GROUND WATER IN OGALLALA FORMATION IN THE SOUTHERN HIGH PLAINS OF TEXAS AND NEW MEXICO

By James G. Cronin

INTRODUCTION

The Ogallala Formation of Tertiary (Pliocene) age is the principal aquifer in the Southern High Plains of western Texas and eastern New Mexico. This heavily pumped aquifer supplies practically all the water used for irrigation, municipal, industrial (except oil-field repressuring), and domestic purposes.

Although the ground water in the Ogallala Formation in the Southern High Plains is common to both Texas and New Mexico, the State laws concerning ownership of the water are different. The New Mexico statutes provide that all underground waters of the State belong to the public and are subject to appropriation for beneficial use (Reynolds, 1961, p. 79). Under conditions specified in the law, the State Engineer may declare certain areas as underground water basins in which the State Engineer has jurisdiction over the drilling of wells. The approximate boundaries of two such basins in New Mexico are shown on the maps. In Texas, the landowner owns the underground water. Under a law passed by the Texas State Legislature in 1949, underground water conservation districts may be formed with the authority to make rules and regulations for the conservation of ground waters, such as rules governing the minimum spacing of wells, and rules for the prevention of waste and contamination of fresh water, and other practices for the conservation of ground water. The approximate boundaries of two underground water conservation districts in Texas are shown on the maps.

Purpose and Scope of This Atlas

The purpose of this atlas is to show in convenient form the current information about the ground-water reservoir in the Ogallala Formation in the Southern High Plains of Texas and New Mexico. The maps show the saturated thickness of the Ogallala Formation, the approximate altitude of the base of the Ogallala Formation, the approximate altitude of the water table in the Ogallala Formation, and the approximate decline of the water table since the beginning of large-scale withdrawals for irrigation. The maps illustrate the continuity of the principal ground-water reservoir between the two States.

Location and Description of the Area

The Southern High Plains of western Texas and eastern New Mexico is the southernmost part of the High Plains section of the Great Plains Physiographic province (Fenneman, 1931, p. 10). It is the High Plains area south of the Canadian River, known locally as the South Plains. The name "Llano Estacado," given to the area by the early Spanish explorers, is less often used.

The Southern High Plains has a total area of about 32,000 square miles in western Texas and eastern New Mexico. The peninsula-like part of the area, about 4,000 square miles, extending eastward from Potter and Randall Counties through Carson and northern Armstrong Counties, Texas, between the Canadian River and Prairie Dog Town Fork of the Red River, is not included in this atlas. In general, the included area is rectangular, averaging about 190 miles from north to south and about 150 miles from east to west.

The region is essentially a plateau, bounded on the north by the deep valley of the Canadian River and on the east and west by prominent escarpments rising as much as 300 or more feet above the stream-eroded lower lands. The top of the escarpment, which is usually capped with caliche, is referred to as the "caprock." On the south, the Southern High Plains merges without a sharp physiographic break into the Edwards Plateau.

Canyons have been cut into both the eastern and western escarpments. The larger and more striking are along the eastern escarpment, where erosion is more effective because of the surface slope and heavier rainfall.

The surface of the plains is remarkably flat throughout much of the area and gently undulating in the remainder. Features of relief that interrupt the flat surface are numerous shallow depressions or playas, sand dunes, and small stream valleys. An exception to the flat surface is the Portales Valley in eastern New Mexico which is a major topographic feature of the plains.

The amount and direction of the maximum slope of the plains surface vary somewhat in different places, but in general the surface slopes east-southeasterly from the escarpment on the west in New Mexico at rates ranging from about 8 to 20 feet per mile. The steeper slopes are generally in the western part of the area.

Undrained depressions or playas ranging from a few feet to 50 feet or more in depth and from a few hundred feet to a mile or more in diameter are characteristic of the topography in the Southern High Plains. The drainage area of the playas may range from a few square miles to as much as 50 square miles, and during periods of heavy rainfall, runoff collects in the depressions to form temporary ponds or lakes. Some of the larger and deeper playas contain "alkali" or "saline lakes." The high mineral content of the water results from concentration of the salts by evaporation.

