THE WATER CYCLE

Water is perhaps the ultimate example of recycling. Water constantly renews its purity by cycling itself from a liquid (or a solid) into vapor and back again. The change to a vapor removes most impurities and allows water to return to Earth in its clean form. (Exception: **acid rain**, see F-51, Surface Water Issues.)

The study of water, or **hydrology**, starts with the **water cycle**, or the process by which water renews itself. Since the cycle is continuous, it doesn=t really have a beginning, but a convenient place to start studying it is with **precipitation** (rain, snow, sleet and hail). When precipitation falls to earth, several things can happen. It can be absorbed into the soil. This is called **infiltration**. This process allows water to seep into the earth and be stored underground as **groundwater**. Precipitation can also become **runoff**, flowing into rivers and streams. Water can **evaporate**, or it can be returned to the atmosphere by **transpiration** through plants. Since it is often difficult to separate these two processes, they are often lumped together and called **evapotranspiration**.

Precipitation can also be **stored**. An ice cap is a form of storage. In temperate climates, water is found in depression storage or surface waterCpuddles, ditches, and anywhere else that runoff water can gather. This is a temporary form of storage. Water will evaporate from the surface and will infiltrate into the ground below it. It will be absorbed by plants and transpired back into the air. It will flow to other areas. This Acycling@ of water is continuous.

A number of factors such as soil type, slope, moisture conditions, and intensity of storm event affect how water travels through this cycle. For example, when rain falls, some of it will infiltrate into the ground, but this rate of infiltration may be fast or slow. If the soil is already wet and saturated, much of the rain will become runoff. If the soil has low moisture content, a large percentage of it may be absorbed. The type of soil will also impact the rate of infiltration. Clay or packed soil allows little water to seep in. Sandy or loose soils allow more infiltration.

The rate of rainfall is a factor to consider. If rain is hitting the ground faster than it can infiltrate, it becomes runoff. The grade or slope can also influence runoff. Water infiltrates very little on steep grades. Human-made structures can reduce infiltration even further. Virtually no water infiltrates through paved roads and parking lots, so almost all of it becomes runoff. This affects the entire water cycle.

WATERSHEDS

Watersheds have a big impact on the water cycle. A watershed, also called a drainage basin, is the area in which all water, sediments, and dissolved materials drain from the land into a common body of water, such as a river, lake or ocean. A watershed encompasses not only the water but the surrounding land from which the water drains. This can be an area as large as the Mississippi River drainage basin or as small as a backyard.

A watershed may be either a large or small area, and its characteristics can greatly affect how water flows through the watershed. For example, the flow in a particular stream may fluctuate dramatically with rainfall because of the characteristics of the watershed. Heavy storms may cause streams to rise rapidly. Human-made features of the watershed like dams or large paved areas can change stream flow and alter the watershed. If the topography is steep, changes in stream flow due to runoff can be significant.

In some watersheds, stream flow may take a long time to respond to rainfall runoff. On heavily vegetated, relatively flat terrain, infiltration is great, or runoff is slowed by vegetation. Eventually, however, runoff will make its way through the watershed and become stream flow. In these areas, stream flow will rise slowly, but also recede slowly.

The stream flow characteristics of a watershed can be a key to evaluating the quality of the water in the watershed. Streams start out in higher elevations, and flow downward, eventually finding their way to the sea. But they don=t travel in straight lines. Their paths vary. The terrain may be steep in some areas, causing rapid flow, and flat in other areas, allowing the water to get deeper and spread out. These grade changes create different habitats in the stream which support different forms of life and change the quality of water in the watershed.

Water quality is critically impacted from everything that goes on within the watershed. Mining, forestry, agriculture, and construction practices, urban runoff from streets, parking lots, chemically treated lawns, and gardens, failing septic systems, and improperly treated municipal sewage discharges all affect water quality. Reducing pollution and protecting water quality requires identifying, regulating, monitoring, and controlling potential pollutants. Some examples of control practices include protecting streambanks and shorelines by maintaining vegetated buffer strips, treating all wastes to remove harmful pollutants, or using grass-lined catchment basins in urban areas to trap sediment and pollutants.

THE COMMUNITY WATER ENVIRONMENT

C**ommunity water environments**, have their own water Acycle within a cycle@ based on the factors within the community that affect water uses and flow.

Rainfall, soil composition, terrain, large surface bodies of water, human-made structures, pollution sources, surface water, weather patterns, and other factors can all have an impact on the Acommunity@ water environment. For example, a desert community may have a water environment with very little rainfall, while a marine coastal climate like the Northwest will see months of rain. An urban community will have its water environment affected by fast runoff due to paved areas, high water consumption due to large populations, water contaminants from industrial operations, urban runoff, domestic sewage, and construction. A rural area may have its water environment affected by lakes and streams that put large amounts of water into the air through evaporation or forests that contribute water vapor through evapotranspiration. Agriculture often uses large amounts of water for irrigation and watering livestock. Agricultural practices can also pollute the rural water environment with fertilizers and pesticides, if improperly applied, or animal wastes if improperly managed.

In most urban communities, water is withdrawn from either a surface waterbody like a lake, reservoir, or stream, or from a underground aquifer. This water is usually treated at a drinking water treatment plant and distributed to individual homes, businesses, and industries through a vast network of underground pipes. Water is then used by citizens, businesses, and industries. Used water either flows into a drain and travels to a wastewater treatment plant though a network of sewer pipes or is deposited onto the ground. For example, water used to wash the car or water the lawn may either soak into the ground or flow over the earth and run into nearby waterbody or a network of storm drains which flow into a nearby waterbody. Some storm drains are connected to wastewater treatment plants. At the wastewater treatment plant, most pollutants are removed and the treated water is released into a nearby surface waterbody and the cycle begins again.

In rural areas, water is usually withdrawn directly from the ground through a well and piped into the house and other buildings via a network of pipes. Used water is either deposited onto the ground where is soaks in or runs off or it flows through pipes into a septic tank. Wastewater in the septic tank undergoes treatment and flows from the tank into a series of pipes called a drainfield where it percolates into the soil.

In both urban and rural communities the primary source of water is from precipitation which is either stored as surface water or groundwater. In special cases, some communities store water in water towers.

WATER QUALITY

Every time water completes its cycle from vapor to liquid or solid and back to vapor again, its quality is renewed. However, water quality can be damaged by any number of pollutants in the air, on land, or from other water supplies. The amount of water available for use depends on its quality, and the availability of water dictates where we can live, build cities, and create industry.

On the average, every American uses about 150 gallons of water a day. That makes daily water consumption in the United States in 1996, approximately 39 **billion** gallons per day. It=s no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies.

Each time we use water, we change its quality by adding substances to it. These materials are such things as municipal sewage, toxic chemicals, solvents, automotive oils, fertilizers, detergents, pesticides, and even extra heat. Some materials, even in small quantities, can damage water quality to the point to make it unusable. A single quart of motor oil, for example, could pollute as much as 250,000 gallons of water.

WATER QUALITY STANDARDS

Water may have different quality Astandards,@ depending on its use. For example, water can be of high enough quality for livestock to drink but not be pure enough for humans to consume. Or, water may provide a fine environment for bass, bluegill and other lake fish while not being cold enough or having enough oxygen content to support trout. Water quality is often in the Aeye of the beholder.@

Laws involving water quality date back as far as 1914. The first Federal law dealing exclusively with water quality was passed in 1948. Under this law, the states retained primary responsibility for water quality standards and protection. The Federal government supplied money primarily for research. The law provided only weak punishments for offenders. During the 1960s, amendments provided for Federal water quality standards, Federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern resulted in passage of three more very important environmental laws.

The National Environmental Policy Act of 1969 (NEPA) required federal agencies to consider the environmental impacts of their actions. All federal agencies must prepare environmental impact statements to assess the impacts of major federal actions, such as large building or industrial projects. Because of NEPA, federal undertakings have been conducted in a manner to ensure protection of all natural resources, including water.

The Federal Water Pollution Control Act (Clean Water Act) which was passed in 1972 and amended in 1977, 1981, and 1987 provides the basis for water quality standards today. The Clean Water Act (CWA) also established the National Pollutant Discharge Elimination System (NPDES), a permitting program which has assisted in reducing discharges of pollutants to surface waters. The Safe Drinking Water Act (SDWA), passed in 1974 and amended in 1986 and 1996, requires public drinking water systems to protect drinking water sources, provide water treatment, monitor drinking water to ensure proper quality, and notify the public of contamination problems. The Environmental Protection Agency is responsible for implementing or authorizing states to implement the NPDES permitting program, establishing drinking water standards, and enforcing other provisions of the CWA and SDWA.

LAND USE AND WATER QUALITY

Land use can have a tremendous effect on water quality. Farmlands can be the source of sediment, fertilizer, pesticides, and animal waste pollution. When forests are cut down, they can be major sources of sediment pollution. Cities pose numerous water quality problems due to: the demand for clean water, industrial and commercial pollutants, and human and pet wastes, and urban runoff from lawns and paved areas.

So it=s important that when we decide to use land for a specific purpose, we take into account water quality, not just in the immediate area but within the whole watershed. This means considering the **amount** of water available as well as how it must be processed before and after use. For example, crops require tremendous amounts of water. If there=s not enough rainfall to support their growth, crops must be irrigated, which means transporting water from lakes, streams, or wells. Irrigation may require so much water that aquatic life in lakes and streams may be adversely impacted, or the water table may be lowered, causing wells and wetlands to dry up. Another good example is the case of a computer chip manufacturer in California. The manufacturing plant owner/operator may take great care to avoid discharging dangerous pollutants, but still come under attack by environmentalists for the amount of water it uses in an area where water supplies are severely limited. To avoid such attacks or criticism, the plant owner/operator can make sure that it withdraws water only during periods of high flows after rain and storm events.

Certain land use practices can minimize negative impacts to the environment. For example, planting trees and other vegetation to protect soil and reduce erosion, fencing livestock to prevent access to streams, properly treating animal wastes, minimizing use of fertilizers and pesticides, properly treating all waste products from industries, using less harmful chemicals and other products in homes, businesses, and industries, and reducing, reusing and recycling commercial products can all help reduce water pollution.

WATER POLLUTION

Water has the remarkable ability to renew and cleanse itself. When waste materials are deposited into a receiving stream, they often settle out, break down, or become diluted in the stream. However, pollution can occur if too much of a substance or too many substances are discharged so that it overwhelms the capacity of the stream to assimilate the substance(s) or cleanse itself. Water pollution may also occur if even just a little of a highly toxic substance is discharged into a receiving stream (e.g., dioxin).

Water pollution can be classified into two main categories: **point source** pollution and **nonpoint source** pollution. The difference between the two categories is simple. Point source pollution is any type of pollution that can be identified as coming from a clearly established source. This may be a factory, a previously polluted stream, or other source that is obviously causing pollution. Point source pollution problems are often simpler to control because it=s easier to see the cause of the pollution and to do something about it.

Nonpoint source pollution problems are more difficult to resolve because they often cannot be traced to one specific location. Nonpoint source pollution includes sediment from rainwater runoff or fertilizer pollution as storms wash nutrients from fields. Nonpoint source pollution can be runoff from animal wastes, construction sites or mines, and leachate from landfills. Nonpoint source pollution could even be acid rain from atmospheric pollutants that falls to earth in polluted rain or snow and contaminates waterbodies.

There are six major types of water pollutants:

*Biodegradable wastes

*Plant nutrients

*Heat

*Sediments

*Hazardous and toxic chemicals

*Radioactive wastes

Biodegradable wastes include human and animal wastes, food scraps, and other types of organic materials. Biodegradable wastes can cause water pollution by providing nutrients for bacteria. If there are excessive nutrients, aerobic (oxygen-consuming) bacteria multiply too rapidly, consuming the oxygen in a stream and making it uninhabitable for some species of fish and other aquatic life. In fact, if the bacteria grow too fast, they consume enough oxygen so that virtually everything in the water dies, leaving only anaerobic bacteria (bacteria that do not require oxygen to live) that create foul smelling gases.

Biodegradable wastes can also cause water pollution by spreading disease-causing bacteria. This type of pollution was the cause of typhoid fever and cholera epidemics that led to the development of public water treatment systems.

Many of the **nutrients** used to bring the earth to life can Aoverfeed@ a waterway to death. Sources of

nutrient pollution are sewage and septic runoff, livestock waste, fertilizer runoff, detergents, and industrial wastes. Some of these are point source causes, while others are nonpoint source.

Nutrients like phosphates and nitrates stimulate plant growth, and are primary ingredients in fertilizers. These compounds occur naturally, but in excess quantities they can cause great damage. Approximately 80 percent of nitrates and 75 percent of phosphates added to lakes and streams in the U.S. are the result of human activities.

Natural nitrates and phosphates usually are **limiting factors** in the growth of plant life. In other words, they occur in limited amounts that help govern the growth of different organisms and keep nature in balance. But when excess amounts of these nutrients are introduced into a waterway, some plant species can experience explosive growth, literally choking off other life forms.

When soluble inorganic nitrogen concentrations in water reach just 0.3 parts per million and inorganic phosphorus concentrations reach 0.01 parts per million, algae Ablooms,@ or multiplies rapidly. The algal blooms can become so severe that an entire lake can be fouled with a green, foul-smelling slime. Clear water can become so cloudy that visibility is restricted to a depth of a foot or less, destroying the aesthetics of the lake.

Once a bloom occurs, its negative effects can multiply rapidly. The green slime can foul up boat propellers and make swimming unpleasant. Nutrients can also cause weeds and other undesirable plants to flourish, increasing the problem. The algal bloom impairs water quality, and if the waterway is a source for municipal water supplies, it can be expensive to remove impurities and odors. Masses of algae can wash up on shore, decaying and producing hydrogen sulfide gas, which smells like rotten eggs. Certain marine algae can also release toxics that concentrate in fish and shellfish which cause human digestive problems. In fact, in some areas it is dangerous to eat foods like oysters at certain times of the year because of "red tide," a phenomenon caused by a marine algal bloom.

When an algal bloom clouds water, it can block sunlight from other plants and aquatic life, killing them or limiting their growth. And as the algae die, the bacteria which feed on them can deplete oxygen levels in the water to the point where it cannot support other life forms. This condition leads to **eutrophication.** Eutrophication is a naturally-occurring process of changes that take place after a waterbody receives inputs of nutrients, mostly nitrates and phosphates from erosion and runoff of surrounding lands. Usually this process occurs slowly over millions of years. Human activities can accelerate this process and the results can be very serious. Eutrophication caused Lake Erie to Aage@ nearly 15,000 years between 1950 and 1975.

Heat, or **thermal pollution**, can be a deadly water pollutant. An important relationship exists between the amount of dissolved oxygen in water and its temperature. The warmer the water, the less dissolved oxygen. Thermal pollution can be natural, such as in hot springs or shallow ponds during summer months, or it can be human-made, when water used to cool power plants or other industrial equipment is discharged back into streams. The amount of oxygen in water affects the life it can support. Some sport fish, such as trout, need cold water with high levels of dissolved oxygen and cannot live in warm water. Other nongame fish like carp and suckers thrive in warm water and can take over habitats from other fish if waters become too warm. This can result in greatly reduced diversity of fish species important for the environmental health of the stream.

Thermal pollution has been such a problem that most states have passed laws requiring power plants and industries to cool water before releasing it back into streams.

Sediment is one of our most destructive water pollutants. America=s water is polluted by more than one **billion** tons of sediment annually. Every day, Americans lose about one million dollars because of sediment pollution.
Sediment is mineral or organic solid matter that is washed or blown from land into lakes, rivers, or

streams. It can be point source or nonpoint source pollution. Typically, it comes from nonpoint source causes. Sources of sediment pollution include construction, row cropping, livestock operations, logging, flooding, and runoff from city streets, parking lots, and buildings. Sediment by itself can be a dangerous pollutant, but it is also considered serious because other contaminants such as heavy metals and toxic chemicals can be transported with it.

