Texas Water Development Board

Report 322

Ground-Water Evaluation in and Adjacent to Dripping Springs, Texas

By

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Texas Water Development Board

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INTRODUCTION

Purpose and Scope

This project is authorized under the Texas Water Development Board's mandate from the 69th Texas Legislature and House Bill 2 which requires the Board to identify areas of the State that are experiencing or that may experience in the near future critical ground-water problems. One such area so identified is a portion of the Texas Hill Country which covers an area on and adjacent to the Edwards Plateau between the Llano uplift and the Balcones fault zone (Figures 1 and 2). Geologically, much of this portion of the Hill Country is underlain by the Glen Rose Formation of Cretaceous age. The City of Dripping Springs, which lies within this area, requested that the Board conduct a ground-water study to address a water-quality problem perceived to be related to septic tanks. It is hoped that this investigation will help resolve this problem and will serve as a pilot project that can be used as a guide to study other areas with similar ground-water quality problems.

It is the intent of this study to evaluate the current ground-water conditions, primarily in terms of water quality, in the Dripping Springs area. In this endeavor, the hydrogeological characteristics of the Glen Rose Formation will be emphasized and described to gain insight into the existing ground-water quality conditions of the formation in the study area. Subsequent to the completion of the study, a ground-water quality monitoring program will be implemented to evaluate seasonal as well as long-term changes in ground-water quality at Dripping Springs.

Location

The study area includes most of the incorporated limits of the City of Dripping Springs and the immediately adjacent areas in northern Hays County, Texas (Figure 1). Dripping Springs lies in a natural geomorphic and topographic valley whose tributary streams flow southwestward into Onion Creek. The northern and eastern boundaries of the study area are represented by the topographic divide between the Onion Creek watershed and the Barton Creek watershed. The southwestern boundary of the area is Onion Creek. Arbitrary boundaries on the west and south near the city limits complete the delineation of the study area.

Geography

Topography and Drainage

The "Dripping Springs Valley" has been incised by several unnamed intermittent tributaries that flow over the Glen Rose Formation into Onion Creek. It is along some of these creeks that springs and seeps appear. The most noteworthy is Dripping Springs from which the City gets its name. Another well known spring is Walnut Springs south of the City near Ranch Road 12.

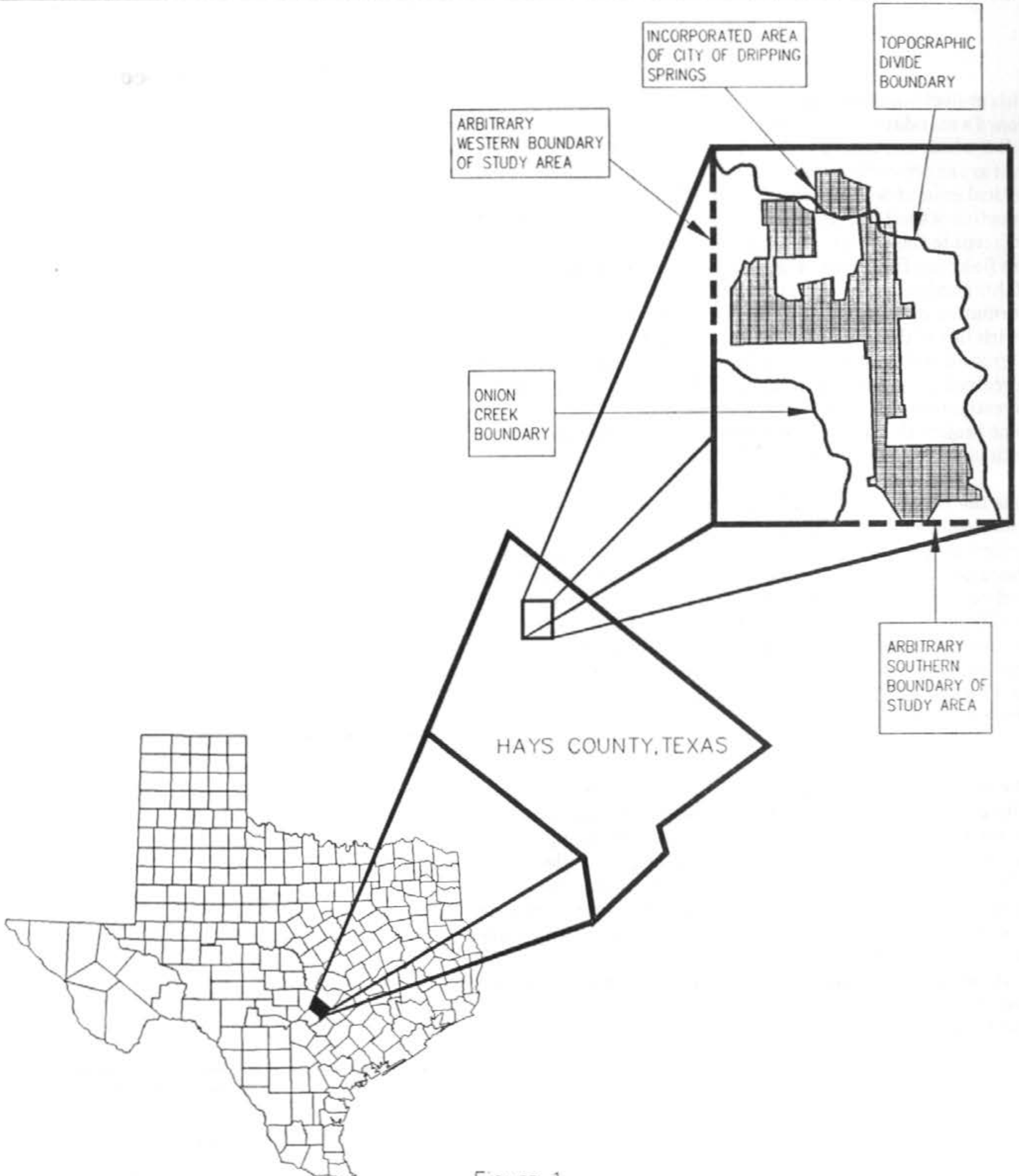
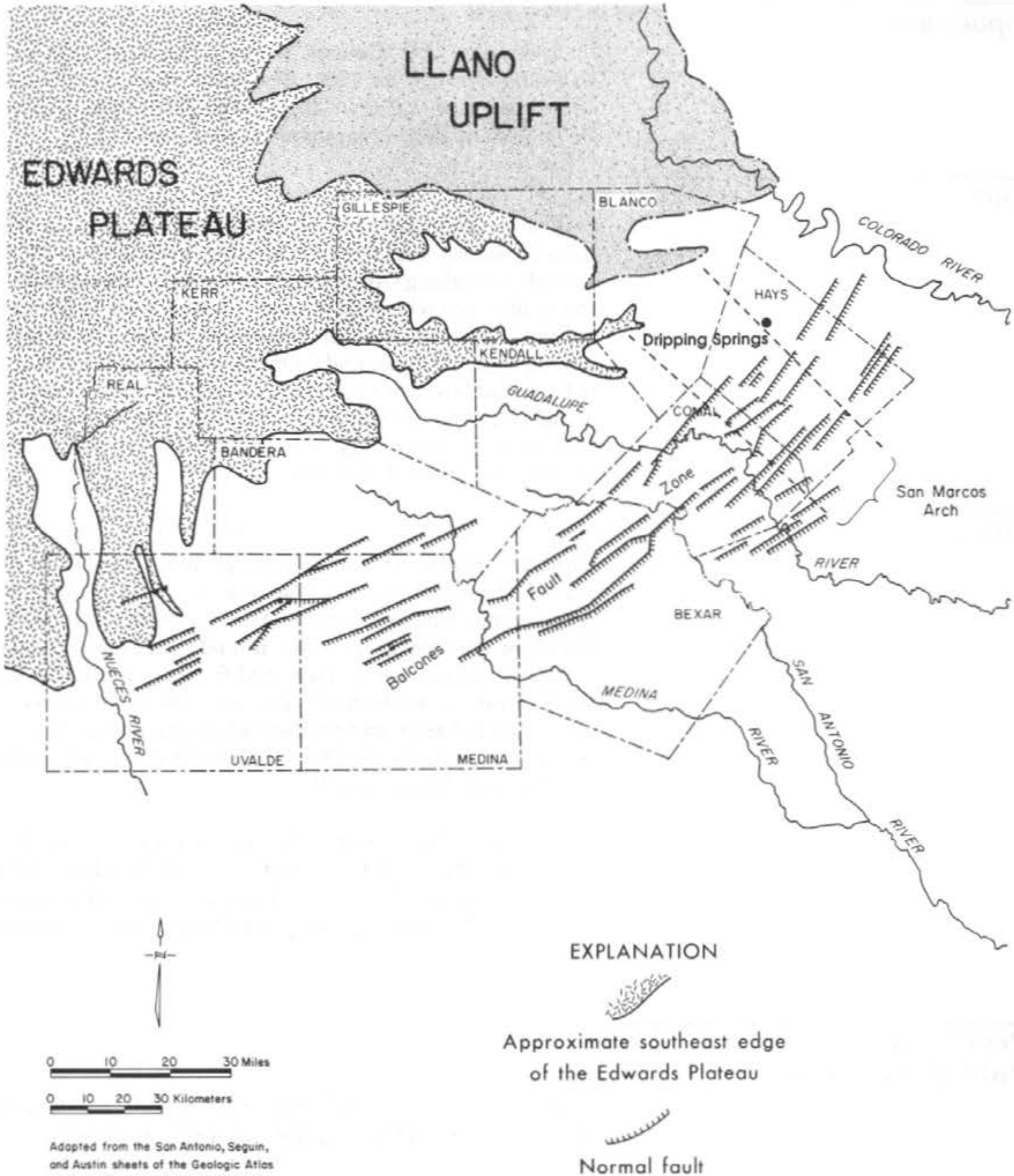


Figure 1
MAP SHOWING LOCATION AND BOUNDARIES OF STUDY AREA



Adapted from the San Antonio, Seguin, and Austin sheets of the Geologic Atlas of Texas, Bureau of Economic Geology

Figure 2
Regional Structural Map

After: Ashworth, 1983

In the northwestern portion of the study area, on the topographic divide which separates the Onion Creek and Barton Creek watersheds (Figure 1), the elevation reaches almost 1,400 feet. To the southeast, elevations approach 1,100 feet.

Population

In 1980, the U.S. Census Bureau listed the population of Dripping Springs as 779. The most recent estimate of the population was 1,010 in July 1986 (Bill Moltz, Texas Water Development Board, personal communication).

Soils

Soils are rather thin, and the maximum depth to bedrock less than 18 inches, over most of the study area (Figure 3). There is a small area along Onion Creek in the extreme southern part of the study area where soils reach depths of 48 to 60 inches. In general, the soils consist of shallow loamy and clayey soils among rock outcrops, and form convex slopes that range from 1 to 8 percent. In terms of sanitary facilities, such as septic tanks, cesspools, and privies, particularly in populated areas, the thin soils and the proximity of a locally shallow water table are critical aspects of this study.

Climate

Climatologically, Dripping Springs lies in an area of Texas classified as subtropical. The area is influenced by the flow of tropical maritime air from the Gulf of Mexico that decreases in moisture content as it flows inland. Seasonal intermittent intrusions of continental air modify the climate which ranges from humid to subhumid. The average annual precipitation from 1951 to 1980 was 32 inches, while the average annual gross lake surface evaporation from 1950 to 1979 was about 64 inches (Larkin and Bomar, 1983).

Maximum and minimum temperatures are expressed in terms of the 1951 to 1980 temperature record (Larkin and Bomar, 1983). The annual average of daily high temperatures is about 78.5°F and the average daily low temperature is about 53.5°F.

Previously Published Reports

Previous reports describing the geology, soils, and hydrogeology pertinent to the Dripping Springs study area are as follows:

1. ***Stratigraphy of Lower Cretaceous Trinity Deposits of Central Texas***, by F. L. Stricklin, Jr., C. I. Smith, and F. E. Lozo; University of Texas Bureau of Economic Geology Report of Investigations No. 71. This 1971 publication is the basic geological reference used to describe and delineate the stratigraphic framework of the upper and lower limestones of the Glen Rose Formation. The important water-bearing units in the Dripping Springs area pertinent to this study occur in these limestones.

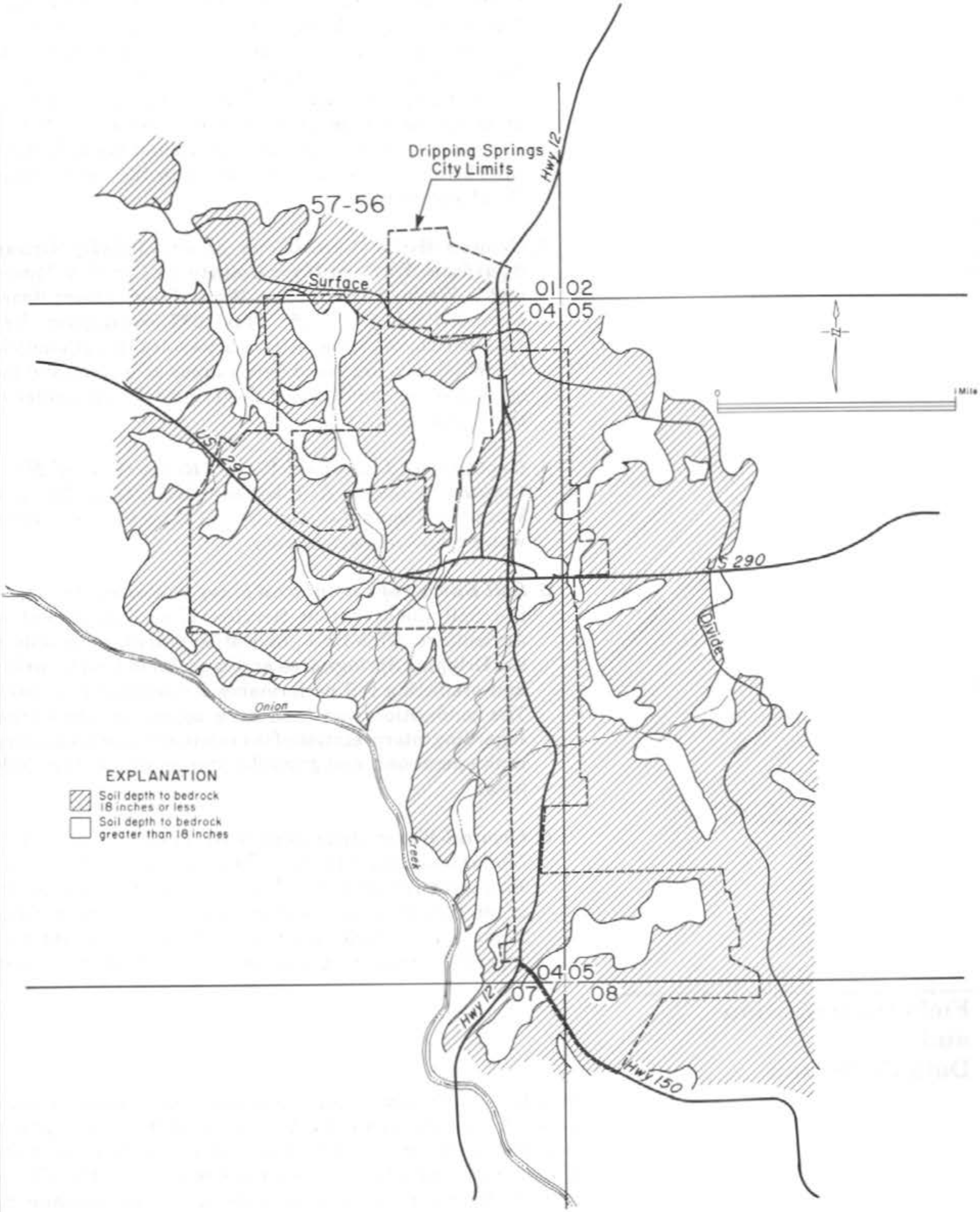


Figure 3
Soil Depth to Bedrock in the
Dripping Springs Area, Hays County, Texas

2. ***Ground-Water Availability of the Lower Cretaceous Formations in the Hill Country of South-Central Texas,*** by John Ashworth, Texas Department of Water Resources Report 273. Covering 11 counties, including Hays County, this 1983 publication is a regional overview of the Trinity Group aquifer of which the upper and lower limestones of the Glen Rose Formation are a part. Part of this region has been identified as Ground Water Critical Area 2 and is currently under study by the Texas Water Development Board.

3. ***Ground-Water Conditions of the Trinity Group Aquifer in Western Hays County,*** by Daniel A. Muller and T. Wesley McCoy, Texas Water Development Board Limited Publication 205. This 1987 investigation was conducted to assist the citizens of western Hays County in the Wimberly and Wood Creek areas to understand the ground-water conditions of the Trinity Group aquifer in their area.

4. ***Geology and Ground-Water Resources of Hays County, Texas,*** by K. J. DeCook, 1960, Texas Board of Water Engineers Bulletin 6004. This is a basic ground-water report of Hays County.

5. ***Soil Survey of Comal and Hays Counties, Texas,*** by the Soil Conservation Service, U.S. Department of Agriculture. This 1984 publication describes the soils in the Dripping Springs area and is useful in land planning and predicting soil performance for selected land uses. The publication was used as a source of information regarding interpretation of the relationship of soils, septic tank operations, and ground-water quality in the study area.

6. ***Ground-Water Availability in Texas,*** by Daniel A. Muller and Robert D. Price, Texas Department of Water Resources Report 238. This 1979 report evaluated the ground-water resources of the State for the Texas Water Plan, and is included here primarily as a basic reference regarding general hydrogeological concepts and principles.

Field Investigation and Data Collection

In addition to the above mentioned hydrological and geological works, it was necessary to conduct a current field investigation to collect information fundamental to the evaluation of the ground-water conditions within the study area. The City of Dripping Springs provided large-scale (200 feet equals one inch) topographic maps with two-foot contour intervals which had surface features such as buildings, roads, and vegetation. The City also made available an ownership map and a preliminary list of land owners, water wells, and septic systems.