Stream drainage is very poorly developed and stream dissection is very light. Long shallow valleys, almost devoid of tributaries, follow the general slope of the land surface at widely spaced intervals. These valleys form the headwater reaches of three major rivers: the Red, the Brazos, and the Colorado. The drainage area of the intermittent streams that occupy the valleys is limited to the stream valley and to narrow belts of sloping land adjacent to the valley. Surface water accumulating in the streams ordinarily flows for only short distances before being lost by seepage or evaporation.

The Southern High Plains area generally does not contribute to streamflow east of the eastern escarpment except during rare periods of excessive rainfall. The western escarpment forms the eastern boundary of the Pecos River drainage basin in the area of this atlas. Runoff is generally channeled to the southeast, away from the escarpment, because of the general slope of the land surface. A few small intermittent streams may divert some water into the Pecos River, but the amount is probably very small.

The Portales Valley extends from near Krider, New Mexico, east-southeastward through Portales, into west-central Bailey County, Texas. The valley is about 30 miles wide in the vicinity of Portales and about 250 feet deep (Theis, 1932, p. 103).

Sand dunes and areas of deep sandy soils, where present, give the plains surface a billowy appearance. The location of one of the most extensive sand dune areas is shown on the maps. Other sand dune areas are generally in the southern and southwestern part of the area.

Climate

The Southern High Plains of western Texas and eastern New Mexico has a semiarid climate. Factors which characterize the climate are: Low average annual precipitation, which varies in amount annually and seasonally and in geographic distribution; a high rate of evaporation; low relative humidity; high average wind velocity; warm to hot summer days followed by cool nights; and moderate winters with some severe cold spells. The average annual snow fall is light; the snow usually melts within a few days. Hail occasionally damages crops in local areas. Dust storms occur often, especially during the months of January through June. Tornadoes occur during late spring and early summer.

Climatological data from records of the United States Weather Bureau are summarized in table 1 for several stations in Texas and New Mexico

TABLE 1.—*U.S. Weather Bureau climatological data for the Southern High Plains of Texas and New Mexico*

Station	Altitude, feet above mean sea level	Average annual precipitation, inches	Mean annual temperature, degrees F	Evaporation, inches
Amarillo	3,590	19.21	57.5	
Big Spring	2,533	14.19	64.5	
Crosbyton	3,037	18.67	60.0	
Midland	2,854	12.41	64.0	
Caprock	4,335	12.09		
Clovis	4,280	17.14	57.3	[1] 104.15
Hobbs	2,615	13.71	62.2	
Melrose	4,599	12.97	57.5	
Portales	4,004	15.43	58.2	[2] 92.52
Ragland	4,900	17.27		

[1] Station located 13 miles north of Clovis

[2] Station located 7 miles west-northwest of Portales.

for the period 1951-60. These data indicate that the precipitation decreases from east to west and in general from north to south.

Economic Development

The economy of the Southern High Plains of Texas and New Mexico is based largely on the presence of fertile soil, an abundance of ground water, and large quantities of oil and gas. During the early period of development, beef cattle was the principal product; later, dry-land farming became important. In the 1930's and 1940's, large-scale irrigation began and large oil and gas fields were discovered.

Approximately 5,000,000 acres are now irrigated (1967) from an estimated 50,000 or more wells, of which about 300,000 acres and about 4,300 wells are in New Mexico. The principal crops are cotton and grain sorghums. Other crops include wheat, oats, barley, corn, sesame, surgar beets, and various vegetables. Peanuts are an important crop in the Portales Valley in New Mexico. The raising of beef cattle and cattle-feeding are still important parts of the economy and may become more so in the future because of increased interest in developing local facilities for slaughtering and processing.

Large amounts of oil and gas are produced in several of the counties, especially in the southern half of the area which includes some of the leading oil-producing counties of both Texas and New Mexico.

Acknowledgments

This atlas was prepared from information in published reports describing the geology and hydrology of certain areas of the Southern High Plains of Texas and New Mexico; from unpublished data from the Albuquerque, New Mexico, and Austin, Texas, District Offices of the Water Resources Division, U.S. Geological Survey; New Mexico State Engineer Office, Roswell, New Mexico; Texas Water Development Board, Austin, Texas; and the High Plains Underground Water Conservation District No. 1, Lubbock, Texas. Recognition of the authors of published reports is given at appropriate places in the atlas; appreciation is expressed to the organizations and to water-well drillers who contributed information.