The effects of sediment pollution can be devastating. It can clog municipal water systems. Lakes or reservoirs can receive so much sediment that they actually fill in. Sediment can turn a deep lake into a shallow wetland area over time. Fine sediment can blanket the bottoms of lakes and rivers, smothering aquatic life such as fish eggs and insects and damaging fish gills. This can disrupt the entire food chain, and cause great damage to an ecosystem. Sediment can also be detrimental before it settles, while it is still suspended in water. It can make water cloudy, or turbid. High turbidity makes water aesthetically unpleasant and can destroy recreational opportunities. Some species of fish, such as smallmouth bass, will not thrive in a highly turbid aquatic environment, and studies indicate that high turbidity decreases fishing success.

Sediment in water can also create thermal pollution problems. Sediment darkens water, and allows it to absorb more solar radiation. This raises water temperatures to the point where it may not support some forms of life. At the same time, sediment blocks light from reaching aquatic plant life, slowing or stopping plant growth. And since plants add oxygen to water, oxygen levels can be reduced to the point that fish kills can occur.

This type of damage to the ecosystem is cumulative. As plants and fish die, the waterway loses its ability to break down wastes and materials that are naturally washed into it. These materials begin to accumulate and form another source of pollution.

Chemical pollution is usually human-made. Modern nations rely on thousands of organic and inorganic chemicals in industry, agriculture, and the home. These materials provide many benefits, and new chemical compounds are constantly being developed to improve existing processes.

But with modern chemicals come modern pollution problems. Improperly used or disposed of, reasonably safe chemical compounds cause toxic reactions. The effects of such toxics can be short term or long term and are regarded as a major national and international health concern.

Toxic water pollution is most often linked to point source causes, such as improperly treated industrial discharges or accidents in transportation (such as oil spills). But it can also come from nonpoint source causes. These include runoff from both urban and rural areas, and atmospheric transport.

Hard-surfaced roads and parking lots and urban areas collect toxics such as lead, oil, cadmium (from tires) and other pollutants, which can be washed into streams through storm drains. These materials can cause immediate toxic effects as well as long-term effects by accumulating in sediment or in living organisms. In the 1970s, many people suffered severe health problems from eating swordfish and tuna containing high levels of mercury, which accumulated in the fish over a long period of time. In agricultural areas, pesticides containing toxic compounds are applied to crops to improve crop quality and increase yields. Their proper use has helped eliminate hunger in many parts of the world. But improper application of pesticides can create serious water pollution problems, because runoff from fields can introduce large amounts of toxics into waterways. Pesticides can also cause groundwater contamination. Techniques of integrated pest management that involve a combination of biological control (natural predators) and reduced application of pesticides can help eliminate some of the potential problems of excessive pesticide application.

The cost of disposing of toxic chemicals created by industry is high. Federal and state laws require careful monitoring of industrial processes and specific storage and disposal procedures of these materials. This cost has caused some unscrupulous people to illegally dispose of toxic chemicals, a process called Amidnight dumping.@ Pollution from this source may go undetected for years, and when discovered, it can be very difficult to determine the source. Legislation adopted since the late 1970s has imposed large fines and jail sentences for people caught illegally dumping toxic wastes.

Another, perhaps surprising, source of toxic water pollution comes from individuals. Household chemicals such as cleaners, dyes, paints, pesticides, and solvents are a large source of toxic water pollution, particularly in urban areas. Many of these materials are simply poured down drains or flushed down toilets with no regard to their consequences. And while the toxic chemicals from one household may not seem like much, they can cause problems. In fact, a single quart of used motor oil can pollute a quarter of a million gallons of water. And homeowners may use ten times the amount of pesticides per acre as farmers do. The amount of toxics released by an entire cityCone person at a timeCcan be staggering. EPA and other agencies have published educational materials to explain ways to properly apply and dispose of pesticides. (See AA Citizen=s Guide to Pesticides,@ U.S. EPA, Office of Pesticides and Toxic Substances, 3rd Edition, OPA 008-89, Washington, D.C., 1989.)

Radioactive pollution can be human-made or natural. It can come from wastewater discharges from factories, hospitals or uranium mines, or it can come from naturally-occurring radioactive isotopes in water like radon. Radiation accumulates in the body, and children are more sensitive to the effects of radiation than adults. Radiation can cause cancer, and in high concentrations, death.

Facilities that use radioactive materials are highly regulated and carefully monitored to prevent pollution. However, one of the potential problems of radiation pollution is stored radioactive wastes. Tons of waste have accumulated over the years, and the waste will remain dangerous for centuries. Unless suitable storage methods are found, these wastes could pollute groundwater or streams through improper storage. Work continues to create ways to safely dispose of radioactive wastes.

WATER CONTAMINATION (NATURAL DISASTERS)

Water pollution can also come from natural occurrences. Storms can create large amounts of runoff that carry pollutants into water supplies. Fires destroy ground cover and cause sediment pollution. Earthquakes can break sewer lines and cause pollution from human-made sources, or they can even change river courses, destroying some aquatic habitats while creating others. Naturally occurring elements in soils can cause water pollution when they leach into water in concentrations that exceed water quality standards or criteria. For example, desert soils are naturally high in concentrations of salt, boron, and other trace elements. Irrigation can cause these elements to wind up in high concentrations in the water supply, causing pollution that is a danger to crops and wildlife.

WATER POLLUTION PREVENTION

Different pollution sources have different methods of prevention. The fight against **biodegradable wastes and bacterial water pollution** is almost as old as human beings. Epidemic diseases such as cholera killed hundreds of thousands of people before the link to polluted water supplies was established. In third world countries, the lack of clean water still results in critical health problems.

Proper sewage treatment is key to stopping bacterial pollution. Modern municipal sewage treatment plants typically are capable of controlling bacterial pollution, unless storm water loads overwhelm the treatment systems. Private septic systems, however, can be a significant problem. Well-designed and properly operating septic systems will safely treat wastewater, but a failing system can lead to pollution of both ground and surface water. The Environmental Protection Agency reports that many waterborne diseases are caused by old or poorly operating septic systems. Systems should be periodically pumped out and cleaned, with the removed material disposed of properly.

Proper management of livestock and domestic animal wastes can eliminate bacterial pollution problems affecting both humans and animals. Well designed and properly managed animal waste management systems prevent water pollution and use the wastes to fertilize crops and condition soil. Special devices like "pooper-scoopers" are now required in larger cities to collect and dispose of pet waste before it washes into nearby water bodies.

Since many sources of **nutrient pollution** are human-made, they have the potential to be controlled. It has been estimated that fertilizer use has increased more than 15 times since 1945. There is discussion of reducing the use of high phosphate and nitrate fertilizers in areas where nutrient pollution is a problem, even though crop yields would be reduced. Land management practices, such as crop rotation to reduce fertilizer requirements, and biological pest control, are other options.

Homeowners can also adopt more environmentally sound lawn and garden practices. In many places, chemical tests indicate that individuals use 10 to 50 times more fertilizer than necessary for good plant health. Substituting compost as a mulch and fertilizer for gardens and landscaping can eliminate this potential pollution source. Care should also be taken when using fertilizer. (Composting also reduces waste going into landfills.)

Good sewage treatment plants only remove about 50 percent of the nitrogen and 30 percent of the phosphorus from domestic sewage. This still allows an estimated 200 to 500 million pounds of phosphates into waterways every year. The use of lower phosphate detergents has been encouraged to reduce this, along with providing more advanced sewage treatment systems to remove more nutrients before water is released.

Proper management of livestock can reduce nutrient pollution from animal wastes. Catch basins in feedlots can trap nutrient pollution. Federal and local wastewater release regulations govern industrial releases of many materials that could contribute to nutrient pollution.

Heat or thermal pollution from human-made sources can be controlled by requiring power plants and industry to have cooling towers, holding ponds, and other facilities that allow water to cool before being released back into lakes or streams.

Because many causes of **sediment pollution** are nonpoint source, finding solutions to the problem can be difficult. In some cases, solutions are ongoing activities like dredging sediment deposits and water filtration. Over 2 trillion gallons of drinking water are filtered annually to remove silt.

Many causes of sediment water pollution can be reduced or eliminated through proper land management, particularly for activities that create erosion, such as agriculture, construction, mining, or logging. Farming accounts for the largest amounts of sediment pollution. However, careful land management can cut erosion and sediment problems dramatically.

Bare earth erodes quickly, since there is no plant cover to protect soil from rainfall or wind. Construction sites and strip mined areas can lose soil to erosion at a rate up to 70 tons per acre per yearCfifteen times higher than the normal rate from croplands. Many federal and local laws require construction and mining companies to reclaim land instead of leaving it bare to the ravages of erosionCand subsequent sediment pollution. In some cases, certain harmful land use practices have been eliminated completely.

Since sediment pollution is often caused by nonpoint sources, new ways of identifying sources have been created. Aerial photography is now being used to determine land use in specific areas, identify drainage patterns, and erosion rates. Information can be quickly gathered in this manner and steps taken to reduce problems.

Better livestock management practices have also been used to reduce sediment pollution from livestock runoff. Runoff is channeled into lagoons, where sediment settles before water is released into streams. The nutrient-rich sediment is then used to fertilize croplands. And proper management of croplands and logging areas can reduce runoff, improving crop yields and making reforestation easier.

Increased concerns over **chemical pollution** have created strict regulations for most companies, ranging from large plants to small businesses such as dry cleaners, which use potentially toxic solvents. Since the effects of some toxics have not yet been determined, it is expected that even more regulations will be created in the future to limit the material that can be released into the nation=s waterways. The introduction of many new chemicals for industrial, mechanical, and other uses presents difficult challenges in determining their safety and impact on the environment. This creates a major challenge for industry to keep up with changing regulations and develop ways to meet new requirements.

Control of air emissions that cause acid precipitation are critical to eliminating this pollution problem. Burning of fossil fuels like coal, oil, and gasoline are prime contributors. The use of non-polluting methods of electric generation, such as hydroelectric, thermal, and solar, can help, as can making sure automobiles are adequately tuned, tires are properly inflated, and pollution control devices are working. Reformulated gasoline is also designed to reduce these emissions.

Solid wastes buried in landfills can cause pollution problems if harmful leachate percolates into aquifers and contaminates groundwater supplies. Newer landfills are being constructed with double liners and monitoring wells to prevent leachate from reaching groundwater supplies and detect leaks before they become a problem. Solving past problems will take research and work. One way to reduce this dilemma is to reduce the amount of waste going into landfills through recycling and by using products with less packaging and discardable materials.

RIPARIAN AREAS

Riparian areas are the green zones along the banks of rivers and streams. These are some of the most productive ecosystems in nature, and display a wide diversity of plant and animal life. In the south, Abottom lands@ are an example of riparian areas. These areas are important for flood storage, water quality, cover and shade for plants and animals.

Because of their value, rights to riparian lands are a subject of great interest, especially on public lands. Federal and state agencies have created a variety of land management programs designed to protect public riparian lands. These include leaving vegetation strips along fish bearing streams to prevent stream erosion and maintain habitats. Livestock may be prohibited from riparian lands during summer months to keep them from Acamping@ at the water=s edge and destroying vegetation or causing animal waste pollution. In some areas, beavers have been introduced into ecosystems to provide Anatural engineering@ to rehabilitate eroding streams. Land uses around riparian areas must be taken into account.

BEST MANAGEMENT PRACTICES

Not all water pollution can be avoided. Some manufacturing processes, farming, and other activities create pollutants that can contaminate water. In cases where water pollution is expected to happen, companies and individuals can use **best management practices** to control pollutants and keep them from causing damage to water supplies.

Examples of best management practices include the agricultural practice of collecting animal wastes in a lagoon to settle before discharging wastewater into streams. It may also mean waiting until certain times to spray pesticides or apply fertilizers to prevent runoff. Best management practices can mean taking water quality into account when planning a housing development or new factory, or it may mean controlling wastewater discharges and storm water discharges in conjunction with stream flow. Best management practices may mean planning wastewater treatment for a mine in advance of mining operations. Operators of saw mills can reduce pollution by storing their materials and processing their products indoors so they do not come in contact with storm water runoff. Airport employees can reduce storm water runoff pollution by using deicing chemicals only in designated collection areas and by cleaning oil and grease spills from pavement immediately. Best management practices are designed to keep any unavoidable water pollution in as much control as possible.

INDIVIDUAL ACTIONS

Individual actions can also have a big impact on pollution problems. One very effective way to reduce water pollution is to simply reduce water consumption. This can be done by changing a few habits. For example, put a bottle of water in the refrigerator rather than letting water run from the tap until it gets cold. Wash full loads. Turn off the water while brushing your teeth. Take shorter showers. Install low flow showerheads and toilets, faucet aerators, and/or toilet dams. Wash the car using buckets of water instead of a hose. And finally, water plants in early morning or late evening only when they really need it. Better yet, choose plants which require less watering. Other ways to reduce water pollution are to keep litter, pet wastes, and debris out of street gutters and storm drains as they flow directly to waterbodies. Apply lawn and garden chemicals sparingly according to package directions. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds. The use of herbicides should also be avoided.

Virtually every liquid in an automobile is a serious pollutant, and care should be taken to avoid spilling oil, antifreeze, or other fluids from automobiles. In some cases, it may be more ecologically sound to have repairs done by a reputable garage than to attempt messy do-it-yourself work (especially if a community does not have proper disposal centers). Dispose of used oil and antifreeze properly by taking them to a local service station or recycling center.

Household cleaners can add toxics or nutrients to water. In most cases, harsh chemicals are not necessary to do an effective cleaning job, and less damaging substances can be substituted. Baking soda can be used as a scouring powder and water softener to increase the cleaning power of soap. Soap biodegrades safely without adding phosphates or dyes to water like many detergents. Borax cleans, deodorizes, and disinfects. An all-purpose cleaner made of a teaspoon of liquid soap, two teaspoons of borax and a teaspoon of vinegar in a quart of water is an effective grease cutter. A quarter cup of baking soda followed by a half cup of vinegar makes a good drain cleaner. Consumers should also take care in disposing of potentially dangerous household chemicals like batteries, nail polish, drain cleaner, and paint. Do not dispose of any unused portions of these items down drains, toilets, or storm sewers. Many communities offer regular hazardous waste pickups to collect these items. If your community doesn't have one, ask your local government to establish one. The EPA Resource Conservation and Recovery Act hotline (1-800-424-9346) can supply more information.

Citizens can also become more politically involved. For example, encourage local government officials to enforce construction/sediment ordinances in your community or encourage city officials to use sand instead of salt to deice roads. Participate in public meetings to plan water policy. Organize litter clean-up campaigns and hold local fairs to educate your community about water resource issues.

WATER QUALITY LEGISLATION

Laws involving water quality date back as far as 1914. The first Federal law dealing exclusively with water quality was the Water Pollution Control Act, passed in 1948. Under this law, the states retained primary responsibility for water quality standards and maintenance. The Federal government supplied money primarily for research. There were no water quality standards established, and the law provided only weak punishments for offenders. During the 1960s, amendments provided for water quality standards for interstate waterways, Federally approved state standards, and increased funding for research. However, as water pollution increased in many areas of the country, public concern resulted in passage of two more very important environmental laws.

The National Environmental Policy Act of 1969 (NEPA) required federal agencies to consider the environmental impacts of their actions. All federal agencies must prepare environmental impact statements to assess the impacts of major federal actions, such as large building or industrial projects. Because of NEPA, federal undertakings have been conducted in a manner to ensure protection of all natural resources, including water.

The Federal Water Pollution Control Act (Clean Water Act) which was passed in 1972 and amended in 1977, 1981, and 1987, provides the basis for water quality standards today. The Clean Water Act allowed the Federal government to assume a lead role in cleaning up the nation=s waterways. National goals for pollution elimination were set, and the National Pollution Discharge Elimination System (NPDES) was established. The NPDES permitting system made pollution discharge without a permit illegal. Generators of pollution to surface waters (sources) must apply for NPDES permits, which are issued by EPA or EPA-approved state agencies. The limits on what the generators may release vary from small amounts (for suspended biodegradable organic material and solids) to none allowed (for some toxics). The stringency of the requirement is greatest for the most dangerous water pollutants. The public is invited to participate in the permit issuance process through public notice of proposed permits, and opportunity to comment or request a public hearing.