Additionally, 7.5-minute quadrangle topographic maps of the area published by the U.S. Geological Survey were used for hydrological and geological field work. The Hays County Tax Appraiser's Office in San Marcos was also a source of information on land and well owners.

Field work and data collection was conducted during the summer of 1988. Data collection activities included the inventory or updating of information on 101 water wells and springs. These include 40 domestic wells, nine irrigation wells, four public-supply wells, and 48 unused, abandoned, or destroyed wells. There were 29 water samples collected for chemical analyses and 19 water samples collected for bacteriological analyses. The Board's Logging Unit logged three unused water wells to ascertain the subsurface geology. Data on these water wells and springs appear in Tables 5 and 6 and on Figure 17 following the "Selected References" of this report.

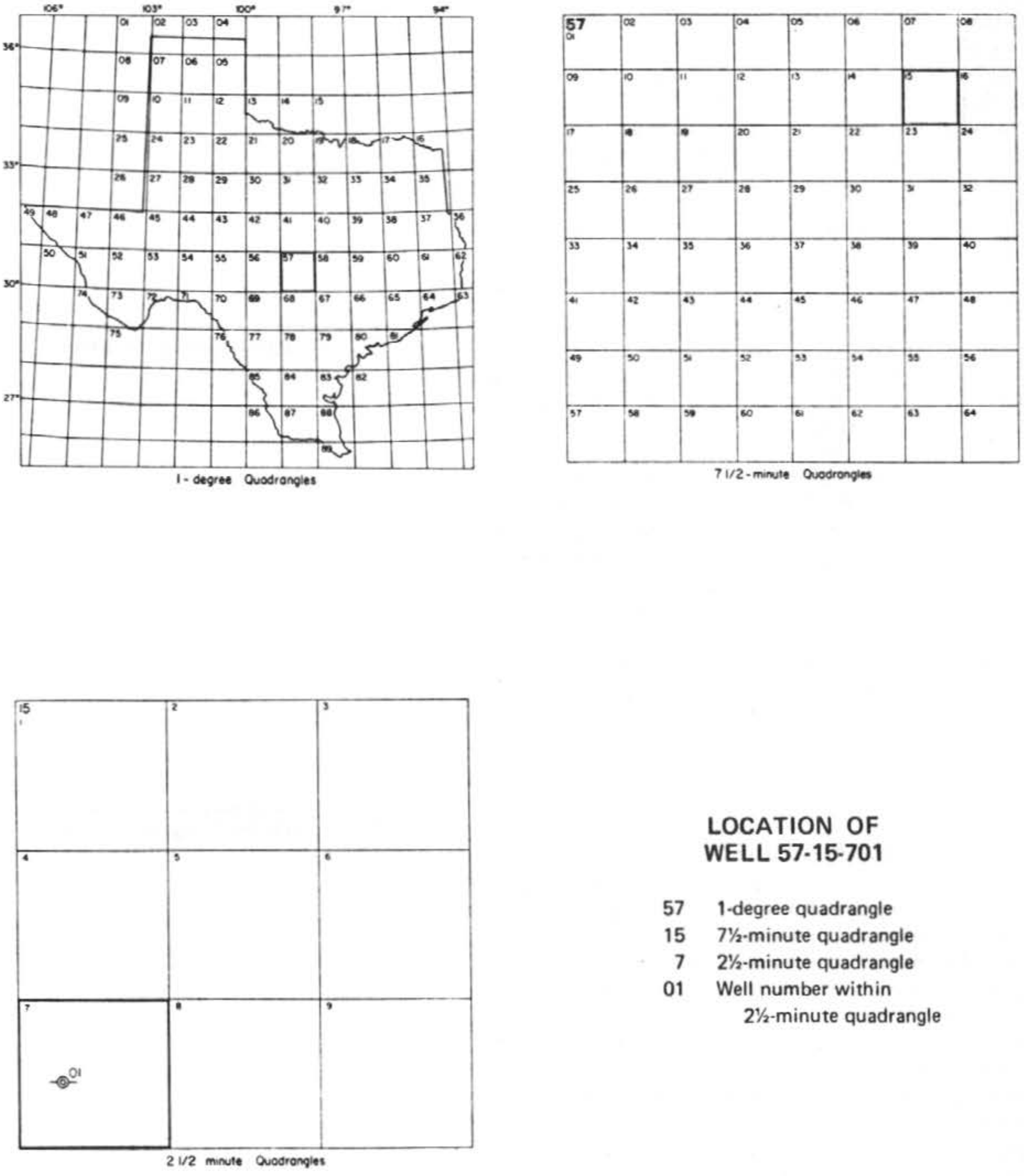
Acknowledgements

This study would not have been possible without the cooperation of many of the citizens of Dripping Springs to whom appreciation is expressed. The city council provided continued support by furnishing special topographic maps of the study area. Much of the work was coordinated with Bill Bassett, the Water and Wastewater Coordinator for Dripping Springs. A special note of gratitude is extended to him. Robert L. Bluntzer had direct supervision of the study while Henry J. Alvarez and Tommy R. Knowles furnished general supervision. T. Wesley McCoy, Steve Gifford, Elaine Singley, Mike McCathern, and Mark Hayes assisted in the preparation of the illustrations. Wanda Cooper, Cheri Kokel, and Deborah Schultz typed the report. Carol Silberman provided coordination of copying and accessing files.

Well-Numbering System

To facilitate the location of wells and avoid duplication of well numbers, the Texas Water Development Board has adopted a statewide well-numbering system. It is based on division of the State into a grid of 1-degree quadrangles formed by degrees of latitude and longitude, and the repeated division of these quadrangles into smaller ones as shown on Figure 4.

Each 1-degree quadrangle is divided into sixty-four 7 1/2-minute quadrangles, each of which is further divided into nine 2 1/2-minute quadrangles. Each 1-degree quadrangle in the State has been assigned an identification number. The 7 1/2-minute quadrangles are numbered consecutively from left to right, beginning in the upper left-hand corner of the 1-degree quadrangle, and the 2 1/2-minute quadrangles within each 7 1/2-minute quadrangle are similarly numbered. The first 2 digits of a well number identify the 1-degree quadrangle; the third and fourth digits, the 7 /12-minute quadrangle; the fifth digit identifies the 2 1/2-minute quadrangle; and the last 2 digits identify the well within the 2 1/2-minute quadrangle.



1 - degree Quadrangles

7 1/2 - minute Quadrangles

2 1/2 minute Quadrangles

LOCATION OF WELL 57-15-701

57	1-degree quadrangle
15	7½-minute quadrangle
7	2½-minute quadrangle
01	Well number within 2½-minute quadrangle

Figure 4

GENERAL HYDROGEOLOGICAL CONCEPTS AND PRINCIPLES

For the benefit of the general reader this section is included for familiarization of some basic hydrogeological concepts and principles. It is a synopsis applicable to this study from the publication: ***Ground-Water Availability in Texas*** (Muller and Price, 1979).

Hydrologic Cycle

Water available for use by man, whether as rain, water from wells, or stream discharge is captured in transit and, after its use and reuse, is returned to the hydrologic cycle from which it came (Figure 5). Graphically, Figure 5 shows the continuing movement of water from the oceans through evaporation to precipitation and its return, either directly or indirectly, to the ocean. Ground water is part of the returning water which has entered the subsurface and filled the void spaces of the porous rocks which are within the zone of saturation. The primary source of ground water is precipitation, and in general, only a small percentage of the precipitation actually becomes ground water by the process of recharge or percolation.

Occurrence of Ground Water

In the Dripping Springs area, ground water is contained in the interstices or void spaces of rocks. Two rock characteristics fundamental 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, such as sandstone, gravel, clay, and silt the porosity is a function of the size, shape, sorting, and degree of cementation of the grains. In limestones another type of porosity exists. It is a function of openings such as cracks, crevices, caverns, and vugs caused in part by dissolution of the limestone by ground water.

Fine-grained sediments, such as clay and silt, usually have high porosity; but, due to the restricted connection and small size of the voids, the permeability is low and these formations do not readily yield or transmit water. Therefore, in order for a geologic formation to be an ***aquifer*** it must be porous, permeable, and water-bearing. In general, to be an aquifer the water-bearing formation should yield water in sufficient quantities to provide a usable supply; otherwise, the formation may be either an aquitard or aquiclude. An ***aquitard*** is a semipermeable, semiconfining geologic formation adjacent to or between aquifers and partially restricts the movement of ground water. Clay lenses interbedded with sands or even porous limestones are characteristic of "leaky" aquitards. Where the clay beds are sufficiently thick and widespread, the impediment to ground-water movement is greater and confinement of the aquifer is greater; the formation is called an ***aquiclude.***

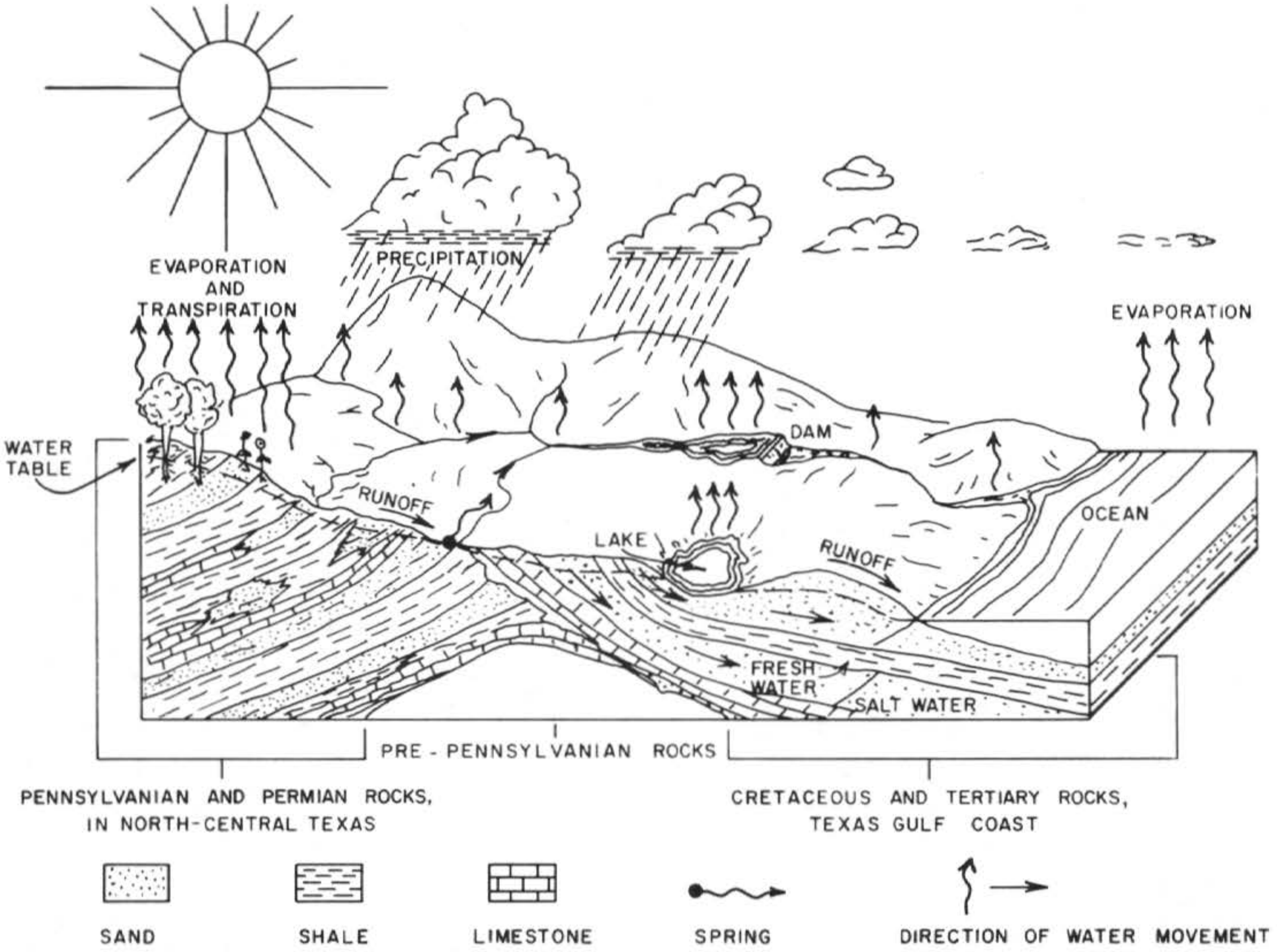


Figure 5 -- Hydrologic Cycle

When precipitation falls on the outcrop of an aquifer, it may take one of many component courses in completing the hydrologic cycle. A large portion of it returns to the atmosphere by ***evaporation***. Vegetation utilizes a part of it and returns moisture to the atmosphere by ***transpiration***. Some of the precipitation will run off the land surface into streams and return to the sea. A small percentage will percolate downward into formations by the force of gravity and recharge the ***zone of saturation***. The upper surface of this zone is called the ***water table,*** and the hydrostatic pressure of the water-filled interstices at this surface is equal to atmospheric pressure. Water entering this zone of saturation moves to lower elevations where it is discharged naturally, for example, by springs, or artificially by wells. Above the zone of saturation, the rock void spaces are partially filled by moisture and partially by air. This zone is known as the ***zone of aeration***. Occasionally, local clay or impermeable layers of limited lateral extent can intercept the downward percolating water, thus creating a perched saturated zone above the main water table or saturated zone which causes a ***perched water table*** of limited areal extent. Some wells in the Dripping Springs area are possibly completed in perched saturated zones which are present in many areas in the Glen Rose Formation.

An aquifer is under ***water-table conditions*** or ***unconfined*** when the ground water encountered by a well is in direct contact vertically with the atmosphere. In an unconfined aquifer, the zone of saturation extends from the underlying confining bed to the above water table. The aquifer is confined when the ground water contained in it is separated from the atmosphere by impermeable material (aquiclude) of a confining bed and the water is under sufficient pressure to rise above the level at which it is encountered by a well. In this case, the water is under ***artesians conditions***, whether it flows at the land surface or not, and the levels to which the water rises in well bores define an imaginary surface called the ***piezometric surface***. For a confined aquifer, the zone of saturation represents complete saturation of the water-bearing formation and is equal to its thickness. The term ***potentiometric surface*** applies both to the piezometric surface of a confined aquifer and the water-table surface of an unconfined aquifer. The ***hydraulic gradient*** or ***pressure gradient*** of an aquifer is exemplified by the slope of the potentiometric surface.

The water-producing capability of an aquifer depends upon its ability to store and transmit water. Although the porosity of a rock is a measure of its capacity to store water, not all of this water in storage may be recovered by pumping of wells. Some of the water stored in the interstices is retained because of the molecular attraction between the rock particles and the water.

The ***coefficient of storage*** is the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in the component of hydrostatic pressure (change in water level) normal to that surface. In confined or artesian aquifers, it is the result of two elastic effects – compression of the aquifer and expansion of the contained water – when the hydrostatic pressure is reduced by pumping. The value of the coefficient of storage is small, and it is dimensionless. In the unconfined case, the storage coefficient is also dimensionless and is equal to the specific yield of the rock material. The ***specific yield*** is a measure of the water removed from an aquifer by the force of gravity or drainage and is expressed as a percentage of the total saturated volume of rock.

Recharge, Movement, and Discharge of Ground Water

Recharge is the addition of water to an aquifer and may be derived from precipitation, streams, and lakes, either directly into a formation or indirectly by way of another formation. Also, it may mean the quantity of water that is added to the zone of saturation which results in an increase in aquifer storage. Among the factors that influence the amount of recharge received by an aquifer are: the amount and frequency of precipitation, the topography of and the areal extent of the outcrop or intake area, the type and amount of vegetation, the condition of soil cover in the outcrop area, and the ability of the aquifer to accept recharge and transmit it to areas of discharge.

The quantity of water the aquifer absorbs as recharge and the ability of the aquifer to transmit water to the areas of discharge are the principal factors that must be considered in determining the amount of water available for withdrawal and spring discharge. The ***coefficient of transmissivity*** provides an index of an aquifer's ability to transmit water. By using the coefficient of transmissivity, the amount of water that will flow through an aquifer under various hydraulic gradients can be determined.

Ground water moves from areas of recharge to areas of discharge or from points of higher water level to points of lower water level. Movement is in the direction of the hydraulic gradient just as in the case of surface-water flow. Under normal artesian conditions, movement of ground water usually is in the direction of the regional dip of the water-bearing formation. Under water-table conditions, the slope of the water table and consequently the direction of ground-water movement may be closely related to the slope of the land surface. The rate of ground-water movement in an aquifer is normally very slow, being in the magnitude of a few feet to a few hundred feet per year. Limestones with solution channels and caves have greater rates of ground-water movement.

Discharge is the loss of water from an aquifer. The discharge may be either artificial or natural. Artificial discharge takes place from flowing and pumping water wells, drainage ditches, gravel pits, and other excavations that intersect the water table. Natural discharge occurs as effluent seepage, springs, evaporation, transpiration, and interformational leakage.

Changes in Water Levels

Changes in water levels indicate a change in the ground-water storage of an aquifer. Basically, water-level fluctuations are caused by the relationship between changes in the amounts of recharge and discharge.

When water levels do not fluctuate and steady-state conditions exist, the aquifer storage stays constant and recharge and discharge are in equilibrium. Under natural conditions when discharge is only from springs, interformational leakage, and possibly, effluent seepage, evaporation, and transpiration; the water levels will decline when the amount of recharge is negligible, as in the case of a drought. Spring flow will gradually decrease and even cease as the hydraulic gradient decreases as the water levels decline. Ground water is taken from the storage of the aquifer since discharge exceeds recharge. Artificial discharge, such as pumpage by wells, will only intensify these drought conditions and the quantity of ground water available to wells may become a problem.

