

CHAPTER 1 – THE IMPORTANCE OF WATER QUALITY

Water is one of the most important natural resources, but it is not always in the right place, available at the right time or of the right quality. Improperly discarded chemical wastes of the past, stormwater runoff, poorly maintained septic systems and many land-disturbing activities add to the problems of quality and quantity of our water supplies today. The science of hydrology has evolved to help us understand the complex water systems of the Earth and help solve water quality and quantity problems. Hydrology evaluates the location, distribution, movement and properties of water and its relationship with its environment. We must understand all of the physical, chemical and biological processes involving water as it travels through the water cycle if we are to learn how to protect it.

1.1 SUMMARY OF THE HYDROLOGIC CYCLE (A.K.A. WATER CYCLE)

The hydrologic cycle (also known as the water cycle) is complex. It describes the existence and movement of water on, in and above the earth. It involves climatic changes, the earth materials that water flows across and through and land modifications by both natural events and human activities (USGS, September 2006; Winter et al., 1998). Water is always in motion and changing forms, from liquid to vapor to ice and back again. The water cycle has been working for billions of years and all life on Earth depends on it.

There really is no starting point for the water cycle, and there are many pathways it can travel (Figure 1-1). Water may fall as rain or snow, or it may return to the atmosphere through

evaporation. Water can be captured in polar ice caps or flow off the land to rivers and eventually to the sea. It can absorb into the soil and evaporate directly from the soil surface or be transpired by growing plants. Water can percolate through the soil to groundwater reservoirs (aquifers) where it is stored for many years. Water can also be drawn from wells or find openings in the land surface and emerge as freshwater springs. Water keeps moving only to repeat the cycle all over again (USGS, September 2006; USGS, August 2005a).

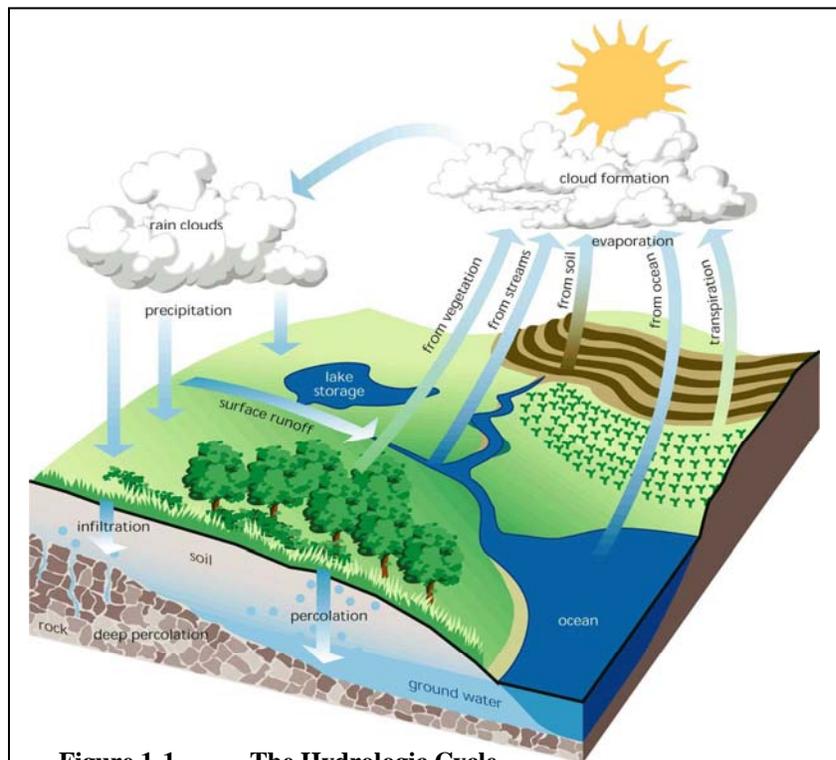


Figure 1-1 The Hydrologic Cycle

The transfer of water from precipitation to surface water and groundwater, to storage and runoff and eventually back to the atmosphere is an ongoing cycle (FISRWG, 1998).

Precipitation, infiltration, evaporation, transpiration, storage and water use all play a significant role in the water cycle. Precipitation is the amount of rainfall or snowfall. Precipitation can impact streamflow, stormwater runoff, water quality and water quantity. Not all of the precipitation that falls on the land, however, flows off. Instead, some of the water will absorb into the soil where it can be used by plants and/or recharge a groundwater aquifer. Water's ability to infiltrate, or absorb, into the soil depends on many factors. The most important are soil properties, vegetation (amount and type), existing land use, and storm characteristics (i.e., amount and rate of rainfall). These same factors will also determine the quality and quantity of runoff into streams, rivers and oceans. Water that stays in the shallow soil layer will gradually move downhill, through the soil and into a stream through the streambank.

Temperature, solar radiation, wind and atmospheric pressure control the amount of water that returns to the atmosphere through evaporation. Evaporation in turn can influence the amount and type of precipitation. Transpiration is controlled by many of the same factors as evaporation but the type and amount of vegetation present within the watershed are also important. Plant roots absorb water from the surrounding soil. The water then moves through the plant to escape into the atmosphere through the leaves. Vegetation slows runoff from the land surface and allows water to seep into ground.

Reservoirs store water. They also increase the amount of water that evaporates and/or infiltrates. The storage and release of reservoir water can significantly affect streamflow patterns below the outlet. Natural lakes, groundwater aquifers and wetland may also serve as storage areas that can influence streamflow and the water cycle.

Water withdrawal also impacts how a watershed functions and interacts with the water cycle. Use might range from a few homeowners or businesses pumping small amounts of water to irrigate lawns. It could also include large municipalities, industries, mining operations and agricultural producers pumping large amounts of water to support water demands in the region (USGS, August 2005c). Either way, withdrawing water will affect the rate of evaporation, transpiration and infiltration in a watershed.

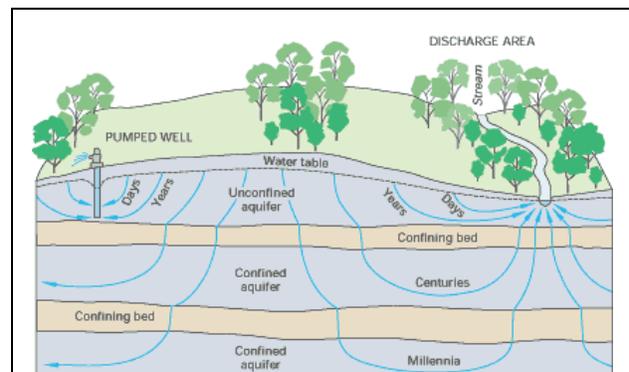


Figure 1-2 Groundwater Movement

Groundwater flow paths vary greatly in length, depth and traveltime from points of recharge to points of discharge (Winter et al., 1998).

