves personal attacks, will quickly diminish the organization's effectiveness.

Mutual respect means that all group members have the opportunity to participate in group meetings and discussions and that no one person is allowed to dominate discussions. In addition, group members must be open to new ideas, listen actively and carefully to what others have to say, and be constructive in their criticisms of decisions and ideas. Group members should focus on ideas, rather than on the personalities of those offering the ideas, when providing constructive feedback.

Being an Effective Watershed Group Member

There are specific roles and responsibilities for individual group members that help ensure a successful group dynamic. Group members should:

- Be advocates for the group's vision, mission, goals, and objectives
- Serve as liaisons between interested community citizens and other group members
- Actively assist in creating innovative solutions to water quality issues in the watershed
- Listen to the ideas of other group members and provide constructive feedback
- Follow the rules of the group, actively participate in group discussions, and be involved in group decision making
- Be willing to serve on committees and/or work groups when necessary

What Kinds of Activities Do Local Watershed Groups Do?

Community watershed groups can partner with all types of federal, state, and local organizations, including city and county governments, state (TSSWCB, TCEQ) and federal agencies, Soil and Water Conservation Districts, environmental groups, farmers, businesses, and nonprofits to improve their watershed.

Watershed groups often organize and participate in many different types of activities and projects in their watershed to help increase visibility for their cause, get other members of the community involved, and improve overall watershed health. Take a look at Appendix B to find a more detailed list of activities that watershed groups can organize and participate in.

Some examples of activities and projects include:

- Organize or sponsor special activities in your watershed (listed below)
- Help establish communication networks with other watershed residents and groups
- Educate others and motivate them to get involved
- Conduct demonstration and field trials of best management practices (Fig. 59)
- Collect local data from water quality monitoring, wildlife inventories, resource inventories, and surveys of farmer and resident land use practices
- Identify priorities for allocating limited public financial resources
- Set local water quality and quantity goals and plan strategies for achieving those goals
- Offer innovative solutions for controlling potential runoff pollution
- Identify and seek funding sources to support local efforts to solve water quality problems

Figure 59. Community members stand next to a display for a watershed demonstration project. (Photo courtesy of USDA Natural Resources Conservation Service.)

Some of the special activities to consider include:

<u>Stakeholder survey</u>. A watershed partnership should always function with the best interests of all community members in mind. A good way to find out what the community wants for the watershed, and any concerns they might have, is to conduct a brief stakeholder or community survey. Ask residents how much they know about their watershed, what issues they might have, and if they want to get involved to help improve the health of the watershed. Survey results will help the partnership decide which management activities might be most successful.

<u>Civic involvement.</u> Watershed groups can greatly influence local decisions about water quality management, but they must actively participate in the community to make these positive changes happen. This could include being on the mailing

list for new wastewater permit applications received by the TCEQ, and monitoring city council agendas for new development plans or water/wastewater issues. Individuals can also become members of local planning and zoning commissions and economic development boards to ensure that environmental considerations are included in long-term planning for their communities. As a Watershed Steward, or as an organized watershed group, you should seek opportunities to work constructively with local and state entities to improve and protect your watershed and its resources.

<u>Field trips</u>. Take a field trip anywhere you want to--a local park, ranch, lake, etc. Field trips help group members get to know each other and feel comfortable with each other, especially if the group is just forming. Field trips also help build group coherency by getting other members of the community involved, and they can be a lot of fun. In addition, field trips can help community members discover all the different ways the watershed is used and how those different uses are connected.

<u>Watershed tours</u>. There is no better way to learn about your watershed than by taking a tour of the watershed itself. A watershed tour is a great way to bring a wide variety of people together to learn about the watershed, visit different areas in the watershed (such as an urban area, agricultural area, industrial area, etc.), and have an open dialogue about issues that should be addressed. Invite technical experts along to share their knowledge and facilitate discussions.

<u>Canoe/float trips</u>. This is a great way to help community members get an "up close" look at streams, rivers, and lakes in the watershed. A float trip can help people understand how bodies of water are connected to the watershed, learn more about water and watersheds in general, and just have fun. This might be an effective way to

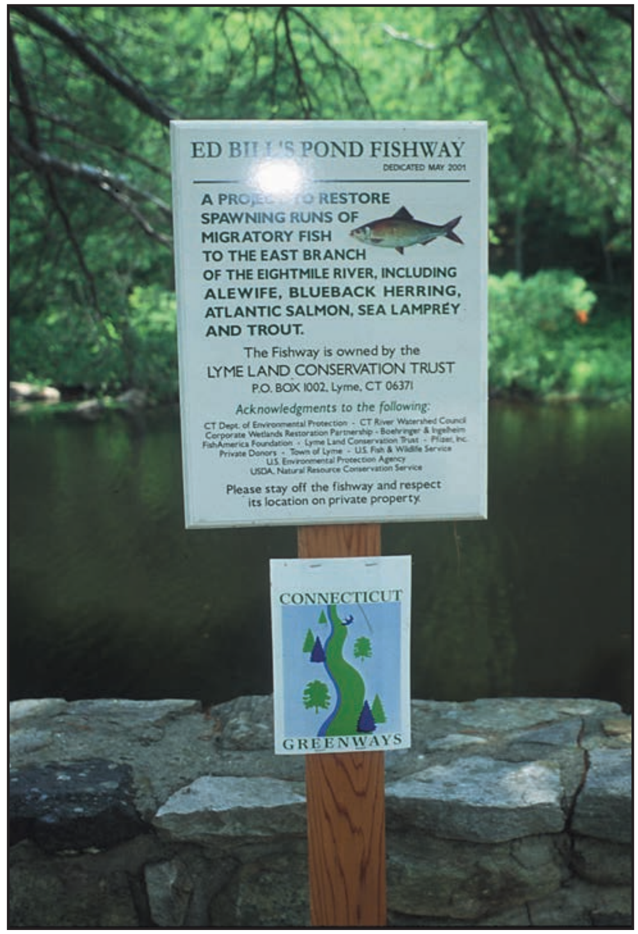

Figure 60. Interpretive signage helps raise awareness in the community. (Photo courtesy of USDA Natural Resources Conservation Service.)

bring group members closer together, especially if the group is just starting out. It could also be a great way to attract different members of the community to your group's cause—people who otherwise wouldn't have known about or gotten involved with the group.

<u>Volunteer water quality monitoring</u>. Volunteer water quality monitoring is a special way for people to be actively involved in gauging the health of their watershed. To start a volunteer water quality monitoring group, consider contacting Texas Stream Team, a network of volunteers and partners who are trained to collect water quality data. Pick some easily accessible sites along a popular stream, river, lake, or other

body of water and test the quality of the water at those sites regularly. Keep track of your data and monitor how it changes over time. If problems are identified, the partnership could encourage action to protect or restore watershed health.

Stream cleanups. Stream cleanups can be very successful, because participants can see a visible effect afterward and know they are making a difference to the land and water resources in their community. There are many federal, state, and local entities (EPA, TCEQ, Keep Texas Beautiful, etc.) that have experience in organizing and conducting stream cleanups. They will often sponsor the event and provide trash bags and other materials at no cost.

Educational programs and exhibits. These are great tools for increasing community awareness about the watershed and informing people of steps they can take to help improve watershed health (Fig. 60). A short presentation to a school class or community group can really make a difference while garnering more support for watershed improvement. You can also create posters and other visuals to display at local libraries, shopping centers, coffee shops, and other popular places around town. For example, an exhibit that showcases your group's mission and goals, and describes concerns the group has about the community watershed, would be a great place to start.

Media campaign. An effective way to get the word out about water quality issues in your watershed is to advertise. Options include mass mailings, flyers, public service announcements, watershed fact sheets, newsletters, and newspaper articles. These efforts help raise awareness in the community, get more individuals to join your watershed group, and encourage people to take personal action to protect your water resources.

Watershed festival. Watershed festivals are fun community events that increase the awareness and motivation of community residents and other stakeholders. Invite people from state and local environmental organizations, as well as other local entities and businesses, to celebrate in protecting and caring for the watershed.

How to Obtain Funding For Your Watershed Group or Partnership

Water quality improvement projects and activities don't just happen. Most require some type of funding. And all watershed groups need funding to support their operational costs. However, some activities can be carried out at very little cost by using the expertise of group members. For example, if a member of the watershed group works in marketing, that person could develop marketing tools for the partnership rather than having to pay someone to do it. It is also a good idea to regularly encourage members of the media to participate in the group and to publicize group meetings and activities. This will undoubtedly increase visibility for the group and may increase your funding opportunities. Other types of in-kind contributions that can be provided by group members include accounting skills, planning, public relations, technical expertise, office equipment donations, and more.

One of the biggest frustrations for watershed groups can be funding the activities and operations of the group as a whole. Locating and securing funding from external sources can be challenging. Most watershed groups acquire funding from a number of different sources, often tied to specific tasks or projects. Examples of funding sources include:

- Membership dues: Most groups do not require direct financial support from members. Their contribution is in the form of their time and energy in serving on the partnership team. However, some watershed groups collect annual membership dues that can range from a few dollars to a few hundred dollars, depending on the circumstances. These funds, even if nominal, can go a long way in paying for operating costs and in supporting watershed activities. Groups that don't require membership fees generally rely more on government funding, private foundation funding, special event revenue, general donations (discussed below), and in-kind contributions in the form of time, talents, and goods.

- Grants: Grants can be obtained from a number of different sources, including government-sponsored funding programs that are specific to watershed-related projects, community/philanthropic foundations with specific interest in the group's mission and objectives, eco-friendly corporations and businesses, and even local banks. Some examples of funding sources include the EPA, CSREES, TSSWCB, TCEQ, NRCS, GLO, river authorities, and more.

  A written grant proposal is usually required to obtain these funds. Although the requirements of each proposal will vary, most granting agencies expect a project summary, problem statement, project description, and detailed budget description. The Internet is a great tool to use when researching potential funding sources. Use your group members and stakeholders who might have connections within the community and who might specialize in grant writing.

- Special event revenue: Your watershed group may decide to sponsor a special event such as a dinner, some type of sports tournament (golf, baseball, etc.), a concert, or some other special event to generate revenue. Such events are fun for the community and also productive for the watershed partnership, especially if they generate enough funds to help cover some operational costs and/or project costs.

DID YOU KNOW??

Many foundations and corporations will give grant money only to 501(c)3 non-profit organizations. But, if you choose not to pursue non-profit status right away (or not at all), you can still often access this funding by working with another group that is a non-profit. The other group doesn't even have to be involved in your specific project and can simply agree to serve as a "fiscal sponsor." You can then explain this relationship and agreement in the grant proposal.

For more information for your watershed organization, visit the following USDA website found at *https://www.rd.usda.gov/programs-services/programs-services-communities-nonprofits.*

Source: Watershed Council Toolkit, Sierra Nevada Alliance

Regardless of how the group initially obtains funds, it is important to always be on the lookout for the next funding opportunity. Simply relying on one or two funding sources to support the full work of the organization can be risky. It is important to diversify the group's funding base to ensure that its work will be sustainable. Take a look at Appendix C to learn where to find funding opportunities for your watershed group.

Characteristics of Unsuccessful Watershed Groups

While there are many benefits associated with watershed partnerships, creating them and making them successful can be challenging. New groups just starting out often want to see positive results right away. This is not realistic. Maintaining the motivation, enthusiasm, and leadership of a group is perhaps the single greatest challenge. Securing funding to accomplish some of the major goals of a group also can be difficult. But, all groups encounter challenges. The way in which they tackle and overcome these challenges will be the deciding factor in their long-term success. Always remember that the overall benefits of watershed partnerships far outweigh the challenges associated with them.

While there are many characteristics that help make a watershed partnership or organization successful, there are many more that can spell the end for a new or even veteran watershed group. If your group has any of the following characteristics, it isn't necessarily destined for failure. But it might mean that there are issues among members or with the watershed partnership itself that need to be addressed and resolved right away. Otherwise, conflicting interests and differing opinions might cause the group to end in failure. Look for these characteristics of unsuccessful watershed groups:

- Conflict among key interests remains unresolved
- Size and complexity of the watershed is too overwhelming and the group flounders
- The group has no clear purpose
- The group is unable to overcome past failures
- Goals or deadlines are unrealistic
- Covert agendas exist
- Key interests or decision makers are not included or refuse to participate
- Not all participants stand to benefit from the partnership
- Some members stand to benefit considerably more than others
- Some members have more power than others
- The partnership isn't needed because one entity could achieve the goals alone
- "Experts" are unwilling to give up their role and share authority with lay persons
- Financial and time commitments outweigh potential benefits; funding runs out
- Members are uncomfortable with the commitments required

Most of these obstacles are related to internal group conflict-the main reason watershed partnerships fail. To help overcome these potential stumbling blocks, it is important to clearly identify problems and address them directly. If at all possible, however, try to anticipate and prevent problems from occurring in the first place. One way to do this is to spend a lot of time at the beginning getting to know each other, establishing ground rules, and agreeing to individual roles and responsibilities. Then, when a conflict occurs, the group knows right away how to resolve the issue and move on.