Even though water normally moves very slowly through water-bearing rocks, except in the case of fractured, solution-channeled limestone, the above conditions may reverse when recharge exceeds discharge during wet periods. Water levels rise, aquifer storage increases, and spring flow increases. There should also be more ground water available for artificial discharge such as pumpage from wells.

Ground-Water Quality

The natural chemical quality of ground water depends on the environmental geochemistry of the earth's crust in which it has come into contact during the hydrologic cycle. An extraordinary characteristic of water as a liquid is its capacity to dissolve a large variety of minerals with which it has come into contact. The process of disintegration of rock minerals during weathering and the very slow percolation of water through the soil and bedrock causes the water to become progressively more saturated with dissolved minerals. As long as the water remains unsaturated with minerals, the dissolving process will continue until a chemical equilibrium is reached between the water and the minerals. The final result will be the chemical nature or chemical quality of the ground water.

In general, ground water is clear and odorless, contains no suspended particles, and practically no bacteria or organic matter. This is in contrast to surface water, which usually contains suspended matter and considerable quantities of bacteria. Ground water normally is more healthy, even though it can contain more dissolved minerals than surface water. Within limits, some of these dissolved minerals can be of benefit for good health.

Leaky Aquifer Conditions

Leaky aquifer conditions exist in a heterogeneous assemblage of interrelated permeable, poorly permeable, and relatively impermeable formations that function regionally as a leaky aquifer system. Such a system may consist of two or more discontinuous aquifers separated laterally and vertically by discontinuous aquitards or aquicludes. In general, the system is characterized by differing hydrostatic pressures (water levels) each of which represents a different water-bearing formation of the aquifer system. If the hydrostatic pressure is successively lower in progressively deeper water-bearing formations, then there is a vertical component of ground-water movement downward, and the lower aquifers are being recharged at a very slow rate from above.

Perched Ground-Water Conditions

Hydrological characteristics of an aquifer such as vertical and lateral permeability are a function of the geology. As such, the distribution of permeability within and adjacent to the water-bearing units of the Glen Rose Formation is dependent on the character of the rocks and the geological processes (fracturing, weathering, and dissolution) which have physically and chemically altered the rocks. The Glen Rose Formation, as indicated in Table 1, is composed of a relatively large variety of discontinuous and intermingled rocks represented by limestone, dolomite, mudstone, shale, clay, claystone, collapsed breccia, and sand (calcarenite). Each of these rock types, depending on their exposure and subsurface position, have varying alterations from the result of fracturing, weathering, and dissolution. Consequently, the permeabilities of the Glen Rose Formation within and adjacent to its water-bearing units are highly variable both vertically and laterally.

Such complexity of rock types and alteration can result in perched ground-water bodies or zones which occur in many areas of the Glen Rose Formation. Under these conditions, the very slow downward movement of percolating ground water is inhibited by the less permeable rocks or aquitards such as clay and mudstone, thus creating an unconfined saturated zone of limited areal extent above the general zone of phreatic water or zone of extensive saturation. Therefore, a ***perched ground-water body or zone*** consists of an unconfined water-bearing unit of limited lateral extent underlain by an aquitard both of which are above and separated from an underlying main water-bearing unit by an unsaturated zone (modified from Driscoll, 1986).

Table 1 notes under the "Hydrologic Units" column the approximate stratigraphic position of these perched (ground-water) zones in the Glen Rose Formation. Even so, for the purposes of this study, the static water-level measurements and well depths in two apparent phreatic zones in the Dripping Springs area have been used to delineate two distinct, main

Table 1. Geologic and Hydrologic Units and Their Water-Bearing Properties in the Dripping Springs Area, Hays County, Texas

Era	System	Series	Group	Geologic Units			Approximate Maximum Thickness (feet)	Character of Rocks	Hydrologic Units		Water-Bearing Properties
Mesozoic	Cretaceous	Comanche	Trinity	Glen Rose Formation	Upper Glen Rose Limestone	Unit 8	25	Interbedded finely crystalline dolomite and dolomitic clay.	Upper Trinity	(Perched Zone)*	Locally can yield small quantities of fresh water from perched water tables.
						Unit 7	85	Alternating beds of fossiliferous limestone, dolomite, and clay.			
						Unit 6	75	Predominately clay with thin limestone beds, resistant beds of calcarenite and few dolomite stringers.			
						Unit 5	25	Solution zone recrystallized limestone, dolomite and clay, collapsed breccia.		Shallow Aquifer	Yields small quantities of fresh water, locally contains high sulfate.
						Unit 4	40	Nodular limestone, calcarenited and clay, forms ledges.			Can yield small quantities of fresh water yet, forms underlying confining bed causing springs.
						Unit 3	55	Abundantly fossiliferous nodular limestone and clay with floating *Orbitolina texana*.		(Perched Zone)*	Locally can yield small quantities of fresh water from perched water table.
						Unit 2	45	Sparsely fossiliferous, thinly bedded combination of clay, claystone, and limestone.			
						Unit 1	20	Solution zone recrystallized limestone, dolomite, and clay.			Can yield small quantities of fresh water, locally contains high sulfate.
					Lower Glen Rose Limestone	Unit 2	70	Fissile dolomitic shale and dolomite beds in the lower part and alternating beds of clay and limestone in the upper part.		(Perched Zone)* Deep Aquifer	Yields small to large quantities of fresh to slightly saline water which can contain high concentrations of sulfate and fluoride.
						Unit 1	150	Massive ledge-forming limestone with shell fragments, limy mudstone interbedded with clay, varies in thickness, and locally contains sporadic rudist and coral reef deposits.			
				Travis Peak Formation	Hensell Sand		80	Sand, gravel, caliche, oxidized clay and dolomite. **Angular Unconformity**			Yields small to moderate quantities of fresh to slightly saline water which can have high concentrations of sulfate and fluoride.
					Cow Creek Limestone		70	Massive fossiliferous, white to gray, argillaceous to dolomitic limestone with local thinly bedded layers of sand, shale, and lignite.			
					Hammett Shale		30	Dark blue to gray, fossiliferous, calcareous and dolomitic shale with thinly interbedded layers of limestone and sand.	Confining Bed		Not known to yield water.
					Sligo Limestone		50	Sandy dolomitic limestone.	Lower Trinity		Yields small to moderate quantities of fresh to slightly saline water which can have high concentrations of sulfate and fluoride.
					Hosston Sand		200	Basal conglomerate grading upward into a mixture of sand, siltstone and shale with some limestone beds.			
								Major Unconformity			
Paleozoic	Silurian	Undifferentiated		Missouri Mountain Formation	Undifferentiated		300	Hard brown and blue shale, green hard siliceous, sandy in part and can have thin beds of laminated chert and quartzose sandstone and local lenses of sandy chert conglomerate. Part of the Ouachita Belt Facies.	Confining Bed		Not known to yield water.

Modified from: Ashworth, 1983; Stricklin, Smith, and Lozo, 1971; and Flawn, Goldstein, King, and Weaver, 1961.

* Perched zones are of erratic occurrence.

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water-bearing units of broad lateral extent. These two main water-bearing units are designated the Deep aquifer within the Lower Glen Rose limestone and the Shallow aquifer within the Upper Glen Rose limestone.

GEOLOGICAL SETTING

Depositional History

About 135 million years ago at the beginning of Cretaceous time, the Llano region of Texas was a topographic high land mass or island(s) in a westward encroaching shallow Trinity sea. As this shallow sea transgressed, and occasionally regressed, over the southeastern, seaward-projecting flank of the Llano uplift, the formations of the Trinity Group were deposited. Collectively, these formations comprise a wedge-like, overlapping sequence which abuts against the older rocks of the Llano uplift and the Quachita structural belt and ranges in thickness from less than 150 feet in the outcrop in northern Hays County to more than 1,000 feet in the vicinity of the Balcones fault zone (Figure 6). A varied array of clastic and carbonate sediments, along with remains of the associated paleofauna, were deposited.

The depositional history of the Trinity Group is comprised of three clastic-carbonate sequences, separated by disconformities, that reflect a pattern of cyclic sedimentation during the essentially advancing or transgressing sea. Such a history is indicated by the overlap of marine carbonates on terrigenous facies representative of nearshore or onshore deposition.

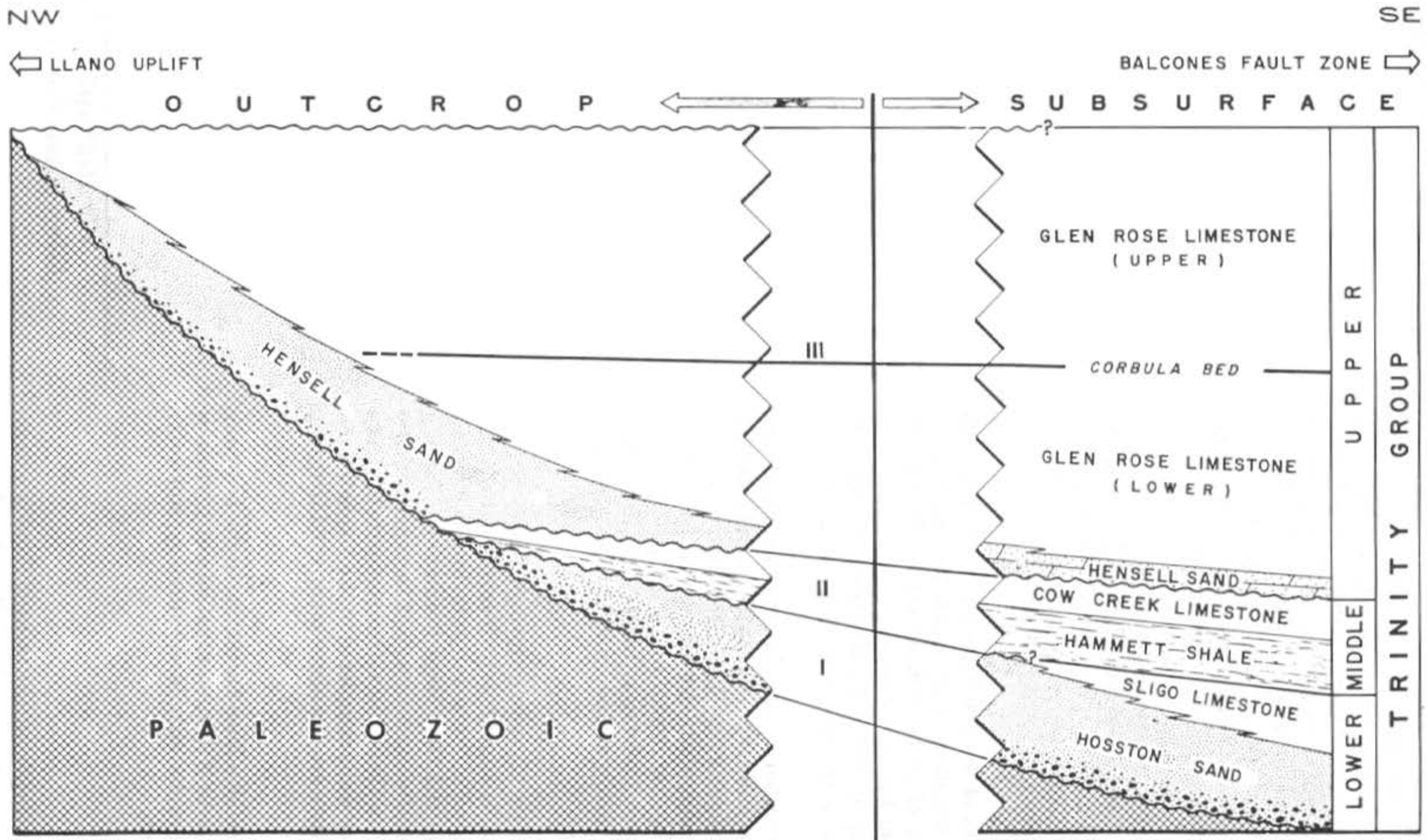
Shallow-water environments on the marine shelf are demonstrated by rudist and coral reefs, widespread tidal-flat deposits, and shallow-water evaporites (Stricklin and others, 1971). In ascending order, a stratigraphic subdivision of the Trinity Group can be arranged into clastic-carbonate sedimentary sequences of Hosston sand-Sligo limestone, Hammett shale-Cow Creek limestone, and Hensell sand-Glen Rose Formation (limestone).

With the exception of the Dripping Springs Water Supply Corporation (WSC) public supply wells located south of the City near Onion Creek, all of the water wells included in this study are completed in the Glen Rose Formation. Table 1 indicates that the Lower Glen Rose limestone together with the Hensell Sand and the Cow Creek Limestone comprise the Deep aquifer. The only water wells completed in the Hensell Sand and Cow Creek Limestone are the above mentioned Dripping Springs WSC wells.

The hydrogeology of the Glen Rose Formation in the Dripping Springs area will be the focus of this investigation with particular emphasis on the stratigraphy, structure, hydrology, and water quality of the formation.

Stratigraphy of the Glen Rose Formation

In terms of the time of deposition, the Hensell Sand is a near-shore lithologic unit made up primarily of alluvial and marine sands which are time-equivalent to the off-shore carbonate deposits of the Glen Rose Formation. That is, the Hensell is a



Modified from: Stricklin, Smith, and Lozo, 1971

Figure 6
Trinity Group Depositional Wedge

time-transgressive single lithologic unit (Figure 6). Together, the Hensell and Glen Rose form a massive wedge which thickens from about 50 feet at its updip limit near the Llano uplift to about 1,000 feet near the Balcones fault zone (Stricklin and others, 1971). The gradational relationship of the Hensell clastics and the Glen Rose carbonates indicates the marine transgressive nature of their sedimentary history illustrated in Figure 6.

To the northwest of Dripping Springs, the oldest Hensell can be examined on the outcrop along the Pedernales-Colorado drainage divide in the area where Hays, Blanco, and Travis Counties join. Here the Hensell is comprised of both continental and marine deposits. The Glen Rose Formation time-equivalent beds were deposited seaward, south and southeast of this area.

The outcrop of the Glen Rose Formation is the most widespread of the Trinity Group. The Glen Rose also attains the greatest thickness and, based on distinctive differences in lithologic characteristics, is divided into the Lower Glen Rose limestone and the Upper Glen Rose limestone separated by the "Corbula" bed, a readily identifiable fossiliferous limestone marker bed of regional extent (Figures 7 and 8).

The Lower Glen Rose limestone is divided into two stratigraphic units based on lithology (Table 1 and Figure 7). Unit 1 (the lower unit), which overlies the Hensell Sand of the Travis Peak Formation (Table 1), can vary in thickness and is difficult to map laterally. It is known locally to have sporadic rudist and coral reef deposits, and in places cave development. In general, it mostly consists of massive ledge-forming limestone with fragments of shells in limey mudstone interbedded with clay. In contrast, Unit 2 (the upper unit) is much more uniform in thickness. The limestones of Unit 2 are more traceable over broad areas and are characterized by intertidal depositional features. Lithologically, Unit 2 contains fissile dolomitic shale and dolomite beds in the lower part and alternating beds of clay and limestone in the upper part. In the Dripping Springs area, the Lower Glen Rose limestone is the strata in which most of the deep wells are completed and, combined with the underlying Hensell Sand and Cow Creek Limestone, is considered the Deep aquifer.

The Lower Glen Rose limestone is topped by a widespread marker bed which is characterized by a thin accumulation of the fossil Corbula *harveyi* ("Corbula" bed), a borrowing clam (Perkins, 1974). The marker bed can be recognized by a thin, seldom over one foot thick, iron-stained ledge between an underlying white-to-cream colored marl and an overlying porous zone of brown-to-red rocks stained by circulation of ground water. This solution zone marks the base of the basal unit of the Upper Glen Rose limestone and lies beneath the surface in the Dripping Springs area (Table 1 and Figure 8).

The Upper Glen Rose limestone is distinguished on the land surface by its "stairstep" topography caused by alternating resistant and nonresistant beds. Based on distinctive lithologic differences, the Upper Glen Rose is divided into eight units (Table 1 and Figure 8). The first unit (Unit 1), located at the bottom, is a solution evaporite zone containing gypsum which in most areas has been leached out resulting in a collapsed brown-to-red-stained breccia. Then in ascending order, Unit 2 is a sparsely fossiliferous, thinly bedded combination of clay, claystone, and limestone; Unit 3 is an abundantly fossiliferous, nodular limestone and clay which contains Orbitolina *texana*, a discoid foraminifer described as "coolie hats", and several species of steinkern gastropods and pelecypods; Unit 4 is a sequence consisting of nodular limestone and calcarenite which is quite pronounced in the Dripping Springs area, forming ledges from which springs and seeps discharge; Unit 5 is a solution zone similar to Unit 1 containing water-bearing collapsed breccia which together with Unit 4, make up the Shallow aquifer in the Dripping Springs area; Unit 6 is predominately a clay section with thin, resistant beds of calcarenite and a few dolomite stringers; Unit 7 is a section of alternating beds of fossiliferous limestone, dolomite, and clay of which the lower dolomite bed is exposed in the parking lot of the Dripping Springs United Methodist Church and the surrounding hills; and Unit 8 is a sequence of clay and finely crystalline dolomite.

Structure

The Dripping Springs area is located between two major regional geological structures, the Llano uplift to the northwest and the Balcones fault zone to the southeast (Figure 2). In the Dripping Springs area, the Hosston Sand of the Travis Peak Formation is deposited on an uneven surface composed of Paleozoic (Ouachita facies) rocks of the Ouachita structural belt. This pre-Cretaceous surface slopes gently to the southeast at about 30 feet per mile away from the Llano uplift. In western Hays and Travis Counties, seismic interpretations reveal that Ouachita facies and foreland facies Paleozoic rocks are more than 12,000 feet thick. This indicates that the Precambrian basement rocks exposed in the Llano uplift plunge steeply to the southeast. The Ouachita facies Paleozoic rocks are structurally complex due to thrust faulting over the underlying foreland facies Paleozoic rocks. Many of the Ouachita facies Paleozoic rocks are incipiently to weakly metamorphic (Flawn, 1961).