1.1.1 GROUNDWATER

Infiltration is the downward movement of water from the land surface into soil or porous rock. Whenever water falls as rain or snow, some of the water absorbs into the subsurface soil and rock. Part of the water that infiltrates will remain in the shallow soil layer. Here, it will gradually move vertically and horizontally through the soil and subsurface material. Plants, grass and trees will use some of the water in the shallow soil layer (unsaturated zone), but some of the water will move deeper, recharging groundwater aquifers (Winter et al., 1998).

Like water in the shallow soil layer, groundwater can move both vertically and horizontally (Figure 1-2). Water moving downward may meet more dense and water-resistant, non-porous rock and soil (confining bed). When this happens, groundwater flows in a more horizontal direction, generally towards streams and oceans (Winter et al., 1998).

Depending on the geography and geology of the area, groundwater can also move into deeper aquifers. Downward movement depends on the permeability and the porosity of the subsurface rock. If the characteristics of the rock allow water to move freely, groundwater can move significant distances in a matter of days. Groundwater that sinks into deep aquifers can take thousands of years to move back to the surface and into the water cycle. When it reenters the water cycle, groundwater is a major contributor to streamflow, influencing river and wetland habitats for plants and animals (Winter et al., 1998).

1.1.2 GROUNDWATER AND SURFACE WATER INTERACTIONS

Nearly all surface waters (i.e., lakes, streams, reservoirs, wetlands, estuaries) interact with groundwater. As a result, removing water from streams can deplete groundwater supplies, and conversely, groundwater pumped from an aquifer can deplete water from streams, lakes or wetlands. For these reasons, polluted surface water can degrade groundwater just as contaminated groundwater can degrade surface water (Winter et al., 1998). These interactions can influence water supplies, water quality and aquatic environments characteristics. Both groundwater and surface water are essential for watershed management and water quality protection.

Until recently, scientific understanding of groundwater and surface water interactions was limited to large alluvial stream and aquifer systems. In recent years, however, interest in interactions between groundwater and surface water has grown. This interest is the result of widespread concerns related to water supply, contamination of drinking water supplies, acidification of surface waters caused by atmospheric deposition, eutrophication of lakes, loss of wetlands due to development and other changes in aquatic environments. Because of these concerns, groundwater and surface water studies have expanded to include many other settings, including headwater streams, lakes, wetlands and coastal areas (Winter et al., 1998).

STREAMS

Streams interact with groundwater in three ways. Streams can gain water from the inflow of groundwater through the streambed (gaining stream, Figure 1-3A); streams can lose water to groundwater by outflow through the streambed (losing streams, Figure 1-3B); or they can do both, gaining in some reaches and losing in others. In gaining streams, the water table near the stream must be higher than the altitude of the stream itself. The opposite is true for losing streams. Losing streams can be connected to the groundwater system by a continuous saturated zone, or it can be “disconnected” (Figure 1-3C). Water withdrawn from either the groundwater or surface water can influence the water level in the stream. Streamflow in streams that are disconnected from the groundwater system, however, are not affected when water is withdrawn (Winter et al., 1998).

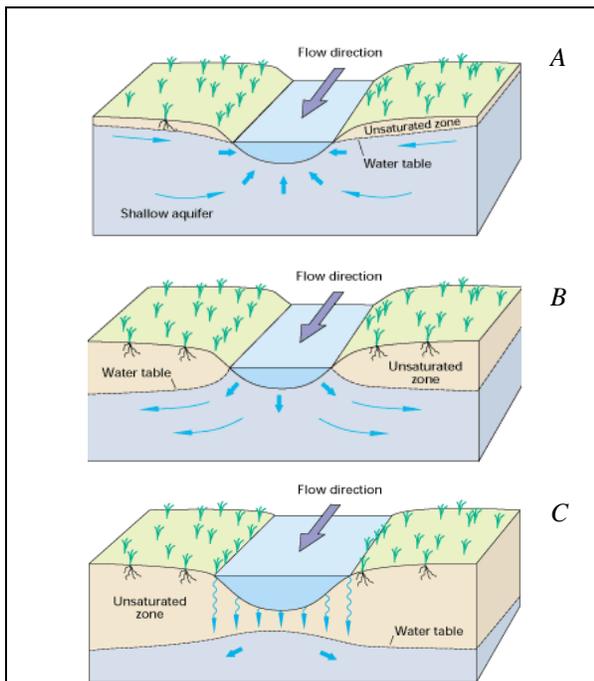


Figure 1-3 Groundwater and Stream Interactions

Gaining streams receive water from groundwater systems (A) and losing streams lose water to groundwater systems (B). Disconnected streams are separated from the groundwater system by an unsaturated zone (C) (Winter et al., 1998).

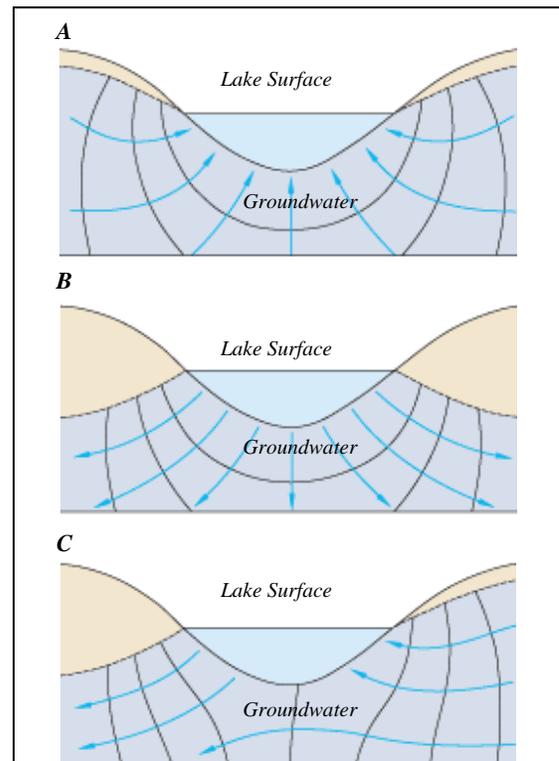


Figure 1-4 Groundwater and Lake Interactions

Lakes can receive groundwater inflow (A), lose water (B) or both (C) (Winter et al., 1998).