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GROUND-WATER GEOLOGY OF THE SOUTHERN HIGH PLAINS

The rocks that crop out the Southern High Plains range in age from Permian to Holocene. Older rocks are present in the subsurface, but they are not important as sources of ground water.

Rocks of Permian to Cretaceous Age

Rocks of the Permian System underlie all of the Southern High Plains and are the oldest rocks that crop out in the area, but occur at the surface only at the extreme northern and northeastern edges of the escarpment. Saline water is produced from the Permian and older Paleozoic rocks along with oil and gas; but at no place in the area is potable water known to be pumped from these formations. Any water available from them would probably be saline.

The beds of the Dockum Group of Late Triassic age lie unconformably on the eroded surface of the Permian rocks throughout the area of this atlas. Triassic rocks crop out along the escarpments and in small, scattered areas in the interior. The a ount of water pumped from aquifers in the Dockum Group is small, and the water is used mainly for stock and industrial purposes. Although wells pumping from aquifers in the Dockum Group have been reported to yield as much as 700 gpm (gallons per minute), (Cronin, 1964, p. 17-19), current information indicates that the yields of wells completed in these aquifers would range from meager or low to moderate—possibly 100 gpm or less. The water would probably be saline and probably unsuitable in most instances for irrigation or public supply. The water might be suitable for certain industrial uses.

Rocks of Jurassic age crop out along the northwest margin of the escarpment in Quay County, New Mexico; but they have not been found in other parts of the Southern High Plains. The extent of these rocks in the subsurface is probably limited to a small area adjacent to the outcrop. Because of the limited extent and the probability that the yields of wells tapping these rocks would be small, the Jurassic rocks are not considered an important source of ground water.

Rocks of Early Cretaceous age were deposited on the eroded surface of the older rocks, probably throughout the entire Southern High Plains. After deposition, they were removed from a large part of the area by erosion. The Cretaceous rocks crop out along the northwest margin of the escarpment in Quay County, New Mexico; along the eastern escarpment south of Lubbock County, Texas; along the margins of some of the deeper playa basins; and at scattered outcrops mainly in the southern part of the area.

The ground water in the Cretaceous rocks is in hydraulic continuity with the ground water in the Ogallala Formation in the vicinity of Causey and Lingo in Roosevelt County, New Mexico (Cooper, 1960, p. 15); in southeastern Hale County, Texas; in north-central Lubbock County, Texas (Cronin and Wells, 1963, p. U14-U15, and Cronin, 1964, p. 24); and in eastern Gaines County, Texas (Rettman and Leggat, 1966, p. 20). Wells in these areas tapping aquifers in the Cretaceous rocks or tapping both the Cretaceous aquifer and the Ogallala Formation have been known to yield moderate to large (500 or more gpm) amounts of water suitable for irrigation. However as the water table in the Ogallala Formation has declined, the yield of some of these wells has decreased. Some ground water, but probably not a large amount, may be produced from Cretaceous rocks in the southern counties of the Southern High Plains in Texas where it is impossible, because of lithologic similarities, to distinguish the Ogallala Formation from the Cretaceous rocks (Cronin, 1964, p. 25).

Thus locally, the aquifers in the Cretaceous rocks, especially where they are in hydraulic continuity with the Ogallala Formation, furnish some water, mainly for irrigation. However, for the Southern High Plains as a whole, reports by Leggat (1952 and 1957), Rayner (1963), Ash (1963), and Cronin (1964) indicate that the Cretaceous rocks do not constitute an important source of ground water for large-scale irrigation, municipal supply, or other uses.

Ogallala Formation

The Ogallala Formation in the Southern High Plains is formally defined as a stratigraphic unit of Pliocene age (Keroher, 1966), but as discussed in this atlas, as the principal aquifer of the region, includes the valley-fill deposits of Quaternary age that are the major sources of ground water in the Portales Valley, Roosevelt County, New Mexico. The physical characteristics of the valley fill and the Ogallala Formation are discussed separately, but because they form a single hydrologic unit, their hydrologic characteristics are discussed together under the heading "Ground Water in the Ogallala Formation."