This pre-Cretaceous surface has a positive anticlinal feature known as the San Marcos arch (Figure 2), an extension of the Llano uplift that plunges southeastward beneath San Marcos. The Trinity Group units that were deposited over the San Marcos arch occur at significantly higher stratigraphic altitudes than correlative beds on the flanks. These units generally have less bed thickness over the arch, especially on the northwest flank of the arch in the Dripping Springs area (Ashworth, 1983, Figure 7).

In terms of the structural or geometric orientation of the Glen Rose Formation, the strike was measured in the parking lot of the Dripping Springs United Methodist Church to be about north 10 degrees east. Actual formation dip was not measured on beds, but was estimated from the geological map (Bureau of Economic Geology, 1981) by extrapolating the contact of the Trinity Group with the overlying Fredericksburg Group between two isolated exposures west and east of Dripping Springs near U.S. Highway 290. These outcrops are several miles apart and are on line with the direction of formation dip. The western group of detached outcrops is about four miles west of Dripping Springs. The eastern group is 4 to 5 miles east of the City. The difference in elevation of the geological contacts at these outcrops results in an east-southeast dip of about 17 to 18 feet per mile. Another determination of formation dip was conducted in the Glen Rose outcrop area by using structural graphic methods and the results were essentially the same (Bureau of Economic Geology, 1981).

The Lower Glen Rose limestone can have significant structural features, particularly in the lower part or Unit 1. In areas to the south-southwest of Dripping Springs, rudist and coral reef development provide the geological conditions for increased porosity, and fractures caused by jointing and faulting, provide conduits for ground-water movement, resulting in locally developed solution channels and caverns. These are not as well developed however in the Dripping Springs area as to the south and southwest. The dominant structural and sedimentary characteristics of Unit 2 are its uniform thickness and laterally persistent dolomite and limestone beds.

The Upper Glen Rose limestone is also more uniform in thickness. In the Dripping Springs area, individual beds of limestone can be more massive and attain thicknesses of a few feet. The total thickness of Unit 4 is about 40 feet. The weathering and dissolution of fractures have caused ground water to discharge as springs from various horizons of the limestone. The overlying Unit 5 is greatly influenced by weathering and the topography. The solution zone is characterized by slumped brecciated structure and can be as much as 20 feet thick. The structural complexity of this formation explains to some extent the erratic occurrence of ground water in the Upper Glen Rose (Shallow) aquifer in the "Dripping Springs Valley".

HYDROGEOLOGY OF THE GLEN ROSE FORMATION

As a whole, the Glen Rose Formation is a leaky aquifer system. Its hydrologic characteristics are determined by the lithology of individual beds and geological structure. The Lower and Upper Glen Rose limestones are hydrologically connected due to the lack of a dominant confining bed or aquiclude of significant areal extent. Over time, water percolates downward in the formation creating perched ground-water conditions or discontinuous aquifers of limited lateral extent at various depths. Even though the Deep aquifer includes the Lower Glen Rose limestone, Hensell Sand, and Cow Creek Limestone based on their hydrological continuity, it is the Lower Glen Rose limestone that will be emphasized in this report since most of the deep wells in the Dripping Springs area are completed in this limestone.

Lower Glen Rose (Deep) Aquifer

Occurrence and Relationship to Underlying Water-Bearing Units

The hydrogeological complexity of the Deep aquifer can be traced to the manner in which ground water occurs in the combined section of the Lower Glen Rose limestone, Hensell Sand, and Cow Creek Limestone (Table 1). Since a dominant confining bed or aquiclude is not present, ground water is free to move at a very slow rate downward from the Lower Glen Rose limestone into the Hensell Sand and thence into the Cow Creek Limestone below. There also is a component of ground-water movement along formational dip from areas of recharge in the outcrop. Under these conditions and within each of these stratigraphic units, there are zones, not clearly defined, where ground water occurs in sufficient quantities in terms of permeability and storage which supply water to large-yield wells. Furthermore, compounded within this setting, there are zones of perched ground water, again not clearly defined, which add to the complexity of the Deep aquifer. The water wells included in this report which are completed in the Deep aquifer, with the exception of the Dripping Springs WSC wells, penetrate only the Lower Glen Rose limestone. Therefore, subsequent references to the Deep aquifer in this report mean the Lower Glen Rose (Deep) aquifer.

In the Dripping Springs area, the depth of water wells differs in terms of the Deep and the Shallow aquifers (Tables 1 and 6). The Deep aquifer wells are usually 100 to 200 feet deeper and can range in depth from 99 to 580 feet. There is also a corresponding difference in the depth to water from the land surface. Static water levels can be over 100 feet lower in the Deep aquifer than in the Shallow aquifer, and range from 81 to 296 feet below the surface. The altitude of water levels in the Lower Glen Rose (Deep) aquifer is shown on Figures 9 and 10.

Recharge, Movement, and Discharge

The interpretation of Figure 9 along with the aid of Figure 10 involves the application of ground-water flow principles. Like surface-water runoff on the land surface where water flows under the influence of gravity and "water runs downhill", ground water in the Deep aquifer moves similarly down the hydraulic gradient from higher altitudes to lower altitudes. The direction of ground-water flow is normal or perpendicular to the water-level contours shown on Figure 9.

In general, the regional ground-water movement in the Deep aquifer is from the north-northwest to the south-southeast. A trough-like ground-water depression (low-altitude area on Figure 9) directs ground-water movement to the southwest contrary to the regional trend. There are two ground-water mounds (high-altitude areas on Figure 9) which are located northwest and southeast of the ground-water depression. These ground-water mounds indicate areas where recharge occurs and it is possible that these ground-water mounds also represent areas having perched ground-water conditions.

Since there is not a laterally extensive confining bed or aquiclude in the Glen Rose Formation, recharge water from part of the precipitation on the land surface percolates downward via erratic pathways at very slow rates and replenishes the perched zones as well as the Shallow and Deep aquifers. Some recharge is also derived from part of the precipitation on the Glen Rose Formation outcrop area which lies west of the study area, the percolating water generally following the easterly dipping bedding planes of the geological strata.

Water Quality

While the chemical quality of the ground water in the Lower Glen Rose (Deep) aquifer is not the focus of this study, it is nevertheless discussed here in order to compare it to the quality in the Upper Glen Rose (Shallow) aquifer (Table 6 and Figure 11). Table 2 compares the chemical quality of the ground water in the Deep and Shallow aquifers, and indicates that the overall chemical quality is better in the Shallow aquifer.

Susceptibility of the Deep aquifer to contamination from the land surface at Dripping Springs appears to be remote except for the improper completion of many of the existing water wells in the Dripping Springs area. The boreholes of these wells are usually open (uncased) with only a few feet of uncemented surface casing at the top of the well bore. The lack of maintaining safe health conditions at the land surface due to faulty septic systems and contaminated surface-water runoff can provide a source of pollutants that can enter the well boreholes. Faulty cement foundations or slabs at the surface that were either installed improperly or have deteriorated and cracked with age, coupled with the condition that surface casing in most wells is uncemented downhole, can allow polluted waters at or

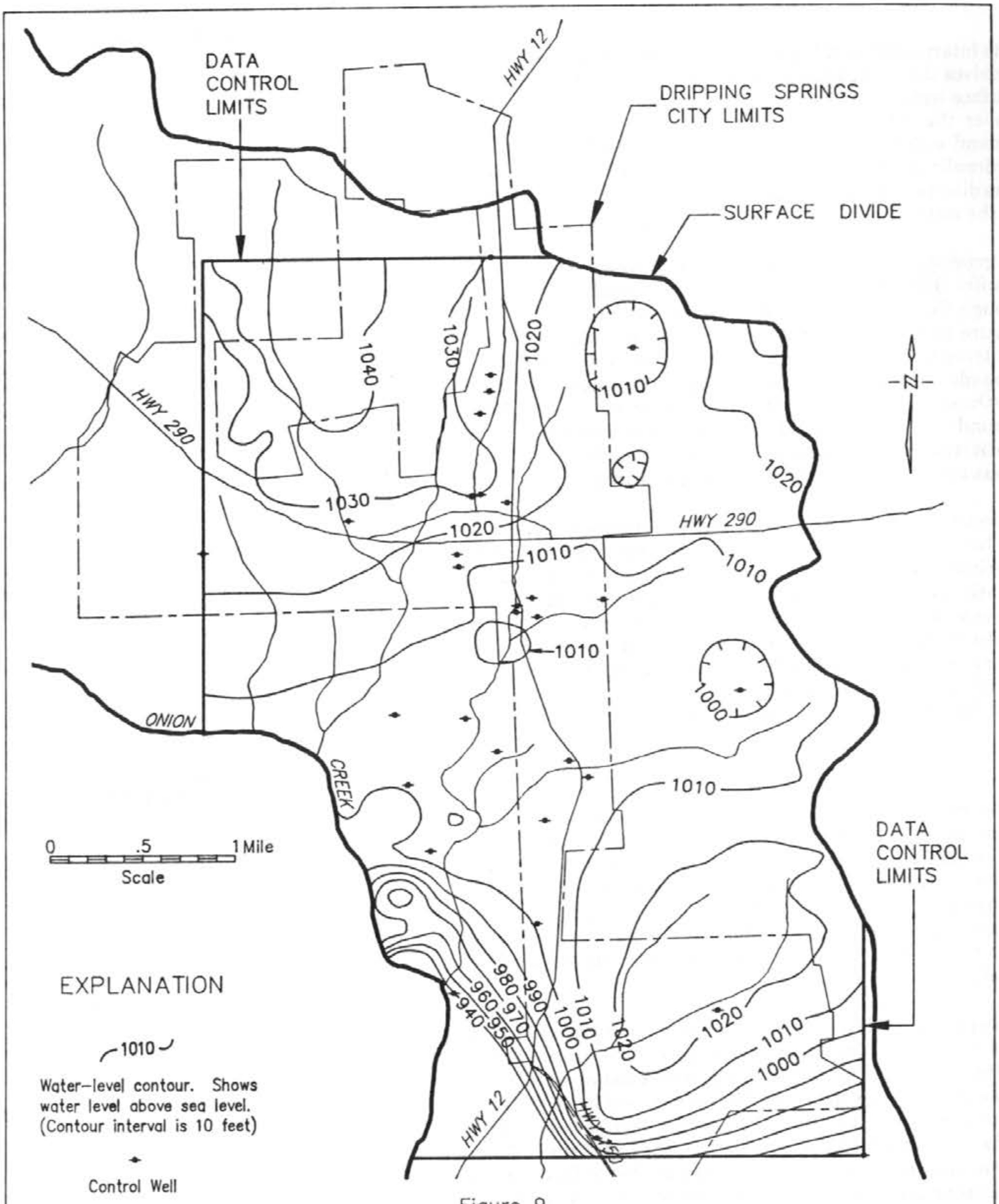


Figure 9

ALTITUDE OF WATER LEVELS IN THE LOWER GLEN ROSE (DEEP) AQUIFER, SUMMER 1988

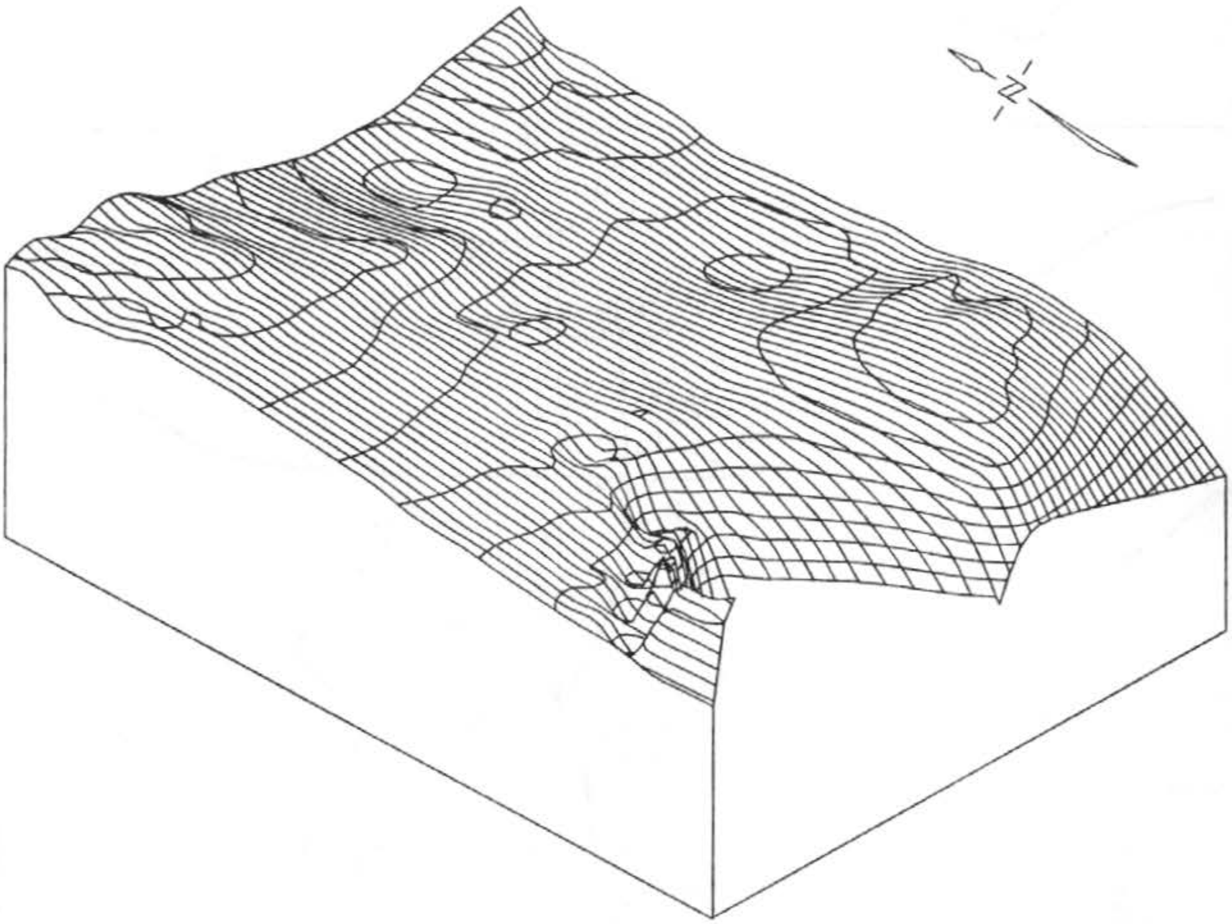


Figure 10

THREE-DIMENSIONAL SCHEMATIC OF THE WATER LEVELS IN THE GLEN ROSE (DEEP) AQUIFER, SUMMER 1988

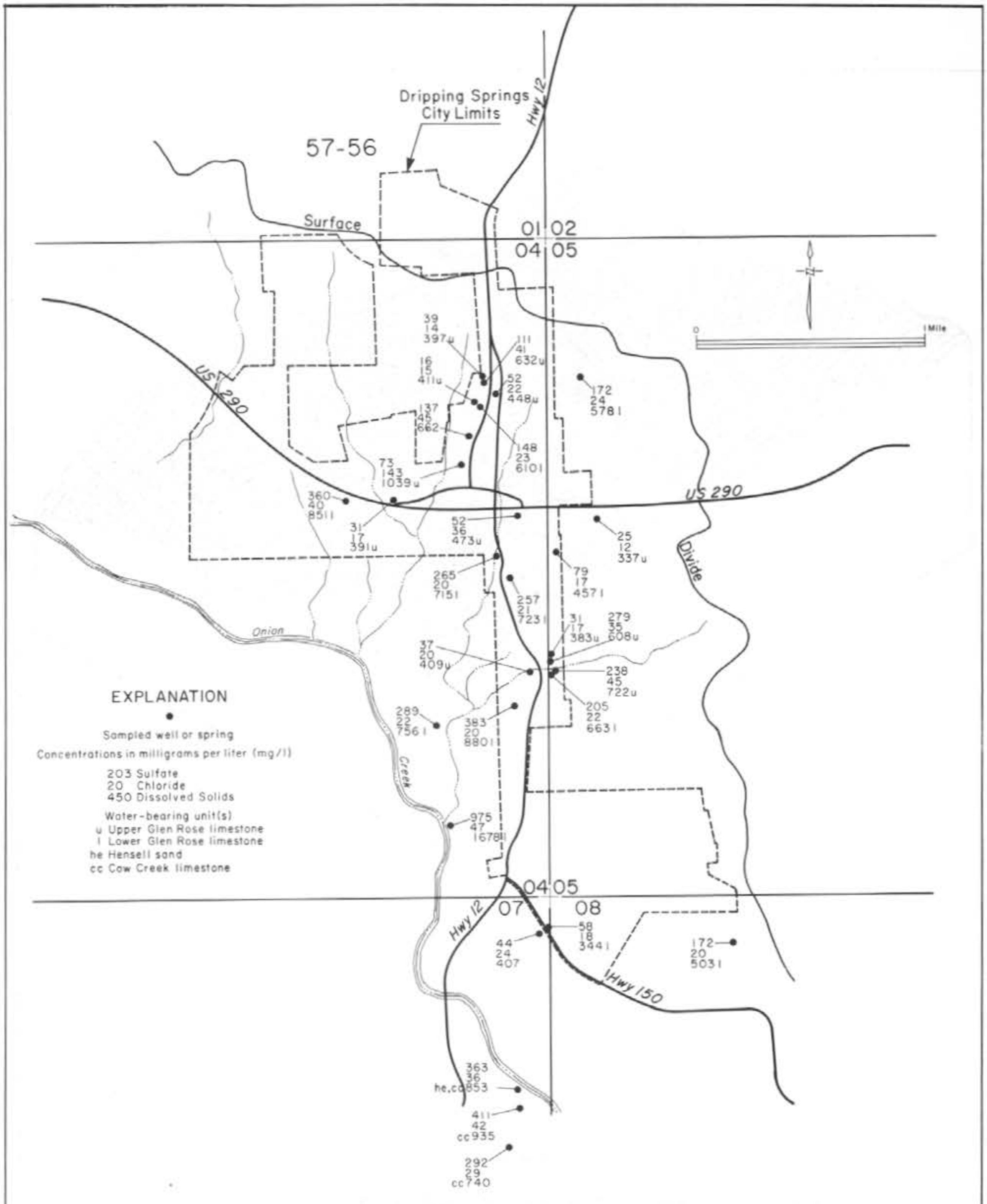


Figure 11

Ground-Water Quality of the Deep and Shallow Aquifers

Table 2
Comparison of Ground-Water Chemical Quality in the Lower Glen Rose (Deep) Aquifer and the Upper Glen Rose (Shallow) Aquifer

Concentrations in Milligrams per Liter (mg/l)

Constituents	**Deep Aquifer**	**Shallow Aquifer**
Sulfate (SO_4)		
Average	246	86
Range	15-975	16-279
Chloride (Cl)		
Average	23	36
Range	10-47	12-143
Fluoride (F)		
Average	1.46	0.78
Range	0.20-2.80	<0.10-190
Dissolved Solids		
Average	671	532
Range	209-1678	337-1039

through the uncemented annulus between the surface casing and the borehole. Therefore, the open boreholes of these improperly constructed wells can be a conduit for contaminants to reach the water-bearing rocks below.