The Clean Water Act also established four national policies for water quality:

1. Prohibit the discharge of toxic pollutants in toxic amounts

2. Assist publicly owned treatment works with Federal grants and loans

3. Support area-wide waste treatment planning at Federal expense

4. Create a major research and development program for treatment technology

Future amendments to the Clean Water Act are likely to make ecosystem protection as important as providing potable water for human use. Amendments are also likely to establish water quality standards for lakes and to focus more specifically on preventing storm water nonpoint source pollution.

Other federal laws that deal with water quality are the Safe Drinking Water Act & Amendments of 1986 and 1996, the Toxic Substances Control Act of 1976, the Resource Conservation and Recovery Act of 1976, the Surface Mining Control and Reclamation Act of 1977, and the Rivers and Harbors Act of 1899.

WASTEWATER TREATMENT

Wastewater is water that has been spent or used in a domestic waste, agricultural, or industrial process. After water is used, it must often be treated to avoid polluting another body of water. Almost any use adds contaminants to water that must be removed before it can be returned to the environment.

WASTEWATER TREATMENT PROCESS

Wastewater treatment is designed to kill dangerous bacteria and reduce or remove chemicals and solids before water is returned to lakes and streams or groundwater.

Wastewater treatment may be a simple process or it may be complex, depending on how many pollutants are added to water during use. Water from a household may require minimal treatment before it can be returned to natural bodies of water, while industrial wastewater may need several processes before it is safe to release. Municipal and home treatment systems have been in use for years to prevent health risks from wastewater. Laws enacted in the 1960s, 70s, and 80s began placing more stringent controls on water released from industrial plants to reduce pollution from these wastewater sources. Since this water quality Awake-up call,@ anti-pollution laws have progressively become more strict about protecting water quality.

Most municipalities with wastewater treatment systems are required to have two stages of treatment. In the primary treatment stage, screens and settling tanks remove most of the solids in the water. Solids make up about 35 percent of the pollutants in wastewater. In the secondary treatment stage, bacteria are used to digest the remaining pollutants in the water. The activated sludge process mixes microorganisms and oxygen with wastewater to speed up the digestion process. A trickling filter process allows the wastewater to trickle down through a layer of rock and gravel covered with bacteria that break down pollutants. Large settling tanks then allow most of the remaining solid material to settle out, and some systems will run the water through sand filters to further cleanse it. Finally, the water is disinfected with chlorine, ozone, or ultraviolet light and discharged. By the time it is discharged, about 85 percent of the biochemical oxygen demand (BOD) and total suspended solids (TSS) should be removed from the wastewater. The solids remaining in the treatment plant are rich in nutrients and can often be used on farm and forest lands as fertilizer.

In some cases, tertiary (advanced) treatment of wastewater is done. This is a third stage of treatment that is designed to remove more of the impurities from wastewater. This step may involve filtering the wastewater through carbon or sand filters to remove solids or even allowing the water to flow into a natural or constructed wetland area to purify it further.

In 1988, the wastewater from more than 144 million people received secondary or more advanced levels of wastewater treatment. More than 23 million households had on-site disposal systems such as septic tanks.

MICROBIAL DIGESTION OF WASTES IN WASTEWATER

Microorganisms need nutrients to survive, and they can process the nutrients in wastewater, providing a very effective method of treatment. Anaerobic bacteria break down waste materials without oxygen or aeration. Aerobic bacteria break down waste material with oxygen. Both types reduce concentration of nutrients, making it safe to dispose of wastewater. Aerobic bacteria break down wastes without as much odor, but require more surface area (for aeration) than do processes using anaerobic bacteria. Both types of bacteria are usually present in wastewater treatment systems.

BIOSOLIDS

The solids recovered during wastewater treatment are not worthless; in fact, they can be used as high quality fertilizers in many cases. Wastewater solids that meet government criteria for beneficial use are called biosolids. The nutrient rich biosolids can be spread on croplands.

Biosolids must be treated before use. Primary sludge is combined with microorganisms for partial digestion, and then it is thickened by using centrifugal force, gravity, or pressure to remove water. It is then collected and transported to the site of disposal or spreading.

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM (NPDES)

The single most important provision of the Clean Water Act is the National Pollutant Discharge Elimination System (NPDES). The Clean Water Act requires that each source of water pollutionCcities, factories, power plants, animal feedlots, and so onCtreat their wastewater as necessary to meet effluent discharge limits and performance standards set by the EPA or EPA before releasing the wastewater to streams or lakes. Generators of pollution (sources) must apply for NPDES permits, which are issued by EPA or EPA-approved state agencies. The limits on what the generators may release vary from small amounts (for suspended solids) to none allowed (for some toxics). The stringency of the requirement is greatest for the most dangerous water pollutants. Each pollution source is evaluated separately, and it may take a number of years for a permit to be issued, depending on what is to be discharged.

NPDES also makes it illegal to discharge pollutants without a permit, and sets civil and criminal penalties for violations. Criminal penalties can include fines of up to $100,000 per day of violation and imprisonment of up to 30 years for repeat offenders. Civil fines can be up to $25,000 per day per violation.

ALTERNATIVE WASTEWATER TREATMENT METHODS

Smaller communities may have different approaches to wastewater treatment. Some communities, hotel complexes, or apartment buildings use package plants to process wastes. These prefabricated units utilize procedures similar to those used by as full-scale plants. Lagoons are another form of treatment. Lagoons allow solid wastes to settle, and then rely on a biological interaction of sunlight, algae, and oxygen to clean wastewater.

CONSTRUCTED WETLANDS TO TREAT WASTEWATER

In some cases, constructed wetlands can be used to treat wastewater. They can be used to treat domestic, agricultural, industrial and mining wastewaters. They generally cost less than conventional wastewater treatment systems and operating costs are very low. They are also more aesthetically pleasing than wastewater plants and attract desirable wildlife.

Wastewater to be treated flows into a constructed cell that has been lined to prevent leaks and assure adequate water for wetland plants. Flow is distributed evenly across the cell. Plants such as cattails, phragmites, and bulrushes are planted in the cell, and their roots produce a dense mat of materials through which the wastewater circulates. Chemical, biological, and physical processes filter out contaminants from the wastewater. A second cell may be added for more treatment. It may be unlined to allow water to filter and can contain attractive wetland plants like irises, elephant ears, and arrowheads. Plants transpire water into the atmosphere and provide oxygen for bacteria and other organisms to break down biodegradable wastes.

Wetlands may or may not discharge treated waters into surface waters, depending on their size, design, and local site conditions.

RAPID INFILTRATION

Rapid infiltration is a wastewater treatment method that can be used in areas where solid permeability is moderate to high. A basin area can be flooded with appropriately pre-treated wastewater and allowed to infiltrate into the ground. The ground then filters the wastewater as it infiltrates into the groundwater or into the local surface waters. After a basin is filled, it is allowed to drain and dry, which restores aerobic soil conditions and helps treat the wastewater as it infiltrates.

OVERLAND FLOW

Overland flow is a process where water is allowed to flow down a sloped surface, usually planted with thick grasses. Soils are nearly impermeable, which forces the water to flow through the vegetation, where physical, chemical, and biological processes treat it. It is then collected into runoff channels and discharged.

SLOW RATE IRRIGATION/SILVICULTURE

These two processes are related in that in both, wastewater is used to irrigate land and is used to treat wastewater. Slow rate irrigation allows wastewater to flow onto land parcels at a rate that doesn't overburden the land's ability to allow the water to infiltrate and process impurities. Silviculture is the practice of using large areas of land as a treatment site for wastewater and planting the land with crops or trees that will flourish during the treatment. Both processes are based on ancient ideas and practices of wastewater treatment that have proven themselves for centuries.

AQUACULTURE

Aquaculture is the practice of using aquatic plant and animal species to treat wastewater, similar to the use of wetlands for this purpose. An aquaculture area might be constructed with a number of ponds for different levels of wastewater treatment. Each pond contains specific plant and animal life for wastewater treatment, and wastewater may be allowed to flow from one pond to another as it is being treated. Plant life may be harvested or maintained in the ponds to maximize system performance. Aquaculture systems have been able to remove impurities such as heavy metals from wastewater.

SEPTIC TANKS AND SEPTIC SYSTEM ALTERNATIVES

Septic systems are the wastewater treatment method for most Americans in rural areas. Septic systems typically consist of an underground **septic tank** that collects wastewater from a home. Solids from wastewater are allowed to settle in the tank, and bacteria in the tank digest some of the heavier solids and household grease and oils. During the decomposition, gas is produced and usually vented through a pipe in the roof of the home. The partially treated water, or effluent, flows out of the tank into a **distribution box** where it is channeled into a series of perforated pipes or open tile. Water percolates out of the pipes into the system=s **drainfield**, where it is filtered and treated by organisms in the soil. Eventually, treated wastewater returns to the groundwater supply.

Well operating septic systems will safely treat wastewater, but a failing system can lead to pollution of both ground and surface water. The Environmental Protection Agency reports that many waterborne diseases are caused by old or poorly designed septic systems. Systems should be periodically pumped out and cleaned, with the removed material disposed of properly. To avoid septic system problems, systems should be regularly inspected and solids pumped out when necessary. Avoid putting solids such as coffee grounds, disposable diapers, cigarette butts, plastics, and other bulky wastes into the septic system. Pouring liquid fats and grease down the kitchen sink can cause problems as these wastes solidify and block the system=s operation. Use of a kitchen sink garbage disposal should also be avoided unless the septic system has been designed to accommodate extra wastes. A garbage disposal can increase loads on the system by as much as 50 percent. Keep toxic and hazardous chemicals like paint thinner, petroleum products, and pesticides out of the septic system. Systems don=t break down these materials, and pouring them into a septic system is like pouring them directly into the groundwater supply.

Alternatives to septic systems may be used when soil does not readily allow systems to work or there are too many households in an area to provide adequate septic fields. Alternatives to septic fields are also used as ways to conserve water. Some systems separate **blackwater** (water predominantly from toilets or associated with human waste) from **graywater** (water from showers, dishwashers, etc.). Blackwater requires more treatment, while graywater may need only minimal treatment before it can be used for other household purposes, such as watering the lawn. Other alternatives to septic systems include devices such as incinerating, chemical, or composting toilets, which process wastes before they are released; and holding tanks that are regularly pumped out instead of processed on site. Water conservation methods like low-flow faucets and shower heads, energy efficient appliances, and other products also reduce septic system loads.

COMMERCIAL/INDUSTRIAL WASTEWATER TREATMENT

Wastewater treatment for industrial plants may be more complex than that for residential areas due to hazardous pollutants added to wastewater during manufacturing. Many plants have invested millions of dollars into their own wastewater treatment facilities. Even small businesses such as dry cleaners, gas stations, restaurants, and photo labs may have specialized treatment processes to clean wastewater. For example, a photo lab may have an electroplating system to remove silver from wastewater. The silver can then be processed and sold back to photographic film companies for use in making new film.

INDUSTRIAL WASTEWATER TREATMENT METHODS

Public wastewater treatment plants were not designed for industrial wastes, especially toxic substances. Toxic wastes from industrial plants can actually damage public systems by killing useful bacteria. So modern industrial plants separate their wastewater into several categories for treatment:

*Wastewater that can be treated and reused within the plant

*Wastewater that can be treated in a wastewater treatment plant designed to accommodate the needs of industry

*Wastewater that can be sent to public treatment facilities, either directly or after treatment at the industrial site

*Wastewater that is so toxic that it must be treated on site or disposed of as hazardous waste

New techniques for treating industrial wastewater are continually being developed. These can include chemical reactions to remove hazardous materials from the wastewater. New processes even use ultraviolet radiation to kill microorganisms or break down chemicals into more common biodegradables.

MINING WASTEWATER TREATMENT METHODS

Mining is an industry that can create severe water pollution problems from sediment, chemicals, metals, and acids. Federal law now requires mines to treat wastewater before releasing it into waterways. Since most mine sites are remote, lagoons are a common form of treatment. Lagoons (which must be lined to prevent groundwater pollution) allow sediment to settle out, eliminating a major water contaminant, and depending on the type of mining, other water treatment processes can be applied as necessary. These may include adding lime to reduce acidity, removing heavy metals, or skimming off oils or petroleum wastes. Constructed wetlands have also been used to treat mining wastewater.

OTHER WASTEWATER TREATMENT ISSUES

RECLAMATION AND REUSE OF WASTEWATER

For industry and municipalities, water use efficiency means cost efficiency. Wastewater treatment is expensive, so most industries analyze water use as carefully as they do any other raw material. Many industrial plants have wastewater treatment plants to treat wastes that can't be handled by public treatment plants, but they may also treat wastewater for reuse instead of paying for additional water or discharge. Efficient uses of reclaimed water in industry can be for heating or cooling, irrigation, or materials processing. Many municipalities also reclaim wastewater with calcium, fluoride, and argon for other uses.

STORM WATER TREATMENT

Storm water runoff can be a serious wastewater treatment problem because large amounts of runoff can overload wastewater treatment systems and cause untreated water to be released into streams. Another problem with storm water runoff is chemical contamination from industrial sources or simply from the greases and oils it picks up when flowing across parking lots and roadways. The debris, chemicals, and other pollutants in the storm water runoff may be deposited, untreated, into our waterways. The result can be the closing of beaches; no swimming, fishing, or boating; and injury to the plants and animals that live in or use the water.

Provisions of the Clean Water Act Amendments of 1987 are designed to reduce pollution from storm water. These amendments require certain industries and municipalities, with populations exceeding 100,000, to have permits for storm water runoff and to prepare and implement storm water pollution prevention plans. Such plans describe how they will prevent storm water from becoming polluted in the first place. Making sure that potential pollutants are not left outside uncovered, cleaning up spills right away, and planting grass and other vegetation as quickly as possible after soils are disturbed can all be part of a storm water pollution prevention plan.

DRINKING WATER

WATER SUPPLY

The world=s supply of water is 326 million cubic miles. If it were poured on the United States, it would submerge the country to a depth of 90 miles. But only a small portion of the world=s water supply is usable fresh water. In fact, of the Earth=s total water supply, less than one-half of one percent is usable fresh water. Only 0.03 percent is surface water. Of every 10,000 gallons of water on Earth, fewer than 50 are potentially usable fresh water; only 3 gallons are found in surface water bodies such as rivers, lakes, and streams.

The United States is water Arich.@ We have 39,400,000 acres of lakes and reservoirs, and over 35,000 square miles of estuaries. The Great Lakes cover 98,000 square miles and contain about 1/5th of the world=s fresh water supply. About four percent of the U.S. land mass is covered by surface water.

The United States has nearly 60,000 community water supply systems, but only 20 percent of these systems use surface water as their primary source. Groundwater is the primary source of water for 80 percent of U.S. communitiesCnearly half of the entire U.S. population.

INTRODUCTION TO DRINKING WATER

Water is vital for life. Our bodies are approximately 75 percent water. Water makes up 83 percent of our blood, transports body wastes, lubricates body joints, keeps our temperature stable, and is a part of every living cell in our bodies. On the average, every American uses about 150 gallons of water a day. With a 1996 U.S. population of approximately 260 million, that makes daily water consumption in the United States over 39 **billion** gallons per day. It=s no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies. One aqueduct in California is over 450 miles long and transports water from its source to Los Angeles where it is needed.

DRINKING WATER STANDARDS

In 1974, Congress passed the Safe Drinking Water Act (SDWA), setting up a regulatory program among local, state, and federal agencies to help ensure safe drinking water in the United States. The Safe Drinking Water Act states that public water systems must provide water treatment, monitor drinking water to ensure proper quality, and provide public notification of contaminant problems. Regulations implementing the act established drinking water standards (maximum contaminant levels and treatment technique requirements) for a variety of chemicals, metals, and pathogens. Amendments continue to strengthen the act and enhance drinking water quality. Significant penalties are imposed for non-compliance.