Another way to approach conflict among members is to have the group think of it as a group challenge rather than a problem of individuals. It is human nature to blame an individual when, in fact, many conflicts occur because the group lets them happen. One of the best ways to overcome obstacles is to build consensus among group members. Confronting and overcoming conflict as a group will unite group members toward a common vision and strengthen the group's resolve. When a group member is being difficult and seems to be a constant cause of conflict, it is especially important to handle the situation carefully and not over-react. The entire group should speak with the person, hear his or her thoughts and concerns, and work toward a group resolution.

A common stumbling block many groups face is waning participation of group members in community watershed activities and projects. Even if a group has members, a mission statement, an organizational structure, a planned project, and maybe even a little project funding, it may not know how to maintain its longevity in the community and keep its members interested. It isn't enough to simply announce meetings and activities and assume people will show up because they "should." To encourage participation from stakeholders and partners, communication and education are critical. In addition, watershed groups should:

- Use the media to announce ongoing events and meetings, and to publicize special activities such as a watershed festival or stream cleanup
- Use peer-to-peer networking by having group members talk to neighbors, colleagues, and others who may have an interest in learning more about the group's activities
- Use field or site visits to make the issues more tangible and to build enthusiasm
- Use newsletters and brochures to advertise the partnership's efforts
- Work through local schools to educate the public about partnership goals and activities
- Consider innovative outreach methods such as photography and fun displays to publicize the partnership
- Appeal to people's sense of stewardship, citizenship, and service. Let them know that the problems being addressed by the partnership affect all citizens in the watershed, and that each person can contribute to the solution.

To maintain participation among group members, it is necessary to constantly motivate them and keep them enthusiastic. To accomplish this:

- Start with small, manageable projects that are likely to be successful
- Document and celebrate success
- Use on-the-ground projects to give participants a sense that they are making a difference (stream cleanups, tree planting, etc.)

WATERSHED PARTNERSHIP SUCCESS STORY

Plum Creek begins in Hays County north of Kyle and eventually joins the San Marcos River near the Caldwell-Gonzales County line. The main stem of Plum Creek is a 52-river mile segment with a drainage area of approximately 397 square miles.

Segment 1810 of Plum Creek was listed on the 2004 TWQI and 303(d) list, now called the Integrated Report, for having elevated nutrient levels and bacteria concentrations. These water quality impairments, as well as increasing urban development, resulted in the Plum Creek Watershed being selected for Watershed Protection Plan development and implementation.

The Plum Creek Watershed Partnership (PCWP) was formed by the Texas State Soil and Water Conservation Board (TSSWCB) and the Texas A&M AgriLife Extension Service as a way to promote a sustainable, proactive approach to improving water quality at the local level. The partnership's main purpose is to guide the planning and implementation process of the Watershed Protection Plan that is being developed for the Plum Creek Watershed.

The PCWP consists of a steering committee of local stakeholders; a technical advisory group of local, state, and federal agencies; and five work groups made up of steering committee members, agency personnel, and other interested citizens. All stakeholders and project partners have a vested interest in improving the water quality in the Plum Creek Watershed. The goal of the partnership is to develop and implement a Watershed Protection Plan that protects water resources in the region now and into the future.

To learn more about the Plum Creek Watershed Partnership, visit http://plumcreek.tamu.edu/.

Plum Creek Watershed Partnership

- Use positive feedback, recognition, and rewards as incentives for continued participation
- Maintain a stable structure to reassure members that the partnership is accountable to them and that something will get done
- Offer opportunities to participate at different levels (regularly, occasionally, professionally, etc.)
- Build on sources of community pride
- Make explicit what member organizations and individuals stand to gain and specifically identify these benefits
- Continually revisit and stress successes and achievements
- Make group meetings and activities fun (plan social events, provide refreshments at group meetings, etc.)

Summary

As a Texas Watershed Steward, you have a wonderful opportunity to help protect your community's water resources and your entire watershed. Becoming educated about the issues that affect your watershed is only the first step. The next step is committing just a little of your time and energy to applying this knowledge and creating solutions that will improve the water quality and overall health of your watershed. Get your friends, neighbors, family, and colleagues involved as well, start a watershed organization, and make a difference. Only you, and other citizens like you, can protect water quality in your community. Working together, you can help ensure that future generations of Texans will be able to enjoy the state's valuable water resources.

TEXAS Watershed Steward

IMPORTANT THINGS TO THINK ABOUT...

- Local groups must understand their water problems and feel they can make a difference. Agencies that convene local groups must be prepared to let citizens make a difference.
- Communication among citizens and agencies supporting local groups must be as open and voluntary as possible.
- Local citizen priorities (as well as the resource system they are a part of) are dynamic and will be constantly changing.
- Free exchanges of information and communication among citizens and natural resource experts is essential if they are to learn from each other and develop action strategies that make a difference.
- Local groups are always nested in other decision-making structures – within the county, region, state, and nation. Environmental, economic, social, and political decisions within and outside of the watershed influence what kinds of actions are possible.
- Reliance on government agencies alone to solve complex resource management problems may miss important water problems and solutions.
- People engage in change best when given an opportunity to co-create their environment.
- Conflict is inevitable when people feel strongly about their environment. The challenge is to redirect conflict and controversy to energize people to better manage and protect their water resources.

Source: Lois Wright Morton et al., 2002/RV2006, Department of Sociology, Iowa State University Extension.

KEY POINTS TO REMEMBER:

- Water pollution is a local issue that affects the quality of life of everyone in Texas.
- Community-driven watershed protection and management is an approach that encourages local stakeholders to become involved in identifying and addressing key issues within a watershed, with the goal of improving water quality and watershed health.
- Stakeholders at the watershed level include any individuals, or groups of individuals, who have a stake in the outcome(s) of watershed management and protection activities.
- One of the most important ways stakeholders can become actively involved in watershed protection and make a real difference is to form a community watershed group.
- Community watershed groups can use many strategies to reach their goals.
- Forming a watershed group does not guarantee its success. Groups need time to develop, and all members must commit to achieving shared goals.
- Local involvement at the watershed level is critical to improving and protecting water quality in your watershed!

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Portions of this chapter were adapted, with permission, from Patrick Corcoran, Oregon Sea Grant.

Notes

Glossary of Terms and Acronyms

Can't find it here? More water-related terms can be found at http://www.aces.edu/waterquality/glossary/glossary.htm.

303(d) List: A list of water bodies that do not meet state water quality standards that each state is required to submit to the Environmental Protection Agency (EPA) every 2 years.

Acre foot: The volume of water required to cover one acre of land to a depth of 1 foot (43,560 cubic feet or 325,851 gallons).

Ammonia (NH_3): A common form of nitrogen that can be toxic and also contribute to the nutrient enrichment of waters.

Annual: A plant that completes its life cycle within a single growing season.

Antidegradation policy: A policy designed to prevent deterioration of existing levels of good water quality and further deterioration of water bodies exhibiting poor water quality.

Aquifer: An underground geological formation, or group of formations, containing water; they are sources of groundwater for wells and springs.

Army Corps of Engineers: The federal agency responsible for implementing Section 404 of the Clean Water Act dealing with wetlands and assisting with engineering projects for the United States.

Atmospheric deposition: The process by which particles suspended in the atmosphere are deposited by precipitation or wind in a body of water or on a land surface.

Bacteria: A single-cell organism. Some bacteria can cause disease.

Benthic macroinvertebrate: Bottom-dwelling organisms that are large enough to be seen with the naked eye and that lack a backbone.

Best management practice: As defined by the EPA, methods that have been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources. Abbreviated as BMP.

Bioaccumulation: The net accumulation of a chemical in the tissue of a living organism as a result of uptake from the surrounding environment.

Biochemical oxygen demand: A measure of the amount of oxygen consumed by microorganisms in the process of decomposing organic matter in a body of water. Abbreviated as BOD.

Biocriteria: The biological characteristics that quantitatively describe a water body with a healthy community of fish and associated aquatic organisms. Components of biocriteria include the presence and seasonality of key indicator species; the abundance, diversity, and structure of the aquatic community; and the habitat conditions required for these organisms.

Biodiversity: The variety of life on our planet; refers to the types and kinds of plants, animals, and humans.

Bioengineering: Also referred to as biological engineering. It is a broad-based engineering discipline that deals with the design, sustainability, and analysis of biological systems.

Biofilter: The use of living organisms to filter out pollutants contained in water.

Biogeochemical: Refers to the chemical, physical, and biological reactions and transformations that occur in soil, water, and air.

BMP: Acronym for Best Management Practice. As defined by the EPA, they are methods that have

Glossary of Terms and Acronyms

Can't find it here? More water-related terms can be found at http://www.aces.edu/waterquality/glossary/glossary.htm.

been determined to be the most effective, practical means of preventing or reducing pollution from nonpoint sources.

BOD: Acronym for Biochemical Oxygen Demand. It is a measure of the amount of oxygen consumed by microorganisms in the process of decomposing organic matter in a body of water.

CAFO: Acronym for Confined Animal Feeding Operation. It is an agricultural operation where animals are raised in confined conditions to maximize production.

Capture: The process by which water is transferred from the atmosphere and stored in the soil.

Clean Rivers Program: A fee-based water quality assessment, monitoring, and public outreach program created by the Texas Legislature in 1991 to address water quality issues in each river basin in Texas.

Clean Water Act: Set of laws passed in 1972 to regulate water pollution in the United States. Today, it forms the basis of water quality protection in all surface water and groundwater sources. Abbreviated as CWA.

Clean Water Act Section 303(d): The section of the federal Clean Water Act that requires states, territories, and authorized tribes to develop a list of water bodies that do not or are not expected to meet water quality standards. States are then required to prioritize listed water bodies for TMDL development.

Clean Water Act Section 319(h): The section of the federal Clean Water Act that provides grants to states, territories, and authorized tribes to implement projects under the Nonpoint Source Pollution Management Program. CWA 319(h) grants are available to projects that reduce, control, and prevent nonpoint source pollution with the ultimate goal of improving water quality.

Climate: The average weather conditions (i.e., temperature, precipitation, wind, etc.) over a long period of time.

CMP: Acronym for Coastal Management Program. A water quality monitoring and management program that is implemented by the Texas General Land Office to ensure the long-term ecological and economic productivity of Texas' coastline.

Coastal basin: A collection of watersheds adjacent to a coastline that water flows across or under on its way to the ocean.

Coastal management program: A water quality monitoring and management program that is implemented by the Texas General Land Office (GLO) to ensure the long-term ecological and economic productivity of Texas' coastline. Abbreviated as CMP.

Condensation: The process by which water vapor changes into liquid water.

Confined animal feeding operation: An agricultural operation where animals are raised in confined conditions to maximize production. Abbreviated as CAFO.

Consensus: A collective opinion or general agreement.

Conservation tillage: A tillage practice that leaves the soil surface covered with plant residue for erosion control and moisture conservation. Often used as an agricultural BMP.

Constructed wetland system: Constructed wetland systems include BMPs designed to

Glossary of Terms and Acronyms

Can't find it here? More water-related terms can be found at http://www.aces.edu/waterquality/glossary/glossary.htm.

mimic the natural functions of wetlands to aid in pollutant removal from urban stormwater. In a constructed wetland system, the water, plants, animals, microorganisms, and environment (sun, soil, and air) work together to improve water quality.

Consumptive water use: Water that, when used, is no longer available because it has evaporated or has been transpired by plants, incorporated into products or crops, consumed by people or animals, or otherwise removed from the water supply.

Contour farming: Contour farming is the alignment and operation of all farm tillage, planting and harvesting practices as close as possible to the true contour of the land. The goal is to reduce erosion and surface runoff and, thus, the transport of sediments, nutrients, and pesticides from the field.

Contour planting: Contour planting is the alignment and operation of all tree planting and harvesting practices as close as possible to the true contour of the land. The goal is to reduce erosion and surface runoff and, thus, the transport of sediments, nutrients, and pesticides from the field.

Cover crop: A close-growing crop that is planted in the absence of the normal crop to provide erosion control, nutrient cycling, carbon addition, wildlife habitat, and moisture regulation.

