INTRODUCTION

Water is one of the state's most precious natural resources and basic economic commodities. It interrelates with and affects almost every aspect of human and natural existence. The purpose of this report is to provide a general overview of this resource in Texas and the aquifers in which it resides.

Ground-water sources supplied 56 percent of the 13.5 million acre-feet of water used in the state in 1992. Figure 1 illustrates the level of ground-water pumpage by county in 1992. More than 75 percent of the 7.6 million acre-feet of ground-water pumpage was for irrigated agriculture, with municipal use accounting for almost 17 percent of the total pumpage (Fig. 2). Due to its widespread availability and relatively low cost, ground water accounts for about 69 percent of the total water used for irrigation and about 41 percent of the water used for municipal needs (Fig. 3).

The Texas Water Development Board (TWDB) has identified and characterized nine major and 20 minor aquifers in the state based on the quantity of water supplied by each. A major aquifer is generally defined as supplying large quantities of water in large areas of the state. Minor aquifers typically supply large quantities of water in small areas or relatively small quantities in large areas. The major and minor aquifers, as presently defined, underlie approximately 81 percent of the state. Lesser quantities of water may also be found in the remainder of the state.

The surface extent, or outcrop, of each aquifer is the area in which the host formations are exposed at the land surface. This area corresponds to the principal recharge zone for the aquifers. Ground water encountered within this area is normally under unconfined, water-table conditions and is most susceptible to contamination.

Some water-bearing formations dip below the surface and are covered by other formations. Aquifers with this characteristic are common, although not exclusive, east and south of Interstate Highway 35. Aquifers covered by less permeable formations, such as clay, are confined under artesian pressure. Delineations of the downdip boundaries of such aquifers as the Edwards (BFZ), Trinity, and Carrizo-Wilcox are based on chemical quality criteria.

Aquifer water quality is described in terms of dissolved-solids concentrations expressed in milligrams per liter (mg/l) and is classified as fresh (less than 1,000 mg/l), slightly saline (1,000 - 3,000 mg/l), moderately saline (3,000 - 10,000 mg/l), and very saline (10,000 - 35,000 mg/l). Aquifer downdip boundaries shown on the maps delineate extents of the aquifers that contain ground water with dissolved-solids concentrations that meet the needs of the aquifers' primary uses. The quality limit for most aquifers is 3,000 mg/l dissolved solids, which meets most agricultural and industrial needs. However, the limit for the Edwards (BFZ) is 1,000 mg/l for public water supply use. The limit for the Dockum and Rustler is 5,000 mg/l, and10,000 mg/l for the Blaine for specific irrigation and industrial uses. Some aquifers, such as the Hueco Bolson and Lipan, have depth limitations at which water of acceptable quality can be obtained.

The following descriptions provide general information pertaining to location, geology, quality, yield, common use, and specific problems of the aquifers throughout their Texas extents. Geologic ages of the aquifers are summarized in Table 1. The aquifers are organized in the order of their magnitude of annual withdrawals, with the aquifer experiencing the largest amount of pumpage listed first. A more thorough understanding of each aquifer may be gained by referring to the suggested reports following each aquifer description.

The characterization of the state's ground-water resources and the development of the maps depicting these aquifers have been accomplished by many staff members of the TWDB over many years. The aquifer maps and reports undergo continual revision to reflect the latest information available. Individual aquifer maps accompanying each description are shown at different scales, but are configured from the same map projection as the major and minor aquifer maps.

The authors gratefully acknowledge all who provided input into this report and specifically thank Phil Nordstrom, Richard Preston, and David Thorkildsen for their valuable contributions. Mark Hayes and Steve Gifford also gave significantly of their time and talents in producing the illustrations.