The SDWA applies to all public water systems, defined as having at least 15 service connections or Aregularly@ serving at least 25 individuals. States are required to enact their own drinking water regulations that are at least as stringent as Federal standards. SDWA protects drinking water supplies through required treatment, testing, and reporting. The SDWA established a permitting program for underground injection wells. It also requires protection of aquifers and groundwater and surface water sources for drinking water supplies.
The SDWA requires that **maximum contaminant levels** or **treatment technique requirements** be

established for specific inorganic chemical, organic chemicals, bacteria, and radioactive elements. SDWA also sets **secondary (non-enforceable) standards** for parameters that affect aesthetic qualities relating to public acceptance of drinking water. These include color, corrosivity, foaming agents, odor, and metals. EPA is continually in the process of selecting new contaminants for which to establish **drinking water standards.**

RESERVOIRS FOR SUPPLY/DAM CONSTRUCTION ON STREAMS - TVA

Reservoirs from dams serve a variety of water needs. They provide ways of storing large supplies of water for industrial and residential use. They control floods and other natural disasters that can cause water pollution. They generate power and provide sources for recreation. While creating dams removes certain types of habitats, it also creates new habitats which support thousands of species of wildlife.

Since 1933, the Tennessee Valley Authority has been charged with developing and managing water resources in the Tennessee Valley. This has meant constructing more than 30 dams, including the largest dams east of the Mississippi River. TVA has also assumed management of a number of dams already constructed in the area before the agency came into existence.

TVA=s role in protecting and improving water quality differs from that of any other federal, state, or local water quality program. TVA monitors water quality to identify problems and detect changes. TVA research programs study the relationships among water quality and land use, wastewater treatment, stream flow, and other factors. Reservoir water quality management plans identify better ways to protect and use the Valley=s water resources. Monitoring for problems and changes, working with others to correct identified problems, demonstrating new solutions, and planning to prevent pollution are cornerstones of TVA=s approach to water quality management.

DRINKING WATER TREATMENT

Water is in its purest form the moment it condenses from vapor into a liquid, but it quickly picks up impurities. Rain or snow can pick up dust, smoke, and other particles in the air. Runoff water dissolves minerals and carries small particles of soil. Streams can carry sediment, human-made pollutants and other materials. Once water is used by humans, it picks up even more pollutants and impurities before it is returned to nature. The need for a supply of clean water required water treatment methods to be developed, so that it can be safely used.

Since very early times, people have created ways to remove debris from drinking water to make it look and taste better. Ancient Egyptian inscriptions describe water purification by boiling, exposure to sunlight, charcoal filtration, and settling in an earthen jar. The Chinese were the first to discover the purifying effect of boiling water, and as early as 400 B.C., Hippocrates, the father of medicine, recommended boiling water and straining it through cloth to remove particles.

However, it wasn=t until the 1850s that scientists suspected that disease could be spread through water. The rise of microbiology identified a number of diseases that were transmitted by water supplies, and the first attempts were made to disinfect drinking water by using chlorine. Around the turn of the century, Middlekerke, Belgium became the first city to install a permanent chlorine disinfection system. Chlorination was first used in the United States in 1908 to destroy bacteria in drinking water. The widespread use of chlorination wiped out waterborne diseases such as typhoid and cholera.

Obviously, water used for drinking requires more treatment than wastewater, which is returned to a lake or stream. But the two can have an impact on each other. The extent to which drinking water must be treated depends on the quality of the raw water supply, so a community downstream from other cities may find its water quality affected by the wastewater released by those cities.

Drinking water from a well may require little or no treatment before it is used. Water from a lake exposed to recreational activities or sewage contamination may need significant treatment before it can be used as drinking water. The Safe Drinking Water Act requires EPA to establish national drinking water standards and implement source water protection to help ensure water quality.

Conventional water treatment for drinking water consists of the following steps:

*Water is pumped from the water source, such as a lake, river, or reservoir and is strained to keep fish and large objects out of the system.

*Alum or other materials are added to the water to cause the dirt and other particles to coagulate, or clump together and fall to the bottom of settling basins.

*The then-clear water is filtered through layers of sand, charcoal/anthracite, and gravel to remove more impurities.

*Chlorine is added to kill bacteria remaining in the water. Most water systems add fluoride to help prevent tooth decay. Other chemicals (lime or phosphate) may be added to adjust the pH of the water.

*Finally, the treated water is pumped through pipelines to homes and businesses or it is stored for future use. At various points in the process, water is monitored to make sure it meets the requirements of the Safe Drinking Water Act, which measures some contaminants in concentrations as low as parts per quadrillion.

Public water supply systems in the United States produce more than 34 **billion** gallons of drinking water per day. The United States= more than 60,000 community water supply systems are valued at over $175 billion. The price in a 1990 survey of water in North America was $1.66 per 1000 gallons; however, the average price, in 1996, increased to approximately $2.00 per 1000 gallons.

DRINKING WATER CONTAMINATION

Drinking water can be contaminated from a variety of sources and by a variety of contaminants. Contaminants can come from runoff from precipitation, spills of hazardous chemicals, leaking underground storage tanks, animal wastes, leachate from landfills, excess fertilization of farmland and other sources. Groundwater protection from pollution is especially important since groundwater is a major source of drinking water. Individuals can pollute their own drinking water from wells if they overuse pesticides on their lawns, dump even small amounts of petroleum products, flush household chemicals into a septic field, or fail to keep their septic systems functioning properly.

WELLHEAD CONTAMINATION

Wellhead contamination is the contamination of a well from pollutants that come from around the well itself. Wellhead pollution protection requires the protection of the area around the well from pollutants that could affect the groundwater and therefore, the well water supply. A wellhead protection area (WHPA) can be established for any type of aquifer and can include the well=s cone of depression, recharge area, and surrounding aquifer. A growing number of states and communities are starting to create wellhead protection areas to guard against contamination of well water. These areas may be large or small, depending on the characteristics of the aquifer and the potential hazards that could threaten groundwater. States and communities can apply for wellhead protection grants from EPA and other organizations to protect groundwater supplies.

OTHER ISSUES: DRINKING WATER

DESALINATION

Since sea water makes up over 97 percent of the Earth=s water supply, it is a readily available and plentiful water source. However, because of its salinity, sea water is unsuitable for drinking, and it must be treated before it can be used. Desalination is a relatively expensive process that is principally used in arid and coastal areas where water is so scarce that the process becomes cost effective. One desalination process is simple evaporation, where water vapor from salt water is collected and allowed to recondense as fresh water. Another process is reverse osmosis, in which water is filtered through membranes with holes large enough to allow water molecules to pass through, but small enough to the keep the larger salt molecules from following. The salt can then be collected and used for other purposes.

As water supplies become tighter, desalination becomes more cost effective and more practical to use. Some desalination plants are operating in Southern California to meet the area=s tremendous water demand.

WELLHEAD PROTECTION

Amendments in 1986 to the Safe Drinking Water Act (SDWA) called for wellhead protection programs to identify the land area around wells and wellfields that need protection and to set up measures to protect these areas from contaminants. The SDWA also calls for contingency plans to locate alternate drinking water supplies in the event that a well or wellfield does become contaminated. Under the 1996 Amendments to the SDWA, the wellhead protection concept, was extended to address surface water intakes in what is called **source water protection.**

SDWA applies to public water sources, but individuals who use private wells need to have their own groundwater protection strategies. Such strategies include not dumping household wastes that could pollute groundwater, making sure septic systems are in proper working condition, and avoiding overfertilization of lawns or excessive accumulation of livestock wastes that could damage groundwater supplies.

Federal and state laws protect groundwater supplies. SDWA sets specific goals for implementation of groundwater protection. SDWA requires states to prohibit the use of underground injection wells for waste disposal except by permit. Permit applicants are required to satisfy the state that underground injection would not endanger drinking water sources, and permit holders are required to inspect, monitor, and keep records on injection well use.

LEAD IN PIPES

Lead is a cumulative poison and can interfere with the formation of red blood cells, reduce birth weight, cause premature birth, delay physical and mental development in babies and young children and impair mental abilities in children in general. In adults, lead can increase blood pressure and interfere with hearing. At high levels of exposure, lead can cause anemia, kidney damage, and mental retardation. Health effects from lead generally depend upon total exposure to all sources. Pregnant women are also at risk if exposed to high concentrations of lead. Since lead is a very soft, easy to work with metal, it was often used in pipes before it was determined that lead in pipes could poison human beings. Lead solder was also used to help seal pipes to prevent leaks.

The SDWA amendments of 1986 ban future use of lead pipe and solder in all public drinking water systems because of the possibility of leaching. This provision of the SDWA requires the use of Alead-free@ pipe, solder, and flux in the installation or repair of any public water system or any plumbing in a residential or non-residential facility connected to a public water system. Solders and flux are considered to be lead-free when they contain less than 0.2 percent lead. (Before this ban took effect in 1986, solders used to join water pipes typically contained about 50 percent lead.) The Lead Ban requires that any lead solders carry a warning label indicating that they are not to be used in connection with potable water plumbing. Pipes, pipe fittings, faucets, and other fixtures are considered lead-free under the Lead Ban when they contain less then 8 percent lead. In 1988, SDWA was amended by the Lead Contamination Control Act (LCCA) requiring that a number of activities be conducted by Federal and other parties to identify and correct lead-in-drinking-water problems at schools and day care facilities. One principal activity to be conducted by EPA was the development of a guidance document and testing protocol that could be used by schools to determine the source and degree of lead contamination problems and how to remedy such contamination if found.

At the time the LCCA was passed, considerable attention was being given to water coolers with lead-linked tanks. The law defined these sources as Aimminently hazardous consumer products.@ As a result, the legislation specifically stated requirements to result in the repair, replacement, or recall and refund of these water coolers and attached civil and criminal penalties to the manufacture and sale of any drinking water cooler containing lead.

Lead contamination of tap water is also regulated by EPA=s Lead and Copper Rule. This drinking water regulation requires that: certain **action levels** be met as calculated via measurements taken at customer=s taps; treatment technique requirements be met; and if necessary, public education materials be distributed to customers. EPA also requires that public notification be given to customers of water systems which exceed EPA action levels, to inform them of the harmful effects of lead.

NITRATE CONTAMINATION

Nitrate contamination can make water taste and smell bad and cause algal growth, but except in excessive concentrations, is not dangerous for adults and older children. However, in infants, stomach acids are not strong enough to prevent some forms of bacterial growth. Bacteria can convert benign nitrates into harmful forms that bind with hemoglobin in the blood to prevent oxygen from getting to the rest of the body. The result is methemoglobinemia, which can cause Ablue baby@ symptoms and can be fetal.

Nitrates get into drinking water from fertilizers, animal wastes, malfunctioning septic systems, air deposition to surface water, and normal vegetation decay. The nitrates may reach drinking water by runoff air deposition into surface water, runoff into sinkholes, soil leaching into groundwater, and improperly protected wellhead areas.

WATER CONSERVATION

On the average, every American uses about 150 gallons of water a day. That makes daily water consumption in the United States in 1996, approximately 39 **billion** gallons per day. It=s no wonder that in some highly populated areas, water supplies are getting tight. Some areas, such as Southern California, have water conservation laws in effect to manage limited water supplies.

Of the 150 gallons each of us uses every day only, one half-gallon is used for drinking. The other 149 and a half gallons go for cleaning, cooking, flushing, watering the lawn, washing cars, and other uses. One very effective way to reduce water pollution is to simply reduce water consumption. Wastewater treatment plant operators report that they treat millions of gallons of water that shouldn=t have been used in the first place.

Effective personal water conservation can be done by changing a few habits. A bottle of water in the refrigerator for drinking saves water over letting water run into the sink until it gets cold. Peel fruits and vegetables and **then** rinse them. That can save two gallons every minute. A dishwasher uses less water than washing by handCabout six gallons a load. And washing an entire load of dishesCor clothesCsaves water over washing several partial loads.

New washing machines can reduce water consumption by one third, or more than 400 gallons monthly for a family of four. But the most water use occurs in the bathroom. Simply turning off the water while brushing your teeth could save as much as ten gallons per person per day. Taking a shower instead of a bath can save about 25 gallons, and new low-flow shower heads can reduce consumption even more.

A large percentage of the water used every day is flushed down the toilet. New toilets use less than one-third the water of old models, and older toilets can still work effectively with less water. Devices like toilet dams block part of the water in the tank and reduce the amount used with each flush. If installing a toilet dam sounds too difficult, the same effect can be achieved simply by putting a water-filled plastic bottle in the toilet tank. This displaces water and means that less is used. Don=t use a brick; it can break apart and clog pipes.

Repair leaks immediately. Even a small drip can waste hundreds of gallons of water a dayCand add to the treatment loads of the sewer or septic system. Watering the lawn or garden is more efficient in the early morning or at night when the sun won=t cause as much evaporation. It is best to water lawns and plants early in the morning. Washing the car with a running hose will use more than 100 gallons of water. Using a bucket and sponge cuts that by 90 percent.

XERISCAPING

Xeriscaping is a landscaping program that can help in water conservation. It was developed in 1981 in Colorado in response to prolonged drought. Xeriscape landscaping is a package of seven common-sense steps for making a landscape more water-efficient. These are:

! Planning and design to minimize expense and maintenance.

! Using turf only where needed for functional purposes. Turf alternatives such as mulches and drought-tolerant ground covers are substituted.

! Using drought-tolerant plants and planning placement around sun exposure.

! Using mulches for water retention, long-term fertilization, and weed control.

! Efficient irrigation through grouping plants according to water needs.

! Improving the soil to allow for better absorption of water.

! Maintaining the landscape properly to save maintenance costs.

For more information on xeriscaping, please call the American Water Works Association at 800-559-9855, web site at http:\\www.waterwiser.org, or e:mail bewiser@waterwiser.org.

SURFACE WATER

When runoff from precipitation occurs, it goes downhill, eventually winding up at a point where it gathers, such as a stream, lake, river, pond, wetland, ocean, or reservoir. This is **surface water**, or water you can see.

Surface waters are a major source of the usable water on the planet. Surface waters supply water for drinking, recreation, transportation, crop irrigation, and power generation. Most of our major cities have grown up around large bodies of surface water. More than 80 percent of the Earth=s surface is covered by water, but less than 0.03 percent of all water is found in surface water bodies other than oceans.

The world=s supply of fresh water is 326 million cubic miles. If it were poured on the United States, it would submerge the country to a depth of 90 miles. The United States is water Arich.@ We have 39,400,000 acres of lakes and reservoirs, and over 35,000 square miles of estuaries. The Great Lakes cover 98,000 square miles and contain about 1/5th of the world=s fresh water supply. About four percent of the U.S. land mass is covered by surface water.

Even though the U.S. is water rich this water is not distributed evenly across the country. For example, the western parts of the country contain large desert areas and limited fresh water supplies.

AQUATIC ECOSYSTEMS

Surface water can be broken down into five major categories:

- ! Oceans
- ! Lakes
- ! Rivers and Streams
- ! Estuaries
- ! Wetlands

Oceans cover two-thirds of the earth=s surface. These salt water bodies also contain much of the world=s plant and animal life. The resources of the world=s oceans are vast, and although ocean water is too salty to drink, the plant and animal resources of the ocean are harvested for food and hundreds of other uses.

Lakes are bodies of fresh water contained within a larger land mass. Lakes can be natural or human-made. Lakes are used by humans for many purposes, such as water storage, flood control, recreation, and fisheries. The number of lakes has increased as humans have created them to provide clean, fresh water resources.

Rivers and Streams are created from runoff water and water that previously infiltrated and is now coming up out of the ground and entering the stream as well. Streams, therefore, are made up of two distinct water sourcesCrunoff and groundwater. The fast-moving action of rivers and streams causes the mixing of water and air, which allows oxygen to be dissolved into the water. This process, **aeration**, gives rivers and streams the oxygen levels they need to support wide varieties of life. If oxygen levels drop, then streams can lose their ability to be habitats for many life forms. Rivers are often used to dilute pollution, such as water released from wastewater treatment plants.

Estuaries form where rivers meet oceans. This unique environment serves as a spawning ground or nursery for many animal species. Shellfish are a good example of creatures who thrive in estuaries. Estuaries are rich in commercial fishing and recreational opportunities, but because of their complexity and their location at the end of rivers, they can be seriously affected by deposits of sediment and pollutants. They can also be adversely affected when channel dredging changes the salt/freshwater balance in the estuary. Some estuaries, such as the Chesapeake Bay and Puget Sound, have become seriously polluted.