Cross Drain: A pipe or culvert installed under roads to transmit water from the road side ditch, storm runoff, seeps, and drains without eroding the drainage system or road surface.

Crowning: The sloping of a road surface toward either side to allow for proper drainage.

CRP: Acronym for Clean Rivers Program. A fee-based water quality assessment, monitoring, and public outreach program created by the Texas Legislature in 1991 to address water quality issues in each river basin in Texas.

CWA: See Clean Water Act.

Decomposition: The breakdown or decay of organic matter.

Department of State Health Services: The state health agency in Texas responsible for promoting optimal health for individuals and communities while providing effective health, mental health, and substance abuse services to Texans. With regards to water quality, they conduct a fish tissue sampling program in surface waters where fish consumption is a designated use.

Designated use: Simple narrative description of water quality expectations or water quality goals. A designated use is a legally recognized description of a desired use of a water body, such as (1) support of communities of aquatic life, (2) body contact recreation, (3) fish consumption, and (4) public drinking water supply. These are uses that the state or authorized tribe wants the water body to be healthy enough to fully support. The Clean Water Act requires that water bodies attain or maintain the water quality needed to support designated uses.

Detention system: Detention systems include urban BMPs that are designed to intercept and temporarily store stormwater runoff for gradual release into a receiving water body or storm sewer system.

Diffusion: The movement of a substance, such as oxygen or water vapor, from an area of high concentration to an area of low concentration.

Dioxins: Dioxins are formed as unintentional by-products of many industrial activities, forest

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fires, and human activity. Dioxins bioaccumulate in the food chain. Eating fish containing dioxins may cause chloracne, a severe skin disease, and can cause skin rashes, skin discoloration, excessive body hair, liver damage, weight loss, reproductive damage, and birth defects.

Discharge: The volume of water that moves over a designated point during a fixed period of time. Used to describe stream flow and the release of wastewater.

Dissolved oxygen: A measure of the amount of gaseous oxygen (O_2) dissolved in water and other aqueous solutions. Abbreviated as DO.

Divide: The boundary between two watersheds.

DO: Acronym for dissolved oxygen. It is a measure of the amount of gaseous oxygen (O_2) dissolved in water and other aqueous solutions.

DSHS: Acronym for Department of State Health Services. The state health agency in Texas. To protect human health, they conduct a fish tissue sampling program in surface waters where fish consumption is a designated use.

Effluent: Treated or partially treated wastewater that flows out of a treatment plant, septic system, pipe, etc.

Electrical conductivity: The measurement of a solution's ability to conduct an electrical current which is used as an estimate for salinity.

Environmental Protection Agency: The federal agency responsible for enforcing and regulating environmental laws such as the National Environmental Policy Act, Clean Air Act, and Clean Water Act. Abbreviated as EPA.

EPA: Acronym for the Environmental Protection Agency.

Erosion: The wearing away of the land surface by rain, running water, wind, ice, gravity, or other natural or man-made agents.

Estuary: Region of interaction between rivers and near-shore ocean waters, where tidal action and river flow mix fresh and salt water. Such areas include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

Eutrophication: Enrichment of an aquatic ecosystem with nutrients (nitrogen, phosphorus) that accelerates biological productivity (growth of algae and weeds) and the undesirable accumulation of algal biomass.

Evaporation: The process by which liquid water changes into water vapor.

Fecal bacteria: Microscopic organisms that are found in the waste of humans and other warm-blooded animals. Detection of fecal coliform bacteria may indicate the presence of pathogenic bacteria, viruses, and parasites.

Federal Safe Drinking Water Act: Federal law that established drinking water standards to protect surface and groundwater sources used for drinking water.

Filtration system: Filtration systems include a variety of urban BMPs that use sand, gravel, peat, compost, or other types of vegetative media to remove contaminants found in urban stormwater runoff.

Floodplain: The flat or nearly flat land along a river or stream or in a tidal area that is covered by water during a flood.

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Forming stage: The first stage in watershed group development; the group begins to form and realize its identity and starts laying the groundwork for its future goals and expectations.

Fossil fuel: Oil, coal, and natural gas that originates from decayed plants and animals.

GLO: Acronym for General Land Office. The state agency in Texas primarily responsible for managing the 367 miles of Texas coastline and the lead agency for the Texas Coastal Management Program, which focuses on the protection of Texas' coastal resources.

Goals: General, broad statements of desired outcomes for an organization or entity. Goals differ from objectives in that goals are generally more long-term in nature, while objectives are much more specific and short-term.

Grassed waterway: A grassed waterway is a natural drainage way that is planted to sod-forming grasses to help control runoff water from agricultural lands. Covering the drainage way with grass helps prevent gullies from forming in the fields, traps sediment, absorbs chemicals and nutrients in runoff water, and provides cover for small birds and mammals.

Green manure crop: A crop (such as rye grass, vetch, clover) that is grown specifically to be plowed back into the soil to increase soil fertility and organic matter content.

Groundwater Conservation District: Created by the Texas Legislature to implement groundwater management and conservation practices in the state. Districts are in charge of addressing various issues such as drought, waste, and conservation as they relate to groundwater.

Groundwater: The fresh water found beneath the Earth's surface, usually in aquifers, which supplies wells and springs.

Groundwater recharge: The downward replenishing flow of rainfall through the soil profile to an underground aquifer.

GWCD: Acronym for groundwater conservation district. Created by the Texas Legislature to implement groundwater management and conservation practices in the state. Districts are in charge of addressing various issues such as drought, waste, and conservation as they relate to groundwater.

Habitat: The natural home of a plant or animal.

Hydrocarbons: A chemical compound consisting of carbon and hydrogen. They can be found in gaseous, liquid, or solid forms. Petroleum, natural gas, and other fossil fuels are examples of hydrocarbons.

Hydrologic cycle: The movement or exchange of water between the atmosphere and earth; also known as the water cycle.

Hydrology: The science dealing with the properties, distribution, and circulation of water.

Hypoxia: A condition describing low levels of oxygen in the blood and tissue.

Impermeable: Not easily penetrated. The property of a material or soil that does not allow, or allows only with great difficulty, the movement or passage of water.

Indicator: Direct or indirect measurements of some valued component or quality in a system. Can be used to measure the current health of the watershed and to provide a way to measure progress toward meeting the watershed goals.

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Infiltration: The movement of surface water into soil or rock through cracks and pores.

Infiltration system: Types of urban BMPs designed to capture and store stormwater runoff so that it can infiltrate into the soil profile. Infiltration BMPs include infiltration basins, porous pavement systems, and infiltration trenches and wells.

Inorganic: Substances such as sand, salt, iron, and other materials that have their origins from non-living minerals, not from living or once-living organisms. The opposite of organic.

Integrated pest management: An ecologically based, integrated pest control strategy that uses a series of pest management evaluations, decisions, and controls aimed at reducing pesticide use and the movement of pesticides into the environment. Abbreviated as IPM.

I-Plan: The implementation plan for a Total Maximum Daily Load (TMDL). The I-Plan specifies limits for point source dischargers and recommends best management practices for nonpoint sources. It also lays out a schedule for implementation. Together, the TMDL and the I-Plan serve as the mechanism for reducing the pollutant level so as to restore the full use of the water body and removing it from the 303(d) list.

IPM: Acronym for Integrated Pest Management. An ecologically based, integrated pest control strategy that uses a series of pest management evaluations, decisions, and controls aimed at reducing pesticide use and the movement of pesticides into the environment.

Land cover: Refers to the observed biological or physical features on the surface of the Earth. Land cover types include forests, agriculture fields, lakes, rivers, buildings, streets, and even parking lots.

Land use: Refers to the way in which land is used. Examples include agriculture, industry, recreation, residential, and urban.

Leaching: The movement of pollutants through the soil by percolating rain, melting snow, or irrigation water.

LID: See low-impact development.

Low-impact development: Types of structural and non-structural BMPs that are designed to significantly reduce urban runoff volumes to minimize impacts from urban runoff and to remove pollutants from urban runoff. The overall goal of a low-impact development approach is to balance urban growth with environmental integrity. Abbreviated as LID.

Maximum contaminant level: The maximum amount of primary contaminants (pathogens, radioactive elements, toxic chemicals) that can be present in drinking water supplied by a public water system. Abbreviated as MCL.

MCL: See maximum contaminant level.

Meander: A turn or winding portion of a stream or river.

Minimum tillage: A tillage practice that leaves at least 30 percent of the soil surface covered with plant residue for erosion control and moisture conservation. Often used as an agricultural BMP.

Mission: A concise statement that defines the core purpose of the organization or entity.

Model: A representation of an environmental system obtained through the use of mathematical equations or relationships.

Glossary of Terms and Acronyms

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Monitoring: With regard to water quality, it is the process of sampling and analyzing water quality parameters over a period of time.

National Pollutant Discharge Elimination System: Portion of the Clean Water Act requiring municipal and industrial wastewater treatment facilities to obtain permits that specify the types and amounts of pollutants that may be discharged into water bodies. Abbreviated as NPDES.

Nitrate (NO_3): A common form of nitrogen that is produced from decomposing organic materials like manure, plants, and human waste.

Nitrite (NO_2): An intermediate form of nitrogen produced during the conversion of ammonium to nitrate.

Nitrogen: Chemical, gaseous element that makes up almost 80 percent of the Earth's atmosphere. It is found in the cells of all living things and is a major component of proteins.

Non-consumptive water use: Water that is withdrawn for use, but is not consumed, transpired, or evaporated. An example is water used for bathing/showering.

Nonpoint source: Diffuse pollution source; a source without a single point of origin or not introduced into a receiving stream from a specific outlet. The pollutants are generally carried off the land by storm water. Common nonpoint sources are agriculture, forestry, urban areas, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

No-till: No-tillage is the practice of leaving the soil undisturbed from harvest to planting except for nutrient injection. During planting, crop seeds are placed into the soil by a device that opens a trench or slot through the sod or pervious crop residue.

NPDES permit: National Pollutant Discharge Elimination System permit to discharge treated wastewater into a body of water.

NPS: Acronym meaning nonpoint source. See definition for nonpoint source pollution.

Objectives: Expected achievements or outcomes that are well defined, specific and measurable. Objectives are derived from the written goals of the organization/entity.

Organic: Substances that have their origins from living, or previously-living, organisms. The opposite of inorganic.

Outsloping: The sloping of a roadbed on a hill so that water will flow across the road toward its downhill side.

Overland flow: The flow of water above the ground surface; it occurs when precipitation exceeds the soil's infiltration rate and flows over the soil surface.

Particulate: Very fine solid particles that are not dissolved in water.

Pathogenic: Capable of causing disease. Pathogenic organisms include bacteria, viruses, and parasites that cause disease and illnesse.

PCB: Acronym for polychlorinated biphenyl. Synthetic (man-made) substances once used commercially in electrical transformers, carbonless copy papers, cutting oils, and hydraulic fluids. PCBs were banned in 1979 by the EPA because they bioaccumulate in the internal organs of fish and other animals.

Percolation: The downward movement of water through subsurface soil layers.

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Perennial: A plant that completes its life cycle in three or more growing seasons.

Performing stage: The fourth stage of group development; this is the optimal stage of group development during which members are more like a close-knit family and trust is at its highest.

Permeable: The opposite of impermeable; refers to the ease with which water is allowed to move through the soil profile.

pH: A measure of the concentration of hydrogen ions found in a solution that describes whether a solution is acidic or basic. pH is measured on a scale that ranges from 0 (very acidic) to 14 (very basic).

Phosphorus: A natural element found in rocks, soils and organic material; a nutrient required by all organisms for the basic processes of life.

Photosynthesis: The process by which plants use sunlight to convert water and carbon dioxide into carbohydrates. All green plants rely on photosynthesis for their growth.

Point source: A stationary location or fixed facility from which pollutants are discharged; any single, identifiable source of pollution, such as a pipe, ditch, ship, ore pit, or factory smokestack.

Pollutant: A contaminant in a concentration or amount that adversely alters the physical, chemical, or biological properties of the natural environment.

Pollutant Load: The amount of a specific pollutant in a water body.

Pollution: Contamination of air, soil, or water with harmful substances.

Porosity: Degree to which soil, gravel, sediment, or rock is permeated with pores or cavities that are filled with water and air or other fluids and gases.

Precipitation: Any or all forms of water particles that fall from the atmosphere, such as rain, snow, hail, and sleet.

Pre-harvest planning: A process that identifies and summarizes pertinant information about a tract of land where timber will be harvested in order to best meet both the harvest objectives and address the environmental characteristics of the site.