LAKES

Like streams, lakes interact with groundwater systems in three basic ways. Some lakes receive groundwater inflow throughout the entire lakebed; some lose water throughout the lakebed; and (perhaps most) lakes receive inflow and lose water at the same time (Figure 1-4). The water levels in natural lakes do not change as quickly as levels in streams. They also take longer to replenish. Lakes have a larger surface area and often less shaded than stream segments.

Consequently, evaporation has a greater influence on lakes than on streams. Lake sediments can play a significant role in the amount of inflow or loss. Sediments can also influence the cycling of chemical and biological material (Winter et al., 1998).

RESERVOIRS

Reservoirs are man-made lakes designed primarily to control the flow and distribution of surface water. Since most reservoirs are constructed in stream valleys, they share many characteristics with streams and lakes when it comes to groundwater interactions. Like streams, reservoirs can have widely fluctuating water levels. The continuous flushing of water is affected by climatic events and water use. Like lakes, reservoirs can experience significant water loss to evaporation. They also direct the cycling of chemical and biological materials (Winter et al., 1998).

WETLANDS

Wetlands can be found in climates and landscapes that cause groundwater to discharge directly to the land surface or in areas that prevent water from draining from the land. Wetlands can receive groundwater inflow, recharge groundwater or both. Those found on low points or depressions in the landscape interact with groundwater much like streams and lakes. Unlike streams, lakes and reservoirs, however, wetlands do not always occupy low points or depressions in the landscape. They can also be found on slopes (i.e., fens) or on drainage divides (i.e., some types of bogs). Wetlands found on slopes commonly receive a continuous supply of water from a groundwater source. Wetlands on drainage divides, uplands or extensive flat areas, receive much of their water from precipitation (Winter et al., 1998). Different water sources often lead to very different chemical and biological characteristics.

COASTAL SYSTEMS

Because coastal freshwater aquifers are so physically close to saltwater, unique issues arise. Two primary issues are saltwater intrusions into freshwater aquifers and changes in the amount and quality of freshwater discharging to coastal saltwater ecosystems. Saltwater intrusion is the movement of saline water into freshwater aquifers.

In coastal areas where groundwater is the primary source of drinking water, saltwater can enter into the freshwater aquifer especially in areas of heavy groundwater use. It is most often caused by groundwater pumping from coastal wells but can also occur during times of drought. Saltwater intrusion is unique because it reduces the freshwater storage capacity and can lead to the abandonment of water supply wells where concentrations of dissolved ions exceed drinking water standards. Salinity and nutrient concentrations can also significantly alter a coastal ecosystem. Excess nitrogen and phosphorus from groundwater or surface water can lead to red tides, fish kills and destroy coral reefs, sea grass habitats and shellfish growing areas (Barlow, 2003).

1.1.3 STREAMFLOW

Streamflow is the movement of water in a natural channel. A major element of the water cycle, it is always changing. It is also the main pathway by which water moves from the land to the ocean. Streamflow is largely influenced by the amount of precipitation (i.e., rain, snow, hail, sleet) that runs off of the land surface and into streams or rivers. Streamflow also determines the size and shape of a stream channel.

Nature and humans can impact streamflow. Surface runoff, evaporation, transpiration, groundwater discharge, groundwater recharge, sedimentation, the formation or dissipation of glaciers, snowfields and permafrost are all natural mechanisms influencing streamflow. Human impacts include surface water withdrawals and interbasin transfers, construction and removal of reservoirs and stormwater detention ponds, stream channelization, drainage or restoration of wetlands, land-use changes (i.e., urbanization of forests and agricultural lands) and wastewater outfalls (USGS, August 2005b).

Baseflow is precipitation that infiltrates the ground and moves slowly through the substrate before it reaches the stream channel. Baseflow and stormflow can greatly influence the quantity and speed of water moving through a stream channel. Groundwater sustains streamflow during periods of little or no precipitation. Stormflow, on the other hand, is precipitation that reaches a stream channel within a short period of time through overland or underground routes. At any given time, streamflow may contain water from one or both sources. Streams can be categorized based on the balance and timing of baseflow and stormflow.

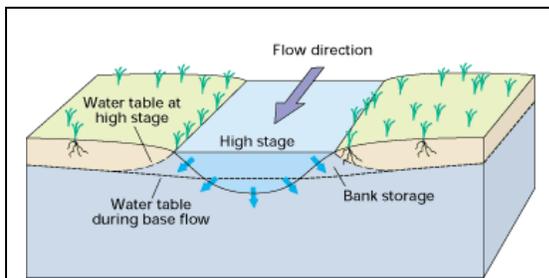


Figure 1-5 Streamflow and Bank Storage

When stream levels rise higher than adjacent groundwater levels, stream water moves into streambanks as bank storage (Winter et al., 1998).

Under normal weather conditions, streamflow is largely composed of groundwater (baseflow), and it follows the natural flow and movement of the stream channel. Bank storage, or bankfull stage, occurs when there is a rapid rise in the stream's water level. This causes water to move from the stream into the streambanks. Bank storage usually occurs during storm events, rapid snowmelt or release of water from an upstream reservoir. The water absorbs into the streambanks, maintaining streamflow and keeping the stream within its channel. As long as the water does not overtop the streambanks, most of the water that enters the streambanks returns to the stream within a few days or weeks.

Bank storage tends to reduce flood peaks and supplements streamflow during low flow conditions. If the rise in water overtops the streambanks and exceeds the stream's carrying capacity, flooding occurs on the land surface. Depending on the frequency, magnitude and intensity of the flooding, water may infiltrate and recharge groundwater aquifers or it can slowly return to the stream channel (USGS, September 2006; Winter et al., 2006).