Upper Glen Rose (Shallow) Aquifer

Occurrence

As a whole, the depth of wells and the corresponding static water levels are much shallower in the Shallow aquifer than in the Deep aquifer. Well depths range from 11 to 169 feet. Depending on the land surface elevations, static water levels can range from 5 to 91 feet. The altitude of water levels in the Upper Glen Rose (Shallow) aquifer is shown on Figures 12 and 13.

The water-bearing rocks of the Shallow aquifer are Units 4 and 5 of the Upper Glen Rose limestone (Table 1 and Figure 8). Figure 14 shows the relationship of these units to the land surface. Unit 5 first appears at the surface north of the City Hall on the Mercer Street loop. The geological contact between Units 4 and 5 crops out between Mercer Street and U.S. Highway 290. Ground water can appear at the land surface during wet periods where these units of the Shallow aquifer outcrop. The underlying confining bed or aquiclude of the Shallow aquifer, Unit 3, crops out south of the City along Texas Ranch Road 12 and appears along re-entrants of tributaries draining into Onion Creek. The geological contacts of these units generally trend east-west through the townsite and follow the topography.

The approximate location at the land surface of the geological contact between Units 5 and 6 is about 1,200 feet north of the Mercer Street loop along the Old Fitzhugh Road known locally as "Widow's Row". The contact between Units 4 and 5 lies between U.S. Highway 290 and Mercer Street in the "old town site" area. The contact between Units 3 and 4 lies south of U.S. Highway 290 and generally follows along the re-entrants of the main tributaries, then along the salient topography of the divides between these tributaries.

Prominent springs of the area, such as Dripping Springs and Walnut Springs, issue from Unit 4 above the confining beds of Unit 3. Other springs discharge from various levels of Unit 4. Seeps and waterlogging of the soil occur at the land surface where Units 4 and 5 of the Shallow aquifer crop out.

It follows from the above explanation that the geology of the land surface in the City of Dripping Springs can be related to the surficial hydrological conditions which occur during wet periods, namely, waterlogging of the soil, seeps, and increased spring flow.

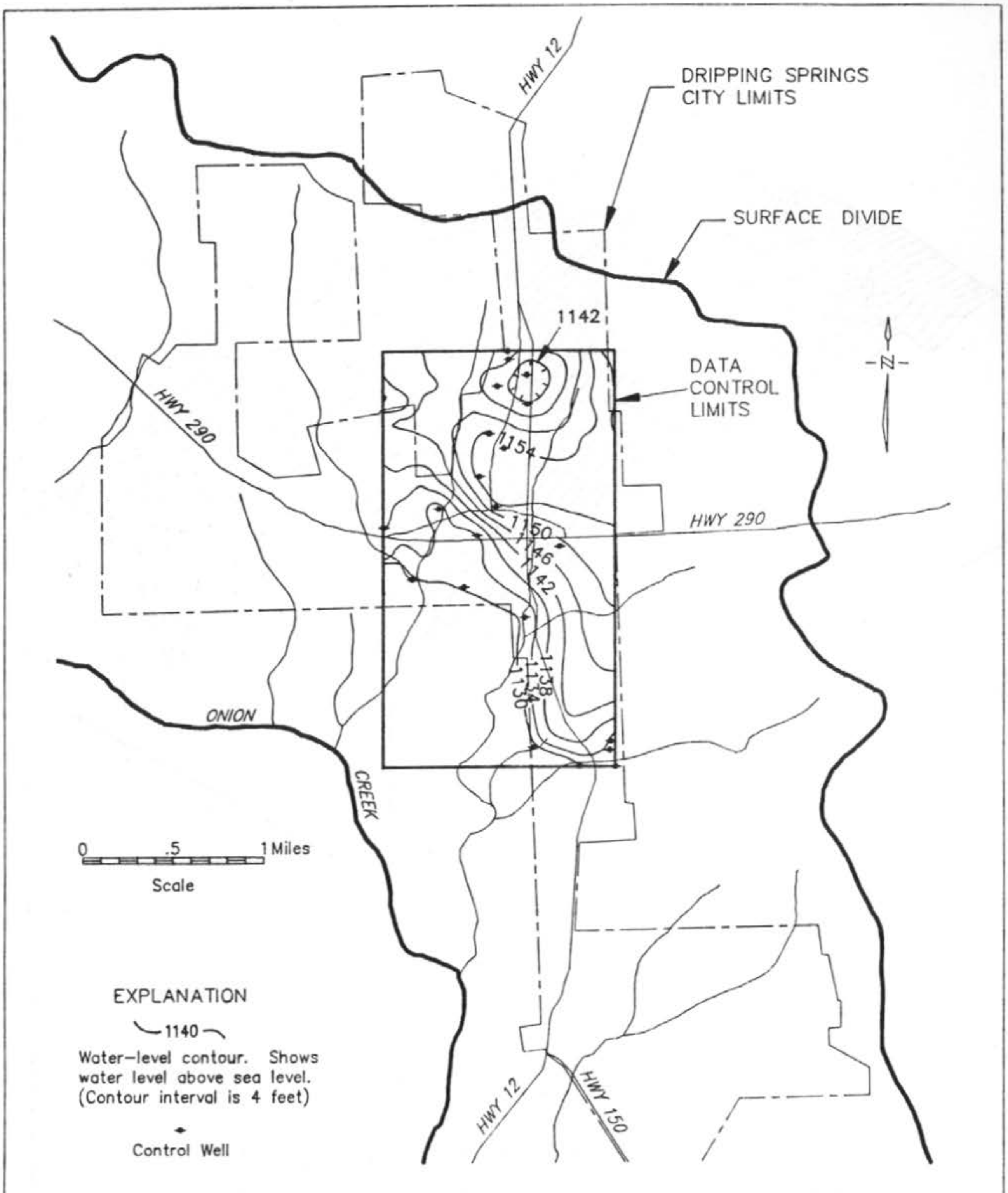


Figure 12

ALTITUDE OF WATER LEVELS IN THE
UPPER GLEN ROSE (SHALLOW) AQUIFER,
SUMMER 1988

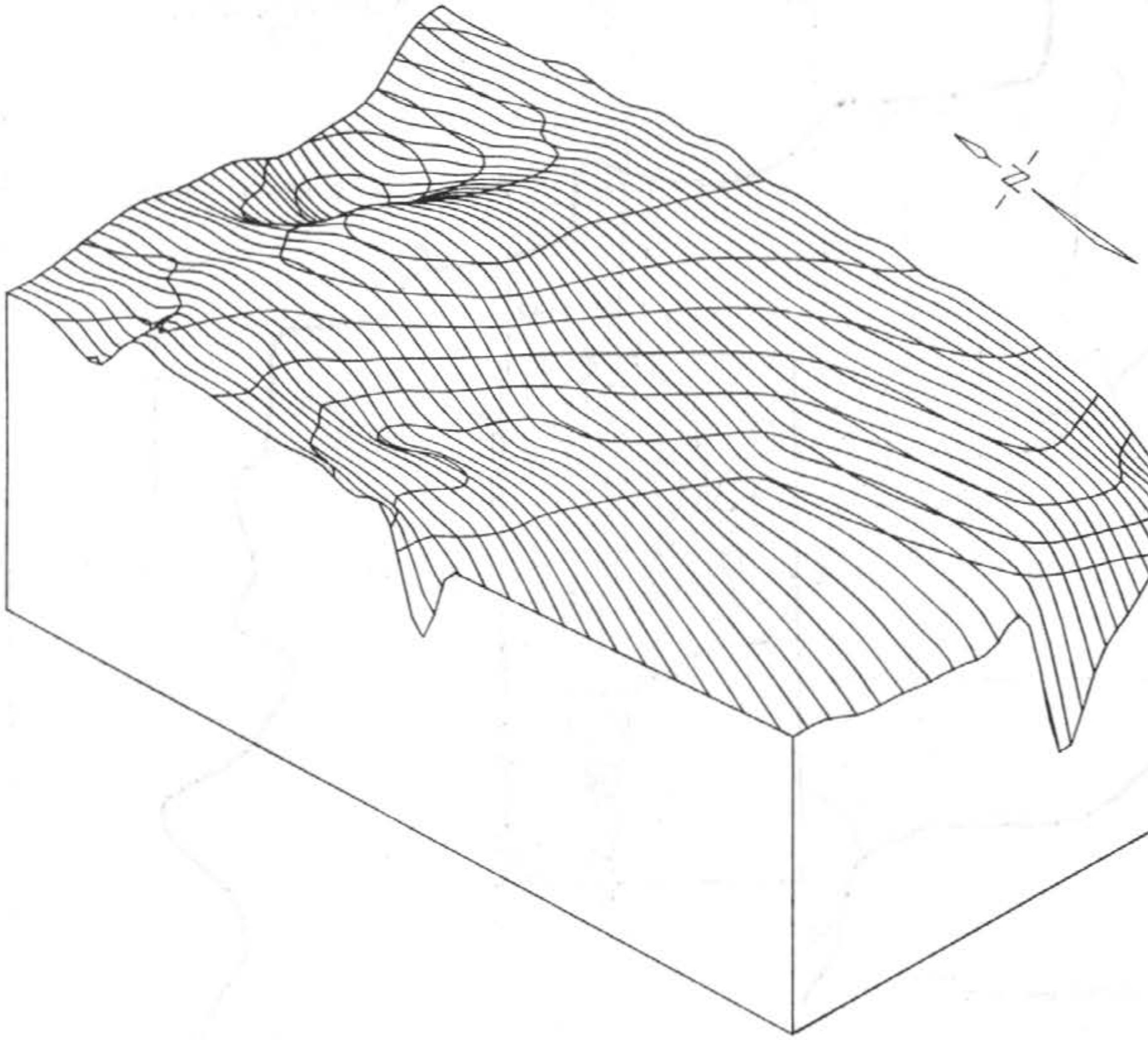


Figure 13

THREE-DIMENSIONAL SCHEMATIC OF THE WATER LEVELS IN THE UPPER GLEN ROSE (SHALLOW) AQUIFER, SUMMER 1988

Recharge, Movement, and Discharge

Ground-water movement in the Upper Glen Rose (Shallow) aquifer is generally from areas of recharge to seeps and springs of the area and to heavily vegetated areas subject to evapotranspiration located near seeps, springs, and along streams. Springs are located on the main tributaries draining into Onion Creek and represent points of natural ground-water discharge from the Shallow aquifer (Figures 12, 13, and 17). The area-wide trend of ground-water movement is interrupted by a prominent ridge-like ground-water mound lying just north of the City Hall located on the Mercer Street loop. Water moves away from this mound toward the north into a ground-water depression in the northern portion of the mapped area. It is possible that perched ground-water conditions and water encountered in wells at different horizons within the Shallow aquifer may be the cause of this mounded feature. In any event, this is a region where recharge is occurring. South of this water-level ridge, the water in the Shallow aquifer moves southwestward to the springs as indicated by the contours. The apparent steep hydraulic gradient is probably due to the low permeability of the water-bearing rocks of the Shallow aquifer.

Shallow depth to the water table is an important concept when considering areas of waterlogged soils and ground-water contamination induced by man's activity on the land surface, such as wastewater discharge through septic systems, lawn fertilizing and watering, and other activities producing pollutants. Figure 15 shows the proximity between the first ground water encountered in wells and the land surface. Notice the areas in the vicinity of the intersections of Mercer Street, the Old Fitzhugh Road, and U.S. Highway 290 east, where the depth to water is less than 10 feet. During wet seasons, these are areas where the soil is waterlogged. Additionally, these are areas where Unit 5 and the upper part of Unit 4 of the Shallow aquifer crop out.

Water Quality

The overall chemical quality of the Upper Glen Rose (Shallow) aquifer is better than that of the Lower Glen Rose (Deep) aquifer (Table 2). As such, the Shallow aquifer represents a valuable ground-water resource for the Dripping Springs area. Another noticeable difference in the chemical quality between the Deep and Shallow aquifers is the presence of unusually high nitrate concentrations in the Shallow aquifer (Table 6 and Figure 16).

Even though the unusually high concentrations of nitrate do not exceed the Texas Department of Health standard (maximum constituent level or MCL) for drinking water of 45 milligrams per liter (mg/l) for nitrate, and therefore, do not pose a health hazard, the presence of unusually high nitrate concentrations in the ground water in a significant number of shallow aquifer wells is enough to warrant concern that nitrate pollution is occurring.