The Ogallala Formation consists of clay, silt, fine to coarse-grained sand, gravel, and caliche. The lithology varies within short distances, both vertically and horizontally, and individual beds or lenses are not continuous over wide areas. Instead, the individual beds or lenses generally pinch out or grade into finer or coarser material. Ash (1963, sheet 1) indicated that the lower one-third of the Ogallala Formation in northern Lea County, New Mexico, contains a higher proportion of coarse sediments than the upper two-thirds. General conclusions made by Cronin (1964, p. 32) from geologic sections measured along the eastern escarpment by Frye and Leonard (1957, p. 40-51) indicated that silt is commonly associated with the fine to medium-grained sand in the upper part of the formation; coarse-grained sand generally occurs in the lower part of the formation; gravel is present in many places at the base of the formation where it is commonly associated with sand and silt and may be cemented; at other horizons gravel is also present as lenses or is interbedded with sand.

Most of the Ogallala is unconsolidated, although near the top and locally within the formation, the sediments have been cemented, chiefly by calcium carbonate, to form beds of caliche. The degree of cementation varies greatly from well cemented to partially cemented. The caliche occurs in single or multiple layers in the uppermost part of the formation throughout much of the Southern High Plains. Because it is resistant to erosion it forms the "caprock" of the escarpment and the topographic prominences of the plains surface. The caliche also crops out around the margins of some of the larger lakes and along some stream valleys.

The Ogallala Formation overlies an erosional surface cut into Cretaceous, Jurassic, Triassic, and Permian rocks. The configuration of this surface is shown by contours on the base of the Ogallala Formation (sheet 1). The contours show that the slope of this erosional surface is generally east-southeast. The relief is moderate, except in the northwestern part of the area where the erosional surface rises as much as 500 or more feet above the floor of the Portales Valley.

The Ogallala Formation ranges in thickness from zero where the formation wedges out against older rocks to as much as 500 feet in places in east-central Curry County, New Mexico; east-central Parmer, west-central Castro, and southwestern Floyd Counties, Texas. Near Mescalero Ridge in northern Lea County, New Mexico, the thickness is about 350 feet (Ash, 1963, sheet 1).

The valley fill of the Portales Valley was deposited on rocks of Triassic age. The fill is as much as 100 feet or more in thickness and consists of gravel, sand, and silt (Theis, 1932, pp. 109-110). Except in a few places, the gravel is confined to the lower part of the deposit, in a bed 1 foot to 10 feet or more thick; the upper part of the deposit consists of material ranging from medium-grained sand to silt. Fragments of caliche are present in the gravel, and well logs indicate that caliche is present near the surface in some places.

GROUND WATER IN THE OGALLALA FORMATION

Source and Occurrence of Ground Water

The ground-water reservoir in the Ogallala Formation is continuous throughout most of the Southern High Plains. It is absent in some of the larger playa lakes where the formation has been removed by wind erosion and in some places where the altitude of the underlying consolidated rocks is above the water table. Ground water in the Ogallala Formation is unconfined and is contained in the pore spaces of the unconsolidated or partially consolidated sediments, which are underlain in most of the area by relatively impermeable clays and shales. In places where the underlying Cretaceous rocks are in hydrologic continuity with the Ogallala Formation, the Cretaceous rocks are in effect a part of the aquifer. The saturated section in the Cretaceous rocks, as in the vicinity of Causey and Lingo in New Mexico, is not included in the estimate of the saturated thickness in the Ogallala Formation (sheet 4); except in those places where a distinction between the two geologic sections could not be made.

Recharge, Discharge, and Movement of Ground Water

The principal source of recharge to the Ogallala Formation is precipitation on the land surface of the Southern High Plains. The bounding escarpments on the east, west, and southwest, and the valley of the Canadian River on the north, hydrologically isolate the Ogallala Formation and prevent the movement of water from those directions. Because the water table slopes to the southeast, water does not move to the Southern High Plains from that direction. An unknown amount of water pumped from the Ogallala Formation for irrigation percolates back to the aquifer. This water does not constitute an addition to the supply of water, but only a reduction in net discharge.