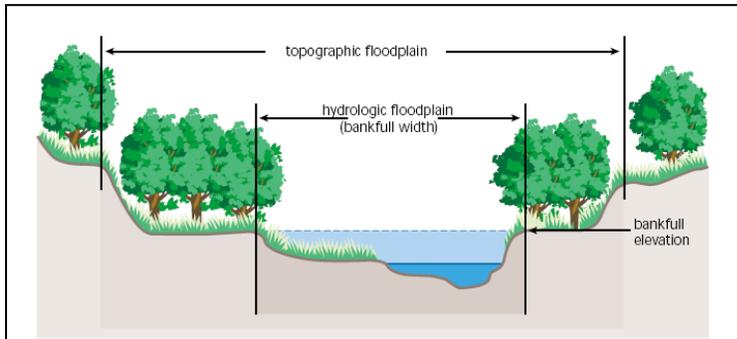


Figure 1-6 Hydrologic and Topographic Floodplains

A hydrologic floodplain is defined by the bankfull elevation. The topographic floodplain includes the hydrologic floodplain and other land features up to a defined elevation. Both floodplains store water and sediment during heavy rain events (FISCRWG, October 1998).

Almost all natural streams have a bankfull stage with a recurrence interval of one to 1½ years. This means that during a two-year storm event, unaltered or natural stream channels will flood. Water will move through the channel and the floodplain until the stream is back to its normal elevation. Depending on the amount of precipitation or snowmelt, excess streamflow will either enter the hydrologic or topographic floodplain. The hydrologic floodplain is land adjacent to the baseflow channel, but below the bankfull stage (Figure 1-

6). Because many streams have been channelized over the years, not every stream has a hydrologic floodplain. The topographic floodplain is land adjacent to the channel. It includes the hydrologic floodplain and other land features up to an elevation based on the flood peaks and frequency (i.e., 100-year and 500-year flood). Floodplains provide temporary storage for water and sediments moving through the watershed during rain events (FISCRWG, October 1998).

Rivers react differently to storms and rain events depending on their size. In a small watershed, a storm can cause 100 times more water to flow by each minute, compared to normal flow conditions. Water levels in small rivers tend to rise and fall in just minutes or hours. Larger rivers, however, may take days to rise and fall. The flooding can last for a number of days because it may take several hours or even days for water to travel from the upper part of the watershed to the lower part of the watershed.

Streams are classified as ephemeral, intermittent or perennial based on their baseflow. Ephemeral streams flow only during or immediately after periods of precipitation. Ephemeral streams usually flow less than 30 days per year. Intermittent streams flow only during certain times of the year (i.e., seasonal streams) and streamflow usually lasts longer than 30 days per year. Perennial streams flow continuously. If neither baseflow nor stormflow provides water to a channel, the stream will go dry (FISCRWG, October 1998).

Stream ecosystems depend on variable streamflow. High flows carry and disperse nutrients and sediments. High flows also reconnect floodplain wetlands to the stream channel. Low flows, especially in large rivers, allow stream vegetation to disperse so that populations of a single species exist in several locations along the stream corridor (FISCRWG, October 1998). Both high flows and low flows are important. Each improves biological productivity and maintains diversity throughout the stream corridor.

1.1.4 MINIMUM STREAMFLOW

Because stream ecosystems depend on streamflow, conditions may be placed on dam operations. Some conditions specify mandatory minimum releases in order to maintain adequate water quantity and quality in the length of stream affected by an impoundment. One of the primary purposes of the North Carolina dam safety law is to ensure minimum streamflows below dams. The North Carolina (NC) Division of Water Resources (DWR), in conjunction with the Wildlife Resources Commission (WRC), recommend conditions related to flow release to satisfy minimum instream requirements. The NC Division of Land Resources (DLR) issues permits for dam construction, repair and maintenance. The permits specify minimum release requirements.

Under the authority of the U.S. Federal Power Act, the Federal Energy Regulatory Commission (FERC) licenses all non-federal dams located on navigable United States waters that produce hydropower for interstate commerce. The license may include requirements for flows for either designated in-stream or off-stream uses.

Under the authority of Section 404 of the Clean Water Act (CWA), the U.S. Army Corps of Engineers (USACE) issues permits for the discharge of fill material into navigable waters. The permit may also include requirements for flows for designated in-stream or off-stream uses. A Section 404 permit applies to dams under state and federal regulatory authorities mentioned above. It also covers structures (i.e., weirs, diversions, small dams) not under the USACE authority.

1.1.5 STREAMFLOW AND WATER QUALITY UNDER DROUGHT CONDITIONS

Water quality problems associated with rainfall events usually involve degradation of aquatic habitats. High flows may carry increased amounts of substances like metals, oils, herbicides, pesticides, sand, clay, organic material, bacteria and nutrients. These substances may be toxic to aquatic life (fish and insects), deplete oxygen and/or cause sedimentation. During drought conditions, these pollutants become more concentrated in streams due to reduced flow. Summer months are generally the most critical months for water quality. Dissolved oxygen is naturally lower due to higher water temperatures, algae grow more readily due to longer periods of sunlight, and streamflows are reduced. Long-term drought can compound these problems and impacts to water quality and aquatic life can be catastrophic.

Acute impacts due to stormwater runoff are actually minimized during a drought. However, when rain events do occur, the pollutants collected on the land surface are quickly delivered to streams. When streamflows are below normal, the polluted runoff makes up a larger percentage of the water flowing in the stream.

Point sources may also have water quality impacts during a drought, even though permit limits are being met. Facilities that discharge wastewater have permit limits based on the historic low flow conditions. During droughts, these wastewater discharges make up a larger percentage of the water in streams. Consequently, this may result in lower dissolved oxygen concentrations and a temporary increase in other pollutants.

As streamflow decreases during drought conditions, habitat areas decrease, particularly along lake shorelines. Dry conditions combined with increased water withdrawals strains available water resources even further. Less habitat, lower streamflows, low dissolved oxygen levels and higher water temperatures increases the potential for large fish kills. These conditions may stress fish to the point where they become more susceptible to disease and stressors that normally would not harm them.

These are also areas where longer retention times due to decreased flows allow algae to take full advantage of the nutrients present. The result is algal blooms. During the daylight hours, algae greatly increase the amount of dissolved oxygen in the water, but at night, algal respiration and die off may cause dissolved oxygen levels to drop low enough to cause fish kills. Besides increasing the frequency of fish kills, algal blooms may also cause problems for water treatment plants because of taste and odor problems in the finished drinking water.