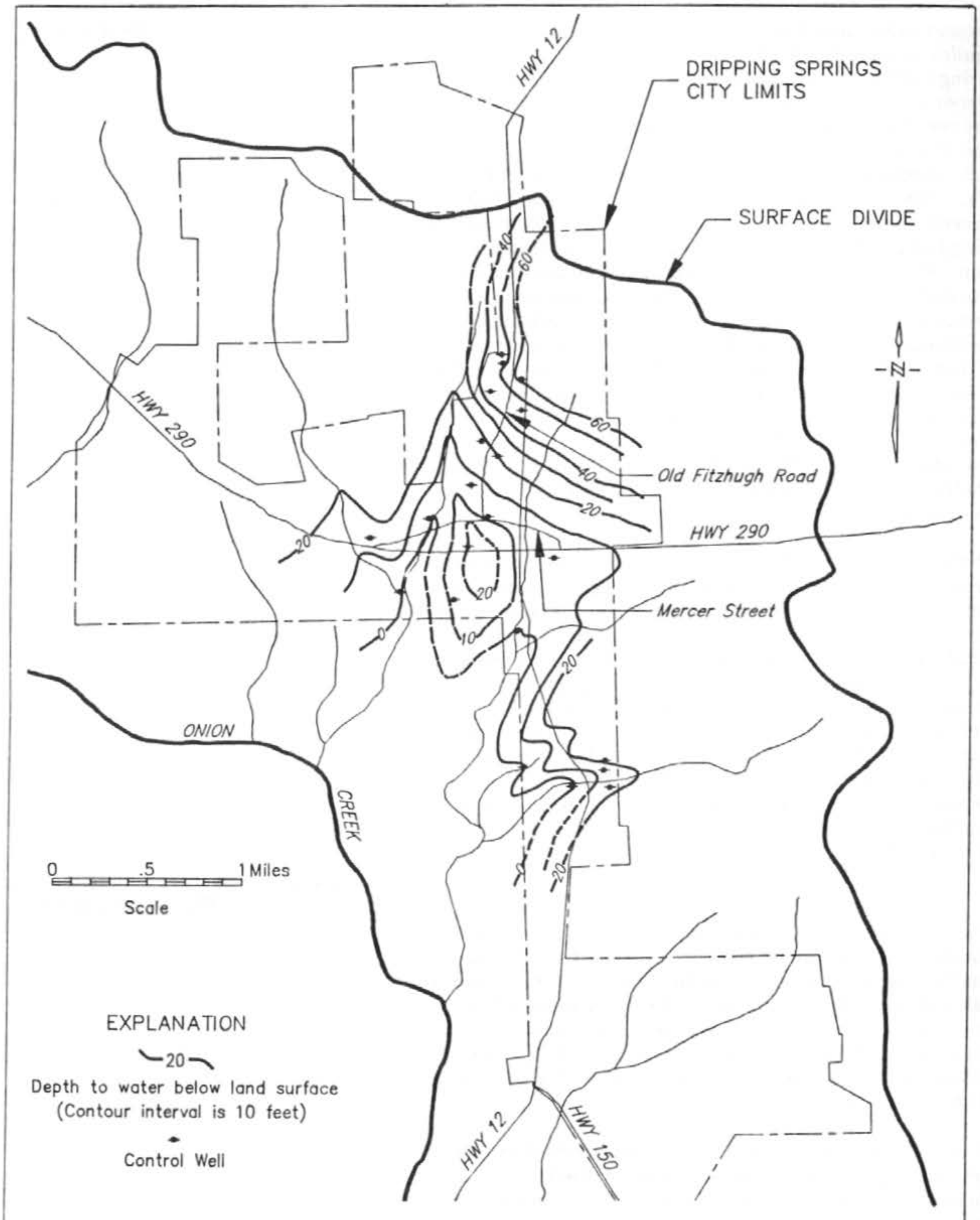


Figure 15

DEPTH TO WATER IN THE UPPER GLEN ROSE (SHALLOW) AQUIFER SUMMER, 1988

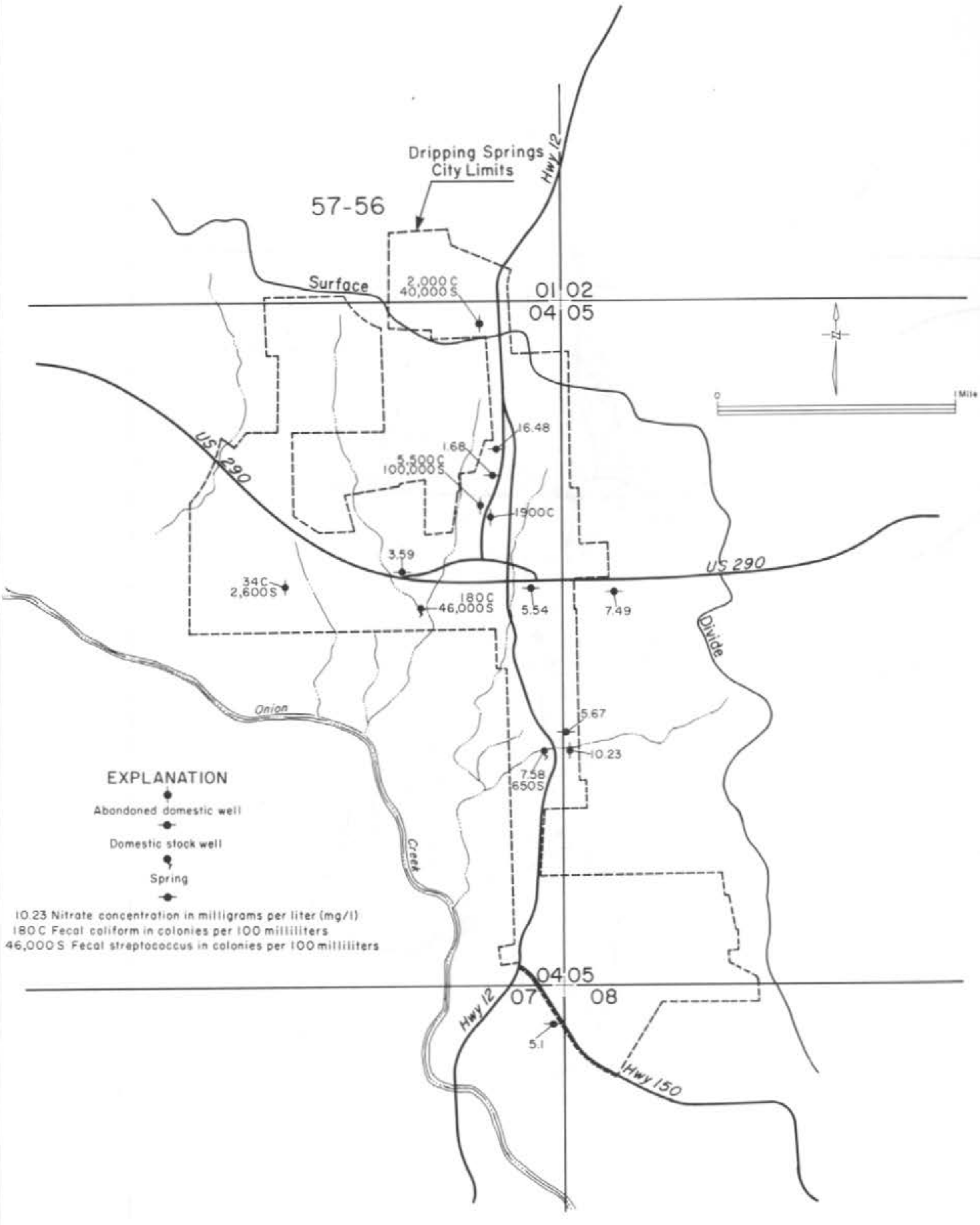


Figure 16

Occurrence of Nitrate and Bacteria in Ground Water and Well Boreholes

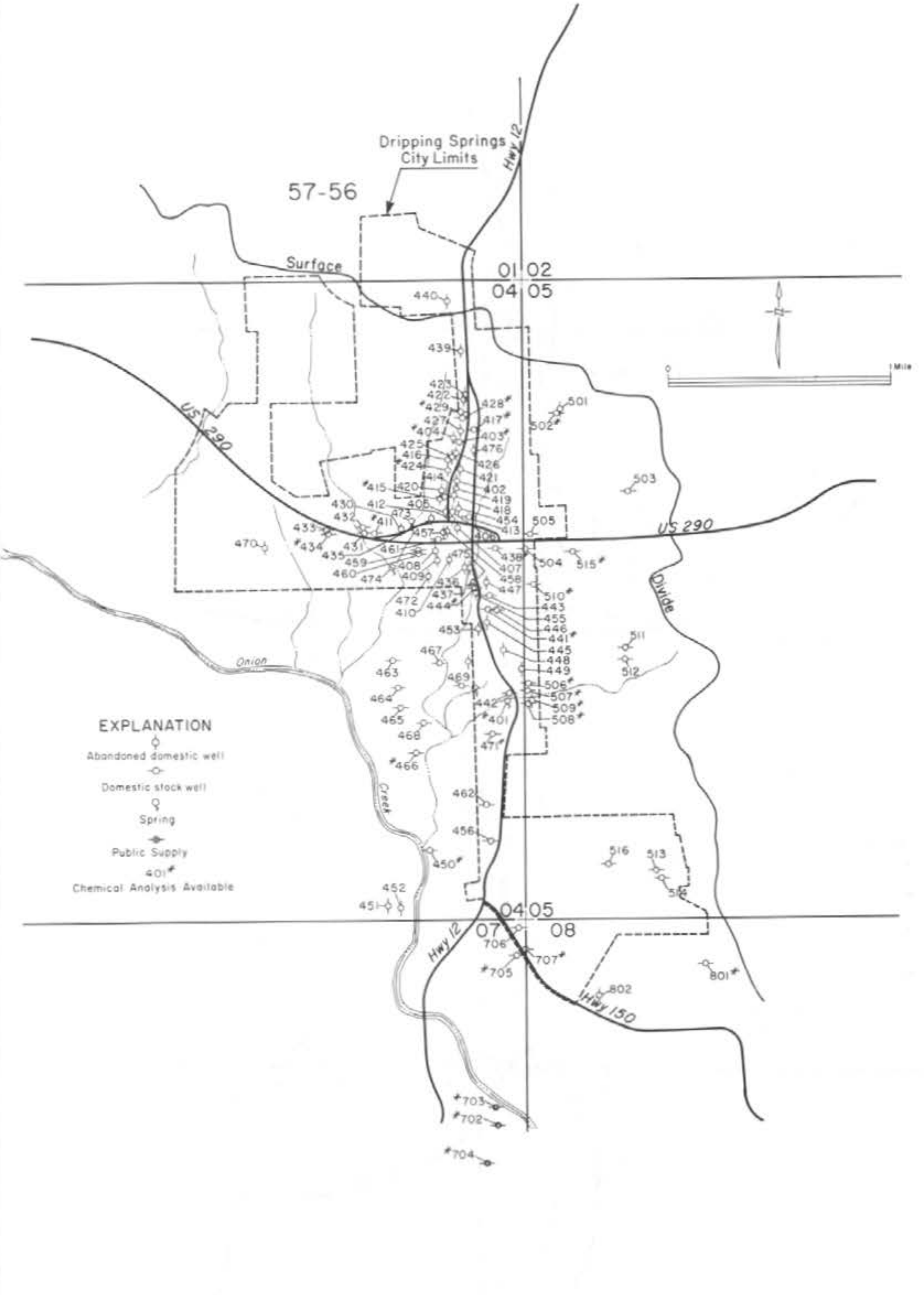


Figure 17

Location of Wells & Springs in the Dripping Springs Area

During the field investigation of this study, ground water from 13 Shallow aquifer wells were sampled for chemical analyses, each of which included an analysis of the nitrate concentration (Table 6). Consideration of the 13 nitrate analyses indicates a range in nitrate concentration from less than 0.04 mg/l (minimum detectable limit) to 16.48 mg/l, and an average nitrate concentration of 4.36 mg/l. Each concentration of less than 0.04 mg/l was set at zero concentration for the calculation of the average.

Seven of the 13 nitrate analyses, or about 54 percent, were equal to or greater than a near average concentration of 3.59 mg/l. Six of the 13 nitrate analyses, or about 46 percent, were 0.04 mg/l or less. Clearly, a significant number (7 of 13) of the nitrate concentrations fall in an unusually high group with concentrations ranging from 3.59 to 16.48 mg/l, and that another significant group (6 of 13) of the nitrate concentrations fall in a very low group of 0.04 mg/l or less.

The large numerical gap of 3.55 mg/l between the very low and unusually high groups of nitrate concentrations in the ground water of the Shallow aquifer strongly suggests that the very low group of nitrate concentrations represent the ambient or naturally occurring nitrate concentrations for the Shallow aquifer, and that the unusually high group of nitrate concentrations represent local nitrate pollution of this aquifer in the Dripping Springs area.

There is no indication that the rocks of the Shallow aquifer contain any significant amount of naturally occurring nitrate minerals in the Dripping Springs area.

The probable sources of the unusually high concentrations of nitrate in the ground water of the Shallow aquifer are lawn and garden fertilizers, animal wastes, and human wastes. These pollutants can reach the aquifer in percolating recharge that moves downward through the thin soils (Table 3) and fractured bedrock, and by seepage into wells with open borehole completion. Also during wet seasons, the water table can rise and intercept near-surface soils and bedrock, thus leaching nitrate into solution. Even though the occurrence of nitrate in the Shallow aquifer is not currently a health hazard, its presence indicates that contaminants at the land surface, such as wastewater from septic systems, can reach the shallow water table. This alone is sufficient evidence to show the vulnerability of the Shallow aquifer to the surface activities of man.

Additionally, the proximity of and the hydrological connection between the land surface and the shallow water table also raises the question of the susceptibility of the Shallow aquifer to bacteriological contamination from man-induced pollutants from the surface. Preliminary testing for bacteria in the ground water of the Shallow aquifer was conducted during the

Table 3. Dripping Springs Area Soil Characteristics and Their Relationship to Septic Tanks

Soil Name/ Symbol	Soil Depth Inches	USDA Soil Texture	Permeability Inches/Hour	Available Water Capacity Inch/Inch	Septic Tank Absorption Field Hazard	Remarks
		Soil Depth to Bedrock 18 Inches or Less				
Brackett/BtD	0-17	Gravelly clay loam.	0.2 - 0.6	0.10 - 0.20	Severe	Depth to rock.
	17-18	Weathered bedrock.	---	---		
Brackett/BtG	0-14	Gravelly clay loam.	0.2 - 0.6	0.10 - 0.20	Severe	Depth to rock, slope.
	14-18	Weathered bedrock.	---	---		
Comfort/CrD	0-6	Extremely stony clay.	0.06 - 0.2	0.07 - 0.15	Severe	Depth to rock, large stones.
	6-13	Stony clay, very stony clay, extremely stony clay.	0.06 - 0.2	0.07 - 0.15		
	13-20	Unweathered bedrock.	---	---		
Doss/DoC	0-18	Silty clay, clay loam.	0.2 - 0.6	0.15 - 0.20	Severe	Depth to rock, percs slowly.
	18-24	Unweathered bedrock.	---	---		
Eckrant/ErG	0-10	Extremely stony clay.	0.2 - 0.6	0.05 - 0.12	Severe	Depth to rock, slope, large stones.
	10-20	Unweathered bedrock.	---	---		
Comfort/RcD	0-6	Extremely stony clay, very stoney clay.	0.06 - 0.2	0.07 - 0.15	Severe	Depth to rock, large stones.
	6-13	Stony clay, very stony clay, extremely stony clay	0.06 - 0.2	0.07 - 0.15		
	13-20	Unweathered bedrock.	---	---		
Tarpley/TaB	0-6	Clay.	0.2 - 0.6	0.15 - 0.20	Severe	Depth to rock, percs slowly.
	6-17	Clay.	0.06 - 0.2	0.12 - 0.18		
	17-21	Unweathered bedrock.	---	---		
		Soil Depth to Bedrock Greater than 18 Inches				
Anhalt/AnB	0-18	Clay.	<0.06	0.15 - 0.18	Severe	Depth to rock, percs slowly.
	18-28	Clay.	<0.06	0.15 - 0.18		
	28-35	Unweathered bedrock.	---	---		
Bolar/BrB	0-14	Clay loam.	0.6 - 2.0	0.11 - 0.20	Severe	Depth to rock.
	14-28	Clay loam, loam, silty clay loam.	0.6 - 2.0	0.11 - 0.20		
	28-30	Weathered bedrock.	---	---		
Denton/DeB	0-25	Silty clay.	0.06 - 0.2	0.15 - 0.20	Severe	Depth to rock, percs slowly.
	25-36	Silty clay, clay, silty clay loam.	0.06 - 0.2	0.15 -0.20		
	36-40	Weathered bedrock.	---	---		
Krum/KrB, KrC	0-16	Clay.	0.2 - 0.6	0.15 - 0.20	Severe	Percs slowly.
	16-66	Silty clay, clay.	0.2 - 0.6	0.14 - 0.20		
	66-80	Silty clay loam, silty clay, clay.	0.2 - 0.6	0.14 - 0.20		
Lewisville, LeB	0-17	Silty clay.	0.6 - 2.0	0.16 - 0.20	Moderate	Percs slowly.
	17-36	Silty clay, clay loam, silty clay loam.	0.6 - 2.0	0.14 - 0.18		
	36-61	Silty clay, clay loam, silty clay loam.	0.6 - 2.0	0.14 - 0.18		
Ortif/Or	0-20	Gravelly loamy sand.	6.0 - 20	0.03 - 0.08	Severe	Flooding, poor filter.
	20-60	Stratified very gravelly sand to very gravelly loamy sand.	6.0 - 20	0.03 - 0.08		
Purves/PuC	0-10	Clay.	0.2 - 0.6	0.12 - 0.18	Severe	Depth to rock.
	10-19	Gravelly clay, very gravelly clay, gravelly clay loam.	0.2 - 0.6	0.08 - 0.18		
	19-20	Weathered bedrock.	---	---		
Seawillow/SeD	0-26	Clay loam.	0.6 - 2.0	0.12 - 0.20	Slight	
	26-48	Clay loam, silty clay loam.	0.6 - 2.0	0.12 - 0.18		
Sunev/Sub	0-11	Clay loam.	0.6 - 2.0	0.11 - 0.16	Slight	
	11-35	Loam, clay loam, silty clay loam.	0.6 - 2.0	0.11 - 0.16		
	35-60	Loam, clay loam, silty clay loam.	0.6 - 2.0	0.11 - 0.16		

Compiled from USDA Soil Conservation Service: *Soil Survey of Comal and Hays Counties, Texas.*

field investigation of this study, and the results of the testing are provided in Table 7 which follows the "Selected References" of this report.

The Texas Department of Health has not prescribed standard sterile procedures for bacteriological sampling of ground water from wells without pumps. Also, there is not currently a standard sterile bacteriological sampling procedure for collecting ground-water samples from springs. The preliminary sampling results provided in Table 7 indicate that high levels of bacteria occurred in samples bailed from wells and collected from springs (Figure 16). The possibility of contaminated samples is likely; that is, not all bacteria detected necessarily occurred in the water. Also, only single samples were collected at each site rather than a standardized series over a period of time.

Based on Texas Department of Health water-quality standards, fecal coliform must not exceed 200 bacteria colonies per 100 milliliters within 30 days when expressed as a geometric mean of at least five samples (Texas Water Commission and others, 1988); this level was exceeded in several of the preliminary results shown in Table 7. Because of the need for improved sampling procedures noted above, however, the results are not considered conclusive.

The City of Austin, utilizing U.S. Geological Survey sample data collected on Barton Creek between 1983 and 1986, analyzed bacteria concentrations to evaluate the extent of animal versus human wastes associated with coliform levels. This analysis, using coliform:streptococcus ratio as an indicator, determined that a 4:1 or greater ratio indicates a human waste origin; a 1:1 ratio or less an animal waste origin; and a ratio between 1:1 and 4:1 indicates a combined human and animal waste source.

According to the data in Table 7, most of the water wells showing excessive bacteria levels indicate a coliform:streptococcus ratio which indicates animal waste as a source. One exception is noted that shows human waste as the origin, and this well is not used. Pumping these wells for a period of time before sampling could be expected to result in more accurate ground-water sampling and might greatly reduce the bacteria count results.

Soils and Ground-Water Quality

Soils developed on the Glen Rose limestone in the Dripping Springs area are usually thin. The map shown on Figure 3 illustrates that most of the study area is covered by soils that have depth to bedrock of less than 18 inches. This map was constructed by combining soils listed on Table 3 which extended to 18 inches or less. Table 3 also indicates that these soils have a severe septic tank absorption field hazard.

Ground-water quality in the Shallow aquifer in the Dripping Springs area has been affected by characteristics of the soils; namely, that they are thin and do not provide sufficient filtering and absorption of contaminated surface water prior to itspercolation to the water table. To aid in understanding the effects of soil conditions, the following paragraphs are quoted from the ***Soil Survey of Comal and Hays Counties, Texas***, pages 55 and 59. The underlining in the quoted text below signifies a definition or classification.

"Sanitary facilities"--Table 3 "shows the degree and the kind of soil limitations that affect septic tank absorption fields, sewage lagoons, and sanitary land fills. The limitations are considered ***slight*** if soil properties and site features agree generally favorable for the indicated use and limitations are minor and easily overcome; ***moderate*** if soil properties or site features are not favorable for the indicated use and special planning, design, or maintenance is needed to overcome or minimize the limitations; and ***severe*** if soil properties or site features are so unfavorable or so difficult to overcome that special design, significant increases in construction costs, and possibly increased maintenance are required.

"***Septic tank absorption fields*** are areas in which effluent from a septic tank is distributed into the soil through subsurface tiles or perforated pipe. Only that part of the soil between depths of 24 and 72 inches is evaluated. The ratings are based on soil properties, site features, and observed performance of the soils. Permeability, a high water table, depth to bedrock or to a cemented pan, and flooding affect absorption of the effluent. Large stones and bedrock or a cemented pan interfere with installation.