Primary standard: Refers to drinking water standards that protect against contaminants (pathogens, radioactive elements, toxic chemicals) that are harmful to human health. Maximum limits on these contaminants are established through Maximum Contaminant Levels (MCL).

Rangeland: Land on which the natural plant cover is made up primarily of native grasses, forbs, or shrubs valuable for forage.

Respiration: The process by which living organisms use oxygen from the atmosphere to breathe.

Retention system: Includes a number of BMPs such as retention ponds (also called wet ponds or stormwater ponds) and a variety of underground vaults, pipes, and tanks that are designed to intercept, store, and treat urban stormwater runoff. In retention systems, water is held for indefinite periods of time.

Revegetation: The establishment of grass and/or legume vegetation on disturbed soil that is not expected to naturally revegetate in time to prevent erosion.

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Riparian zone: Anything connected with or immediately adjacent to the banks of a stream or other body of water.

River Authority: Multi-county water districts created by the Texas Legislature and whose governing members are appointed by the governor or the Texas Water Development Board. There are 15 river authorities in Texas.

River basin: A collection of watersheds that are drained by a river and its tributaries.

Runoff: That part of precipitation, snow melt, or irrigation water that runs off the land into streams or other surface water; typically occurs when the rate of precipitation exceeds the rate at which the water can be absorbed into the ground.

Salinity: A measure of the amount of dissolved materials contained in water. It is the same as Total Dissolved Solids (TDS).

Saturation: The act of soaking thoroughly with a liquid.

SAV: Acronym for Submerged Aquatic Vegetation. Refers to plants that float or grow below the surface of the water.

SDWA: Acronym for Safe Drinking Water Act. Federal law that established drinking water standards to protect surface and groundwater sources used for drinking water.

Secchi disk: A black and white patterned disk used for measuring the turbidity, or clarity, of water. Water clarity decreases as turbidity increases.

Secondary maximum contaminant level: The maximum amount of secondary contaminants (contaminants not harmful to human health) that can be present in drinking water supplied by a public water system. Abbreviated as SMCL.

Secondary standard: Refers to drinking water standards that protect against contaminants that are not harmful to human health, but pose a nuisance because they cause unacceptable odor, taste, color, corrosion, foaming, or staining. Maximum limits on these contaminants are established through Secondary Maximum Contaminant Levels (SMCL).

Sediment: Topsoil, sand, and minerals washed from the land into water, usually after rain or snow melt.

Sediment control basin: An erosion control structure commonly installed across the bottom of a drainage way to prevent bank and gully erosion on farmland and to minimize sedimentation of nearby water bodies. Basins help improve downstream water quality by trapping sediment, controlling water flow within a drainage area, and by storing runoff water and allowing it to slowly infiltrate into the soil profile.

Seeps: Wet areas, normally not flowing, arising from an underground water source.

Sewage: Also known as wastewater.

Silviculture: The management of forests or woodlands for the production of timber and other wood products; growing trees as a crop.

Site Preparation: A general term for removing unwanted vegetation and other material if necessary and any soil preparation carried out before reforestation.

SMCL: Acronym for Secondary Maximum Contaminant Level. It is the maximum amount

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of secondary contaminants (contaminants not harmful to human health) that can be present in drinking water supplied by a public water system.

Solid-phase nutrients: Nutrient concentrations in sediment.

Sonde: A type of instrument that is ideal for profiling and monitoring water conditions in industrial and wastewater effluents, lakes, rivers, wetlands, estuaries, coastal waters, and the open ocean. Torpedo-shaped in appearance, sondes may have multiple sensors that record a range of water quality data including temperature, conductivity, salinity, dissolved oxygen, pH, turbidity, and depth.

Soil and Water Conservation Districts: A subdivision of state government established to provide leadership, technical assistance, information, and education to the counties on proper soil stewardship, agricultural conservation methods, water quality protection, nonpoint source pollution, streambank stabilization, stream health, conservation planning, and various other topics related to watershed planning.

Soil pore: The air space in the soil between soil particles.

Soil profile: A vertical section of the soil through its horizontal layers.

Solubility: A measure of the ability of a substance to dissolve in water and other liquid solutions.

Sonar: A device that takes measurements and pictures of the subsurface by using sound waves.

Stakeholder: Specific individuals or groups of people who have an interest, or stake, in the success of a project, activity, set of activities, or process.

Storming stage: The second stage in group development; the group may experience many conflicts as group members feel the need to exert themselves more as the group dynamic continues to develop.

Stream Crossing: A culvert, bridge, or rock ford that enables equipment to cross streams, drains, and drainage ditches to reduce negative impacts to the stream from traffic.

Stream flow: The volume of water that moves over a designated point during a fixed period of time. Also known as discharge.

Streamflow hydrograph: A graph or chart that depicts changes in water quantity over time.

Sub-basin: A smaller scale basin.

Submerged aquatic vegetation: Refers to plants that float or grow below the surface of the water. Abbreviated as SAV.

Subsurface flow: The flow of water beneath the ground surface; it can eventually return to the surface (e.g., as a spring or by being pumped) or can seep into the oceans.

Sub-watershed: A smaller area of land draining to a single tributary of a larger river.

Succession: The gradual and orderly process of change in an ecosystem.

Surface water: Water on the surface of the ground, (lakes, river, ponds, floodwater, oceans, etc.); precipitation that does not soak into the ground or return to the atmosphere by evaporation or transpiration.

TCEQ: See Texas Commission on Environmental Quality.

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TDS: Acronym for Total Dissolved Solids. It is a measure of the amount of dissolved materials contained in water.

Terrace: Level soil embankments that are usually constructed on the contour of the land and designed to control runoff and soil erosion.

Texas A&M AgriLife Extension Service: The state educational agency provided by the U.S. government, the state government through the Texas A&M University System, and county governments. Extenion provides practical educational programming in the areas of agriculture and natural resources, 4-H and youth development, family and consumer sciences, and community development.

Texas Commission on Environmental Quality: The environmental agency of Texas. With regard to water quality, they are responsible for enforcing and regulating water quality standards and for water quality testing and monitoring. Abbreviated as TCEQ.

Texas General Land Office: State agency primarily responsible for managing the 367 miles of Texas coastline; the lead agency for the Texas Coastal Management Program, which focuses on the protection of Texas' coastal resources. Through its many diverse programs, the GLO supports access to outdoor recreation and protects natural coastal habitats and wildlife.

Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d): A report developed by the Texas Commission on Environmental Quality (TCEQ) every 2 years that lists all of the water bodies in the state that do not meet one or more water standards as outlined in the Texas Surface Water Quality Standards.

Texas Legislature: The law-making body for the state government. It is composed of the Texas House of Representatives and the Texas Senate.

Texas Parks and Wildlife Department: The state agency responsible for protecting, maintaining, and enhancing water quality for fish, wildlife, fishing, and swimming. Abbreviated as TPWD.

Texas State Soil and Water Conservation Board: State agency responsible for managing nonpoint source pollution from agricultural and silvicultural sources. Abbreviated as TSSWCB.

Texas Water Code: A codified law (codify means to arrange laws systematically) passed by the Texas Legislature dealing with the state's water resources.

Texas Water Development Board: State agency responsible for water planning and administration of water financing. Abbreviated as TWDB.

TMDL: Acronym for Total Maximum Daily Load. Refers to the amount, or load, of a specific pollutant that a water body can assimilate on a daily basis and still meet water quality standards.

Topography: The physical characteristics of land, including its elevation, slope, and orientation.

Total dissolved solids: A measure of the amount of dissolved materials contained in water. Abbreviated as TDS.

Total maximum daily load: Refers to the amount, or load, of a specific pollutant that a water body can assimilate on a daily basis and still meet water quality standards. Abbreviated as TMDL.

Total suspended solids: A physical water quality parameter that relates to the amount of solids found in water or wastewater. Abbreviated as TSS.

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Toxicity: A measure of the degree to which a substance is toxic or poisonous.

TPWD: Acronym for Texas Parks and Wildlife Department. It is the state agency responsible for protecting, maintaining, and enhancing water quality for fish, wildlife, fishing, and swimming.

Transforming stage: The fifth stage of group development; this is when groups decide their future direction and work on renewing or redirecting their efforts.

Transpiration: The process by which water vapor is lost to the atmosphere from living plants.

TSS: Acronym for Total Suspended Solids. It is a physical water quality parameter that relates to the amount of solids found in wastewater.

TSSWCB: Acronym for Texas State Soil and Water Conservation Board. It is the state agency responsible for managing nonpoint source pollution from agricultural and silvicultural sources.

Turbidity: A physical water quality parameter that is a measure of the relative clarity of water.

TWDB: Acronym for Texas Water Development Board. It is the state agency responsible for water planning and administration of water financing.

TWQI: Acronym for Texas Water Quality Inventory. It is a report developed by the Texas Commision on Environmental Quality (TCEQ) every 2 years that lists all of the surface water bodies in the state that do not meet one or more of their standards as outlined in the Texas surface water quality standards. The TWQI is now known as the Texas Integrated Report for CWA Sections 305(b) and 303(d).

TWS: Acronym for Texas Watershed Steward.

Uncultivated: Land that is not prepared for growing crops.

Upland: Land that is at a higher elevation than the floodplain.

Vegetated system: Vegetated systems, or biofilters, use natural vegetation to "filter" stormwater as it flows across the land surface. These types of BMPs transport and treat stormwater before it is discharged into a storm sewer system.

Vegetative buffer strip: Strips of grasses or other vegetation placed along streams or drainage areas to trap sediment and to promote infiltration and filtering of nutrients and other pollutants.

Vision: The long-term desired future accomplishments of an organization or entity. Visions should inspire and motivate.

VOC: Acronym for volatile organic compound. These compounds are used to make many products, especially plastics and solvents. Eating fish containing VOCs may cause cancer in animals and humans.

Virus: A microorganism that can infect cells and cause disease. Viruses are not affected by antibiotics, the drugs used to kill bacteria.

Wastewater: Also known as sewage. It is the water that has been used by homes, businesses, and industries that eventually makes its way to a wastewater treatment plant. Examples of wastewater include the water you flush down the toilet and the water that drains from your bathtub, sink, washing machine, and other sources.

Water cycle: See hydrologic cycle.

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Water quality parameters: The chemical, physical, and biological attributes of water that are used to indicate the health of a water body.

Water quality: A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose or designated use.

Water quantity: Refers to the volume or amount of water that is available in the water supply.

Water vapor: The invisible, gaseous state of water.

Waterbar: A cross drainage diversion ditch and/or hump in a trail or road for the purpose of diverting surface water runoff into roadside vegetation, duff, ditch, or dispersion area to minimize the volume and velocity of runoff that can cause soil erosion.

Watershed hydrology: The study of water as it interacts with various parts of the watershed, including the land, the sea, and the sky.

Watershed: Land area that drains to a common waterway, such as a stream, lake, estuary, wetland, or ultimately the ocean.

Watershed approach: A flexible framework for managing the quantity and quality of water resources found within specified watershed boundaries. There are four main features typical of a watershed management approach: (1) Identify and prioritize water quality/quantity problems in the watershed; (2) Develop increased public awareness and involvement; (3) Coordinate efforts with other agencies/organizations in the watershed; and (4) Measure success through monitoring and other data collection.

Watershed partnership: A voluntary organization made up of different stakeholders who all share a common interest in protecting and helping their watershed. Watershed partnerships are also called watershed groups, action groups, coalitions, councils, and associations.

Watershed protection plan: Abbreviated as WPP. A community-driven management framework that uses the watershed approach to address complex water quality problems and to provide solutions for improving and maintaining water quality within the watershed. Ultimately, WPPs aim to protect unimpaired water bodies and to restore impaired water bodies by taking a holistic look at the watershed to address all potential sources of impairments. WPPs are developed and integrated through diverse partnerships within the watershed and rely heavily on stakeholder involvement at the local level.

Wetland: An area inundated by surface or groundwater at a frequency sufficient to support, and under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soils.

Wing Ditch: A water turnout or diversion ditch that moves water away from the road and/or side ditch.

WPP: See Watershed Protection Plan.

Appendix A
Water Quality Agencies and Organizations

Federal Agencies

1. EPA (Environmental Protection Agency)

   The mission of the Environmental Protection Agency is to protect human health and the environment. Since 1970, the EPA has been working for a cleaner, healthier environment for the American people.