1.2 WATERSHEDS

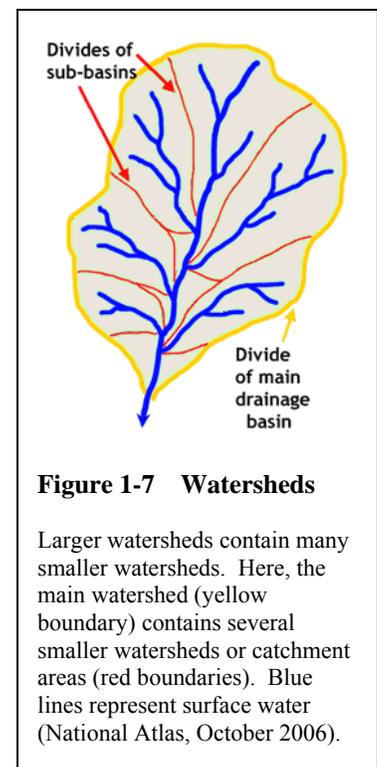
A watershed is the geographic area where all water, sediment and dissolved materials running off of the land drain to a given stream, river, lake, wetland or coastal water (Figure 1-7). Surface water and all of the underlying groundwater make up a watershed. The terms catchment (catchment area, catchment basin), drainage area and river basin are often used interchangeably with the word watershed.

Topographically, ridges, hills or mountains separate watersheds. Watershed sizes vary depending on where the divide falls. A watershed can be as small as a footprint in the mud or large enough to encompass the entire land area that drains water to the Mississippi and Missouri Rivers and the Gulf of Mexico. Larger watersheds contain many smaller watersheds (USGS, September 2006; USGS, August 2005c).

Geomorphology is the study of surface forms on the earth and the processes that developed those forms. Geologically, geomorphic processes are the primary way that drainage patterns, channel design, floodplains and other watershed features. Erosion, sediment transport and sediment deposition are all geomorphic processes that influence watershed function (FISCRWG, October 2006). No matter how you look at it, watersheds are important. Many things (natural and human-induced) affect streamflow, water quality and water quantity.

1.2.1 WATERSHED FUNCTIONS AND STREAMFLOW

Watersheds and their streamflow vary greatly depending on many factors. Some factors are underlying geology, topography, drainage area, soil characteristics, climate and vegetation. Despite their differences, however, all watersheds should perform the same functions – catch, store and safely release water. These functions allow a watershed to recharge a groundwater



aquifer, maintain a normal streamflow and provide clean water for aquatic and terrestrial plants and animals (Palmetto Conservation Foundation and South Carolina DHEC, November 1999; FISCRWG, October 1998).

1.2.2 UNDERSTANDING A STREAM CORRIDOR AND HOW IT INFLUENCES A WATERSHED

Stream corridors are complex ecosystems that have significant economic, social, cultural and environmental value. They regulate streamflow, store water, remove harmful materials (i.e., bacteria and some nutrients) from water and provide habitat for aquatic and terrestrial plants and animals. They also function as dynamic crossroads in the landscape where materials (i.e., minerals, nutrients), energy and organisms meet and interact. Much of this movement is dependent on water. The movement of water, materials, energy and organisms within a multidimensional framework forms the physical structure of a stream corridor (FISCRWG, October 1998).

Stream corridors usually consist of three major elements – stream channel, floodplain and transitional upland fringe. Stream channels and floodplains are discussed in previous sections of this chapter. Transitional upland fringes are defined as the “transitional” zone between the floodplain and the surrounding landscape (FISCRWG, October 1998). Changes within the surrounding watershed will impact the physical, chemical and biological processes within the stream corridor.

Stream corridors work within natural ranges to move sediment, control temperature, streamflow and other variables creating a dynamic equilibrium. When changes in a watershed go beyond their natural range, equilibrium is lost and the watershed no longer functions in the same way. Over the years, human activities have contributed to changes in the dynamic equilibrium of stream systems across the nation. Humans often manipulate the stream corridor for a wide variety of purposes including domestic and industrial water supplies, irrigation, transportation, hydropower, waste disposal, mining, flood control, timber management, recreation, aesthetics, and more recently, fish and wildlife habitat. Increases in human population and industrial, commercial and residential development place heavy demands on the country’s stream corridors (FISCRWG, October 1998).

1.3 STREAM MODIFICATION

Natural streams share certain physical characteristics, regardless of their location or geologic condition. Human activities (particularly engineering activities), however, can greatly influence stream hydrology. Physical activities such as the construction of dams, channels and diversions can dramatically impact the geomorphology and the hydrology of a stream corridor.

While most engineered channel modifications concentrate on the conveyance of floodwater, many often neglect sediment transport. A stream channel that has been straightened, or channelized, and enlarged to carry a 50-year storm, for example, will begin to form a smaller channel, point bars, floodplains and meanders as sediment moves from one point to another. Channelized streams can become unstable as they lose their shape and slope through erosion.

Unstable channel conditions ultimately lead to degraded water quality because of excessive sediment loading.

1.3.1 IMPACTS FROM DAMS

Dams can range in size from small temporary structures constructed of stream sediment to large multipurpose structures for hydroelectric power. No matter their size, dams can alter streamflow, impact migratory aquatic species and affect water quality. Dams also disrupt the flow of sediment and natural organic material, and change the composition of vegetative communities and groundwater infiltration throughout the entire stream corridor.

For dams that release water, discharge may vary widely monthly, daily or even hourly in response to water use and purpose. Because suspended sediment and natural organic materials tend to drop out of the water column behind the dam, the amount of nutrients available to downstream organisms is reduced. In the case of hydroelectric dams, discharge can influence the water temperature, depending on where and how the water is released. Changes in discharge volume can have a significant impact on streambank erosion and the subsequent loss of streambank vegetation and aquatic species. Water discharged from dams can also lower oxygen concentrations immediately downstream of the release, potentially impacting fish and aquatic insect communities (FISCRWG, October 1998).

1.3.2 IMPACTS FROM CHANNELIZATION

Like dams, stream channelization or diversions can significantly alter a stream corridor. Channelization can disrupt riffle and pool sequences, increase stream velocity and even elevate flood heights. Instream modifications, such as creating a uniform cross section or placing the stream in a concrete channel or culvert, result in fewer habitats for organisms living in or on the stream's sediments. When sediments, natural organic material and woody debris are lost, biodiversity and watershed functions are reduced (FISCRWG, October 1998).