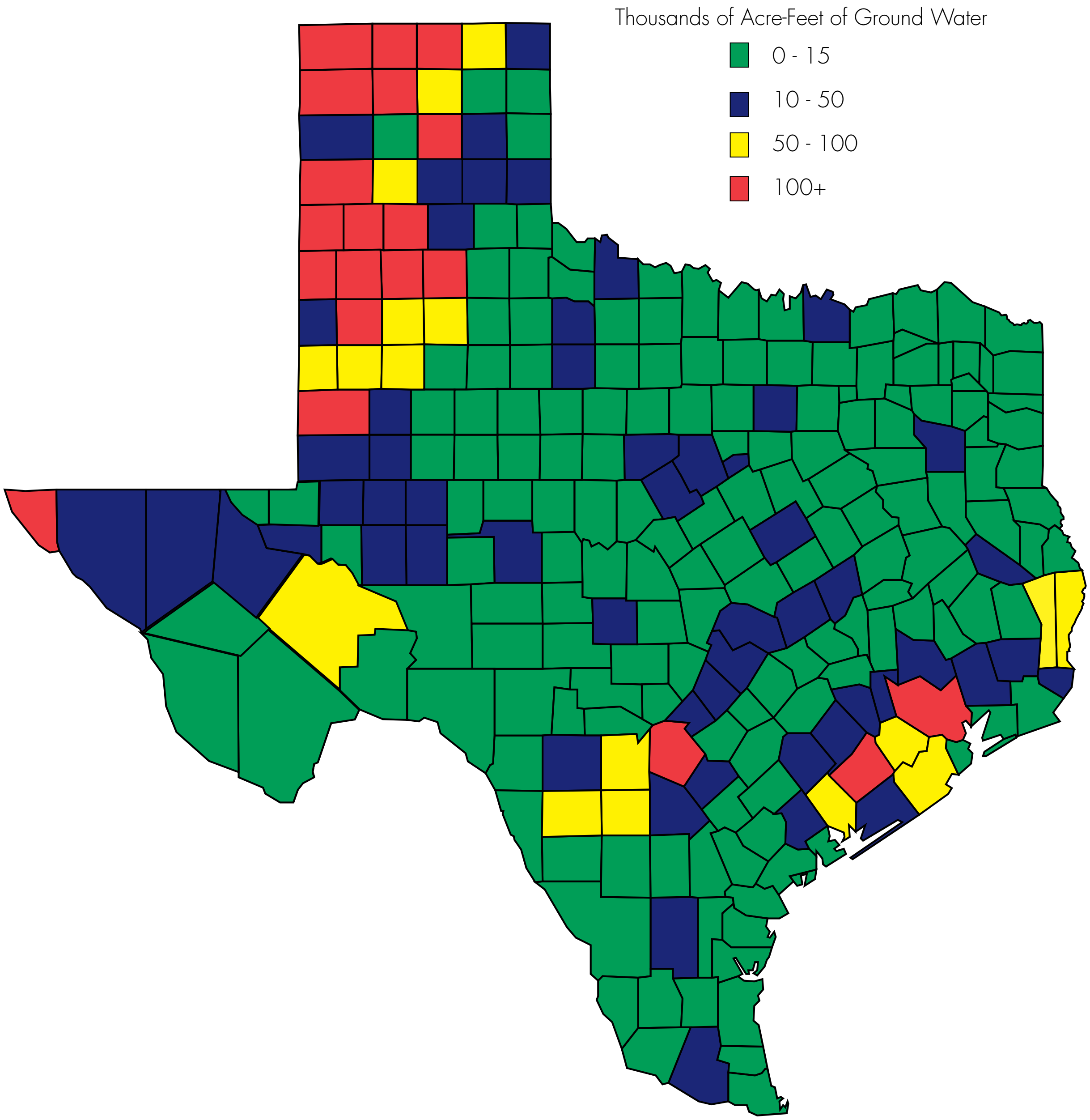


Figure 1. 1992 Ground-Water Pumpage

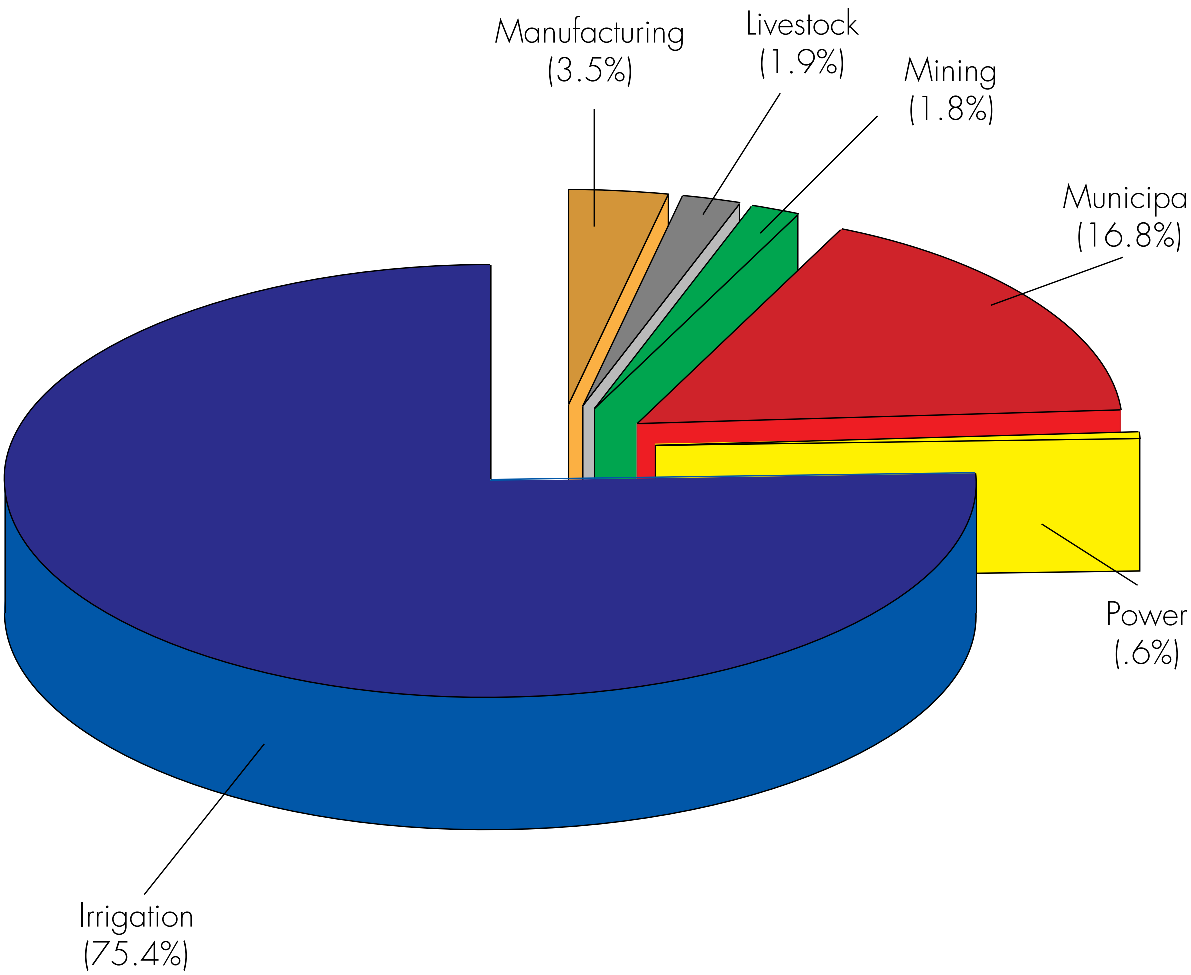


Figure 2. 1992 Ground-Water Use

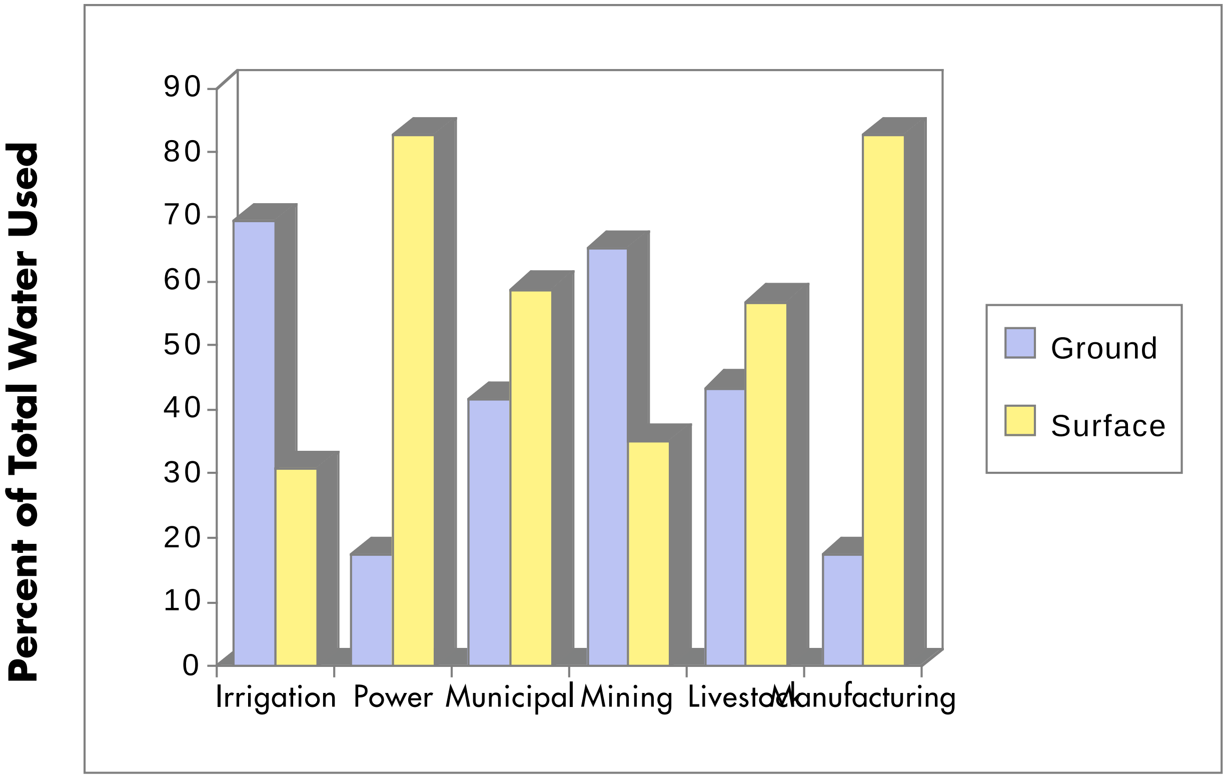


Figure 3. 1992 Water Use by Type

Table 1. Geologic Ages of Aquifers in Texas

Era	Period	Aquifer
Cenozoic	Quaternary	Cenozoic Pecos Alluvium Brazos River Alluvium West Texas Bolsons Seymour Lipan
	Tertiary	Gulf Coast Carrizo-Wilcox Hueco-Mesilla Bolson Ogallala Sparta Igneous Queen City
Mesozoic	Cretaceous	Woodbine Edwards-Trinity (Plateau) Edwards-Trinity (High Plains) Edwards (BFZ) Trinity Nacatoch Blossom Rita Blanca
	Jurassic	Rita Blanca
	Triassic	Dockum
Paleozoic	Permian	Blaine Bone Spring-Victorio Peak Capitan Reef Complex Rustler Lipan
	Pennsylvanian	Marble Falls Marathon
	Mississippian	Marathon
	Devonian	Marathon
	Silurian	Marathon
	Ordovician	Ellenburger-San Saba Marathon
	Cambrian	Ellenburger-San Saba Hickory
Precambrian		

GENERAL GROUND-WATER PRINCIPLES

Vast quantities of water percolate underground through geologic formations known as *aquifers*. The occurrence of water within the formations takes different forms. In sedimentary rocks, such as those composed of sand and gravel, water is contained in the spaces between grains. Some of the largest aquifers in Texas, including the Ogallala, Gulf Coast, and Carrizo-Wilcox, hold water in this fashion. Limestone formations, such as the Edwards, contain water in crevices and caverns caused in part by dissolution of the limestone by ground water. A third occurrence of ground water is within the cracks, fractures, and joints developed in harder formations such as granite and volcanic rock.