Main address: U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Telephone: (800) 887-6063 – Region 6 (Texas)
Main Web site: *http://www.epa.gov/*

Other links: Water information - *http://water.epa.gov/*
Surf Your Watershed - *http://cfpub.epa.gov/surf/locate/index.cfm*
Watershed Information Network - *http://www.epa.gov/owow/watershed/*

2. NRCS (Natural Resources Conservation Service)

   With the mission of "Helping People Help the Land," the Natural Resources Conservation Service (NRCS) provides products and technical and financial assistance to better enable people to be good stewards of the nation's soil, water and related natural resources on non-federal lands.

Main address: Natural Resources Conservation Service
14th and Independence Avenue, SW
Washington, D.C. 20250

Telephone: (254) 742-9800 – Texas NRCS State Office
Main Web site: *http://www.nrcs.usda.gov/*

Other links: Watershed protection and flood prevention -
http://www.nrcs.usda.gov/programs/watershed/
Environmental Quality Incentives Program -
http://www.nrcs.usda.gov/programs/ewp/
Wetlands Reserve Program - *http://www.nrcs.usda.gov/programs/wrp/*

3. NIFA (The National Institute of Food and Agriculture)

   NIFA's unique mission is to advance knowledge for agriculture, the environment, human health and well-being, and communities by supporting research, education, and extension programs in the Land-Grant University System and with other partner organizations. NIFA doesn't perform actual research, education, and extension, but rather helps fund it at the state and local level and provides program leadership in these areas.

Main address: United States Department of Agriculture
National Institute of Food and Agriculture
1400 Independence Avenue SW, Stop 2201
Washington, D.C. 20250-2201

Telephone: (202) 720-4423
Main Web site: *https://nifa.usda.gov/*

Other links: National Water Quality Program - *https://www.usgs.gov/science/mission-areas/water national-water-quality-program*
Southern Region Water Quality Program - *http://srwqis.tamu.edu/*

4. USFS (United States Forest Service)

   The mission of the USDA Forest Service is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations.

Main address: USDA Forest Service
1400 Independence Ave., SW
Washington, D.C. 20250-0003

Telephone: (202) 205-8333
Main Web site: *http://www.fs.fed.us/*

Other links: Watersheds, fish, wildlife, air & rare plants - *http://www.fs.fed.us/biology/*
Ecosystem management - *http://www.fs.fed.us/emc/*

5. USFWS (United States Fish & Wildlife Service)

The U.S. Fish and Wildlife Service is the principal federal agency responsible for conserving, protecting and enhancing fish, wildlife, and plants and their habitats for the continuing benefit of the American people.

Main address: U.S. Fish and Wildlife Service
1849 C Street, NW
Washington, D.C. 20240

Telephone: (800) 344-WILD
Main Web site: *http://www.fws.gov/*

Other links: National Wetlands Inventory- *http://wetlands.fws.gov/*
Division of Environmental Quality - *http://www.fws.gov/contaminants/*
Division of Habitat and Resource Conservation - *http://www.fws.gov/habitat/*

6. USGS (United States Geological Survey)

The USGS serves the nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

Main address: USGS National Center
12201 Sunrise Valley Drive
Reston, VA 20192

Telephone: (703) 648-4000
Main Web site: *http://www.usgs.gov/*

Other links: Water quality data for Texas - *http://waterdata.usgs.gov/tx/nwis/qw*
Underground water data for Texas - *http://waterdata.usgs.gov/tx/nwis/gw*
Science in Your Backyard - *http://www.usgs.gov/state/state.asp*
USGS activities in Texas - *http://tx.usgs.gov/*

State Agencies

1. <u>TCEQ (Texas Commission on Environmental Quality)</u>

   The Texas Commission on Environmental Quality (TCEQ) is the environmental agency for the state. They are responsible for implementing state and federal environmental regulatory laws by issuing permits and authorizations for: the control of air pollution; the safe operation of water and wastewater facilities; and the treatment, storage, and disposal of hazardous, industrial, and municipal waste and of low-level radioactive waste.

   Main address: TCEQ State Headquarters
   12100 Park 35 Circle
   Austin, TX 78753

   Telephone: (512) 239-1000
   Main Web site: *http://www.tceq.texas.gov/*

   Other links: Public participation in environmental permitting - *https://www.tceq.texas.gov agency/working-with-us/permitting-participation/pub_part.html*
   Water quality - *http://www.tceq.texas.gov/waterquality*
   TCEQ data - *http://www.tceq.texas.gov/agency/data/*
   Local hazardous waste contacts - *http://www.tceq.texas.gov/p2/hhw/contacts.html*

2. <u>TSSWCB (Texas State Soil and Water Conservation Board)</u>

   The Texas State Soil and Water Conservation Board (TSSWCB) is a state agency that administers Texas' soil and water conservation law and coordinates conservation and pollution abatement programs throughout the State.

   Main address: TSSWCB State Headquarters
   P.O. Box 658
   Temple, TX 76503
   Telephone: (254) 773-2250; (800) 792-3485
   Main Web site: *http://www.tsswcb.texas.gov/*

   Other links: Water Quality Management Plan Program - *http://www.tsswcb.texas.gov/wqmp*
   Nonpoint Source Management Program - *http://www.tsswcb.texas.gov/managementprogram*
   Total Maximum Daily Load Program - *http://www.tsswcb.texas.gov/tmdl*
   Watershed protection planning - *http://www.tsswcb.texas.gov/wpp*
   Information and education - *http://www.tsswcb.texas.gov/infoedu*

3. TWDB (Texas Water Development Board)

The TWDB provides water planning, data collection and dissemination, financial assistance, and technical assistance services to the citizens of Texas.

Main address: TWDB State Headquarters
1700 North Congress Avenue
P.O. Box 13231
Austin, TX 78711-3231

Telephone: (512) 463-7847
Main Web site: *http://www.twdb.texas.gov/*

Other links: Texas Instream Flow Program - *http://www.twdb.texas.gov/surfacewater/flows/instream/*
Drought Information - *http://www.twdb.texas.gov/newsmedia/drought/doc/weekly_drought_report.pdf*
Water Conservation Brochures - *https://www.twdb.texas.gov/publications/brochures/conservation/*
Data - *http://www.twdb.texas.gov/mapping/index.asp*
Maps - *http://www.twdb.texas.gov/mapping/maps.asp*

4. TPWD (Texas Parks and Wildlife Department)

State agency that manages and conserves the natural and cultural resources of Texas and provides hunting, fishing, and outdoor recreation opportunities for the use and enjoyment of present and future generations.

Main address: Texas Parks and Wildlife State Headquarters
4200 Smith School Road
Austin, TX 78744

Telephone: (512) 389-4800; (800) 792-1112
Main Web site: *http://tpwd.texas.gov/*

Other links: Aquatic species - *http://tpwd.texas.gov/landwater/water/aquaticspecies/*
Conservation programs - *http://tpwd.texas.gov/landwater/water/conservation/*
Habitats - *http://tpwd.texas.gov/landwater/water/habitats/*
Environmental concerns - *http://tpwd.texas.gov/landwater/water/environconcerns/*
Recreation - *http://tpwd.texas.gov/landwater/water/recreation/*

5. GLO (General Land Office)

The GLO's core mission is the management of state lands and mineral-right properties totaling 20.3 million acres. Included in that portfolio are the beaches, bays, estuaries, and other "submerged" lands out to 10.3 miles in the Gulf of Mexico, institutional acreage, grazing lands in West Texas, timberlands in East Texas, and commercial sites in urban areas throughout the state.

Main address: 1700 N. Congress Avenue
Suite 935
Austin, TX 78701-1495

Telephone: (512) 463-5001; (800) 998-4456
Main Web site: *http://www.glo.texas.gov/*

Other links: Texas coastal issues - *http://www.glo.texas.gov/coast/coastal-management/coastal erosion/index.html*
Texas energy resources - *http://www.glo.texas.gov/energy/*
Maps, research and data - *http://www.glo.texas.gov/land/land-management/gis/*

University/Extension

1. The Texas A&M AgriLife Extension Service

The Texas A&M AgriLife Extension Service is an educational organization provided by the U.S. government, the state government through the Texas A&M University System, and your county government. Extension serves every county in the state by providing non-biased, science-based information and education in agriculture and natural resources, community development, and family and youth programs.

Main address: Agriculture and Life Sciences Building
600 John Kimbrough Boulevard, Suite 509
7101 TAMU
College Station, TX 77843-7107

Telephone: (979) 845-7800
Main Web site: *http://agrilifeextension.tamu.edu/*

Other links: Bookstore - *http://agrilifebookstore.org/*
County office contacts - *http://counties.agrilife.org/*
Agriculture and natural resources programs - *https://agrilifeextension.tamu.edu/browse/program-areas/*
Texas Watershed Steward Program - *http://tws.tamu.edu*
Southern Region Water Quality Program - *http://srwqis.tamu.edu*

2. TWRI (Texas Water Resources Institute)

   The Texas Water Resources Institute, a unit of Texas A&M AgriLife Research and the Texas A&M AgriLife Extension Service, and member of the National Institutes for Water Resources, provides leadership to stimulate priority research and Extension educational programs in water resources within the Texas A&M University System and throughout Texas.

   Main address: 1500 Research Parkway A110
   2260 TAMU
   College Station, TX 77843-2260

   Telephone: (512) 463-7847
   Main Web site: *http://twri.tamu.edu/*

   Other links: Current projects - *http://twri.tamu.edu/what-we-do/*
   Water resources research - *http://irnr.tamu.edu/publications/*

3. Texas Sea Grant

   Texas Sea Grant supports university research involving the conservation of marine resources and also supports activities in marine education and outreach through the Marine Information Service (MIS) and the Marine Advisory Service (MAS).

   Main address: Texas Sea Grant
   Texas A&M University, MS-4115
   College Station, TX 77845

   Telephone: (979) 845-3854
   Main Web site: *http://www.meadowscenter.txstate.edu/*

4. The Meadows Center for Water and the Environment at Texas State University

   Supports collaborative research, public advocacy, and education about Texas' river systems.

   Main address: The Meadows Center for Water and the Environment
   201 San Marcos Springs Dr
   San Marcos, TX 78666

   Telephone: (512) 245-9200
   Main Web site: *http://www.rivers.txstate.edu/*

For a list of all Texas Centers and Institutes, visit:
http://ci.tamu.edu/

River Authorities in Texas

Angelina - Neches River Authority
For the upper portion of the Neches River Basin
P.O. Box 387
Lufkin, TX 75902-0387
(210 E. Lufkin Avenue, 75901)
(936) 632-7795
Fax: (936) 632-2564
Web: *www.anra.org/*

Brazos River Authority
For the Brazos River Basin
P.O. Box 7555
Waco, TX 76714-7555
(4600 Cobbs Drive, 76710)
(254) 761-3100
Fax: (254) 761-3201
Web: *www.brazos.org/*

Central Colorado River Authority
For the Colorado River Basin and the Colorado-Lavaca Coastal Basin
P.O. Box 964
Coleman, TX 76834-0964
(325) 625-9001

Guadalupe-Blanco River Authority
For the Guadalupe River Basin and the Lavaca-Guadalupe Coastal Basin
933 E. Court Street
Seguin, TX 78155
(830) 379-5822
Fax: (830) 379-9718
Web: *www.gbra.org/*

Lavaca-Navidad River Authority
For the Lavaca River Basin
P.O. Box 429
Edna, TX 77957-0429
(4631 FM 3131, 77957)
(512) 782-5229
Fax: (512) 782-5310
Web: *www.lnra.org/*

Lower Colorado River Authority
For the Colorado River Basin and the Colorado-Lavaca Coastal Basin
P.O. Box 220
Austin, TX 78767-0220
(3701 Lake Austin Blvd., 78703)
(512) 473-3200
Fax: (512) 473-4066
Web: *www.lcra.org/*

Lower Neches Valley Authority
For the Neches-Trinity Coastal Basin and the lower portion of the Neches River Basin
P.O. Box 5117
Beaumont, TX 77726-5117
(7850 Eastex Freeway, 77708)
(409) 892-4011
Fax: (409) 898-2468
Web: *www.lnva.dst.tx.us/*

Nueces River Authority
For the Nueces River Basin and the San Antonio–Nueces and Nueces–Rio Grande Coastal Basins
Coastal Bend Division
Bayview Tower, 400 Mann St, Suite 1002
Corpus Christi, TX 78401-2045
(361) 653-2110
Fax: (361) 653-2115
Web: *www.nueces-ra.org/*

Palo Duro River Authority
For the Canadian River Basin
P.O. Box 99
Spearman, TX 79081
(806) 882-4401