Wetlands are lands that are periodically covered with water. They may be known as swamps, marshes, bogs, and sloughs. They can be coastal (salt water) or freshwater. The true importance of wetlands is just being realized. Wetlands keep surface waters clean by filtering out sediment and trapping pollutants. Coastal wetlands cushion drier lands from the full impact of storms. They help control floods by temporarily storing runoff waters. They also provide breeding grounds for many of the fish species that make up a $9 billion or more food market.

Wetlands have traditionally been regarded as wastelands, and since colonial times, over half the wetlands in the United States have been destroyed. But new Federal and state regulations are protecting wetlands and regulating the way they are used.

TYPES OF AQUATIC HABITATS

Aquatic habitats are as diverse as the types of surface water. A single stream or body of water may be home to a number of habitats, and during the life of the body of water, habitats may change, due to natural processes or human-made pollution.

The major determinant of aquatic habitats is the amount of dissolved oxygen in water. Cold, fast-running mountain streams that run over rocks and splash down slopes dissolve high amounts of oxygen, making them perfect habitats for fish like trout, which require high levels of oxygen. As waters level out and become more still, they absorb heat from the sun and lose oxygen content. Trout may not be able to survive in them, but other fish like bass and sunfish like crappie and bluegill thrive. If water gets too warm and oxygen content gets lower, then@rough@ fish like carp and suckers move in.

Plant life also thrives around lakes and streams. The immediate area around a waterbody is known as a **riparian** area because it supports so much plant life. Like almost everything else in nature, riparian areas also benefit wildlife and fish populations, providing cover and shade to keep water from getting too warm and losing oxygen content. On public waterways, riparian areas are carefully managed to keep water ecosystems balanced.

Wetland areas have their own unique habitats. They are such complex areas that hundreds of species of plants and animals live there. They are nurseries for many species of animals and provide food to nourish our most productive fishing beds. Over half of all rare and endangered animal species are either located in wetland areas or are dependent on them. About 66 percent of the commercial fish catch taken along the Atlantic and Gulf coasts depend on wetlands for survival.

SURFACE WATER QUALITY STANDARDS

Under the Clean Water Act, water quality standards are based on three key components: an antidegradation statement (stating under what conditions water quality may be lowered), stream use classifications, and water quality criteria, or the degree of water quality needed to support a designated use for a stream. Water quality criteria can include dissolved oxygen content, turbidity, chemical and nutrient contents, and other factors.

Stream use classifications can include:

- Domestic water supply
- Industrial water supply
- Fish and aquatic life
- Recreation
- Irrigation
- Livestock watering
- Wildlife
- Navigation

Streams may be divided into segments with a different set of uses established for each segment. Different uses dictate different levels of water quality.

Criteria used in assessing water quality include:

- Dissolved oxygen
- pH
- Hardness, or mineral content
- Total dissolved solids
- Solids, floating materials and deposits
- Turbidity or color
- Temperature
- Coliforms
- Taste and odor
- Toxic substances
- Other pollutants

Depending on the designated stream use, only certain criteria may be used. To evaluate drinking water quality, all eleven criteria are taken into account, but fewer are used to protect livestock watering and wildlife uses. Individual criterion requirements may also vary with different uses. A trout stream requires 6 mg/l dissolved oxygen on content. For other fisheries, 5 mg/l is sufficient. Allowances may be made down to 3 mg/l based on site-specific conditions and according to designated uses (e.g., for irrigation or livestock watering).

WATER QUALITY MONITORING

Water quality monitoring depends on stream use, land management, and state and federal regulators. Under the Clean Water Act, the owner or operator of a facility covered by a National Pollutant Discharge Elimination System (NPDES) permit is required to monitor effluent or wastewater quality at regular intervals, maintain complete and accurate records, and report the results. Regulators can also monitor water quality at such sites to determine compliance with permit requirements and notify the operator of any violations. Industrial plant operators or land managers may also choose to monitor water quality frequently if changes in quality have an adverse affect on operations or on plant and animal life.

Water quality monitoring measurements can include on-site chemical tests to detect pollutants, laboratory water analysis, observations of plant and animal life in the area, and even catching fish for field or laboratory analysis. Even if other indicators show no problems, changes in fish health may signal a pollutant or ecosystem imbalance that needs to be corrected.

LAND USE AND WATER QUALITY

Land use can have a tremendous effect on water quality. Farmlands can be the source of sediment, fertilizer and animal waste pollution. Forests may not be the source of pollutants, but they can be damaged severely by water pollution. Human activities affecting forests (forestry practices such as clear cutting and road construction that cause erosion and sedimentation) can impact water quality. Cities pose numerous water quality problems due to high water demand, industrial pollutants, nonpoint source pollution, and human wastes.

So it=s important that when we decide to use land for a specific purpose, we take into account water quality, not just in the immediate area, but downstream and upstream as well. This means considering the **amount** of water available as well as how it must be processed before and after use.

For example, crops require tremendous amounts of water. If there=s not enough rainfall to support crop growth, they must be irrigated, which means transporting water from lakes, streams, or wells. Irrigation may require so much water that aquatic life in lakes and streams may be affected, or the water table may be lowered, causing wells to dry up. The complete water cycle must be considered for irrigation. Irrigation drainwater must be properly discharged or recycled to avoid causing pollution as well.

Another good example is the case of a paper mill on a small mountain river. Paper production requires lots of water, and the wastewater discharged back into the stream contains a large number of pollutants, including some toxic chemicals. A paper company might come under attack from environmental groups for this mill but receive praise for how mills are operated in other areas on larger rivers. One reason is the **amount** of water available for use. The small mountain river doesn=t have enough flow to support the operation of the paper mill.

AGRICULTURAL IMPACTS

Agriculture can create serious demands on water supplies and cause several serious types of pollution, as salts and trace elements are leached from the soil. Runoff and seepage of agricultural chemicals like fertilizer, herbicides, and pesticides introduce nutrients, toxics, and sometimes bacteria into waterways and groundwater. Sediment, however, is the major pollution source from this land use.

Animal wastes can enter streams, ponds, or lakes in pasture lands in which animals have direct access to water, or wastes can be washed into streams by rain or enter groundwater through the soil. Animals produce large amounts of waste (cattle create about ten tons of manure per head yearly, swine about two tons), so pollution problems can be severe around large livestock farms. Nutrients, sediment, bacteria, and organic toxics can all come from these Anatural@ sources of pollution.

One practice for reducing erosion and sediment pollution from agriculture is conservation tillage. Instead of plowing under the residue from a previous crop and exposing bare soil, conservation tillage uses a disc or other device to cut through the residue so seeds can be planted. This process allows a protective layer of vegetation to remain on top of the soil to retard erosion and to retain more water in the soil. One negative is that this process may require increased use of herbicides. Another process, called ridge planting, puts seeds in ridges of plowed soil. This method allows warmer soil temperatures for planting and traps rainwater in the furrows between the ridges. Biological pest control or integrated pest management (IPM) can be used to reduce the amount of pesticides needed to protect crops. In IPM, predators like ladybugs or praying mantises are introduced to control the pest that is causing crop damage.

Agricultural extension services also provide soil testing to farmers so that fertilizers can be properly used. The tests indicate which nutrients may be needed for the type of soil and the crop being used so that excess fertilization does not occur. Not only does this practice reduce pollution, it can reduce the cost of producing a crop.

Other best management practices include crop rotation, which may replace a row crop with a grain or other plant that covers more ground and reduces erosion. Planning field layouts can also reduce erosion and sediment pollution by changing the direction of rows or creating runoff channels that allow sediment to settle before the runoff water is released into streams.

There are several best management practices that can be applied to reduce pollution. Examples are diversion channels to direct runoff to a safe outlet, grassed waterways to prevent erosion by small channels, and sediment basins to collect runoff and sediment. These are called structural best management practices.

Management practices are often used. This type of best management practice involves making management decisions that will reduce the potential for pollution. For example, integrated pest management is used to scout for pests and pesticides are applied only when the number of pests reaches a threshold beyond which it is economical for pesticide use. This requires less pesticides and permits natural predators to assist with pest control.

Waste management systems can be used to convert animal wastes to reusable resources such as fertilizer or methane for energy. A ton of animal manure can be equal to about 100 pounds of high quality chemical fertilizer.

There is no one single system that is best for animal waste operations. Depending on the size and type of livestock and the potential for pollution, systems may need to be customized to a particular location. Considerations for system design include local environmental regulations, the number of animals, type of confinement, fertilizer needs, location of water sources, and the location of residences around the livestock operation.

A waste management system has four basic components: collection, transportation, storage, and disposal. For some farms, a system may provide collection and transportation functions, with the wastes delivered to another location for storage, and disposal. Collection methods vary, ranging from scraping to washing and flushing. Transportation methods include conveyors, pumps, wagons or manure spreaders.

Collection and storage methods are based on the principles of either keeping wastes for later use or providing a safe method for their treatment and disposal. Proper storage facilities are important because wastes can lose nutrients and fertilizer value. A common treatment facility is a lagoon. Aerobic lagoons break down waste materials without oxygen or aeration. Aerobic lagoons break down waste material with oxygen. Aerobic lagoons create less odor than anaerobic lagoons, but require more surface area. Both types reduce the concentration of nutrients, making it safe to dispose of wastes by irrigation. Disposal or land application should be done at the time and in a manner that reduces the potential for runoff.

Other alternatives include collection of wastes and drying them for use as household fertilizers or even additions to silage for animal feeds, or as alternative fuel for energy. Dead animals may be composted or processed and used for soil amendments or fertilizer and animal food.

URBAN IMPACTS

Densely populated urban areas, which are covered by non-permeable surfaces like streets, sidewalks and buildings, create a great deal of runoff. The high concentrations of people in these areas tend to produce greater quantities and varieties of pollutants, including nutrients, bacteria, and toxic chemicals. Automobiles and manufacturing are two primary sources of toxics.

Less densely populated suburban areas have three primary water contamination problems. The first is runoff and seepage of lawn and garden chemicals. These chemicals are often used in much higher concentrations than in agriculture, and they can wash off into storm sewer systems or percolate through soil into groundwater. Faulty septic systems are another source of pollution, which can produce nutrient, bacteria, and even toxic contamination. Many household chemicals like pesticides, herbicides, solvents, paints, and cleaners are so toxic that they would require specialized disposal in industrial situations. A third source of pollution is runoff from streets, driveways, and parking lots. This runoff contains large amounts of petroleum contaminants, as well as bacteria and nutrients.

Control of both point source and nonpoint source pollution in urban and suburban areas is increasing. Tremendous investment by government and industry has helped control pollution problems immensely. Municipal sewage treatment facilities have grown faster than the nation=s population. However, more improvements are still needed to make sure that wastewater treatment systems can keep up with needs. Federal and state laws, beginning with the landmark 1972 Clean Water Act, are continually being developed that limit what types of contaminants can be released into wastewater systems. These controls have stopped many of the fish kills and other problems associated with pollution in the 1970s. Many urban area lakes that were considered Adead@ are now healthy enough to support many fish species and other aquatic life. Phosphate based detergents are banned by some communities.

Prior to 1992, urban runoff was controlled primarily by voluntary means. Federal regulations now require cities with a population of greater than 100,000 and certain types of industries to develop and implement plans to control storm water pollution. Cities have adopted new practices like leaf collection and street cleaning at critical times, that can reduce the flow of sediment and other contaminants into waterways. City planning places new emphasis on water conservation and source control, particularly in areas where water supplies may be limited. Detention-retention ponds have been incorporated into some water control systems to allow contaminants to settle, and to feed rainwater into runoff channels at a controlled rate.

In some cases, building codes limit construction based on water demand. A single new household consumes more than a hundred thousand gallons of water each year, placing more demand on water supplies and on wastewater and sewage treatment systems.

Education programs designed to teach people proper use of water and disposal of potential pollutants are also having a positive impact. These programs show people the staggering amounts of water they consume each day, and steps they can take to reduce consumption. Less consumption means less wastewater that has the ability to carry pollutants.

INDUSTRIAL IMPACTS

Industrial impacts on water can be severe. Industry can introduce toxic chemicals into a stream or lake, either through manufacturing or through an accidental spill. Thermal pollution from power plants or factories can raise water temperatures and change the ability of the water to support life. Nutrients from detergents or other organic chemicals can cause nutrient pollution that chokes the life out of waterways.

Since most industrial pollution is point source pollution, cleanup efforts can be focused and effective.

NPDES point source pollution control requires any industry that discharges a pollutant into a water supply to have a permit specifically to do so. Severe penalties are established for failure to have a permit or exceeding permit limits. Many industries are required to treat wastewater before releasing it back into streams.

Construction is an industry that can create nonpoint source pollution as well as point source pollution. Construction contaminates water in two ways. Sediment pollution can be created when plant cover is removed, with erosion occurring at much greater rates than for undisturbed land. Toxics from construction materials, such as paint, solvents, acids, and glues can also pollute water.

Construction must take into account both short term and long term water pollution management practices. Construction removes vegetation from the ground, inviting erosion and sediment pollution. Practices to reduce this include temporary measures such as diverting water flow through trenches or sediment ponds that allow silt and other materials to settle before water runs off into streams. Hay bales, mulch, and other materials may also be used as temporary controls, as well as the planting of temporary grasses to control erosion before more permanent landscaping can be done. Perennials or other long lasting vegetation can be used to provide more permanent ground cover for sites that won't be landscaped.

One key to success in best management practices for construction is proper site planning. The type of soil, the location of streams, and the topography of the area must all be considered before the construction process begins. Permanent measures may have to be taken to ensure that slow erosion doesn=t create problems several years in the future. These measures may include: storm drains, Ariprap,@ a permanent layer of stone that retards water flow and enhances infiltration, or even construction of grassed or lined waterways that convey excess storm water away from developing areas or critical slopes. The construction process itself may be modified to include a stone Apad@ at the construction entrance to reduce the transportation of mud off the building site by vehicles or runoff.

FORESTRY IMPACTS

Forests are one of the least-polluting land uses. However, chemicals like insecticides used on tree farms can soak into groundwater or wash into streams. Logging can cause erosion and sediment pollution, particularly if care is not taken in cutting logging roads and planning loading and stacking areas. Forestry has different environmental impacts in different parts of the country.

Forestry practices have been modified voluntarily and by law to reduce their pollution potential. To reduce soil erosion, many logging companies now employ buffer zones and streambank protection procedure which reduce erosion and other impacts on the land. Many forest product companies have found that proper land management can actually increase their profits by increasing forest yields.

For softwoods like pine, which are used for paper production and lumber, forest product companies manage their own Aplantations@ of timber, replanting several trees for every one cut down. This has increased the amount of usable timber available in the U.S., and has reduced the potential of pollution. Site planning is now an important consideration. Logging road paths may wind around hills to reduce erosion and allow natural growth to quickly Aretake@ the land after cutting is finished.

MINING IMPACTS

Improper mining can threaten ground and surface water supplies. Sediment, toxics, and rubble from mines are water contaminants. Rainwater running through discarded mine material (tailings) can become acidic, poisoning aquatic plant and animal life.
Mining is one activity that is specifically regulated as a potential source of pollution. Since 1965, more

than three million acres of land have been disturbed by strip mining activities. Severe problems have been created by erosion and acidity. However, mined lands must now be Areclaimed,@ or restored to acceptable condition after operations are complete.

The practices included in this process are preplanning to determine how the site will be used after operations are finished, stabilization of the site while work is in progress so that it does not create an immediate source of pollution, creation of storm water control and storage, and re-creation of natural beauty by replanting the site. Since mining can destroy topsoil, new soil or nutrients may need to be added before plants can thrive, or different vegetation requiring less nutrients may be used to start growth.

Underground mines can be pollution sources, particularly for groundwater. These are also subject to reclamation, and laws require that steps be taken to keep sediment or toxics from entering waterways.