Several examples of channelized streams can be found in eastern North Carolina in the middle and lower coastal plains and tidewater regions. Channelization began as early as the 1700s in order to improve overland water drainage and provide more land for agricultural production. Consequently, the groundwater table has been lowered. This impacted the hydrology, and wetlands lost the ability to store water, trap sediments and filter pollutants. Channelization also allows more freshwater to enter estuaries and coastal ecosystems, throwing off the delicate balance of a saline coastal environment (WECO, 2003).

1.3.3 INTERBASIN TRANSFERS

Throughout North Carolina, many users rely on surface water as their sole source for drinking water. Surface water can also be used for commercial, industrial and agricultural purposes, but often there is not enough water in the right place. If this happens, water can be transferred from one watershed to another via pumps and pipelines.

Water users in North Carolina are required to register surface water transfers with the NC Division of Water Resources (DWR) if they transfer 100,000 gallons per day (GPD) or more. Entities that wish to transfer more than the minimum quantity allowed by the Interbasin Transfer (IBT) law (usually 2.0 MGD), must obtain a certificate from the NC Environmental Management Commission (General Statute 143-215.22I). The river basin boundaries that apply to these requirements are designated on a map entitled

Major River Basins and Subbasins in North Carolina, on file in the Office of the Secretary of State (General Statute 143-215.22G). The boundaries differ slightly from the seventeen major river basins delineated by the NC Division of Water Quality (DWQ).

In determining whether an IBT certificate should be issued, the state must determine that the overall benefits of a transfer outweigh the potential impacts (Table 1-1). The IBT law also requires that an environmental assessment (EA) or environmental impact statement (EIS) be prepared in accordance with the State Environmental Policy Act (SEPA) as supporting documentation for a transfer petition.

1.4 WATER QUALITY AND QUANTITY

Water quality is a term used to describe water's chemical, physical and biological characteristics. The term is usually used to describe water's suitability for a particular purpose (i.e., drinking water, recreation, aquatic life) (USGS, August 2005d). The vulnerability of surface water and groundwater to degradation depends on the interactions and interconnections between surface water and groundwater, the atmosphere, natural landscape features, human activities, and aquatic health (Figure 1-8).

Streamflow affects many issues related to water quality and water quantity – pollutant concentration, water temperature, aquatic habitat and recreational uses. One factor cannot be separated from the other (Table 1-2). Reducing the water quantity of any particular waterbody can negatively impact all of the uses for that waterbody (Richter, 2003).

Table 1-1 Interbasin Transfers

Factors that are used to determine whether a certificate should be issued for interbasin transfers.

- Necessity, reasonableness and beneficial effects of the transfer;
- Detrimental effects on the source and receiving basins, including effects on water supply needs, wastewater assimilation, water quality, fish and wildlife habitat, hydroelectric power generation, navigation and recreation;
- Cumulative effect of existing transfers or water uses in the source basin;
- Reasonable alternatives to the proposed transfer; and
- Any other factors and/or circumstances necessary to evaluate the transfer request.

Population growth increases the pressures on natural ecosystems. Bacteria and microorganisms are being found in many drinking water supplies, and chemical pollutants are detected in many streams and rivers. Their presence endangers humans as well as plant and animal species. Sewage spills have occurred, forcing people to boil water, and stormwater runoff is delivering pesticides, fertilizers and automotive fluids to urban and rural streams (USGS, August 2005d). If water pollution is to be reduced or even eliminated, each individual, each municipality, business and industry and each state should be aware of pollution contributions and take actions to reduce them.

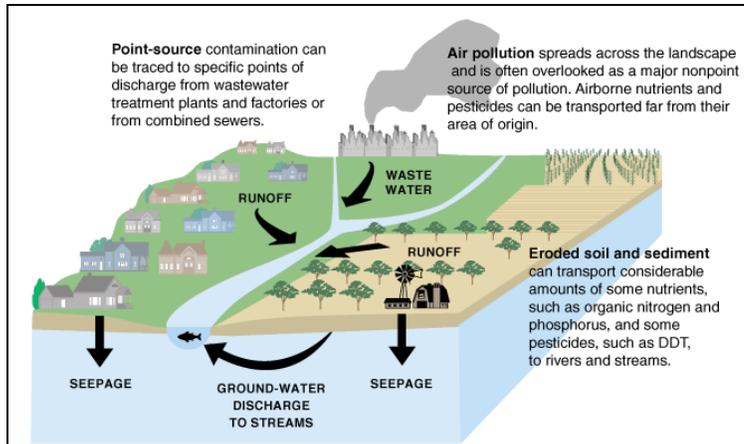


Figure 1-8 Impacts to Water Quality

The vulnerability of surface water and groundwater to degradation depends on the interactions and interconnections between surface water and groundwater, the atmosphere, natural landscape features, human activities, and aquatic health (USGS, August 2005d).

1.4.1 POPULATION GROWTH AND LAND COVER CHANGES IMPACTS ON WATERSHEDS

Population growth results in dramatic impacts on the natural landscape. The most obvious impact is the expansion of urban and suburban areas. New stores, roads and subdivisions are products of growing populations. Not so obvious, however, is the rate at which rural landscapes are converted to developed land. Between 1982 and 1997, the United States population increased by 15 percent. Over the same period, developed land increased by 34 percent – more than double the rate of population growth (USDA-NRCS, 2001; U.S. Census Bureau, 2000).

Locally, the trend can be even more pronounced. For example, the urban area of Charleston, South Carolina expanded 250 percent between 1973 and 1994 while its population grew by only 40 percent (Allen and Lu, 2000).

Impervious surfaces are materials that prevent infiltration of water into the soil and include roads, rooftops and parking lots. Impervious surfaces alter the natural hydrology, prevent the infiltration of water into the ground and concentrate the flow of stormwater over the landscape.

Table 1-2 Water Quality and Water Quantity Issues
Four major issues concerning water quality and quantity (Richter, 2003).