Red River Authority of Texas
For the Canadian and Red River Basins
P.O. Box 240
Wichita Falls, TX 76307
(3000 Hammon Rd, 76310)
(940) 723-2236
Fax: (940) 723-8531
Web: *http://www.rra.texas.gov/*

Sabine River Authority of Texas
For the Sabine River Basin
P.O. Box 579
Orange, TX 77631-0579
(409) 746-2192
Fax: (409) 746-3780
Web: *www.sra.dst.tx.us/*

San Antonio River Authority
For the San Antonio River Basin
P.O. Box 839980
San Antonio, TX 78283-9980
(100 E. Guenther Street, 78204)
(210) 227-1373
Fax: (210) 227-4323
Web: *www.sara-tx.org/*

San Jacinto River Authority
For the San Jacinto River Basin and the San Jacinto-Brazos Coastal Basin
1577 Dam Site Road
Conroe, TX 77304
(936) 588-3111
Web: *http://www.sjra.net/*

Sulphur River Basin Authority of Texas
For the Sulphur River Basin
911 N. Bishop St.
Suite C 104
Wake Village, TX 75501
(903) 223-7887
Fax: (903) 223-7988
Web: *www.sulphurr.org/*

Trinity River Authority of Texas
For the Trinity River Basin
P.O. Box 60
Arlington, TX 76004
(5300 S. Collins, 76018)
(817) 467-4343
Fax: (817) 465-0970
Web: *www.trinityra.org/*

Upper Colorado River Authority
For the Colorado River Basin and the Colorado-Lavaca Coastal Basin
512 Orient
San Angelo, TX 76903
(325) 655-0565
Fax: (325) 655-1371
Web: *www.ucratx.org/*

Upper Guadalupe River Authority
For the Guadalupe River Basin and the Lavaca-Guadalupe Coastal Basin
125 Lehmann Drive, Suite 100
Kerrville, TX 78028
(830) 869-5445
Fax: (830) 257-2621
Web: *www.ugra.org/*

Other Water Organizations in Texas

1. Environment Texas: *http://www.environmenttexas.org/*
2. Take Care of Texas: *http://www.takecareoftexas.org/*
3. Texas Association of Counties: *http://www.county.org/Pages/default.aspx*
4. Texas Environmental Profiles: *http://www.meadowscenter.txstate.edu/rg/database_profile.php?iid=322*
5. Texas Natural Resources Information System: *http://www.tnris.org/*
6. Texas Rivers Protection Association: *http://www.txrivers.org/*
7. Texas Water Information Network: *http://www.rivers.txstate.edu/rg/database_profile.php?iid=18*
8. Texas Water: *http://www.sierraclub.org/texas/water*
9. Texas Water Energy Resources: *http://seco.cpa.state.tx.us/schools/infinitepower/*
10. Texas Water Matters: *http://texaslivingwaters.org/*
11. Texas Water Resources Education: *http://texaswater.tamu.edu/*
12. Texas Water: *http://texaswater.tamu.edu/*

Appendix B
Community Activities for Your Watershed

As official Texas Watershed Stewards, you have the opportunity to make a difference in your community, to raise awareness about issues in your watershed, and to participate in local watershed management and protection activities. The following is a list of activities (roughly arranged by "easiest" to "hardest" to participate in or to organize) that you can be a part of either as an individual or as a local watershed action group.

1. Form a Watershed Organization in Your Community

Ultimately, water quality and watershed protection are the responsibility of the individuals and communities residing in the watershed. Forming a watershed organization, or watershed action group, in your community will help raise awareness of water issues and help foster action to improve water quality. To learn how to form a community organization, visit EPA's Watershed Information Network's (WIN) "How to Start a Watershed Team" Web site at *http://www.epa.gov/owow/watershed/start.html*.

If a group already exists in your community, contact the group and volunteer to help. To find out if a group exists, visit EPA's Adopt Your Watershed "Catalog of Watershed Groups" Web site at *http://www.epa.gov/adopt/network.html.*

Once a group is formed, consider visiting the Community Watershed Resources Clearinghouse at *http://water.epa.gov/type/watersheds/datait/watershedcentral/inventory.cfm* and the Partnership Resource Center at *http://www.fs.usda.gov/prc* to gain access to hundreds of references for resources available to local community groups engaged in local watershed management.

2. Learn About Your Watershed

Start by using EPA's Watershed Information Network (WIN) at *http://www.epa.gov/owow/watershed/* to find your watershed address and learn about its water quality issues. From here, you can surf your watershed and even adopt your watershed.

You can also visit the United States Geological Survey (USGS) Web site to find out about water activities going on in Texas. Go to *http://tx.usgs.gov/* to see real-time water data, river basin maps, flood and drought data, and much more.

To see whether any water bodies in your watershed are listed on Texas' 303(d) list, visit the TCEQ Texas Integrated Report for CWA Sections 305(b) and 303(d) Web site at *https://www.tceq.texas.gov/waterquality/assessment/305_303.html.*

3. Create a Watershed Display

Displays can be developed for local fairs, festivals, public libraries, and community events to raise awareness and spread the word about water quality protection in your watershed. Your display could be a colorful poster full of pictures from different areas in your watershed. And it can provide information about important issues facing your watershed. Part of your display could even be an actual watershed model – visit EPA's "Build a Watershed Model" Web site for more information at *http://water.epa.gov/learn/kids/drinkingwater/activity_grades_9-12_buildyourownwatershed.cfm.*

4. Spread the Word Through an Advertising Campaign

An effective way to get the word out about water quality issues in your watershed is to advertise. Options include mass mailings, fliers, public service announcements, watershed fact sheets, and newspaper articles. It is a great way to raise awareness in the community, get more individuals to join your watershed group, and encourage people to take personal action to protect your watershed's resources.

Take advantage of available resources including:

- Local professionals and community officials (mayors, judges) who might be willing to contribute their time.
- Local newspapers and magazines – request coverage and/or special sections for your group to post information and report activities.
- Real estate and homeowner's association newsletters
- Free inserts in utility bills
- Public service announcements and community radio hours

Seek examples of letters, fact sheets, and fliers. Then, create some for your watershed and distribute them.

5. Give a Presentation to a School Class

By teaching children early about their watershed, we can produce the Watershed Stewards of tomorrow. In addition, it is often said that the best way to reach adults is through their children.

Plan with teachers in the community to make water education a part of their classroom curriculum. A simple and short classroom presentation can make a difference. You can tell students what a watershed is and discuss threats to water quality. Highlight things that kids and parents can do to protect water quality. Gather materials and set up the classroom for hands-on activities. Once the presentation and materials are gathered, the program can be offered over and over again. If all goes well, teachers will be requesting water education instead of you asking to present it.

There are many national water education programs for youth that can give you ideas:

- USGS Water Resources Information for Students and Teachers (*http://water.usgs.gov/education.html)*: Provides links to a variety of water education materials including maps, posters, glossaries, and more.

- USGS Water Science for Schools (*http://water.usgs.gov/edu/*): Provides links to numerous water science topics.
- Give Water a Hand (*http://www.partnersforcleanstreams.org/educational-publications/give-water-a-hand-business-campaign*): A national watershed education program designed to involve young people in local environmental service projects.
- Project WET (*http://www.projectwet.org/*): Water Education for Teachers (WET) is an award-winning, nonprofit water education program and publisher. The program facilitates and promotes awareness, appreciation, knowledge and stewardship of water resources through the dissemination of classroom-ready teaching aids and the establishment of internationally sponsored Project WET programs.
- EPA Nonpoint Source Kids Page (*http://water.epa.gov/polwaste/nps/kids/index.cfm*): Games and links to educational materials to teach children about pollution and the environment. This site features Darby Duck and the Aquatic Crusaders and Masterbug Theater.

6. Become a Volunteer Water Quality Monitor

Help collect water quality data and build stewardship for your local water body. The two organizations listed below can help get you started.

Texas Clean Rivers Program: The Texas Clean Rivers Program (CRP) is a state fee-funded program for water quality monitoring, assessment, and public outreach. The CRP is a collaboration of 15 partner agencies and the TCEQ. The CRP provides the opportunity to approach water quality issues within a watershed or river basin locally and regionally through coordinated efforts among diverse organizations.

Texas Commission on Environmental Quality
12100 Park 35 Circle
Austin, TX 78753

TEL: (512) 239-1000
EMAIL: crp@tceq.state.tx.us
WEB: *https://www.tceq.texas.gov/waterquality/clean-rivers*

Texas Stream Team: Texas Stream Team is a network of trained volunteers and supportive partners working together to gather information about the natural resources of Texas and to ensure the information is available to all Texans. Volunteers are trained to collect quality-assured information that can be used to make environmentally sound decisions. Established in 1991, Texas Stream Team is administered through a cooperative partnership between Texas State University, the Texas Commission on Environmental Quality (TCEQ), and the U.S. Environmental Protection Agency (EPA). Currently, more than 400 Texas Stream Team volunteers collect water quality data on lakes, rivers, streams, wetlands, bays, bayous and estuaries in Texas.

Texas State University
The Meadows Center for Water and the Environment
201 San Marcos Springs Dr,
San Marcos, TX 78666
TEL: (512) 245-9200
FAX: (512) 245-2095
EMAIL: txstreamteam@txstate.edu
WEB: *http://txstreamteam.rivers.txstate.edu/*

7. **Organize a Stream or a River Walk**

This is a great way to bring a group of citizens together to be outside and to make visual observations and assessments on the condition of a water body. If problems or concerns like trash, debris, or other sorts of pollution are discovered, work with the city and/or county to organize a cleanup for that water body.

You can also evaluate the health of a stream by finding and identifying macroinvertebrates during your walk. Go to *http://www.dep.wv.gov/WWE/getinvolved/sos/Documents/Benthic/WVSOS_MacroIDGuide.pdf* to print out an identification chart for macroinvertebrates fand check out *http://vitalsignsme.org/macroinvertebrates* for additional macroinvertebrate identification cards.

8. **Organize a Storm Drain Stenciling Project in Your Community**

Storm drain stenciling is a great way to remind community members that storm drains dump directly into your local water bodies. Visit the EPA's storm water Web site at *http://water.epa.gov/polwaste/npdes/stormwater/index.cfm.* Also consider creating door hangers, press releases, videos, and publications that can be distributed for you event!

For more information on storm drain stenciling in Texas, check out the Texas Storm Drain Stenciling Manual at *http://infohouse.p2ric.org/ref/32/31298.pdf.*

9. **Organize or Join in a Community Cleanup or Recycling Day**

The Texas Commission on Environmental Quality (TCEQ), along with Keep Texas Beautiful, have partnered to create the Texas Waterway Cleanup Program. This program provides free cleanup supplies and helps communities and organizations coordinate waterway cleanups and litter prevention activities. Keep Texas Beautiful is an organization whose mission is to educate and engage Texans to take responsibility for improving their community environment. For more information, visit *http://www.ktb.org/programs.aspx*.

Keep Texas Beautiful also sponsors additional cleanup events including the Great American Cleanup, Don't Mess with Texas Trash-Off, Texas Recycles Day, Illegal Dumping Education and Enforcement, and the Annual Keep Texas Beautiful Conference. For more information on these programs, visit *http://www.ktb.org/*, or write, call, or fax to the address and numbers below.

Keep Texas Beautiful
8850 Business Park Dr., Ste. 200
Austin, Texas 78759
TEL: (512) 478-8813
FAX: (512) 478-2640

For more information on citizen cleanup, recycling and disposal opportunities in Texas, visit *http://www.ktb.org/programs.aspx*.

10. Host a Community Watershed Workshop or Watershed Festival

You can sponsor a community workshop or watershed festival to raise awareness of water quality issues in your watershed. Think about the following questions:

- Are there members of the community with experience in public teaching or education?
- Are local professionals available to speak?
- What community organizations or businesses might serve as potential audiences for speakers?
- Who might co-sponsor a workshop for the public?

11. Create a Community Rain Garden

A rain garden is a neat little garden that is built to reduce runoff and filter sediment and other pollutants before they can enter your local waterways. It is built as a place to direct storm water from roofs, driveways, and parking lots so it can soak into the soil and be used by plants.

For more information, visit the Rain Garden Network at *http://www.raingardennetwork.com/overview.htm*.

12. Install Rain Barrels in Your Community

A rain barrel is a system that collects and stores rainwater from the roofs of buildings. Otherwise, that water would runoff into storm drains and streams. A rain barrel collects water and stores it for when you need to water your plants, wash your car, and do other activities that require water. The EPA estimates that rain barrels can save homeowners 1,300 gallons of water during peak summer months!