COMMERCIAL BUSINESS IMPACTS

We normally think of major industries as creating the most pollution, but small businesses can also be pollution sources. In fact, many small businesses pollute, but do not realize it. Local garages that dump waste oil and anti-freeze instead of collecting it can be serious contributors to water pollution. A single quart of oil can pollute as much as 250,000 gallons of water. Photo labs can be sources of heavy metal pollution, such as silver. Dry cleaners use a variety of solvents that can be toxic. And trash created by businesses that goes into landfills can ultimately result in water pollution.

Many smaller businesses have voluntarily adopted approaches to prevent or reduce pollution. Recycling of automotive wastes is becoming standard practice for many garages, and other businesses regularly practice recycling a variety of materials to reduce cost and waste. Businesses such as photo labs that have installed systems that recover silver used in electroplating and thereby reduce potential water pollution. Laws regarding toxic substances also apply to small businesses, and many wastes that used to be dumped into water supplies are now collected for proper disposal.

RECREATION IMPACTS

Recreation can impact surface water in a number of ways. The improper use of our waterways or overuse by too many people can impair surface waters, destroy habitats, and cause injury or death to wildlife. Litter dumped in and around our waterways can not only cause pollution, but can be mistakenly eaten by wildlife.

Boats cause water pollution through leakage or spilling of petroleum products. Boaters can also damage habitats or hurt endangered species, such as the West Indian Manatee, which lives primarily in warm waters around the coast of Florida. As of 1996, approximately 2000 of these notoriously gentle mammals remain. Yet, each year, many die or suffer injuries at the hands of boaters.

To stem the tide of deaths and injuries to manatees and other aquatic wildlife, state regulations often require safeguards to be implemented, such as boater education and strict speed limits in certain areas. For it is only through the proper management of recreation areas, education to help people protect these areas, and laws that require appropriate human behavior in these areas, that we can begin to protect our aquatic resources from human recreational impacts.

OTHER SURFACE WATER ISSUES

ACID RAIN

The water cycle helps renew water as a pure resource. But the flow and cycling of water can also help spread pollution sources.

Acid precipitation is a prime example. Air pollution from industrial sources and automobiles releases sulphur oxides and nitrogen oxides into the air. When mixed with water vapor, they form sulfuric and nitric acids, which fall to the ground in the form of acid rain, snow, fog, or dew. Acid precipitation, commonly called Aacid rain,@ can cause damage to buildings, car finishes, crops, forests, wildlife habitats, and aquatic life.

This acid precipitation can also pollute clean waterways through runoff. Increased acidity of water can negatively affect fish and other aquatic life. The effects of acid precipitation may not be felt for many months or years.   Acidic snowmelt may create acid Ashock@ in a stream and cause serious fish kills in the spring.

NONPOINT SOURCE POLLUTION

Water pollution is identified in two categories. **Point source pollution** is contamination that comes from a single, clearly identifiable source, such as a pipe which discharges material from a factory into a lake, stream, river, bay, or other body of water. Point source pollution could also include stormwater runoff that is channeled from a drain directly into a waterway, or even a polluted tributary that regularly adds contaminants to a body of water. Point source pollution is relatively easy to identify.

Nonpoint source pollution is more difficult to identify. This is pollution which originates over a broad area from a variety of causes. Examples of nonpoint source pollution include: improper application of pesticides and fertilizers; sediment from construction and logging; leachate from landfills and septic tanks; petroleum-based products from streets and parking lots; and atmospheric fallout. Because of its dispersed sources, nonpoint source pollution can be difficult to control.

GROUNDWATER

Groundwater begins with precipitation that seeps into the ground. The amount of water that seeps into the ground will vary widely from place to place, depending on the slope of the land, amount and intensity of rainfall, and type of land surface. Porous, or permeable, land containing lots of sand or gravel will allow as much as 50 percent of precipitation to seep into the ground and become groundwater. In less permeable areas, as little as five percent may seep in. The rest becomes runoff or evaporates. Over half of the fresh water on Earth is stored as groundwater.

As water seeps through permeable ground, it continues downward until it reaches a depth where water has filled all the porous areas in the soil or rock. This is known as the saturated zone. The top of the saturated zone is called the water table. The water table can rise or fall according to the season of the year and the amount of precipitation that occurs. The water table is typically higher in early spring and lower in late summer. The porous area between the land surface and the water table is known as the unsaturated zone.

AQUIFERS

Water-bearing rock, sand, gravel, or soil that is capable of yielding usable amounts of groundwater is called an aquifer. The water yield from an aquifer depends greatly on the materials that make it up. Mixtures of clay, sand, and fine particles yield small amounts of water because the spaces between the particles don't allow water absorption and flow. Materials sorted into distinct layers will yield high amounts of water from coarse-grained materials like large sand grains and gravel, but low amounts from fine-grained sand, silt, or clay. Bedrock aquifers will yield substantial amounts of water if there are large openings or cracks in the rock. The capacity of soil or rock to hold water is called its porosity; the capacity for water to move through the aquifer is called permeability.

There are two types of aquifers: confined, or artesian aquifers, and unconfined, or water table aquifers. Artesian aquifers contain groundwater that is trapped under impermeable soil or rock and may be under pressure. Artesian wells are wells that pierce artesian aquifers. The water in these wells usually rises toward the surface under its own pressure. If the water level in the well is higher than the land surface, it may be a flowing artesian well. A well in an unconfined aquifer has the same water level as the water table around it.

GROUNDWATER RECHARGE

Water that seeps into an aquifer is known as recharge. Recharge comes from a variety of sources, including seepage from rain and snow melt, streams, and groundwater flow from other areas. Recharge occurs where permeable soil allows water to seep into the ground. Areas in which this occurs are called recharge areas. They may be small or quite large. A small recharge area may supply all the water to a large aquifer. Streams that recharge groundwater are called losing streams because they lose water to the surrounding soil or rock.

GROUNDWATER DISCHARGE

Groundwater can leave the ground at **discharge points**. Discharge happens continuously as long as enough water is present above the discharge point. Discharge points include springs, stream and lake beds, wells, ocean shorelines, and wetlands. Streams that receive groundwater are called **gaining streams** because they gain water from the surrounding soil or rock. In times of drought, most of the surface water flow can come from groundwater. Plants can also contribute to groundwater discharge, because if the water table is close enough to the ground, groundwater can be discharged by plants through transpiration.

GROUNDWATER MOVEMENT

Groundwater usually moves slowly from recharge areas to discharge points. Flow rates within most aquifers can be measured in feet per day, though in karst bedrock the rate of flow can be measured in miles per hour. Flow rates are faster when cracks in rocks or very loose soil allow water to move freely. However, in dense soil, groundwater may move very slowly or not at all.

Groundwater typically moves in **parallel paths**, or layers. Since groundwater movement is slow, it doesn't create enough turbulence to cause mixing the way surface waters mix when a river or stream empties into another waterbody. That is, layers of groundwater remain relatively intact. This can be an important factor in locating and determining the movements of contaminants that might enter the groundwater supply. But eventually contaminants will disperse through part or all of an aquifer.

Wells affect groundwater flow by taking water out of an aquifer and lowering the nearby water table. Removed water is recharged from the water table, and the lowered water table caused by the well is called a **cone of depression**. The cone of depression from a well may extend to nearby lakes and streams, causing the stream to lose water to the aquifer. This is known as **induced recharge**. Streams and wetlands have been completely dried up by induced recharge from well pumping.

GROUNDWATER PROBLEMS

SOURCES OF GROUNDWATER CONTAMINATION

Groundwater contamination can come from a number of natural and human-made sources. These can include:

***Leaks and spills at factories and commercial facilities**

Spills and leaks can result from accidents, lack of employee training, improper planning, and inadequate maintenance. They are especially problematic if proper procedures are not in place to clean them up once they occur. Materials which can cause problems if spilled, include gasoline, other petroleum products, hazardous chemicals, and a variety of other materials.

It=s difficult to eliminate accidental spills, but they can be reduced and the damage they cause can be minimized by proper design and maintenance of facilities and proper employee training. The Emergency Planning and Community Right-to-Know Act of 1986 (SARA Title III) requires states, communities, and businesses to have plans for responding quickly in the event of an accidental spill. Workers must be informed as to what hazardous chemicals they may be working with, and what to do in case of an accident. This act has prevented or reduced many instances of groundwater contamination.

***Improper hazardous waste disposal**

Improper industrial waste disposal can come from a variety of sources, including major industrial plants and small businesses. The local dry cleaner uses a number of solvents and hazardous chemicals for cleaning clothes, and these must be handled as carefully as any other hazardous waste to prevent groundwater contamination. Industrial wastes can create groundwater pollution problems that take years to resolve.

The disposal of hazardous industrial wastes is now carefully regulated under the Resource Conservation and Recovery Act (RCRA), which requires industry to have a Acradle to grave@ system of tracking hazardous wastes. This system is designed to prevent inadvertent (and sometimes purposeful) release of hazardous materials into the environment by requiring businesses to report hazardous wastes and account for their proper disposal (except for some small quantity generators). The law establishes severe penalties for noncompliance. Another Federal law, the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) responds to environmental threats from improper disposal of hazardous wastes and sets standards for cleanupCeven for sites that were contaminated years ago where the source of contamination may not be easily identifiable.

Individuals can also be sources of hazardous waste pollution. If you dump oil in your driveway, pour paint thinner in the toilet, or dispose of wastewater with hazardous cleaners in the bathtub, you could be a source of hazardous pollution. Ways to avoid this are to recycle oil and other petroleum based chemicals at service stations or recycling centers. Avoid using hazardous chemicals when possible and substitute more environmentally friendly materials. Many communities sponsor household chemical disposal days so that individuals can take solvents and other hazardous wastes to a site for proper disposal.

***Improper use and disposal of pesticides**

Pesticides used on farms and even on individual lawns can create serious groundwater pollution. Improper pesticide use can cause people and animals to become ill, kill plants, and have adverse effects on aquatic life in nearby streams. Improper pesticide use can include excessive or ill-timed application, improper storage, or improper disposal of excess pesticides. If you overuse pesticides on your yard, you could be polluting your own groundwater. It=s been estimated that individuals use over 100 times as much pesticides and fertilizer on their yards as farmers use on the same amount of land.

Avoiding pesticide pollution of groundwater is relatively easy. Follow instructions carefully. Reduce pesticide use in areas known to be recharge areas for groundwater. Use natural pest control methods rather than chemicals. Homeowners can substitute biocontrol agents, like praying mantises or ladybugs, for pesticides. Other natural insect repellents include plants like mint (which discourages ants), garlic, and marigolds.

***Leachate from landfills**

If landfills are not properly constructed, liquid from decomposition of materials, or **leachate**, can leak out of the landfill into an aquifer. Leachate can contain high levels of bacteria, hazardous chemicals, metals, and ammonia. Runoff water from landfills after rains can also carry pollution to groundwater recharge areasCand hence into groundwater.

New landfill construction methods are designed to prevent pollution of groundwater. Landfills are now built with liners to prevent leachate from seeping through soil into aquifers. Leachate collection systems store the liquid away from the water table. Clay caps prevent rainwater runoff from carrying pollutants from the landfill into the groundwater.

***Septic systems**

Septic systems can be a source of groundwater pollution if too many systems are located in an area, if a system is overloaded or not working properly, or if a system is improperly used for disposal of chemicals or other materials. If a septic system is not working properly, it can contaminate groundwater with bacteria, viruses, and hazardous cleaning materials or household chemicals. Even properly working well-maintained septic systems can contribute nitrates to groundwater. These can show up in well water around the septic system.

Methods of preventing groundwater pollution from septic systems include proper system installation and maintenance. If the concentration of households in an area is too great, then a public sewer and waste treatment system may be necessary. Dumping hazardous chemicals into septic systems should also be avoided.

***Saline Intrusion**

In coastal areas, too much demand on potable groundwater can create induced recharge from ocean waters, resulting in saline intrusion into groundwater supplies. This can also happen in times of severe drought. (Induced recharge can not only contaminate groundwater, but enough induced recharge has been known to dry up wetland areas and destroy habitats for wildlife.)

Careful planning of coastal communities and water conservation are ways to avoid saline intrusion into groundwater supplies.

***Salts and chemicals used to deice roads**

In northern climates, tons of salt and other chemicals are used for deicing roads, and these can create groundwater contamination problems. Runoff from storage areas and highways can seep into the ground and cause high levels of chlorides in well water. Prevention of pollution from this source can be through protection of storage areas, minimal salt use, and substitution of other materials, such as sand or gravel.

***Liquid waste storage lagoons**

Storage lagoons are used by industries, farms, cities, and mines as a way of preventing pollution by allowing solid wastes to settle before wastewater is released. However, storage lagoons can cause groundwater pollution if they leak or overflow. They can be sources of bacterial or chemical groundwater pollution.

Groundwater contamination from lagoons can be avoided through proper installation and maintenance and by locating lagoons away from sensitive groundwater areas.

***Fertilizers**

Like pesticides, misuse of fertilizers can cause groundwater pollution. Overuse can allow nitrates from fertilizer to seep into the water table. In sensitive groundwater areas, rainfall seepage can cause fertilizer to migrate and contaminate an aquifer.

Careful use can avoid or minimize these problems.

***Animal wastes**

Animal wastes are sources of bacteria and nitrates. They can contaminate groundwater if too many animals are located in too small a lot, or if the lot has improper drainage. Lagoons used to trap animal wastes can be a source of groundwater pollution if they leak or if the water table is too close to the land surface. Proper siting of animal lots, along with regular cleaning and avoiding overloading, can prevent animal waste pollution. Wastes can be recovered and used as fertilizer.

***Leaking underground storage tanks**

Leaking underground tanks are a potentially large groundwater pollution problem. And no one is really sure how large the problem will be. It=s been estimated that the locations of only **half** of all the underground storage tanks are known in the U.S. Many of these are old, corroded, and beginning to leak and cause problems. Underground storage tanks are commonly found at service stations, where gasoline pollution is a potential problem. Many stations have replaced old steel tanks and piping, with fiberglass tanks and piping that don=t corrode.

Federal law now requires that owners/operators of USTs prevent the release of product into the environment. This may require the owner/operator to install storage tanks that have a secondary containment system should the primary tank fail. Careful monitoring of tank inventories can be used to detect leaks and correct them, and tanks that are no longer in use must be closed by either removing them or filling them with inert materials.

***Pipeline breaks**

Pipeline breaks can be sources of localized groundwater pollution. Breaks can be severe enough so that they are immediately detected, or they may be small and cause significant groundwater contamination before they are noticed. Pipeline breaks can cause pollution from sewage, petroleum products, or other chemicals. They can occur around roadways due to vibration from vehicles, or they can even be caused by plant roots, which slowly crack pipes and cause leaks. Careful inspection of pipelines and regular maintenance can reduce pollution problems from this source.

***Inadequately sealed wells or abandoned wells**

It=s sometimes difficult to imagine wells, our chief way of tapping into groundwater supplies, as a source of groundwater pollution, but they can be pathways for pollutants to enter the groundwater system. If a well isn=t sealed or cased properly, polluted water from runoff can enter at the well cover or along its walls and be channeled directly into groundwater. Open abandoned wells can be a significant source of groundwater pollution. And if a well is deep enough to reach a layer of groundwater that is otherwise protected by impermeable soil from pollution from surface seepage, it can create severe contamination of an otherwise pure water source.

Groundwater pollution from wells can be prevented by properly sealing wells which will no longer be used with concrete or earth. Well covers and tight casings are used as temporary measures. Procedures have also been developed to properly seal and plug abandoned wells.

***Underground injection wells**

Underground injection wells are a method of waste disposal. Wastes disposed by this method include industrial chemicals, sewage effluent, cooling water, storm water, and salt water. Typically, injection wells inject wastes below sources of drinking water, but if injection wells have leaks or are used improperly, they can inject wastes directly into a usable groundwater supply.

Injection wells are carefully monitored by state and federal regulations to prevent pollution. Businesses using injection wells are required to have permits for their use and to comply with permit conditions.

***Radon contamination**

Radon is a naturally occurring radioactive element that has been linked to cancer in humans. It occurs in certain geologic areas, and can be an air or water pollutant. Radon can collect as a gas in a basement, or it can contaminate well water. Test kits for radon detection are available for individual use. Once detected, radon can be removed from a home or a water well.