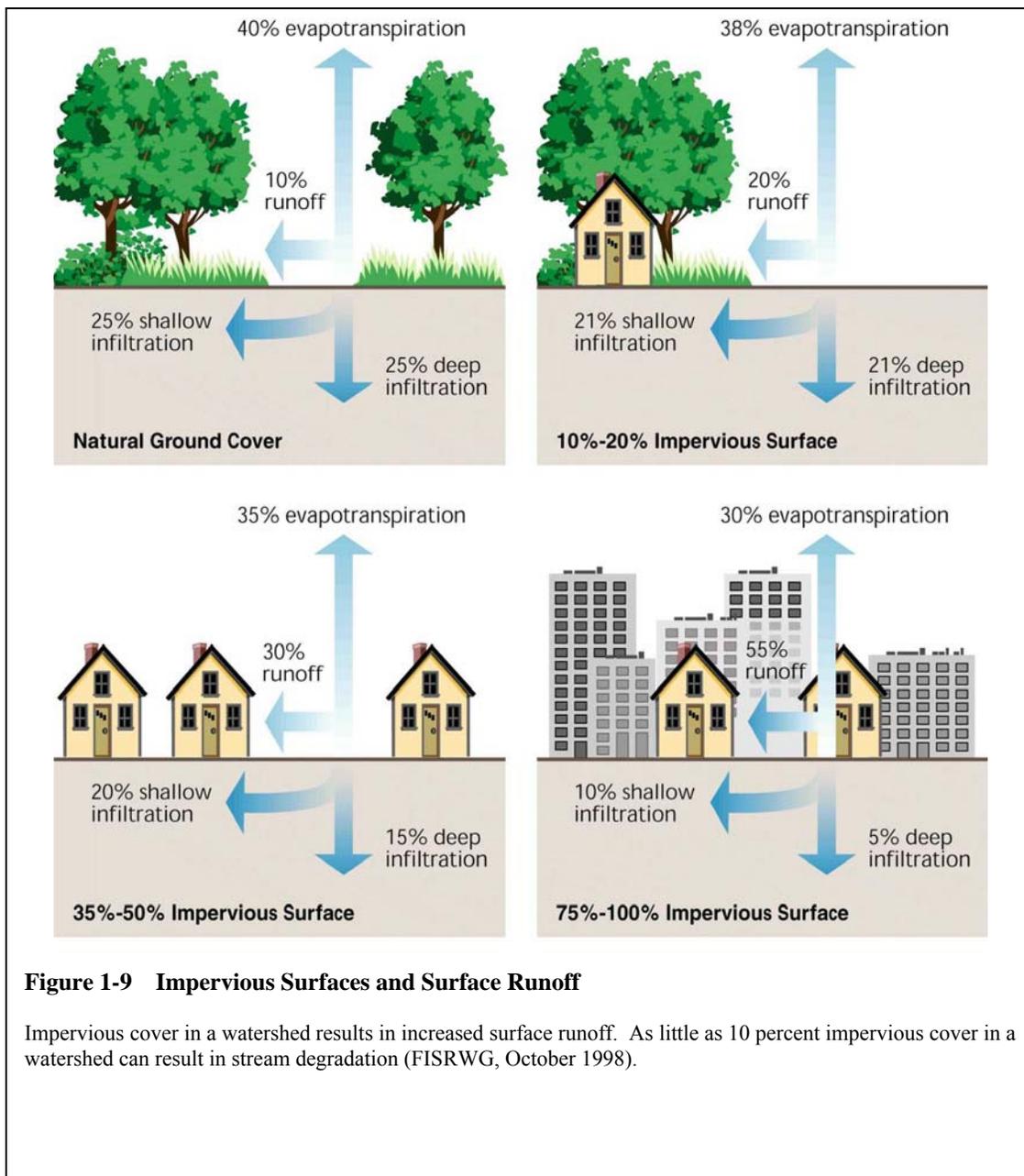
<p>Pollutant Concentration</p> <p>Higher flow is important for dilution of pollutants. Water quality standards are often violated during abnormally low flow conditions.</p>	<p>Recreational Use</p> <p>Many recreational activities (i.e., whitewater rafting, canoeing) depend on certain levels of flow. Flow also affects swimming and fishing.</p>
<p>Water Temperature</p> <p>More water takes longer to warm; therefore, the amount of water in a stream will ultimately influence how warm the water becomes. Higher flows protect sensitive, coldwater aquatic species from harmful or even lethal water temperatures.</p>	<p>Aquatic Habitat</p> <p>A river or stream can support more abundant and diverse aquatic life when flow is higher. Pools, runs and secondary channels are deeper, more varied and more abundant during high flows.</p>

In undeveloped watersheds, stormwater filters down through the soil, replenishing groundwater aquifers. Vegetation holds soil in place, slows the flow of stormwater over land and filters out pollutants by slowing the overland flow of the water and trapping some pollutants in the root system.

When the imperviousness of a watershed increases, the larger volume of stormwater raises the possibility of flooding and reduces the potential for pollutants to settle out. As a result more pollution is delivered to drinking water supplies. Too much paving and hardening of a watershed can reduce infiltration and groundwater levels. This reduction decreases the availability of aquifers, streams and rivers for drinking water supplies (Kauffman and Brant, 2000) (Figure 1-9).

1.4.2 Population Growth and Urbanization Impacts on Aquatic Resources

Urbanization poses one of the greatest threats to aquatic resources. Small towns and communities are usually not considered urban centers, but even small concentrations of urbanization can have significant impacts on local waterways. For example, a one-acre parking lot produces 16 times more runoff than a one-acre meadow (Schueler and Holland, 2000). A wide variety of studies over the past decade converge on a central point: when more than 10 percent of the acreage in a watershed is covered in roads, parking lots, rooftops, and other impervious surfaces, the rivers and streams within the watershed become seriously degraded. Studies show that if urbanized areas cover more than 25 percent of a watershed (Figure 1-10), there is a point where the decline in the health of the ecosystem is irreversible (Beach, 2002; Galli, 1991).



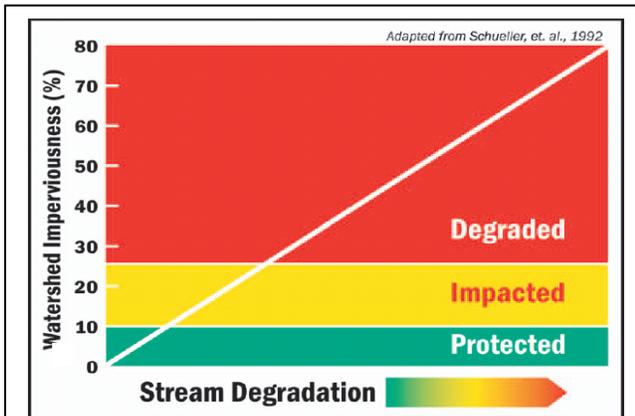


Figure 1-10 Imperviousness and Stream Degradation

Studies show that if urbanized areas cover more than 25 percent of a watershed, there is a point at which there is irreversible decline in the health of the ecosystem (Beach, 2002; Schueller, et al., 1992; Galli, 1991).