The amount and rate of recharge from precipitation depend on the amount, distribution, and intensity of the precipitation; the amount of moisture in the soil when rain or snowmelt begins; and the temperature, vegetative cover, and permeability of the materials at the site of infiltration. Because of the wide variations in these factors and because of the lack of data, it is difficult to estimate the amount of recharge to the ground-water reservoir.

Barnes and other (1949, p. 26-27) indicate that the average annual recharge would be only a fraction of an inch in an area of about 9,000 square miles, roughly in the central part of the Southern High Plains. From studies made in New Mexico and Texas, Theis (1937, p. 546-568) has suggested that the average annual recharge is less than half an inch. Havens (1966, p. Fl) reports that the annual recharge on 1,400,000 acres in Lea County, New Mexico, during the period 1949-60 was about 95,000 acre-feet or about 0.8 inch.

Surface runoff that collects in the depressions is being injected through wells into the ground-water reservoir at many places. Although the amount of water injected is very small in comparison to the amount withdrawn from the aquifer, the practice is an attempt to conserve the present water supply.

The downward seepage of water from oil-field brine-disposal pits is a form of recharge that is detrimental to the quality of ground water in the Ogallala Formation (Broadhurst, 1957, p. 1, and Ash, 1963, sheet 2). This method of disposing of oil-field brines is now being abandoned, at least in some parts of the Southern High Plains.

Ground water stored in the Ogallala Formaion in the Southern High Plains is discharged by both natural and artificial means. Natural discharge is through springs and seeps along the bounding escarpments and around the margins of some of the larger playa lakes, by subsurface flow out of the area along the southern boundary, and by evaporation and transpiration. Some water, but probably a very small amount, may move downward from the Ogallala Formation into the underlying formations. Artificial discharge is through wells.

Irrigation from wells in the Southern High Plains began about 1910, but it was not until the 1930's that development began on a significant scale. At that time, the principal irrigated areas were in the Portales Valley, New Mexico, and in the vicinity of Hereford, Muleshoe, Plainview, and Lubbock, Texas. During the following years, the irrigated areas expanded, especially during the drought years of 1950-56. Development of irrigation in the southern part of the area, in the vicinity of Gaines County, Texas, and Lea County, New Mexico, began on a major scale about 1947. In Curry County, New Mexico, where a large percentage of the area developed for irrigation is adjacent to the New Mexico-Texas State line in the vicinity of Clovis and Pleasant Hill, the number of irrigation wells increased from 90 in 1953 (Howard, 1954, p. 9-10) to an estimated 1,100 in 1967.

The yield of irrigation wells pumping from the Ogallala Formation ranges from less than 100 to 1,000 gpm or more. Yields are generally higher in the areas where the saturated zone is thickest—in general, in the northern half of the area and in western Gaines County, Texas, and adjoining Lea County, New Mexico. Since large-scale development of the ground-water reservoir began, yields have decreased, generally because of a decrease in the thickness of the saturated material. Declines in yields of numerous wells in the heavily irrigated parts of the area were reported as early as 1951 by Leggat (1954, p. 16-17).

The expansion of the irrigated areas, especially during and following the drought years of the early 1950's, prompted the development of wells in places where the zone of saturation was generally thin. In such places the yield of the wells was generally smaller than the yield previously considered economic for irrigating field crops. From studies made in 1962, Hughes and Magee (1964, p. 5, fig. 1) suggested that approximately 200,000 acres were being irrigated with low-capacity wells (generally less than 100 gpm) in parts of Lamb, Bailey, Hockley, Lubbock, Garza, Lynn, Terry, and Borden Counties, Texas.

Only a rough approximation of the total pumpage on the Southern High Plains is possible because of the large number of wells pumping water from the Ogallala Formation, the wide variation in the yield of the wells, the amount of water applied for irrigation, the farming practices of the individual irrigators and the type of crops. The average yearly pumpage from the Ogallala Formation in the Texas part of the Southern High Plains during the years 1954 to 1957 was estimated on the basis of the duty of water on irrigated land to be about 5,000,000 acre-feet (Cronin, 1964, p. 75-76). Data given by Ballance and others (1962, p. 10-49) indicate that pumpage from the Ogallala Formation in New Mexico was about 260,000 acre-feet in 1960. The above data are approximations, but they do indicate the order of magnitude of the pumpage.