Two rock characteristics of fundamental importance related to the occurrence of ground water are *porosity,* which is the amount of open space contained in the rock, and *permeability,* the ability of the porous material to allow fluids to move through it. In sedimentary rocks consisting of sandstone, gravel, clay, and silt, the porosity is a function of the size, shape, sorting, and degree of cementation of the grains. In limestone and other harder rock, the porosity is a function of openings such as cracks, crevices, and caverns. Fine-grained sediments, such as clay and silt, usually have high porosity. However, due to the small size of the voids in these sediments, the permeability is low, and these formations do not readily yield or transmit water. For a geologic formation to be an aquifer, it must be porous, permeable, and yield water in sufficient quantities to provide a usable supply.

Recharge is the addition of water to an aquifer. This water may be absorbed from precipitation, streams, and lakes either directly into a formation or indirectly by way of leakage from another formation. Generally, only a small portion of the total precipitation seeps down through the soil cover to reach the water table. Among the factors that influence the amount of recharge to an aquifer are the amount and frequency of precipitation; the areal extent of the outcrop or intake area; the topography, type and amount of vegetation, and condition of soil cover in the outcrop area; and the ability of the aquifer to accept recharge and transmit it to areas of discharge.

Ground water is said to occur under either *water-table* or *artesian* conditions. Ground water in the outcrop of many aquifers is unconfined and under water-table conditions. Water under these conditions is under atmospheric pressure and will rise or fall in response to changes in the volume of water stored. In most places, the configuration of the water table approximates the topography of the land surface. In a well penetrating an unconfined aquifer, water will rise to the level of the water table.

Away from the outcrop, ground water in the aquifer may occur beneath a relatively impermeable bed. Here, water is under artesian, or confined, conditions, and the impermeable bed confines the water under a pressure greater than atmospheric. In a well penetrating an artesian aquifer, water will rise above the confining bed. If the pressure head is large enough to cause the water in the well to rise above the land surface, the well will flow.

Ground water moves from areas of recharge to areas of discharge, or from points of higher water level to points of lower water level. Under normal artesian conditions, movement of ground water usually is in the direction of the aquifer's regional dip. Under water-table conditions, the slope of the water table, and consequently the direction of ground-water movement, are usually closely related to the slope of the land surface. However, in the case of both artesian and water-table conditions, local anomalies develop in which some water moves toward pumpage areas. The rate of ground-water movement in an aquifer is normally very slow, or in the magnitude of a few feet to a few hundred feet per year.