Greater numbers of homes, stores and businesses require greater quantities of water. They also lead to more discharge and runoff of increased quantities of waste and pollutants into the state’s streams, rivers, lakes and groundwater. Thus, just as demand and use increases, some of the potential water supply is also lost (Orr and Stuart, 2000).

As development in surrounding metropolitan areas consumes neighboring forests and fields, the impacts on rivers, lakes, and streams can be significant and permanent if stormwater runoff is not controlled (Orr and Stuart, 2000). As watershed vegetation is replaced with impervious surfaces, the ability of the landscape to absorb and diffuse the effects of natural rainfall is diminished.

Urbanization results in increased surface runoff and correspondingly earlier and higher peak streamflows after rainfall. Flooding frequency also increases. These effects are compounded when small streams are channelized (straightened) or piped, and storm sewer systems are installed to increase transport of stormwater downstream. Bank scour from these frequent high flow events tends to enlarge streams and increase suspended sediment. Scouring also destroys the variety of habitat in streams, leading to degradation of aquatic insect populations and the loss of fisheries (EPA, 1999).

1.4.3 WATER QUANTITY AND WATER USE

Streams and lakes are the most visible part of the water cycle; however, these freshwater supplies represent only about three percent of all the water on Earth. Freshwater lakes, wetlands and swamps account for only 0.3 percent of that total and rivers only hold about 0.006 percent (Figure 1-11) (USGS, August 2005e). In 2000, the United States Geological Survey (USGS) found that 408 billion gallons of water were withdrawn for use in the United States each day. Seventy-nine percent of the withdrawals were from surface water, and the remaining 21 percent was from groundwater aquifers. Eighty-one percent of the water withdrawals were freshwater and 19 percent were saline. It is interesting, however, that even though the population in the United States increased by about 33 million

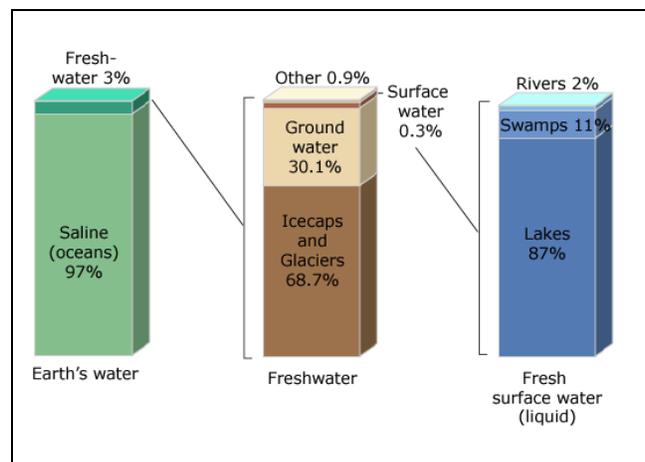
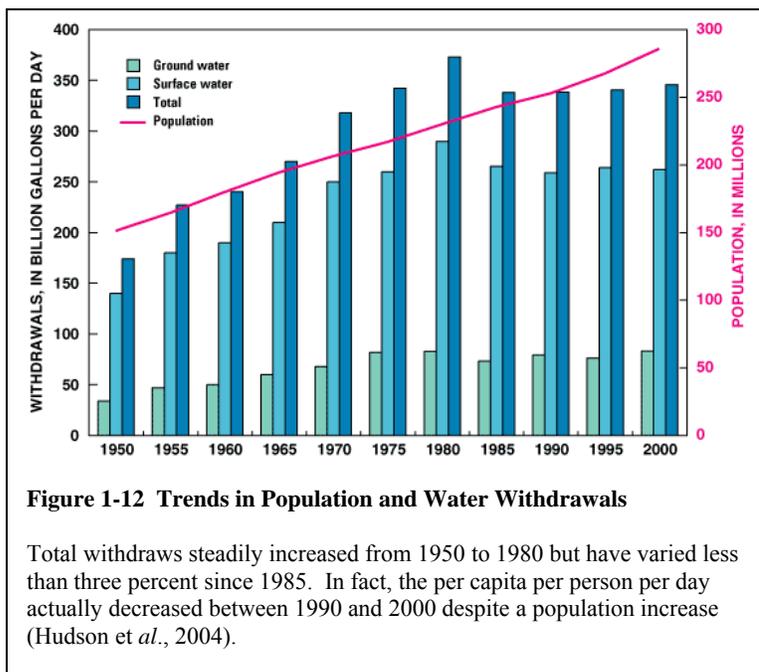


Figure 1-11 Distribution of the Earth’s Water

Only a small fraction of the water on the Earth’s surface is freshwater. Of that, only 0.3 percent is in the form of surface water (USGS, August 2005e; Gleick, 1996).

individuals between 1990 and 2000, the average use per person decreased from 1,620 gallons per person per day to 1,430 gallons per person per day (Figure 1-12).

Over the years, the percent of the population served by public water suppliers (i.e., water treatment plants, commercial use) has risen from 62 percent in 1950 to 85 percent in 2000. Public water suppliers deliver water to households (domestic), industries, commercial businesses, and other municipal users. Public supply and water used for livestock, aquaculture and mining constituted about 14 percent of the total water use. Self-supplied industrial withdrawals were estimated at 5 percent, and withdrawals for irrigation accounted for 34 percent.



By far the largest water withdrawal is associated with thermoelectric power plants. They accounted for 48 percent of the total water withdrawals. Surface water accounted for 99 percent of the total with one-third drawn from saline waters (Hudson et al., 2004; Lumin et al., 2005).

Water is essential for everyday use by both plants and animals. It is generally thought of as a renewable resource even though it depends on various parts of the water cycle. The amount of water in streams, lakes, reservoirs, and groundwater is always changing due to inflows and outflows, land use changes and climatic conditions. Over time, engineering and technology has allowed humans the opportunity to live in places where nature doesn't supply enough water or where water is not available during certain parts of the year. If humans are to continue living in these areas, water will need to be used more efficiently. Additional changes in technology, State and Federal laws, economic factors and an increased awareness of water conservation are necessary if the rivers, lakes, reservoirs and aquifers are to have enough water for future generations.

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