The total amount of ground water discharged naturally from the Ogallala Formation is unknown, but it is probably very small in comparison to the amount withdrawn by wells.

The configuration and approximate altitude of the water table are shown on sheet 2 by contours based on water-level measurements made mostly in 1967. A few measurements were made in previous years, but the data are probably comparable because the water level does not change greatly in short periods. The water table slopes generally east-southeast toward the eastern escarpment. The slope of the water table varies but in general averages 10-12 feet per mile.

The contours on the water table show that ground water moves into the Portales Valley from both the north and south sides of the valley and then moves southeasterly down the axis of the valley. In the vicinity of Monument, Lea County, New Mexico, the contours suggest that the ground water moves in a southerly direction. According to Nicholson and Clebsch (1961, p. 59), the ground water in this vicinity leaves the Ogallala Formation of the Southern High Plains and enters the valley fill that underlies the Laguna Valley area. In the vicinity of some of the larger playa lakes, where the water table may intersect the land surface, the movement is deflected toward the lakes.

The rate of movement of ground water in the Ogallala Formation is controlled by the gradient of the water table and the permeability of the material in the zone of saturation. Variations in the grain size of the material and variations in the degree of sorting and cementation will cause the rate of movement to vary.

Cronin and Wells (1963, p. 36) estimated that ground water in the Ogallala Formation in the vicinity of Plainview, Hale County, Texas, moved at the rate of about 2 inches per day. Ash (1963, sheet 2), on the basis of information obtained from H. O. Reeder (U.S. Geological Survey, oral communication) suggested that the rate of movement of ground water in the Ogallala Formation was on the order of 150 feet per year (a little less than 5 inches per day).

Depth to Water and Water-Level Declines

In January 1967, the depth to water in wells completed in the Ogallala Formation in the Southern High Plains of Texas and New Mexico ranged from about 25 to 300 feet below the land surface. The depth to the ground water is, in general, affected by several conditions, including the topography of the land surface, the proximity to areas of recharge or natural discharge, the proximity to areas of withdrawal of water through wells, and the configuration of the bedrock surface.

Depths to water of 100 feet or more are typical of much of the Southern High Plains. The depth to water is more than 300 feet in places in east-central Curry County, New Mexico, and the adjoining west-central part of Parmer County, Texas. The depth is between 250 and 300 feet near the eastern escarpment in southeastern Floyd and northeastern Crosby Counties, Texas; northwest of Maljamar near the western escarpment in northern Lea County, New Mexico; and in northwestern Deaf Smith County, Texas. The water table is 50 to 100 feet below land surface near Lovington in the principal irrigated district in Lea County, New Mexico; in much of Gaines County, Texas; and in the southwestern part of Yoakum County, Texas. In the Portales Valley, the depth to water ranges from about 25 to 75 feet.

The decline of the water table from the time irrigation was developed on a large scale, about 1937 to early 1967, is shown on sheet 3. The decline began shortly after irrigation was developed on a significant scale and has continued in most places at varying rates to 1967. The amount of ground water discharged annually from the ground-water reservoir greatly exceeds the annual recharge and is therefore being withdrawn from storage.

Declines in the water table range from less than 20 feet to more than 120 feet. The greatest declines are in the northern one-half of the area in Texas—roughly north of the south boundary of Lubbock County, Texas. Despite the huge decline in the water table and the fact that this area is extensively developed and heavily pumped for irrigation, the area also has some of the thickest sections of saturated material remaining in the Southern High Plains in 1967.

Saturated Thickness of the Ogallala Formation

The thickness of the zone of saturation in the Ogallala Formation in 1967 is shown on sheet 4. The saturated thickness ranges from less than 50 feet in many places to more than 300 feet in two small areas in Castro County, Texas. The zone of saturation is generally thicker in the northern part of the Southern High Plains than in the southern part, except in the western part of Gaines County, Texas, and adjoining Lea County, New Mexico.

The volume of water in storage in the Ogallala Formation is calculated as the product of the volume of saturated material times the porosity (the ratio expressed in percentage of void space to total volume). Such an estimate of the volume of water in storage is of little value in itself because much of the water will not drain from the material and will not be available to wells. The quantity of water in storage that will be available is computed by multiplying the volume of saturated material by the specific yield (the quantity of water that a formation will yield under the force of gravity, if it is first saturated and then allowed to drain, the ratio being expressed in percentage of the volume of this water to the volume of the material drained).