"Unsatisfactory performance of septic tank absorption fields, including excessively slow absorption of effluent, surfacing of effluent, and hillside seepage, can affect public health. Ground water can be polluted if highly permeable sand and gravel or fractured bedrock is less than 4 feet below the base of the absorption field, if slope is excessive, or if the water table is near the surface. There must be unsaturated soil material beneath the absorption field to filter the effluent effectively. Many local ordinances require that this material be of a certain thickness.

"Sewage disposal systems -- Many new houses are being built in areas beyond municipal sewer lines. These houses must have onsite sewage disposal systems. The effectiveness of these systems depends largely on the absorptive capacity and permeability of the soils in the filter field and on the percolation rate, wetness, hazard of flood, seepage, and slope.

"The soils in Comal and Hays Counties annually have severe limitations as sites for septic tank absorption fields. Some of the soils in the survey area are clayey and consequently are very slowly permeable. Others are shallow to bedrock."

By using the general soil map to identify the soils and by referring to the ratings in Table 3, "A user of this soil survey can get a general idea of how well a septic tank system functions in a selected area. Nevertheless, a detail inspection of the soils should be made at the exact site that is to be used as a filter field."

The above statements concerning soils and septic tank use amply describe the situation in the Dripping Springs area. Most of the soils are thin with usually less than 18 inches of soil to bedrock. Due to this limiting soil property, site features for septic systems are classified "severe" since to overcome the limitations, special design is needed which increases costs and possible maintenance. A high water table increases the possibility of nitrate being leached from the soil, bedrock, and most importantly, absorption fields.

Water Supply and its Impact on Ground-Water Quality

The Dripping Springs Water Supply Corporation supplies ground water for municipal use in the Dripping Springs area. The reported amounts of water supplied by the Corporation from 1965 to 1986 are shown on Table 4. Note that 1985 was the highest year for the period of record when 95,856,800 gallons were used by 599 connections. This amounts to an average of 160,028 gallons per connection. The amount of water supplied and number of connections served in 1985 were selected in order to determine the best estimate for the annual quantity of wastewater available for recharge from septic systems.

The Texas Water Development Board's Water Use Section estimates that about 60 percent of the domestic water used results in wastewater (Bill Moltz, Texas Water Development Board, personal communication). Therefore, about 57,514,000 gallons, or an average of about 96,000 gallons per connection, was wastewater in 1985. Based on soil percolation rates of the area, it is estimated that possibly 35 percent of this wastewater becomes available for recharge. Therefore, about 20,129,900 gallons, or about 33,600 gallons per connection, becomes wastewater recharge in the Dripping Springs area. This wastewater, most of which is recharged to the Upper Glen Rose (Shallow) aquifer, is believed to be the major source for the unusually high nitrate concentrations detected in the ground water of the Shallow aquifer.

In addition to the amount of wastewater available for recharge, about 4 percent of the average annual precipitation of 32 inches is also naturally recharged to the Shallow aquifer. During wet periods, large amounts of natural recharge, coupled with the wastewater recharge, cause ground-water levels to rise to the land surface and waterlog the soils and near-surface bedrock. Evapotranspiration of this water causes residual nitrogen compounds to become concentrated in the water. During subsequent dry periods when ground-water levels recede, a significant portion of the concentrated nitrogen compounds are carried downward with the receding ground water. Thus, the combined wastewater recharge water and natural recharge water become the significant "carrier of pollutants" that have had a noticeable impact on the ground-water quality in the Shallow aquifer.

Table 4
Reported Annual Amounts of Ground Water Supplied,Related Number of Wells Used, and Number of Water Connections Served by the Dripping SpringsWater Supply Corporation, 1965-1986.

Year	Gallons Supplied	Wells Used	Connections Served
1965	6,867,000	1	115
1966	7,400,000	1	118
1967	9,002,000	1	129
1968	8,893,500	1	130
1969	11,148,200	1	135
1970	8,541,300	1	150
1971	8,000,000	1	160
1972	17,760,700	1	175
1973	17,060,700	1	177
1974	14,730,100	1	176
1975	17,977,300	2	183
1976	19,262,240	2	196
1977	20,260,320	2	226
1978	34,196,800	2	262
1979	38,258,000	1	290
1980	40,886,200	2	317
1981	43,068,400	2	348
1982	50,364,000	2	407
1983	62,935,000	2	455
1984	89,091,900	2	530
1985	95,856,800	2	599
1986	72,656,100	3	615

Table 5
Records of Wells and Springs

Well - Numbering of wells is explained under "Well Numbering System" in the text and on Figure 4. LR is the county prefix for Hays County. Wells and Springs on location map Figure 17.
Water-bearing unit(s) - Kgr means Glen Rose Formation, Kgru - Upper Glen Rose Limestone, Kgrl - Lower Glen Rose Limestone, Khe - Hensell Sand,
Kcc means Cow Creek Limestone, Ksl - Sligo Limestone, Kho - Hosston Sand.
Method of Lift ------- N means no pump installed, S - submersible pump, PJ - pump jack pump, J - jet pump, T - turbine pump, HP - hand pump,
C means cylinder pump, W - pump powered by wind, E - pump powered by electricity.
Use of Water --------- N means not used, D - domestic, Irr - irrigation, P - public supply.

Well	Owner	Driller	Latitude Longitude	Date com-pleted	Depth of well	Dia-meter (ft.)	Casing depth (in.)	Water-bearing unit(s) (ft.)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of mea-surement	Method of Lift	Use of Water	Remarks
LR 57-56-401[1]	Anton B. Allen	--	30-10-52 098-05-03	--	Spring	--	--	Kgru	1120	0.00	6-22-88	--	D	Known as Walnut Springs. Not on city water.
LR 57-56-402[3]	Ollie Roberts	--	30-11-43 098-05-17	--	80.5	6	--	Kgru	1176	20.5	06-28-88	N	N	
LR 57-56-403[3]	J. B. Townsend	--	30-11-52 098-05-16	--	200	6	--	Kgrl	1189	163.9	06-30-88	S,E	D	Not on city water.
LR 57-56-404[3]	do	--	30-11-52 098-05-17	--	74	8	2	Kgru	1188	45.2	06-30-88	N	N	
LR 57-56-405	Masonic Lodge	--	30-11-36 098-05-20	--	--	6	--	Kgrl	1161	130.0	06-22-88	PJ,E	N	
LR 57-56-406	Galen Dodson	--	30-11-36 098-05-18	--	--	6	--	Kgrl	1161	129.4	06-22-88	PJ,E	N	
LR 57-56-407	John McClaferty	--	30-11-33 098-05-18	--	--	6	--	Kgrl	1157	81.2	06-23-88	PJ,E	N	Well bridged over at about 82 feet.
LR 57-56-408	Jack Lyle	--	30-11-27 098-05-24	--	247	6	--	Kgrl	1149	138.5	06-23-88	PJ,E	N	
LR 57-56-409	Julianna Gore	--	30-11-24 098-05-23	--	--	6	--	Kgrl	1147	136.7	06-23-88	S,E	N	
LR 57-56-410	First Baptist Church	--	30-11-24 098-05-20	--	99	6	--	Kgrl	1147	84.2	06-23-88	PJ,E	N	
LR 57-56-411[3]	Alfred Hohman	--	30-11-31 098-05-39	--	58.5	12	--	Kgru	1155	16.0	06-24-88	J,E	D	Not on city water. Well used for rent house.
LR 57-56-412	John W. Chase	--	30-11-34 098-05-19	--	13.5	36	--	Kgru	1159	5.0	06-28-88	N	N	
R 57-56-413	Tom B. Gregory	--	30-11-35 098-05-13	--	--	8	--	Kgrl	1157	130.5	06-28-88	S,E	Irr	Used to water yard.
LR 57-56-414	Commercial Credit Corporation	--	30-11-39 098-05-21	--	--	6	--	Kgrl	1166	[4]	06-28-88	S,E	D	
LR 57-56-415[3]	Bradley Davis	--	30-11-38 098-05-21	--	10.6	36	--	Kgru	1165	9.2	06-29-88	N	N	
LR 57-56-416	Charlie Hayden	--	30-11-45 098-05-20	--	300	6	--	Kgrl	1180	152.2	06-29-88	S,E	D	

Table 5 *(continued)*
Records of Wells and Springs

Well	Owner	Driller	Latitude Longitude	Date completed	Depth of well	Diameter (ft.)	Casing depth (in.)	Water-bearing unit(s) (ft.)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of measurement	Method of Lift	Use of Water	Remarks
LR 57-56-416	Charlie Hayden	--	30-11-45 099-05-20	--	300	6	--	Kgrl	1180	152.2	06-29-88	S,E	D	
LR 57-56-417[1]	Hoyle Gilles (Ilene)	--	30-11-55 098-05-13	--	120	6	--	Kgru	1200	62.6	06-29-88	S,E	D	Not on city water.
LR 57-56-418	C. F. Shelton	--	30-11-40 098-05-18	--	--	6	--	Kgru	1168	[4]	06-29-88	N	N	Well destroyed.
LR 57-56-419	McNair & Samson	--	30-11-42 098-05-18	--	-- -	-	--	Kgru	1172	[4]	06-30-88	N	N	Well reported to be filled due to bacteria contamination.
LR 57-56-420	Bradley Davis	--	30-11-41 098-05-22	--	8	6	--	Kgru	1166	[4]	06-30-88	N	N	Filled in at 8 feet.
LR 57-56-421	Mary Spaw	--	30-11-46 098-05-18	--	--	6	--	Kgr	1181	[4]	06-30-88	T,E	N	
LR 57-56-422	Doris Davidson	--	30-12-02 098-05-16	--	--	6	--	Kgr	1195	111.0	06-30-88	N	N	
LR 57-56-423	do	--	30-12-03 098-05-15	--	--	6	--	Kgru	1200	[4]	06-30-88	HP	N	
LR 57-56-424[1]	Wanda Glass Grieer	--	30-11-46 098-05-19	--	42	6	--	Kgru	1174	19.4	06-30-88	N	N	
LR 57-56-425	Rosemary Brooks	--	30-11-50 098-05-18	--	113	6	--	Kgrl	1182	111.6	06-30-88	N	N	
LR 57-56-426	M. T. Jones	--	30-11-51 098-05-17	--	-- --	--		Kgru	1184	[4]	06-30-88	N	N	
LR 57-56-427	Raymond O. Whisenant	--	30-11-55 098-05-17	--	210	8	4	Kgrl	1191	165.6	06-30-88	N	N	
LR 57-56-428[3]	William Roberts	Sparly Glass	30-11-58 098-05-17	1944	115	6	--	Kgru	1194	46.4	06-30-88	J,E	D	Not on city water.
LR 57-56-429[1]	D. R. Mulhollen	--	30-11-59 098-05-17	1945	90	6	--	Kgru	1196	47.5	06-30-88	S,E	Irr	Used to water yard.
LR 57-56-430	Alva Haydon	--	30-11-32 098-05-	1800's	--	6	--	Kgru	1148	[4]	07-14-88	N	N	Historical Site: The Marshall-Chapman Home
LR 57-56-431	Jessie Sedwick	--	30-11-31 098-05-41	--	--	--	--	Kgru	1154	[4]	07-14-88	N	N	Well destroyed.
LR 57-56-432	Mrs. Quisenberry	--	30-11-32 098-05-43	--	168	6	--	Kgrl	1154	126.0	07-14-88	S,E	Irr	Used at times to water yard.
LR 57-56-433	Nancy Frasher	--	30-11-31 098-05-52	--	142	4	--	Kgrl	1163	117.4	07-14-88	N	N	
LR 57-56-434[3]	do	--	30-11-31 098-05-52	--	--	6	--	Kgrl	1163	117.57	07-14-88	S,E	D	Not on city water.

Table 5 *(continued)*
Records of Wells and Springs

Well	Owner	Driller	Latitude Longitude	Date com-pleted	Depth of well	Dia-meter (ft.)	Casing depth (in.)	Water-bearing unit(s) (ft.)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of mea-surement	Method of Lift	Use of Water	Remarks
LR 57-56-435	Clem K. Best	--	30-11-35 098-05-23	--	--	8	--	Kgru	1157	[4]	07-14-88	N	N	Well destroyed.
LR 57-56-436	William Bassett	--	30-11-23 098-05-15	--	--	6	--	Kgru	1147	[4]	07-14-88	J,E	N	
LR 57-56-437	do	--	30-11-23 098-05-14	--	--	48	11.5	Kgru	1147	[4]	07-14-88	N	N	Dry dug well.
LR 57-56-438[1]	D. N. Cauthen	--	30-11-27 098-05-07	--	--	6	--	Kgru	1157	8.0	07-14-88	S,E	Irr	Used to water yard.
LR 57-56-439	V. Turner	--	30-12-14 098-05-1	--	--	6	--	Kgrl	1217	189.1	07-18-88	S,E	N	
LR 57-56-440[2]	Antonio Nevarez	--	30-12-25 098-05-2	--	169	6	--	Kgru	1230	91.0	07-19-88	N	N	
LR 57-56-441[3]	E. E. "Nukkie" Myers	--	30-11-13 098-05-	--	-- --	--		Kgrl	1146	[4]	07-18-88	S,E	Irr	Used to water yard and garden.
LR 57-56-442	Anton B. Allen	--	30-10-53 098-05-03	--	--	6	--	Kgrl	1141	133.3	07-18-88	S,E	D	Not on city water.
LR 57-56-443	Robert L. Terry	--	30-11-03 098-05-05	--	--	6	--	Kgrl	1146	140.0	07-19-88	S,E	D	
LR 57-56-444[1]	Roger Hanks	--	30-11-18 098-05-12	--	--	6	--	Kgrl	1138	132.7	07-19-88	S,E	D	Not on city water.
LR 57-56-445	West Belt Investments	--	30-11-10 098-05-09	--	--	6	--	Kgrl	1142	[4]	07-19-88	PJ,E	N	
LR 57-56-446	Jim Montague	--	30-11-13 098-05-07	1945	--	6	--	Kgrl	1148	[4]	07-20-88	S,E	D	
LR 57-56-447	Robert L. Terry	--	30-11-19 098-05-10	--	--	6	--	Kgrl	1148	146.2	07-20-88	P	J,E	N
LR 57-56-448	do	--	30-11-04 098-05-05	1945	--	6	--	Kgrl	1145	[4]	07-20-88	PJ,E	N	
LR 57-56-449	M. Burrier	--	30-10-59 098-05-00	--	-- --	--		Kgru	1149	[4]	07-20-88	N	N	
LR 57-56-450[3]	M. K. Hage	Glass & Tucker	30-10-17 098-05-25	1982	340	6	--	Kgrl	1064	122.1	07-21-88	S,E	D	Not on city water.
LR 57-56-451	do	--	30-10-03 098-05-37	--	--	6	--	Kgrl	1079	116.0	07-21-88	S,E	N	
LR 57-56-452	do	--	30-10-03 098-05-33	1940	--	4	--	Kgrl	1055	[4]	07-21-88	N	N	Well destroyed.
LR 57-56-453	Buleau Needham	--	30-11-09 098-05-12	--	30	6	--	Kgru	1039	[4]	07-21-88	HP	N	

Table 5 *(continued)*
Records of Wells and Springs

Well	Owner	Driller	Latitude Longitude	Date completed	Depth of well (ft.)	Diameter (in.)	Casing depth (ft.)	Water-bearing unit(s)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of measurement	Method of Lift	Use of Water	Remarks
LR 57-56-454	J. D. Eckols	--	30-11-37 098-05-16	--	--	6	--	Kgrl	1164	[4]	07-26-88	PJ,E	N	
LR 57-56-455	Roger Hanks	--	30-11-17 098-05-12	--	--	8	--	Kgrl	1140	127.0	07-26-88	S,E	N	
LR 57-56-456	Joan Crosswell	--	30-10-19 098-05-09	--	--	6	--	Kgrl	1137	[4]	07-27-88	S,E	D	
LR 57-56-457	Alva Haydon	--	30-11-32 098-05-24	--	25	--	--	Kgru	1154	[4]	08-02-88	N	N	Well destroyed.
LR 57-56-458	do	--	30-11-33 098-05-24	--	--	6	--	Kgrl	1156	[4]	08-02-88	PJ,E	N	
LR 57-56-459	do	--	30-11-28 098-05-27	--	119	6	--	Kgrl	1147	102.0	08-02-88	C,W	D	
LR 57-56-460	do	--	30-11-27 098-05-26	--	351	6	--	Kgrl	1146	[4]	08-02-88	S,E	D	
LR 57-56-461	Beulah H. Malott	--	30-11-29 098-05-22	--	22.3	6	--	Kgru	1152	20.3	06-23-88	HP	D	
LR 57-56-462	Bobby Joe Needham	--	30-10-27 098-05-10	--	200	6	--	Kgrl	1130	130.0	08-03-88	S,E	D	
LR 57-56-463	Bobby Joe Needham	Richard L.Bible	30-11-01 098-05-35	1984	290	6	--	Kgrl	1116	109.8	08-03-88	S,E	D	Not on city water.
LR 57-56-464	E. J. Needham	do	30-10-55 098-05-33	1984	270	6	--	Kgrl	1114	[4]	08-03-88	S,E	D	do
LR 57-56-465	Ernest Needham	do	30-10-51 098-05-33	1983	250	6	--	Kgrl	1113	110.7	08-03-88	S,E	D	do
LR 57-56-466[3]	Donna C. Needham	do	30-10-40 098-05-29	1984	310	6	--	Kgrl	1092	85.1	08-04-88	S,E	D	do
LR 57-56-467	George A. Fry	James B. TuckerJr.	30-11-01 098-05-23	1982	160	6	--	Kgrl	1116	110.4	08-04-88	S,E	D	do
LR 57-56-468	Ted N. Montgomery	--	30-10-47 098-05-27	--	--	--	--	Kgrl	1115	[4]	08-04-88	S,E	D	do
LR 57-56-469	Joey Needham	Richard L.Bible	30-10-56 098-05-16	1983	210	6	--	Kgrl	1113	108.6	08-04-88	S,E	D	do
LR 57-56-470[2]	Guadalupe Picasio	--	30-11-29 098-06-09	--	178	6	4	Kgrl	1165	141.0	08-04-88	N	N	
LR 57-56-471[3]	M. K. Hage	Raymond Whisenant	30-10-44 098-05-08	1985	200	6	--	Kgrl	1138	137.0	07-21-88	S,E	D	do
LR 57-56-472	Jack Lyle	--	30-11-21 098-05-25	--	--	36	--	Kgru	1142	10.7	07-14-88	N	N	