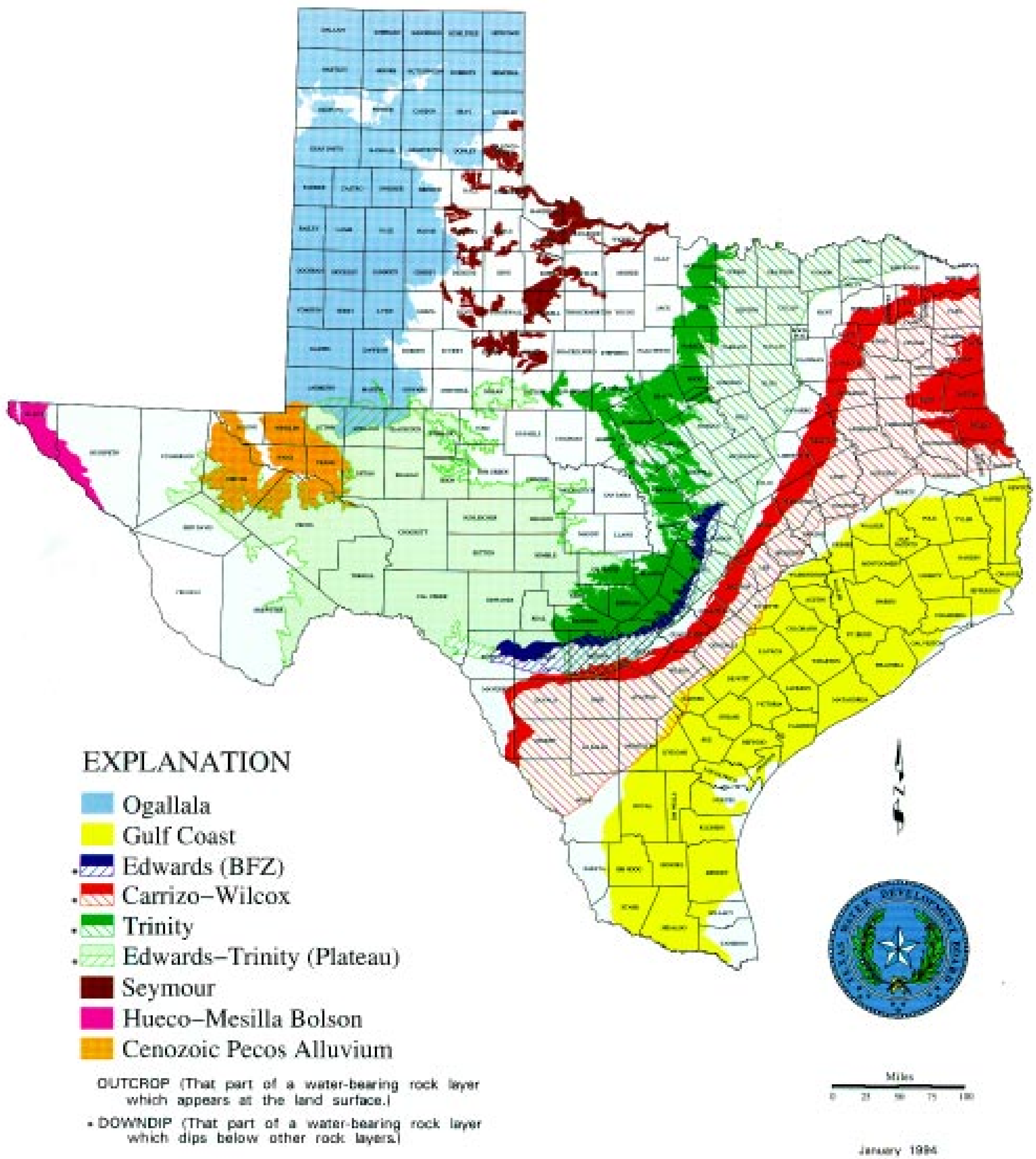
Discharge is the loss of water from an aquifer by either artificial or natural means. Artificial discharge takes place from flowing and pumped water wells, and from drainage ditches, gravel pits, or other excavations that intersect the water table. Natural discharge occurs as springs, evaporation, transpiration, and leakage between formations.

Changes in water levels indicate a change in the ground-water storage in an aquifer. These changes can be due to many causes, with some regionally significant and others confined to more local areas. In short, water-level fluctuations are caused by changes in recharge and discharge.

When recharge is reduced, as in the case of a drought, or when pumpage is greater than recharge, some of the water discharged from the aquifer must be withdrawn from storage, resulting in a decline of water levels. If water levels are lowered excessively, springs and shallow wells may go dry. However, when sufficient precipitation resumes or pumpage is reduced, the volume of water drained from storage may be replaced and water levels will rise accordingly. Changes in water levels in water-table aquifers are generally less pronounced than in artesian aquifers.

When a water well is pumped, water levels in the vicinity are drawn down in the shape of an inverted cone with its apex at the pumped well. The development of these *cones of depression* depends on the aquifer's ability to store and move water and on the rate of pumping. If the cone of one well overlaps the cone of another, additional lowering of water levels will occur as the wells compete for the same water.

MAJOR AQUIFERS OF TEXAS



MINOR AQUIFERS OF TEXAS