For more information, go to *http://rainwaterharvesting.tamu.edu/*. Also, check out the Texas Manual on Rainwater Harvesting at *http://www.twdb.texas.gov/publications/brochures/conservation/doc/RainwaterHarvestingManual_3rdedition.pdf* and the Texas A&M AgriLife Extension Service publication titled, "Rainwater Harvesting" at *http://agrilifebookstore.org.*

13. Conduct a Community Soil or Water Well Testing Campaign

This is a great way to bring your community together to test soil and the water quality of your local water wells. The Texas A&M University Soil, Water, and Forage Testing Laboratory will provide guidance on taking soil and water samples and will also analyze and provide results of your samples (fee based).

Having the soil from your lawn tested is an important first step in determining exactly how much, if any, fertilizer is needed on your lawn, landscape, or garden. Fertilizers should be applied carefully and at the proper rate and time to prevent the negative effects they can have on waterways in your community and state.

Water quality testing campaigns for private well owners can also be great tools for encouraging proper management of the land so that both surface and groundwater resources are protected.

Visit the lab's Web site at *http://soiltesting.tamu.edu/* for more information. You can also write or call the number and address below.

Texas A&M University Soil, Water, and Forage Testing Laboratory
2610 F&B Road
College Station, TX 77845
TEL: (979) 845-4816
FAX: (979) 845-5958

14. Join a Stakeholder Workgroup for a Watershed Protection Plan or TMDL

Stakeholder involvement in the development and implementation of watershed protection plans or TMDLs is absolutely vital. It is a great way to get your voice heard and to bring about positive change for your local water bodies. Volunteer your expertise, or time and energy, to contribute to these important watershed protection activities and to get involved in making a difference.

Find out if a watershed protection plan or a TMDL is planned in your watershed by visiting the Texas State Soil and Water Conservation Board Web site at *http://www.tsswcb.state.tx.us/wpp* for information on current and future watershed protection plans and here *http://www.tceq.texas.gov/implementation/water/tmdl/index.html* for information on current and future TMDLs.

15. Get Your Public Water System Involved in a Source Water Protection Program

The TCEQ provides a Source Water Protection Program (SWAP) for community public water systems at no cost. All it takes to participate is a short letter to the TCEQ requesting their support for the program. Once TCEQ receives your letter, they will work with the public water supply and local partners to set up meetings and get the program off the ground.

For more information, contact the TCEQ's Source Water Protection Program:

Water Supply Division PDWS MC-155
Texas Commission on Environmental Quality
P.O. Box 13087
Austin TX 78711-3087
EMAIL: pdws@tceq.texas.gov
TEL: (512) 239-4691
FAX: (512) 239-6050

16. Get Funding to Help Protect Your Watershed

To sustain public education efforts and do some of the bigger tasks, you'll likely need some sort of funding source. Think about writing a grant to support your local outreach efforts. Start by going to the Catalog of Federal Funding Sources for Watershed Protection at *https://ofmpub.epa.gov/apex/watershedfunding/f?p=fedfund:1*. The EPA also has an Environmental Education Grants Program found at *http://www2.epa.gov/education/environmental-education-ee-grants*. Also, talk with city and county officials about other funding sources in your community or watershed.

17. Develop Your Watershed Protection Plan

A Watershed Protection Plan is a focused effort to bring together all of the different stakeholder groups (city, county, business, industry, agriculture, homeowners, etc.) to work together to plan for the future of a watershed. It requires the dedication of significant time and energy, but the end result is a shared plan that everyone can help implement with the goal of ensuring a healthy watershed.

To learn more about watershed planning, see the Texas A&M AgriLife Extension Service publication titled, "The Watershed Management Approach" at *http://agrilifebookstore.org* and EPAs watershed planning Web site at *http://water.epa.gov/type/watersheds/approach.cfm*.

Appendix C
Water Quality on the Web

Best Management Practices

- EPA Stormwater Best Management Practices Study: Includes technical information on BMP performance measures, BMP design criteria, monitoring issues, costs, and benefits of implementing BMPs. *http://www.epa.gov/waterscience/guide/stormwater/*

- International Stormwater Best Management Practices (BMP) Database: Provides scientifically sound information regarding the design, selection, and performance of urban stormwater BMPs. *http://www.bmpdatabase.org/*

- Irrigation Best Management Practices: An online information source for irrigation BMPs created by The National Environmentally Sound Production Agriculture Laboratory (NESPAL) at the University of Georgia's College of Agricultural and Environmental Sciences. *http://www.nespal.org/irrigation%20tech.html*

- Managing Stormwater Best Management Practices: Interactive Web site created by Greenworks TV that includes several videos and other types of information on stormwater BMPs. *http://greenworkspc.com/works/stormwater-2/*

- National Menu of Stormwater Best Management Practices: Powerful search engine created by the EPA for stormwater BMPs. *http://water.epa.gov/polwaste/npdes/swbmp/*

- NRCS Farm Conservation Solutions: Provides information for some common conservation practices and how they help improve a farm and the environment. *http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/*

- TSSWCB Comprehensive Nutrient Management Plan Program: Provides valuable information on nutrient management plans, their benefits, ways to obtain financial assistance, and additional technical resources. *http://www.tsswcb.state.tx.us/cnmp*

Drinking Water

- EPA Drinking Water Contaminants Web site: Provides a list of drinking water contaminants and their MCLs. *http://www.epa.gov/safewater/contaminants/index.html*

- EPA Drinking Water Standards: Contains information regarding drinking water standards, priority rulemaking, regulatory infrastructure, and additional links. *http://www.epa.gov/safewater/standards.html*

- EPA Local Drinking Water Information: Provides drinking water information for each state, as well as links to safe drinking water organizations in the country. *http://www.epa.gov/safewater/dwinfo/index.html*

- EPA Public Notification for Drinking Water Systems: Public notification is intended to ensure that consumers are immediately alerted if there is a serious problem with their drinking water that may pose a risk to public health. *https://www.epa.gov/dwreginfo/public-notification-rule*

- EPA Source Water Protection: Provides information on protecting drinking water sources. *http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/*

- NSF Drinking Water Web Site: Provides information on drinking water contaminants, home water treatment, testing protocols, rainwater collection, and more. *http://www.nsf.org/consumer/drinking_water/index.asp?program=WaterTre*

- TCEQ Drinking Water and Water Availability Web site: Provides information regarding drinking water supplies and other drinking water issues in Texas. *https://www.tceq.texas.gov/drinkingwater*

- Texas Drinking Water: Provides access to online water quality reports and information about public water suppliers. *http://www.tceq.texas.gov/about/organization/water.html*

Emergency Response

- RWEAC (Rural Water Emergency Assistance Cooperative): Statewide program that focuses on helping small and rural water systems obtain emergency assistance in the form of personnel, equipment, and other materials necessary to protect the health and welfare of the small and rural utilities' customers. *http://www.trwa.org/rweac/*

- TxWARN (Texas Water/Wastewater Agency Response Network): Statewide program that supports and promotes emergency preparedness, disaster response, and mutual assistance matters for public and private water and wastewater utilities. *http://www.txwarn.org/*

Environmental Facts

- EPA Envirofacts Data Warehouse: A national information system that provides a single point of access to data extracted from seven major EPA databases. *http://www.epa.gov/enviro/*

Funding Sources

- Catalog of Federal Funding Sources for Watershed Protection: A searchable database of financial assistance sources (grants, loans, cost-sharing) available to fund a variety of watershed protection projects. *https://ofmpub.epa.gov/apex/watershedfunding/f?p=fedfund:1*

- Environmental Finance Center Watershed Funding Resources: An online, searchable database for watershed restoration funding. *https://www.epa.gov/waterfinancecenter/efcn*

- EPA Targeted Watersheds Grants Program: This program awards capacity-building grants to support local watershed efforts and model watershed projects. *https://www.epa.gov/hwp/healthy-watersheds-consortium-grants-hwcg*

- Plan2Fund: A watershed planning tool developed by the Environmental Finance Center at Boise State University that helps organizations determine their funding needs to meet the goals and objectives of their Watershed Program Plan. *https://wiki.epa.gov/watershed2/index.php?title=Plan2Fund&oldid=536*

- TCEQ Funding Opportunities Web Site: Information on the various funding opportunities offered by TCEQ to groups and individuals to carry out programs related to their mission. *https://www.tceq.texas.gov/agency/funding/*

Glossaries

- Alabama Water Information System Glossary: Contains a helpful list of water-related terms. *http://www.aces.edu/natural-resources/water-resources/*

- EPA Terminology Services (TS): A single resource of environmental terminology. *https://iaspub.epa.gov/sor_internet/registry/termreg/searchandretrieve/home.do*

- USGS Water Science Glossary of Terms: Contains a helpful list of water-related terms. *https://water.usgs.gov/edu/dictionary.html*

Groundwater Management

- TCEQ Groundwater Planning and Management: Information on groundwater protection, Texas Groundwater Protection Committee, Groundwater Conservation Districts, Priority Groundwater Management Areas, pesticide management, and relevant reports and studies. *http://www.tceq.texas.gov/groundwater/districts.html*

- TWDB Groundwater Conservation Districts: Provides useful information on groundwater conservation districts in Texas. *https://www.twdb.texas.gov/groundwater/conservation_districts/*

Mapping/Database Tools

- EPA BASINS (Better Assessment Science Integrating Point & Nonpoint Sources): A multi-purpose environmental analysis system that integrates a geographical information system (GIS), national watershed data, and state of the art environmental assessment and modeling tools into one convenient package. *http://epa.gov/waterscience/basins/*

- EPA Enviromapper for Water: Powerful online mapping tool. Program will map watersheds, impaired waters, assessed waters, beaches, discharge zones, and other features for any state, county, or town in the United States. *https://www.epa.gov/emefdata/em4ef.home*

- EPA STORET: EPA's repository for water quality, biological, and physical data. *http://www3.epa.gov/storet/*

- EPA W.A.T.E.R.S. (Watershed Assessment, Tracking & Environmental Results): A powerful mapping tool that allows users to view data from many EPA databases and find geography-specific water quality information. *http://www.epa.gov/waters/*

- TCEQ Hydrography Maps and Data: Provides links to the Atlas on Texas Surface Waters, GIS data sets, hydrography maps, and water quality viewers. *http://www.tceq.texas.gov/implementation/water/tmdl/hydromaps.html*

- Texas Natural Resources Information System (TNRIS): Provides a centralized information system incorporating all Texas natural resource data, socioeconomic data related to natural resources, and indexes related to those data that are collected by state agencies or other entities. *https://tnris.org/*

- TWDB Data: Links to all kinds of water and natural resource data for Texas. *http://www.twdb.state.tx.us/data/data.asp*

- TWDB Maps: Provides links to all kinds of Texas maps, including maps of major/minor aquifers, major Texas rivers, and major river basins in Texas. *https://www.twdb.texas.gov/mapping/data-services.asp*

Nonpoint Source Pollution

- EPA Polluted Runoff: Provides information about various topics relating to nonpoint source pollution, including information for students, funding opportunities, publications, and outreach. *http://www.epa.gov/OWOW/NPS/*

- EPA Stormwater Program: Contains technical and regulatory information about the NPDES stormwater program. It is organized according to the three types of regulated stormwater discharges and provides links to stormwater outreach materials. *http://water.epa.gov/polwaste/npdes/stormwater/index.cfm*

- Texas A&M AgriLife Extension Service Stormwater Management Publication: A helpful publication about which pollutant sources are regulated and what can be done to control stormwater and the pollution problems they can cause. *http://agrilifebookstore.org*

- TCEQ Nonpoint Source Water Pollution Management Program: The Nonpoint Source Management Program plans and implements activities designed to prevent or remediate urban and other nonagricultural nonpoint source pollution in Texas waters. *http://www.tceq.texas.gov/compliance/monitoring/nps/mgmt-plan/*

- TSSWCB Statewide Nonpoint Source Management Program: Provides information on CWA 319(h) initiatives and active and completed NPS projects in Texas. *http://www.tsswcb.state.tx.us/managementprogram*

- TSSWCB Coastal Nonpoint Source Pollution Control Program: Provides information on the Texas Coastal Management Program and the various agencies involved in managing nonpoint source pollution along Texas' coasts. *http://www.tsswcb.state.tx.us/coastalnps*

Partnerships

- Partnership Resource Center: Provides online resources to build vibrant partnerships and effective collaboration for the nation's forests, grasslands, and other special places. The Web site is a joint project of the National Forest Foundation and the USDA Forest Service. *http://www.fs.usda.gov/prc*

- Catalogue of Watershed Groups in Texas: A list of watershed groups in Texas provided by the EPA. *http://water.epa.gov/action/adopt/network.cfm*