COASTAL WETLANDS

IMPORTANCE OF COASTAL WETLANDS

Coastal wetlands provide a wide variety of important functions, including:

Water quality. Some wetlands contribute to improving water quality by removing excess nutrients and many chemical contaminants. These improvements occur due to uptake by the plants and binding with soil particles.

Barriers to waves and erosion. Coastal wetlands reduce the impact of storm tides and waves before they reach upland areas.

Flood storage. Coastal wetlands can store floodwater and release it slowly, lowering flood peaks.

Sediment control. Reduced flood flow provided by coastal wetlands allows floodwater to deposit sediment, instead of transporting sediment into waterways where it can pose a water quality problem.

Wildlife habitat. Coastal wetlands can support wide varieties of wildlife (i.e., provide nesting areas, produce food, provide spawning areas).

Fish and shellfish. Coastal wetlands are important spawning and nursery areas for fish and shellfish, and provide sources for commercial fishing.

Sanctuary for rare and endangered species. Protection of wetlands often means providing survival habitats for endangered animals. Nearly half of the threatened and endangered species in the U.S. rely directly or indirectly on wetlands for their survival.

Aesthetic value. The natural beauty of wetlands is a source of visual enjoyment, and can be appreciated through observation, art, and poetry.

Education and research. The rich ecosystems of wetlands are natural locations for biological research and observation.

Recreation. Wetlands provide sites for hunting, fishing, canoeing, and observing wildlife.

Food production. Wetlands have potential for the production of plant products, including marsh vegetation, and for aquaculture. Wetlands also produce great volumes of food in the form of decaying plant and animal matter or detritus. Detritus is consumed by many aquatic invertebrates and fish which are food for game fish, waterfowl, and mammals.

Water supply. With the growth of urban areas, wetlands are becoming more valuable as sources for water supply.

COASTAL HABITATS

Coastal salt water wetlands contain a number of habitats. **Marine intertidal** habitats are near the shoreline and are flooded by tidewaters. **Estuarine sub-tidal** habitats are open water and bay bottoms that are continuously covered by salt water. **Estuarine intertidal emergents** are salt marsh areas that are covered by herbaceous vegetation during the growing season. **Estuarine intertidal forested/shrub** habitats contain larger woody plants. **Estuarine intertidal unconsolidated shores** are beaches and sand bars, and **estuarine unconsolidated bottom** habitats are open water estuaries. **Riverine** habitats are tidal or non-tidal river systems that feed into wetlands.

ESTUARIES

Estuaries form where rivers meet oceans. Estuaries are deep water tidal habitats and adjacent tidal wetlands that are usually semi-enclosed by land but have open or at least some access to the open ocean. Ocean water in estuaries is partly diluted by freshwater runoff from rivers, but the salinity of still waters in estuary wetlands may be occasionally higher than that of the ocean due to evaporation.

BAYS

Bays are large estuarine systems. The Chesapeake Bay is the largest estuary in the United States and one of the most productive biological systems in the world. The bay is approximately 200 miles long and ranges from 4 to 30 miles wide, but averages a depth of only about 28 feet. This makes it ideal for shellfish and other productive fish species, but it also makes it sensitive to natural changes in temperature and wind and human-made pollution. Other key bays in the United States include Puget Sound in Washington, Long Island Sound in New York, Albemarle Sound and Pamlico Sound in North Carolina, and San Francisco Bay in California.

A WETLAND BENEFIT- FOOD SUPPLY

Coastal wetlands are critical to human food supplies. About 66 percent of the commercial fish catch taken along the Atlantic and Gulf coasts depends on wetlands for survival. Coastal wetlands produce millions of tons of organic matter that provide food for invertebrates, shellfish, and small fish that are in turn food for larger commercial fish such as bluefish and striped bass. Most freshwater fish feed upon wetland-produced food and use wetlands as nurseries for their young. Waterfowl hunters spend hundreds of millions of dollars annually to harvest wetland-dependent birds. Wetlands also provide blueberries, cranberries, and wild rice. And wetlands have further potential for contributing to the food supply, through the harvesting of marsh vegetation and aquaculture.

FRESHWATER WETLANDS

Like saltwater coastal waters, freshwater wetlands offer a variety of benefits, including:

Water quality. Some wetlands contribute to improving water quality by removing excess nutrients and many chemical contaminants. These improvements occur due to uptake by the plants and binding with soil particles.

Flood conveyance. Wetlands can form natural floodways that allow floodwater to move downstream without causing damage (i.e., contains flood flows within a corridor that should not be developed).

Flood storage. Freshwater wetlands can store floodwater and release it slowly, lowering flood peaks.

Wildlife habitat. Inland wetlands can support wide varieties of wildlife (i.e., provide nesting areas, produce food, provide spawning areas).

Sanctuary for rare and endangered species. Protection of wetlands often means providing survival habitats for endangered animals. Nearly half of the threatened and endangered species in the U.S. rely either directly or indirectly on wetlands for their survival.

Aesthetic value. The natural beauty of wetlands is a source of visual enjoyment, and can be appreciated through observation, art, and poetry.

Recreation. Wetlands provide sites for hunting, fishing, canoeing, and observing wildlife.

Education and research. The rich ecosystems of wetlands are natural locations for biological research and observation.

Water supply. With the growth of urban areas, wetlands are becoming more valuable as sources for water supply. Some wetlands help recharge ground water supplies.

Food production. Wetlands have potential for the production of marsh vegetation and aquaculture for humans; they provide detritus, plants, and insects as food for animals.

Timber production. Properly managed, wetlands can provide good sources of timber.

Historical value. Some wetlands were locations for Indian settlements and provide significant historical and archeological value.

WETLAND HABITATS

Freshwater wetland habitats include **palustrine forested**, or forested swamps and bogs; **palustrine shrub**, or shrub wetlands; **palustrine emergents**, or inland marshes and wet meadows; **palustrine unconsolidated shores**, or freshwater shores and sand bars; **palustrine unconsolidated bottom**, or open water ponds; **palustrine aquatic beds**, or floating aquatic or submerged vegetation; **lacustrine** (lake) habitats; and **riverine** (river) habitats.

DESTRUCTION OF WETLANDS

It is estimated that over 200 million acres of wetlands existed in the United States, at the time of European settlement. In 1975, wetlands were estimated to be 99 million acres. Iowa, for example, has lost 99 percent of its wetland areas. Many wetlands have been converted to agricultural areas, and wetlands have also been lost to real estate development, mining, and drained for timber production. Laws used to encourage wetlands destruction for "useful purposes."

Wetlands are still being destroyed at an alarming rate, but there is a new awareness of wetlands value, and an increased interest in preserving wetland areas. Some wetlands have been restored, and governments and private groups have begun purchasing wetland areas for conservation and preservation.

PROTECTION OF WETLANDS

Because so many acres of wetlands have been lost, Federal and state governments have worked hard to establish ways to protect and revitalize remaining coastal areas and wetlands. Private concerns have also worked toward wetland preservation.

Approaches toward wetlands protection have included acquisition of wetland areas, both by governments and private groups such as The Conservation Foundation and The Nature Conservancy. Buying duck stamps at the post office also raises money for wetlands conservation. Economic incentives for wetland preservation have included tax reductions and deductions for wetland donation; economic **disincentives** to wetland destruction have also been put in place. A provision of the Food Security Act eliminates farm program benefits for farmers using wetlands converted into farmlands.

Specific regulation of wetlands comes with Section 404 of the Clean Water Act, amended in 1987. Under this law, the discharge of dredged or fill materials into the waters of the U.S. requires a permit from the Army Corps of Engineers. This has prevented the loss of many wetlands, but it is not a comprehensive program for protection. For example, some isolated yet ecologically valuable wetlands are not regulated.

Most coastal states have laws in place to protect coastal wetlands, but fewer than 20 states have enacted provisions to protect inland wetland areas. The National Estuary Program (NEP) was established in 1985, to address problems affecting the estuaries, such as loss of habitat, contamination of sediments by toxic materials, depletion of oxygen, and bacterial contamination. As of 1996, 28 of the nation=s largest estuaries were listed under the NEP. Management plans for each estuary are due to be completed and steps taken to restore their environmentalCand economicCbenefits. Another important planning effort is the advanced identification (ADID) of wetlands in the United States.

RESTORED WETLANDS FOR HABITAT

Close to half of all rare and endangered animal species are either located in wetland areas or dependent on them. Government agencies have recently undertaken restoration of wetlands in large-scale projects. One example is the restoration of thousands of acres of floodplain marsh along Florida=s Kissimmee River. Some wetland habitats, such as freshwater marshes can be relatively easy to reproduce and regenerate, while others, such as high salt marshes and forested wetlands, may be more difficult and take generations to recreate.

The restoration of wetland habitats is a young and very complex science that will take years to understand fully. Wetland restoration must overcome a variety of problems, such as financial considerations, invasion of unwanted vegetation, proper water recharge and sediment control, and interaction of wetlands with adjacent waterways.

COASTAL AND COASTAL WETLANDS ISSUES

EROSION

Erosion poses a problem for shorelands by removing soils and sediment that support plant and animal life. Erosion can strip away important sediment layers and change the habitat=s ability to support life. Extreme erosion can create stream flows that drain coastal wetland areas.

DREDGING AND COASTAL WETLAND LOSS

Dredging, filling, and draining of wetlands have destroyed hundreds of thousands of acres of coastal habitat. Also, dredged materials from navigation channels are often deposited alongside streams in wetland areas. For many years, it was thought good land practice to improve wetland Awastelands@ by filing them in or draining them for mosquito control.

Wetlands are now protected by Section 404 of the Clean Water Act. Under this law, the discharge of dredged or fill materials into the waters of the U.S. requires a permit from the Army Corps of Engineers. In order to receive permit authorization, the activity must comply with 40 C.F.R. Section 404 (b)(1) guidelines which stipulate that no discharge can be permitted if a practicable alternative exists that is less damaging to the aquatic environment or if significant degradation would occur. This has prevented the loss of many wetlands; however, wetland loss and degradation continue to be a significant environmental concern.

RED TIDE

Red tide is a natural phenomenon brought on by too many nutrients in the water which can cause uncontrolled growth of microscopic organisms or type of plankton called dinoflagellates. These organisms can multiply to the point where water actually looks red. The organisms contaminate shellfish, making them unsafe for human consumption. Red tide also causes fish kills, can damage vegetation, and as of the mid 1990s, has become a toxic threat to endangered aquatic species such as Florida=s West Indian Manatee.

NONPOINT SOURCE POLLUTION IN BAYS

Nonpoint source pollution is a problem for bays and other waterways, but in bays, its consequences can be more severe. Since bays are typically shallow, nonpoint source sediment pollution can quickly fill and clog waterways and wetland areas. Sediment can also bring about conditions that can reduce oxygen levels and kill marine life. Nutrient pollution from farmlands can also create havoc in bays. Algal blooms from nonpoint source pollution can have similar effects of reducing oxygen levels and killing existing life. Toxic pollution can quickly settle into shallow bay waters and infiltrate productive fishing and spawning beds, killing or contaminating fish and plant life.

DEVELOPMENT OF COASTAL AREAS

Coastal development has been and continues to be a major threat to wetlands. Coastal property has high real estate value, and developers find it difficult to preserve wetland areas when faced with profit potential from private wetland areas. And even if wetlands aren=t destroyed during development, the additional pollution from development can disrupt the delicate environmental balance of wetlands, changing habitats forever. The nation=s largest estuary, the Chesapeake Bay, suffers many environmental problems as a result of extensive development within its watershed.

OCEAN DUMPING AND SPILLS

Ocean dumping and accidental spills pose a severe pollution problem, and many coastal areas have received significant environmental damage. A number of federal laws are now in place to protect the coastal environment. Some of these laws are described below.

*The Rivers and Harbors Act of 1899, was the beginning of laws protecting the oceans. This act was established to prohibit throwing, discharging, or depositing any matter, other than matter flowing in streets and sewers and passing in a liquid state, into navigable waters.

*The Water Pollution Control Act (WPCA) of 1948, was passed by Congress because there was evidence of health dangers that damaged beaches and shellfish beds, and could cause typhoid fever, diarrhea, and dysentery.

*The Federal Water Pollution Control Act (FWPCA) of 1956, amended the WPCA. It authorized grant monies to communities to build sewage treatment plants.

* The 1969 National Environmental Policy Act=s main goal was Ato create and maintain conditions under which man and nature can exist in productive harmony and fulfill the social, economic, and other requirements to present and future generations of Americans.@ (Covering the Coasts: A Reporter=s Guide to Coastal and Marine Resources, page 81) One requirement under this act is for applicable federal agencies to prepare an environmental impact statement (EIS). An EIS is a detailed statement which describes how a project may significantly affect the environment and living things= habitats.

*London Dumping Convention Act of 1972, placed limits on the amount of industrial and municipal waste dumped into international waters. The Marine Protection, Research, and Sanctuaries Act (MPRSA) of 1972, (also called the Ocean Dumping Act), implements the London Dumping Convention Act, in United States= waters.

*The Clean Water Act of 1972, amended the FWPCA. It established the National Pollutant Discharge Elimination System (NPDES). Under the national permitting program, EPA or EPA authorized states issue permits limiting the pollutants from industrial and municipal discharges into United States= waters.

*Coastal Zone Management Act of 1972, provided establishment of the National Estuary Research Reserves for research and environmental education. The goal of this act is to Apreserve, protect, develop, enhance, and restore where possible, the coastal resources.@ (Covering the Coasts: A Reporter=s Guide to Coastal and Marine Resources, page 96)

*Marine Mammal Protection Act of 1972, imposes a moratorium that protects marine mammals and their products for any purpose other than for scientific research or education. This means that no person has the right to Atake@ (harass, hunt, capture, or kill) or import any marine mammal.

*International Convention for the Prevention of Pollution From Ships of 1973 and 1978, known as MARPOL was not effective until 1983, after several modifications. MARPOL=s intent was to end Athe deliberate, negligent, or accidental release of ...harmful substances from ships@ and to Aachieve the complete elimination of international pollution of the marine environment...of harmful substances.@ (Covering the Coasts: A Reporter=s Guide to Coastal and Marine Resources, page 100)

*Fisheries Conservation and Management Act of 1976 (also called Magnuson Act), was established for the conservation and management of all fishery resources within the United States.

*Endangered Species Act of 1973, was established to protect endangered or threatened species. This is accomplished by federal agencies ensuring that their actions do not jeopardize endangered or threatened species or do not adversely affect critical habitats.

*Ocean Dumping Ban Act of 1988, amended the MPRSA. It was established to prohibit ocean dumping of sewage sludge and industrial wastes into waters, effective after December 31, 1991. No sludge or sewage dumping after August 18, 1989, without a MPRSA permit and an enforcement or compliance agreement is allowed. This act enforces that no new dumping of industrial and municipal waste is allowed .

*The Oil Pollution Act of 1990, was established in response to the Exxon Valdez spill off Alaska=s coast in 1989. This act addresses all oil discharges into navigable waters and shorelines, imposing liability limits for vessels where gross negligence or misconduct has been demonstrated.

WATER TESTING

Water quality tests are performed on various types of water or wastewater for a variety of reasons. Surface water quality testing is typically performed by states, who are required by the Clean Water Act Amendments of 1987 to assess their waters every two years. Citizens may also conduct stream or other surface water monitoring programs. Wastewater that is discharged from industrial facilities, wastewater treatment plants, and some municipal storm sewers must be tested and meet certain requirements, as spelled out in National Pollutant Discharge Elimination System (NPDES) permits.

The Safe Drinking Water Act and corresponding regulations are designed to protect groundwater and sources of drinking water supplies. Groundwater monitoring is often performed to determine impacts from activities conducted in the surrounding area. For example, groundwater monitoring may be required in the aquifer(s) above deep injection wells or in the aquifer beneath a landfill to determine if injected or leachate is migrating into the aquifer(s). More intensive groundwater monitoring can be required if aquifers are designated as underground sources of drinking water. As well, monitoring programs for either groundwater or surface waters often form an important part of source water protection programs.