Data from various tests, both in the laboratory and in the field, indicate that the specific yield of the Ogallala Formation in Texas is about 15 percent (Cronin, 1964, p. 40-42). The specific yield of the Ogallala Formation in Lea County, New Mexico, is 20 percent, according to Ash (1963, sheet 2) and Havens (1966, p. 24-25). In this report, a value of 15 percent is used, even though this figure may be conservative for some parts of the area.

The volume of saturated material in the Ogallala Formation was determined from sheet 4, which shows by means of contours the approximate thickness of the water-bearing material. The zero line of the saturated thickness is not shown, but in estimating the volume of saturated material, the zero line was assumed to be the escarpment of the plains or geologic boundary of the Ogallala Formation. On the basis of a specific yield of 15 percent, it is estimated that as of 1967 the Ogallala Formation, in the area of this report, contains approximately 184 million acre-feet of water in storage that is available to wells. Of this volume, about 36 million acre-feet is in New Mexico and about 148 million acre-feet is in Texas.

Continued large-scale withdrawals of water from the Ogallala Formation will result in a continuing decline of the water table and an increase in the pumping lift of the wells. As the water level continues to decline, the zone of saturation will become progressively thinner and the yields of the wells will decrease.

Because of increased pumping lifts and decrease in well yields, it may be impractical or economically unfeasible for irrigation, to recover some of the water available to wells in the lower part of the aquifer.

CHEMICAL QUALITY OF THE WATER

Ground water from the Ogallala Formation in the Southern High Plains is used for irrigation, public supply, industrial supply, and domestic and stock purposes.

The water is typically hard and has an objectionably high concentration of fluoride in many areas. The hardness, in addition to a high concentration of silica, makes it somewhat objectionable for domestic and many industrial uses. Except possibly in the vicinity of the playa lakes and in local areas where the ground water may have been contaminated by seepage from brine disposal pits (Broadhurst, 1957, p. 1, and Ash, 1963, sheet 2), the water is satisfactory for irrigation. Only the excessive fluoride content makes it objectionable for public supply.

The water from the valley fill in Portales Valley is similar to that of the Ogallala Formation (Theis, 1932, p. 126). Hale and others (1965, p. 33) report that the quality of the water in the alluvium of the Portales basin is good, but has deteriorated as a result of recharge from irrigation-return water.

OUTLOOK FOR THE FUTURE

The Southern High Plains of Texas and New Mexico is in a semiarid region that is practically devoid of surface water or streamflow. Fortunately, a large but not inexhaustible supply of ground water is in the Ogallala Formation which underlies most of the area. This aquifer has supplied practically all of the water needs and has been an important factor in the economic development of the area. As a result of large withdrawals, the water table has declined, with a consequent reduction in the thickness of the water-bearing zone and the yields of the wells. Continued large-scale withdrawals of water from the Ogallala will result in a continuing decline in water levels because water is being pumped at a much faster rate than the ground-water reservoir is being recharged.

The annually decreasing supply of ground water is of great concern to the farmers and other residents of the area. As a result, independent citizens groups, local water districts, and State and Federal agencies are considering methods of conserving the present water supply and to devising plans to insure an adequate supply for irrigation and other uses in the future, the most important of these being studies of the feasibility of importing water from areas outside of Texas and New Mexico. No sources of water are known to be available on or in the immediate vicinity of the Southern High Plains that could furnish the quantity of water, of suitable quality, that is needed to sustain the economy of the area.

Some of the cities in the Southern High Plains in Texas are now (1967), and others will be in the near future, using surface water obtained from reservoirs on the Canadian, White, and Colorado Rivers, but the amount of water available will be only a small percentage of the present annual pumpage from the Ogallala Formation.

If the importation of water from areas remote from the Southern High Plains should prove to be feasible, it will still be many years before delivery of the water could be started. Every possible source of a water supply to supplement the ground water in the Ogallala Formation should be fully explored; but while the search continues, recourse must be made to conservation methods and water-use practices that will result in a maximum return from the water now available.

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