Point Source Pollution

- EPA National Pollutant Discharge Elimination System (NPDES): The site contains technical and regulatory information about the NPDES permit program. *https://www.epa.gov/npdes*

Rainwater Collection

- TCEQ Rainwater Collection and Treatment Web site: Contains links to publications and information for rainwater harvesting, storage, and treatment. *https://www.tceq.texas.gov/publications/gi/gi-404.html*

- Texas A&M AgriLife Extension Service Rainwater Harvesting: Provides information on how to develop a rainwater harvesting system for your landscape. *http://rainwaterharvesting.tamu.edu/*

- TWDB Texas Manual on Rainwater Harvesting: A concise guide on installing rainwater harvesting systems in Texas. *https://www.twdb.texas.gov/publications/brochures/conservation/doc/RainwaterHarvestingManual_3rdedition.pdf*

Smart Growth

- EPA Smart Growth Web site: Provides helpful information on smart growth including facts, benefits, examples, and publications. *http://www.epa.gov/smartgrowth/*

- Texas A&M AgriLife Extension Service Choices for Growth: Helpful publication about choices for growth, quality of life, and the natural environment. *http://agrilifebookstore.org*

Texas Integrated Report for Clean Water Act Sections 305(b) and 303(d)

- Texas Integrated Report for CWA Sections 305(b) and 303(d): These reports describe the status of Texas waters based on historical data on surface water and groundwater quality (305(b)) and identify water bodies that are not meeting standards set for their use (303(d)). *https://www.tceq.texas.gov/waterquality/assessment/305_303.html*

Total Maximum Daily Load (TMDL)

- EPA Total Maximum Daily Load Program: Clearinghouse for all things TMDL, including an introduction and access to policy/program documents, technical support documents, sample TMDLs, litigation status, and more. *https://www.epa.gov/tmdl*

- TCEQ Total Maximum Daily Load Program: Provides information on ways to improve water quality in impaired or threatened water bodies in Texas. *http://www.tceq.texas.gov/waterquality/tmdl*

- TSSWCB Total Maximum Daily Load Program: Contains information on TMDLs and current/future TMDLs in Texas. *http://www.tsswcb.texas.gov/tmdl*

Volunteer Water Quality Monitoring

- EPA Volunteer Monitoring Web site: Provides links to volunteer monitoring fact sheets, methods, newsletters, and conferences/events. *http://www.epa.gov/owow/monitoring/vol.html*

- Volunteer Water Quality Monitoring Groups in Texas: *http://water.epa.gov/action/adopt/network.cfm*

Water Conservation

- TCEQ Water Conservation Web site: Provides information on water conservation programs and rainwater harvesting. *http://www.tceq.texas.gov/response/drought/conservation.html*

- TWDB Water Conservation Web site: Contains information on water conservation, including agricultural water conservation, conservation education, municipal water conservation, and more. *https://www.twdb.texas.gov/conservation/*

Watersheds

- EPA Watershed Academy: Online training modules covering various watershed topics from watershed hydrology to water law and policy. *http://www.epa.gov/watertrain/*

- EPA Surf Your Watershed: A service to help you locate, use, and share environmental information on your watershed or community. *http://cfpub.epa.gov/surf/locate/index.cfm*

- EPA Window to My Environment: A powerful web-based tool that provides a wide range of federal, state, and local information about environmental conditions and features in your region. *http://www3.epa.gov/enviro/myenviro/*

- EPA Watershed News: A publication of EPA's Office of Wetlands, Oceans and Watersheds. It is designed to provide timely information to groups working at the watershed level. *http://www.epa.gov/owow/watershed/news.html*

- EPA Water: Contains vast amounts of information on many water topics and issues. *http://water.epa.gov/*

- EPA Watershed Information Network: Find ways to get involved in your watershed and learn more about your watershed. *http://www.epa.gov/owow/watershed/*

- National Watershed Network: The National Watershed Network is a registry of locally led watershed partnerships working to meet local goals through voluntary actions. *http://www.ctic.purdue.edu/Know%20Your%20Watershed/National%20Watershed%20Network/*

- TCEQ Water in Your River or Coastal Basin: Provides information about water quality, water availability, and other environmental issues. *https://www.tceq.texas.gov/publications/gi/gi-316*

- USGS Science in Your Watershed: Clearinghouse for all sorts of information related to watersheds. *http://water.usgs.gov/wsc/index.html*

- USGS Water Science for Schools: Information on many aspects of water, along with pictures, data, maps, and an interactive center where you can give opinions and test your water knowledge. *https://water.usgs.gov/edu/*

Watershed Hydrology

- EPA Water Cycle: Interactive flash movie detailing each step of the water cycle. *http://www.epa.gov/safewater/kids/flash/flash_watercycle.html*

- NASA Observatorium Hydrologic Cycle: Interactive step-by-step lessons on the hydrologic cycle. *http://www.nasa.gov/audience/forstudents/5-8/features/Observatorium_Feat_5-8.html*

- USGS Water Cycle: Contains information related to the water cycle. *https://water.usgs.gov/edu/watercycle.html*

Water Law

- EPA Laws, Regulations, Policy, Guidance, and Legislation: Links to all sorts of information regarding water law and policy. *https://www.epa.gov/laws-regulations*

- Texas Administrative Code: Provides links to the full text of the TAC. The TAC is a compilation of all state agency rules in Texas. There are 16 titles in the TAC. Each title represents a category, and relating agencies are assigned to the appropriate title. *http://www.sos.state.tx.us/tac/*

- Texas Water Code: Provides links to every chapter of the Texas Water Code. *http://www.statutes.legis.state.tx.us/*

- Texas Water Resources Education Water Law Web site: Provides information on Texas water law. *http://water.tamu.edu/water-management-irrigation/texas-water-law/*

Watershed Protection Plans

- TSSWCB Watershed Protection Plan (WPP) Program: Information about WPPs and current/future WPPs in Texas. *http://www.tsswcb.state.tx.us/wpp*

Watershed Publications and Products

- After the Storm: 30-minute video program about watersheds co-produced by the EPA and The Weather Channel. *https://archive.org/details/gov.epa.841-c-06-001*

- Getting in Step: A Guide For Conducting Watershed Outreach Campaigns: A handbook and companion video to help local and state agencies and watershed groups conduct effective watershed outreach campaigns. *http://www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf*

- Handbook for Developing Watershed Plans to Restore and Protect Our Waters: This handbook is intended to help communities, watershed organizations, and others develop and implement comprehensive watershed protection plans. *https://www.epa.gov/sites/production/files/2015-09/documents/2008_04_18_nps_watershed_handbook_handbook-2.pdf*

- Protecting Water Resources with Smart Growth: Documents 75 innovative approaches to help communities protect water resources and achieve smart growth. *http://www.epa.gov/smartgrowth/water_resource.htm*

All EPA publications can be obtained for FREE by calling the National Service Center for Environmental Publications (NSCEP) toll-free at 1-800-490-9198 or by sending an email to: nscep@bps-lmit.com. To search for other EPA publications, visit http://yosemite.epa.gov/water/owrccatalog.nsf/. Use the search feature on the left hand side bar to find publications by topic or title.

Water Quality

- Southern Regional Water Program: Southern section, including Texas, of the NIFA National Integrated Water Quality Program. The Program's web site brings together the collective water quality research, education, and extension resources of Land Grant Universities in 13 states of the Souther Region. *http://srwqis.tamu.edu/*
- USDA NIFA National Integrated Water Quality Program: National program of the National Institute of Food and Agriculture that creates, and disseminates knowledge about water quality across the country. *https://nifa.usda.gov/program/national-water-quality-program*
- USDA Water Quality Information Center: Provides electronic access to information on water quality and agriculture. The Center collects, organizes and communicates the scientific findings, educational methodologies, and public policy issues related to water quality and agriculture. *https://www.nal.usda.gov/waic*

Water Quality Monitoring

- BEACON: Sponsored by the EPA; annual monitoring information available about beach water quality. *http://watersgeo.epa.gov/beacon2/*
- Texas Clean Rivers Program: Provides information on the Texas CRP and the importance of water quality monitoring. *https://www.tceq.texas.gov/waterquality/clean-rivers*
- TCEQ Surface Water Quality Monitoring: Contains information on TCEQ's surface water quality monitoring program, links to supplemental information, monitoring procedures, and monitoring data and maps. *https://www.tceq.texas.gov/waterquality/monitoring*
- TWDB Texas Water Conditions: The TWDB monitors water conditions throughout the state on a monthly basis at selected reservoirs, stream flow sites, and ground-water wells. *http://www.twdb.texas.gov/surfacewater/conditions/report/index.asp*

Water Quality Parameters

- BASIN Water Quality Terminology: Links to helpful information concerning water quality parameters. *http://bcn.boulder.co.us/basin/natural/wqterms.html*
- Kentucky Water Watch Water Quality Parameters: Contains helpful information on important water quality measurements. *http://www.state.ky.us/nrepc/water/wcparint.htm*
- Water on the Web: Online water quality primer about the principle types of water quality problems as well as in-depth descriptions of water quality parameters. *http://waterontheweb.org/under/waterquality/index.html*

Water Quality Standards

- EPA Water Quality Standards: Source for all kinds of information on water quality standards. *http://www.epa.gov/waterscience/standards/*

- EPA Water Quality Standards Database: Provides access to EPA and state water quality standards (WQS) information in text, tables and maps. *http://water.epa.gov/scitech/swguidance/standards/wqshome_index.cfm*

- EPA National Assessment Database: This Web site provides a summary of state-reported water quality information and allows the user to view assessments of individual water bodies. *https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryID=23869*

- TCEQ Texas Surface Water Quality Standards: Information on Texas surface water quality standards. *http://www.tceq.texas.gov/nav/eq/eq_swqs.html*

Water Quantity

- National Drought Mitigation Center (NDMC): Program based at the University of Nebraska-Lincoln to help people and institutions develop and implement measures to reduce societal vulnerability to drought. *http://www.drought.unl.edu/*

- TCEQ Drought and Public Water Systems Web site: Contains information regarding drought planning and guidance. *http://www.tceq.texas.gov/response/drought/drought.html*

- Texas Water Information Network Drought Monitoring: Contains Texas drought information. *http://www.meadowscenter.txstate.edu/rg/database_profile.php?iid=18*

- TWDB Drought Web site: Contains information about drought conditions and drought mitigation in Texas. *http://www.twdb.texas.gov/newsmedia/drought/doc/weekly_drought_report.pdf*

- USDA Water Availability Web site: Information about agricultural water availability in the United States. *http://wqic.nal.usda.gov/water-availability-0*

- USGS Real-Time Water Data for the Nation: Find real-time flow data for all streams and rivers in the United States. Real-time data typically are recorded at 15- to 60-minute intervals, stored onsite, and then transmitted to USGS offices every 1 to 4 hours, depending on the data relay technique used. *http://waterdata.usgs.gov/nwis/rt*

Wells

- EPA Private Drinking Water Wells: Helpful information about private drinking water wells, including basic information, human health information, and precautions to ensure the protection and maintenance of private drinking water supplies. *http://www.epa.gov/safewater/privatewells/index2.html*

- NSF Well Water Web site: Provides private well owners with general information on water quality and the special needs of well water users. *http://www.nsf.org/consumer/drinking_water/dw_well.asp?program=WaterTre*

- TWDB Well Information/Groundwater Data: Provides accurate, objective information on the groundwater resources of Texas. *http://www.twdb.texas.gov/groundwater/data/gwdbrpt.asp*

- USGS Groundwater Wells: Provides information on the different types of groundwater wells. *https://water.usgs.gov/ogw/*

- Wellowner.org: One-stop resource for information relating to private water well systems and groundwater. *http://www.wellowner.org/*

- Texas Well Owner Network (TWON): Comprehensive well owner education program. *http://water.tamu.edu/water-quality/texas-well-owner-network/*

Wetlands

- EPA Wetlands Web site: Provides information on protecting, restoring and monitoring wetlands. *http://www.epa.gov/owow/wetlands/*

- USFWS National Wetlands Inventory: Provides information on the characteristics, extent, and status of the nation's wetlands and deepwater habitats and other wildlife habitats. *http://www.fws.gov/nwi/*

- Wetlands International: Nonprofit organization dedicated solely to wetland conservation and sustainable management. *www.wetlands.org*

- Wetlands Regulation Center: Information on the laws, policies, and regulations concerning activities regulated under Sections 401 and 404 of the Clean Water Act in waters of the United States, including wetlands. *www.wetlands.com*

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