To ensure public health, the Environmental Protection Agency (EPA) and state environmental (or public health) agencies require rigorous testing of water supplies by public water systems. Tests for various parameters are conducted on water samples from different points in the drinking water treatment process: (1) on raw, untreated source water, (2) during treatment processes, (3) on finished water exiting the treatment plant, (4) within the distribution system, and (5) at the tap (for some parameters, such as lead and copper). Citizens may also want to conduct in-home tap testing for particular drinking water contaminants. To protect citizens against waterborne diseases, local health departments test water in community pools and spas.

As consumer and environmental awareness increases, citizens want to know more and more about their water quality. Many resources are available to assist in performing tests on water and wastewater samples. The Code of Federal Regulations (CFR) specifies that certain methods be used in conducting water and wastewater testing. However, these regulations are written in complex terms and can prove difficult for non-technical persons to understand. Also, a book titled Standard Methods for the Examination of Water and Wastewater is used as an industry-wide, comprehensive guide for conducting water quality testing.

Water testing companies have responded to the quest for consumer knowledge by designing simple, inexpensive, ready-to-use test kits (containing necessary materials and instructions). These kits can be mail-ordered by individuals, schools, or other organizations and allow affordable testing for many water quality parameters. Only a few companies are listed on this sheet; there are many more nationally-known water quality testing companies. Also, many smaller companies exist, who may provide excellent technical service (perhaps, on-site) to local customers. Check the Yellow Pages of the telephone directory under Environmental or Ecological Services, Water Purification Equipment, or Water Testing. State environmental agencies, local health departments, and public water suppliers may also provide technical assistance and direction in the area of water quality testing.
The following resources may be used to assist in conducting water quality testing:

References: Code of Federal Regulations, 40 CFR Part 136, Appendix A and Part 141, Subpart (C). Available at cost from the Government Printing Office, Washington, D.C., 202-512-1800.

Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 1015 Fifteen Street, NW, Washington, D.C. 20005.

Water Testing Companies: Carolina Biological Supply Company, 2700 York Road, Burlington, NC 27215, 800-334-5551.

Hack Company, P.O. Box 389, Loveland, Colorado 80539-0389, 800-227-HACK.

LaMotte Chemical Products Company, P.O. Box 329, Chestertown, MD 21620, 800-344-3100.

WATER RELATED CAREERS

Water related careers offer rewarding and challenging work. Water related careers include:

***Chemistry**. Chemists analyze water and determine contaminants that affect its quality. This may involve testing at water treatment plants or analysis of groundwater to see if pollutants have moved through groundwater supplies. Chemistry requires a college education, and quite often, post-graduate work to qualify for more advanced jobs.

***Engineering.** Water can be a focus of engineering studies. Major engineering projects require environmental impact studies and city development may be based on the ability to engineer around available water supplies. Engineers also control surface water flow for navigation, recreation, and power generation.

***Utilities.** Wastewater treatment and management is a field growing in importance and complexity as we work to clean water even more before returning it to nature. Water specialists for utilities become involved with plant operations, planning, emergency procedures, and maintenance of the nation's drinking water and wastewater plants.

***Forestry.** Forests and wetlands contain many water resources. How we manage them will govern the quality of our water supplies in the future. Forestry activities related to water can include timber harvest planning to avoid pollution problems, watershed protection, and water analysis to identify and control pollution problems. Forestry experts may work at the Forest Service, State Forester's Offices, colleges or universities, or other private organizations.

***Agriculture.** Water is essential for agriculture, and as water supplies dwindle, their management in agriculture becomes more important for irrigation purposes and to prevent pollution from agricultural sources. Agricultural activities could include genetically engineering crops that require less water to produce and control of nonpoint source pollution. Careers related to agriculture may include farming, or employment at a local agricultural extension service or soil conservation service.

***Biology.** Since water is necessary for all life, biologists must consider water supplies and water quality in determining the health of ecosystems and humans. For example, biologists can be involved in drinking water and wastewater treatment, land management, and aquatic resource management careers. Specialized jobs include fisheries biologists, limnologists, aquatic entomologists, or malacologists.

There are many other water-related jobs and careers. These include service in the Coast Guard, Marines, Army Corps of Engineers, or Navy; working for the U.S. Environmental Protection Agency, the U.S. Geological Survey, state environmental agencies, state or local health departments, state geological surveys, as well as other environmental agencies or private environmental protection organizations; commercial fishing, wastewater treatment plant technician, construction (such as plumbing or septic system installation), service in the merchant marines, meteorologist or weather person, lifeguard; fishing or rafting guide, and others. Many jobs and careers have either a direct or indirect relationship to water or water supplies.

U.S. EPA
National Primary Drinking Water Regulations

National Primary Drinking Water Regulations are enforceable drinking water standards expressed as Maximum Contaminant Levels (MCLs) or treatment technique requirements. The MCL is the maximum permissible level of a contaminant in water which is delivered to any user of a public water system. A treatment technique is a drinking water treatment requirement established in lieu of an MCL, typically used when setting an MCL would be too difficult or when compliance with an MCL would be too costly.

An action level is not an MCL, it is simply a level that triggers additional action. If a certain contaminant is measured at or above the action level for that contaminant, treatment may be required or recommended by EPA.

Volatile Organic Chemicals (VOCs)	MCL, in mg/l
Benzene	0.005
Carbon Tetrachloride	0.005
1, 2-Dichloroethane	0.005
Trichloroethylene	0.005
p-Dichlorobenzene	0.075
1, 1-Dichloroethylene	0.007
1,1,1-Trichloroethane	0.2
Vinyl Chloride	0.002
cis-1, 2-Dichloroethylene	0.07
1, 2-Dichloropropane	0.005
Ethylbenzene	0.7
Chlorobenzene	0.1
o-Dichlorobenzene	0.6
Styrene	0.1
Tetrachloroethylene	0.005
Toluene	1
trans-1, 2-Dichloroethylene	0.1
Xylenes (Total)	10
Dichloromethane	0.005
1, 2, 4-Trichlorobenzene	0.07
1, 1, 2-Trichloroethane	0.005

Synthetic Organic Chemicals (SOCs)	MCL, in mg/l
Alachlor	0.002
Atrazine	0.003
Carbofuran	0.04
Chlordane	0.002
Dibromochloropropane	0.0002
2, 4-D	0.07
Endrin	0.002
Ethylene dibromide	0.00005
Heptachlor	0.0004

Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.04
Polychlorinated biphenyls (PCBs)	0.0005
Pentachlorophenol	0.001
Toxaphene	0.003
2, 4, 5-TP	0.05
Benzo (a) pyrene	0.0002
Dalapon	0.2
Di (2-ethylhexyl) adipate	0.4
Di (2-ethylhexyl) phthalate	0.006
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Glyphosate	0.7
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Oxamyl (Vydate)	0.2
Picloram	0.5
Simazine	0.004
2, 3, 7, 8-TCDD (Dioxin)	$3x10^{-8}$

(Aldicarb, Aldicarb Sulfone, and Aldicarb Sulfoxide have been remanded back to EPA for further regulation.)

Inorganic Chemicals	**<u>MCL, in mg/l</u>**
Antimony	0.006
Arsenic	0.05
Asbestos*	7 Million Fibers/Liter
Barium	2
Beryllium	0.004
Cadmium	0.005
Chromium	0.1
Cyanide	0.2
Fluoride	4.0
Mercury	0.002
Nitrate (as N)	10
Nitrite (as N)	1
Total Nitrate/Nitrite (as N)	10
Selenium	0.05
Thallium	0.002

*Fibers longer than 10 micrometers
(Nickel has been remanded back to EPA for further regulation.)

Radionuclides

Radionuclides	MCL
Gross alpha particle activity	15 pCi/L
Combined radium-226 and radium-228	5 pCi/L
Tritium	20,000 pCi/L
Strontium	8 pCi/L
Beta particle and photon radioactivity	4 millirem/year
Radioactivity (Total, for 2 or more radionuclides)	4 millirem/year

Radon (proposed for regulation in drinking water; action level for indoor air is 4 pCi/l)

Other Contaminants

Other Contaminants	MCL
Total Coliform Bacteria (depends on system size; includes repeat sampling requirements for fecal coliform bacteria)	No more than 1 sample or 5% of monthly
Total Trihalomethanes, annual average of four quarterly samples (only for systems serving $\geq$ 10,000 people)	0.10 mg/l

Alternate Requirements

Lead and Copper Rule - for all public water systems, treatment requirements depend on system size.

Contaminant	Treatment Technique or Other Requirements
Lead	Below action level of 0.15 mg/l or treatment
Copper	Below action level of 1.3 mg/l or treatment
Acrylamide 0.05%	Based on 1 ppm (or equivalent)
Epichlorohydrin 0.01%	Based on 20 ppm (or equivalent)

Surface Water Treatment Rule - requires filtration for all surface water systems and ground water systems under the direct influence of surface water.

Contaminant	Treatment Technique or Other Requirements
Giardia lamblia	Filtration/Disinfection
Legionella	Filtration/Disinfection
Turbidity	Filtration or other requirements
Viruses	Filtration/Disinfection

Unregulated Volatile Organic Chemicals (VOCs) - Monitoring Requirements

Chloroform
Bromodichloromethane
Chlorodibromomethane
1, 1-Dichloropropene
1, 1-Dichloroethane
1, 1, 2, 2-Tetrachloroethane
1, 3-Dichloropropane
Chloromethane
Bromomethane
n-Propylbenzene
tert-Butylbenzene
Bromochloromethane
Naphthalene
1, 3, 5-Trimethylbenzene
2, 2-Dichloropropane
1, 2, 3-Trichlorobenzene
Fluorotrichloromethane
1, 2, 3-Trichloropropane
1, 1, 1, 2-Tetrachloroethane
Chloroethane
m-Dichlorobenzene
o-Chlorotoluene
p-Chlorotoluene
Bromobenzene
1, 3-Dichloropropene
1, 2, 3-Trichlorobenzene
Isopropylbenzene
sec-Butylbenzene
Dichlorodifluoromethane
n-Butylbenzene
Hexachlorobutadiene
1, 2, 4-Trimethylbenzene
p-Isopropyltoluene

Unregulated Synthetic Organic Chemicals (SOCs) - Monitoring Requirements

Aldrin
Carbaryl
Dieldrin
Methomyl
Metribuzin
Butachlor
Dicamba
3-Hydroxycarbofuran
Metolachlor
Propachlor

U.S. EPA National Secondary Drinking Water Standards

Secondary Drinking Water Standards are not MCLs, but unenforceable federal guidelines regarding taste, odor, color and certain other non-aesthetic effects of drinking water. EPA recommends them to the States as reasonable goals, but federal law does not require water systems to comply with them. States may, however, adopt their own enforceable regulations governing these contaminants. To be safe, check your State=s drinking water rules.

Contaminants	Suggested Level
Aluminum	0.05 - 0.2 mg/l
Chloride	250 mg/l
Color	15 color units
Copper	1 mg/l
Corrosivity	Non-corrosive
Fluoride	2.0 mg/l
Foaming agents	0.5 mg/l
Iron	0.3 mg/l
Manganese	0.05 mg/l
Odor	3 threshold odor number
pH	6.5 - 8.5
Silver	0.1 mg/l
Sulfate	250 mg/l
Total dissolved solids (TDS)	500 mg/l
Zinc	5 mg/l

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American Water Works Association web site: www.awwa.org
Farm*A*Syst/Home*A*Syst web site: www.wisc.edu/farmasyst
Freshwater Foundation web site: www.freshwater.org
National Wildlife Federation web site: www.nwf.org
Sierra Club web site: www.sierraclub.org
U.S. EPA web site: www.epa.gov
U.S. EPA Office of Water web site: www.epa.gov/OW or e:mail at OW-GENERAL@epamail.epa.gov
Water Education Foundation web site: www.water-ed.org
Water Environment Federation web site: www.wef.org

Pollution Prevention Clearinghouse: 202-260-1023

Acid Rain Hotline: 617-674-7377

Radon Hotline: 800-767-RADON

Water Resources Center: 202-260-7786

EPA National Center for Environmental Publications and Information: 800-490-9198

National Technical Information Service: 800-553-6847 or 703-487-4650

U.S. Geological Survey: 800-USA-MAPS

U.S. Department of Agriculture, Soil Conservation Service: 800-THE-SOIL

National Lead Information Center: 800-LEAD-FYI

Government Printing Office, Superintendent of Documents, Washington, D.C. 20402, 202-512-1800.

American Water Resources Association, 5410 Grosvenor Lane, Suite 220, Bethesda, MD, 20814-2192. (Provides posters and booklets on water use at nominal cost).

Earthfax - USGS news releases, project and product information: 703-648-4888

American Water Works Association, 6666 West Quincy Avenue, Denver, CO, 80235-3098. (Operates Blue Thumb campaign to preserve water resources.)

America's Clean Water Foundation, 750 First Street, N.E., Suite 911, Washington, D.C., 20002-4241. (Develops and distributes educational materials.)

National Water Information Clearinghouse, U.S. Geological Survey, 423 National Center, Reston, VA, 22092-0001. (Supplies federal water data.)

Nebraska Groundwater Foundation, P.O. Box 22558, Lincoln, NE, 68542-2558. (Clearinghouse for general groundwater information and produces Children's Groundwater Festival.)

Water Education Foundation, 717 K Street, Suite 517, Sacramento, CA, 95814-3408. (Focuses on water use in western states; provides information to teachers and others.)

Water Environment Federation, 601 Wythe Street, Alexandria, VA 22314-1994. (Publications, slides, videos, available for rent or purchase.)

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National Estuary Program Directors and Coordinators list

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MOTE Marine Laboratory list: 1600 Ken Thompson Parkway, Sarasota, FL 34236, (941) 388-4441.

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800-USA-MAPS

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Water, Water Everywhere (an environmental science curriculum), Hack Company, P.O. Box 389, Loveland, CO, 80539-0389. 1-800-227-HACK; Literature No. 9274.

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DRINKING WATER RESOURCES

Safe Drinking Water Hotline: 800-426-4791

National Drinking Water Clearinghouse: 800-624-8301

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SURFACE WATER RESOURCES

National Small Water Flows Clearinghouse: 800-624-8301

Adopt-A-Stream, P.O. Box 435, Pittsford, NY, 14534-0435. (Organizes volunteer programs to clean up and monitor water quality.)

American Rivers, 801 Pennsylvania Avenue, S.E., Suite 400G, Washington, D.C., 20003-2167. (Seeks to preserve and restore America's river systems.)

Freshwater Foundation, 725 County Road 6, Wayzata, MN 55391-9611. (Provides educational programs and freshwater research.)

Izaak Walton League of America, 1401 Wilson Boulevard, Level B, Arlington, VA 22209-2318. (Operates Save Our Streams program and provides publications.)

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GROUNDWATER RESOURCES

American Ground Water Trust: 800-423-7748

The Groundwater Foundation 402-434-2740 (phone) or 402-434-2742 (fax); P.O. Box 22558, Lincoln, Nebraska 68542; www.groundwater.org.

Groundwater Protection Council: www.site.org

National Groundwater Association: www.h2o-ngwa.org

EPA Office of Groundwater and Drinking Water: www.epa.gov/owow/ogwdw

Safe Drinking Water Hotline: 800-426-4791 (also has groundwater publications)

Articles, Books, Publications, Videos & Computer Courseware

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COASTAL RESOURCES

Coastal Encounters Nature Center: 912-638-0221 or e:mail coastalkids@www.technonet.com

See appendix pages S-1 thru S-6

Articles, Books, Publications, Videos & Computer Courseware

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- Living with the West Florida Shore
- Living with the Alabama-Mississippi Shore
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WETLANDS RESOURCES

EPA Wetlands Hotline: 800-832-7828

See appendix pages T-1 thru T-6

Wetlands Posters are available through Wetlands Hotline or by contacting EPA Region 4, Wetlands Section, 100 Alabama Street, Atlanta, GA 30303-3104.

Articles, Books, Publications, Videos & Computer Courseware

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U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199, 601-634-4217.

Recognizing Wetlands, U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161, 703-487-4650.

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