Table 5 *(continued)*
Records of Wells and Springs

Well	Owner	Driller	Latitude Longitude	Date com-pleted	Depth of well (ft.)	Dia-meter (in.)	Casing depth (ft.)	Water-bearing unit(s)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of mea-surement	Method of Lift	Use of Water	Remarks
LR 57-56-473	Alva Haydon	--	30-11-34 098-05-29	--	Spring	--	--	Kgru	1130	0.0[4]	12-30-88	N	N	Known as Dripping Springs.
LR 57-56-474[2]	Joe O. Miller	--	30-11-24 098-05-35	--	Spring	--	--	Kgru	1120	0.0[4]	12-30-88	N	Irr	Known as Bo Miller Springs.
LR 57-56-475	Roger Hanks	--	30-11-20 098-05-13	--	Spring	--	--	Kgru	1140	0.0[4]	12-30-88	N	N	Known as Hanks Springs.
LR 57-56-476	Stanley Belk	--	30-11-51 098-05-12	--	--	6	--	Kgru	1188	46.0	08-17-88	S,E	N	
LR 57-56-501	City of Dripping Springs	--	30-12-00 098-04-49	1880's	245	6	--	Kgrl	1210	232.8	06-23-88	PJ,E	N	Well in City Park on Old Pounds Place, a historical site.
LR 57-56-502[3]	do	--	30-11-59 098-04-50	--	--	6	--	Kgrl	1210	210.3	06-23-88	S,E	D	do
LR 57-56-503	Katherine Cannon & Frances Michaelis	Glass & Tucker	30-11-41 098-04-30	1984	580	6	--	Kgrl	1274	296.3	07-18-88	S,E	D	
LR 57-56-504	Cecil L. Jenkins	--	30-11-27 098-04-58	--	--	--	--	Kgrl	1169	[4]	07-18-88	S,E	D	Not on city water.
LR 57-56-505	J. F. Walker	--	30-11-31 098-04-57	--	--	--	--	Kgru	1168	[4]	07-18-88	S,E	Irr	Well used to water garden.
LR 57-56-506[1]	Wayne Mathewson,Jr.	--	30-10-56 098-04-58	--	35	6	--	Kgru	1152	20.5	07-20-88	S,E	D	Not on city water.
LR 57-56-507[1]	L. G. Friar	--	30-10-54 098-04-59	--	68	6	--	Kgru	1146	13.3	07-20-88	N	N	
LR 57-56-508[1]	E.L. Russell	--	30-10-50 098-04-59	1957	176	6	--	Kgrl	1145	138.3	07-20-88	S,E	Irr	Well used to water yard.
LR 57-56-509[3]	do	--	30-10-51 098-04-57	1957	93	6	--	Kgru	1149	15.2	07-20-88	N	N	
LR 57-56-510[3]	Episcopal Church of the Holy Spirit	--	30-11-19 098-04-57	--	--	6	--	Kgrl	1173	164.7	07-21-88	S,E	P	Not on city water.
LR 57-56-511	Sam Booth	--	30-11-04 098-04-3	--	--	6	--	Kgrl	1205	211.0	07-26-88	S,E	D	do
LR 57-56-512	Virginia Wesson	--	30-04-02 098-04-31	--	--	6	--	Kgrl	1203	[4]	07-26-88	S,E	D	do
LR 57-56-513	Richard W. Schmidt	James B. Tucker Jr	30-10-11 098-04-24	1979	450	8	240	Kgrl	1166	196	11-14-79	S,E	D,Irr	do

Table 5 *(continued)*
Records of Wells and Springs

Well	Owner	Driller	Latitude Longitude	Date com-pleted	Depth of well (ft.)	Dia-meter (in.)	Casing depth (ft.)	Water-bearing unit(s)	Altitude of land surface (ft.)	Static water Level below LSD (ft.)	Date of mea-surement	Method of Lift	Use of Water	Remarks
LR 57-56-514	do	--	30-10-10 098-04-22	--	--	--	--	Kgru	1172	[4]	07-26-88	--	D	Not on city water..
LR 57-56-515[3]	R.F. Shelton	--	30-11-27 098-04-46	1875	100	6	--	Kgru	1190	[4]	07-20-88	S,E	D	do
LR 57-56-516	Glen C. Iaggi	--	30-10-13 098-04-36	--	--	6	--	Kgrl	1143	200.3	07-26-88	S,E	D	
LR 57-56-701[3]	J. D. Spillar	JamesB. Tucker,Jr	30-08-29 098-06-00	1974	260	5	260	Kgrl	1085	65.0	05-02-74	S,E	D	
LR 57-56-702[2]	Dripping Springs WSC	do	30-09-12 098-05-09	1975	345	6	41	Kcc	1030	45.0	04----75	T,E	P	
LR 57-56-703[3]	Dripping Springs WSC	Texas Water Wells,Inc.	30-09-16 098-05-10	1964	820	8	310	Khe,Kcc Ksl,Kho	1030	[4]	06----64	T,E	P	Casing slotted from 315-345, 395-440, 496-560, 600-640, and 660-690 feet. Open hole completion from 700-820 feet.
LR 57-56-704[3]	do	do	30-09-04 098-05-12	1986	380	12	288	Kcc	1070	108.0	02-06-86	T,E	P	Open hole completion from 288-375 feet.
LR 57-56-705[1]	David Penn	--	30-09-52 098-05-02	--	--	5	--	Kgr	1101	36.6	07-26-88	S,E	D	Not on city water.
LR 57-56-706	W. C. Patterson	Raymond Whisenant	30-09-58 098-05-02	--	--	6	--	Kgrl	1100	[4]	07-27-88	S,E	D	do
LR 57-56-707[3]	Charles Phipps	--	30-09-53 098-05-00	--	--	6	--	Kgrl	1114	109.6	08-04-88	S,E	D	
LR 57-56-801[3]	Howard W. Mittel	Raymond Whisenant	30-09-49 098-04-11	1986	280	6	18	Kgrl	1162	216.6	08-01-88	C,W	Irr	Well used to water garden.
LR 57-56-802	Mrs. Charles Crenshaw	--	30-09-42 098-04-50	--	--	--	--	Kgr	1121	[4]	08-03-88	N	N	

[1] Indicates chemical analysis given in Table 6 and bacteriological analysis given in Table 7.
[2] Indicates bacteriological analysis given in Table 7.
[3] Indicates chemical analysis given in Table 6.
[4] Unable to measure well.

Table 6
Chemical Analyses of Ground Water from Wells and Springs

Analysis constituent units are in milligrams per liter (mg/l) except for pH (dimensionless) or as otherwise designated

Well	Depth of Well	Water-bearing Unit(s)	Date of Collection	Silica (Si02)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (f)	Nitrate (NO3)	Dissolved Solids CaCO3	Total Hardness as @25 C)	Diluted Spec Cond	pH	Temp C
LR 57-56-401	Spring	Kgru	09-02-37	--	--	87	19	--	1	305	20	20	--	--	297	297	--	--	-
	do		04-25-86	11	--	102	19	11	2	362	32	21	0.3	6.60	402	336	--	7.8	--
	do		08-18-88	10	<0.02	107	25	13	1	383	37	20	0.3	7.58	409	369	775	7.7	23
LR 57-56-403	200	Kgrl	08-23-88	11	<0.02	140	40	18	3	456	148	23	0.9	1.68	810	515	1152	8.0	24
LR 57-56-404	74	Kgru	08-23-88	14	<0.02	81	43	12	3	460	16	15	1.0	0.04	411	379	828	7.9	22
LR 57-56-411	59	Kgru	06-27-88	10	<0.02	109	18	10	1	387	31	17	0.3	3.59	391	348	755	7.9	--
LR 57-56-415	11	Kgru	08-17-88	19	0.11	202	47	103	15	889	73	143	<0.1	<0.04	1039	698	2133	7.7	26
LR 57-56-417	120	Kgru	08-18-88	12	1.96	71	56	13	6	437	52	22	1.5	<0.04	448	408	876	7.9	27
LR 57-56-424	42	Kgru	08-16-88	13	0.06	100	69	31	6	526	137	45	1.3	<0.04	662	536	1350	7.8	24
LR 57-56-428	115	Kgru	08-16-88	11	<0.02	134	45	31	2	488	111	41	0.7	16.48	632	520	1200	7.7	25
LR 57-56-429	90	Kgru	08-18-88	9	2.43	72	47	10	4	406	39	14	1.6	<0.04	397	374	781	8.0	29
LR 57-56-434	--	Kgrl	08-18-88	11	0.19	110	86	47	10	375	360	40	2.4	0.04	851	630	600	7.9	28
LR 57-56-438	--	Kgru	08-15-88	11	<0.02	110	27	29	1	410	52	36	0.4	5.54	473	385	906	7.9	23
LR 57-56-441	--	Kgrl	08-16-88	9	0.36	169	45	14	2	416	257	21	1.0	<0.04	723	610	1368	7.7	26
LR 57-56-444	--	Kgrl	08-19-88	9	0.82	156	52	14	3	395	265	20	1.1	0.27	715	604	1341	7.8	25
LR 57-56-450	340	Kgrl	08-17-88	12	0.05	232	155	64	16	355	975	47	2.5	<0.04	1678	1216	3171	7.5	25
LR 57-56-466	310	Kgrl	08-19-88	10	0.036	148	62	14	7	409	289	22	2.8	<0.04	756	625	1440	8.0	28
LR 57-56-471	200	Kgrl	08-23-88	10	0.135	168	73	14	6	412	383	20	2.4	0.09	880	723	1650	8.1	21
LR 57-56-502	--	Kgrl	08-23-88	11	0.061	87	65	17	7	392	172	24	1.8	0.40	578	487	1106	8.2	21
LR 57-56-506	35	Kgru	08-19-88	10	<0.020	101	24	10	1	372	31	17	0.3	5.67	383	350	725	7.7	24

Table 6 *(continued)*
Chemical Analyses of Ground Water from Wells and Springs

Well	Depth of Well	Water-bearing Unit(s)	Date of Collection	Silica (Si02)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (f)	Nitrate (NO3)	Dissolved Solids	Total Hardness as CaCO3	Diluted Spec Cond @25 C)	pH	Temp C
LR 57-56-507	68	Kgru	08-19-88	1	<0.020	57	72	38	8	237	279	35	1.9	<0.04	608	438	1232	8.3	29
LR 57-56-508	176	Kgrl	08-15-88	10	0.059	145	50	13	4	431	205	22	1.3	0.13	663	570	1248	7.6	24
LR 57-56-509	93	Krgu	08-23-88	9	<0.020	113	50	24	54	362	238	45	0.5	10.23	722	489	1359	7.9	21
LR 57-56-510	--	Kgrl	08-15-88	10	<0.020	108	32	11	1	401	79	17	0.7	0.09	457	402	888	8.1	23
LR 57-56-515	100	Kgru	08-16-88	8	<0.020	88	21	8	3	334	25	12	0.3	7.49	337	305	643	7.8	21
LR 57-56-701	260	Kgrl	08-04-76	11	--	48	16	6	1	207	15	10	0.2	0.40	209	186	--	8.1	--
LR 57-56-702	345	Kcc	06-27-88	12	0.06	116	90	55	12	394	411	42	2.7	0.40	935	662	1760	8.1	23
LR 57-56-703	820	Khe,Kcc	04-25-86	13	--	110	91	55	1	392	389	38	2.7	0.04	893	649	1694	7.8	--
	do	Ksl,Kho	06-27-88	12	0.10	114	80	47	10	382	363	36	2.4	<0.04	853	615	1595	8.1	21
LR 57-56-704	380	Kcc	06-27-88	11	0.30	105	69	39	8	375	292	29	2.3	<0.04	740	548	1377	8.1	22
LR57-56-705	--	Kgr	08-19-88	8	<0.020	122	13	13	1	359	44	24	0.2	5.01	407	358	759	7.6	--
LR57-56-707	--	Kgrl	08-18-88	8	<0.020	85	20	12	2	284	58	18	0.3	<0.04	344	298	648	7.9	26
LR57-56-801	280	Kgrl	08-19-88	9	<0.020	91	47	12	3	299	172	20	1.6	<0.31	503	420	952	8.0	26

Table 7
Preliminary Results of Bacteriological Analyses of Ground Water from Wells and Springs Sampled on August 18, 1988 in the Dripping Springs Area

Well	Depth of Well in feet	Water-bearing Unit(s)	Depth to Water in feet	Sampling Method Colonies per 100 ml	Fecal Coliform in coccus in Colonies per 100 ml	Fecal Strepto-	FC:FS Ratio Bacteria	Probable Source of	Remarks
LR 57-56-401[1]	Spring	Kgru	0.0	Spring	9[2]	130[2]	1:14	Animal	Walnut Springs: Water used for garden and yard.[5,6]
			0.0	Spring	9[2,3]	160[2]	1:18	Animal	Owner sampled springs again on 9/8/88 at the source.
			0.0	Spring	90[2]	650[2]	1:7	Animal	Owner sampled springs again on 9/8/88 at the intake.
LR 57-56-402	81	Kgru	20.9	Bailed	1,900[2]	18[3]	106:1	Human	Well is not used.[7]
LR 57-56-403[1]	200	Kgrl	163.9	Pumped	--	--	--	--	Well is used for domestic purposes.[6,8]
LR 57-56-404[1]	74	Kgru	45.2	Bailed	--	--	--	--	Well is not used.[6,8,9]
LR 57-56-415[1]	11	Kgru	9.2	Bailed	--	--	--	--	Well is not used.[7,8,9]
LR 57-56-417[1]	120	Kgru	62.6	Pumped	9[3]	9[2]	1:1	[4]	Well is used for domestic purposes.[6]
LR 57-56-424[1]	42	Kgru	19.4	Bailed	5,500	110,000	1:20	Animal	Well is not used. Dead snake was in well.[7]
LR 57-56-428[1]	115	Kgru	46.4	Pumped	--	--	--	--	Well is used for domestic purposes.[6,10]
LR 57-56-429[1]	90	Kgru	47.5	Pumped	9[3]	9[3]	1:1	[4]	Well is used to water yard.[7]
LR 57-56-438[1]	--	Kgru	8.0	Pumped	9[3]	9[3]	1:1	[4]	Well is used to water garden and yard.[7]
LR 57-56-440	169	Kgru	91.0	Bailed	2,800	40,000	1:14	Animal	Well is not used.[7]
LR 57-56-444[1]	--	Kgrl	132.7	Pumped	9[3]	81[2]	1:9	Animal	Well is used for domestic purposes.[6]
LR 57-56-470	178	Kgrl	141.0	Bailed	54[2]	2,600	1:48	Animal	Well is not used.[7]
LR 57-56-474	Spring #1	Kgru	0.0	Spring	--	--	--	--	Bo Miller Springs: Water used for garden and yard.[7,10]
	Spring #2	Kgru	0.0	Spring	180[2]	46,000	1:256	Animal	Bo Miller Springs: Water used for garden and yard.[7,10]
LR 57-56-506[1]	35	Kgru	20.5	Pumped	9[3]	9[3]	1:1	Animal	Well is used for domestic purposes.[6]
LR 57-56-507[1]	68	Kgru	13.3	Pumped	9[3]	9[3]	1:1	[4]	Well is not used. Test run on city water from faucet.[7]
LR 57-56-508[1]	176	Kgrl	138.3	Pumped	9[3]	9[3]	1:1	[4]	Water used for garden and yard.[7]
LR 57-56-705[1]	--	Kgr	36.6	Pumped	9[3]	9[3]	1:1	[4]	Well is used for domestic purposes.[6]

[1] Indicates chemical analysis given in Table 6.
[2] Texas Department of Health reported result as an estimate.
[3] Texas Department of Health reported result to be less than that shown.
[4] The result of the FC:FS ratio may be animal or not conclusive as to the source of bacteria.
[5] Owner has another well for domestic purposes.
[6] Owner is not on city water
[7] Owner is on city water.
[8] Texas Department of Health reported that the sample was unsuitable to test.
[9] Texas Department of Health reported fecal coliform present.
[10] Texas Department of Health reported no work performed.

DRIPPING SPRINGS WATER SUPPLY CORPORATION PUBLIC SUPPLY WELLS

The Dripping Springs Water Supply Corporation (WSC) wells are located south of the main study area, about 0.25 mile east of Texas Ranch Road 12 near the south bank of Onion Creek. These three wells range in depth from 345 to 820 feet (Table 5). They are completed in water-bearing units of the Trinity Group aquifer below the Glen Rose Formation. Each well is capable of yielding over 100 gallons per minute. Most wells in the Dripping Springs area yield much less. The anomalous occurrence of wells with unusually large yields in a hydrogeological setting where most wells have significantly smaller yields is a matter that could merit further study. In addition, it has been reported that the water levels in the WSC wells recover quickly to their previous levels after pumping ceases. This means that (1) the recharge to the water-bearing units of these wells is at least equal to, or slightly greater than, the yield of the wells, and (2) since the various water-bearing units in the Trinity Group aquifer, including those of the Glen Rose Formation, are functioning as a leaky aquifer system, Onion Creek may serve as a source of recharge for the system at the WSC well field. Consequently, any pollution to Onion Creek could result in contamination to the Lower Glen Rose (Deep) aquifer which is hydrologically connected to underlying water-bearing units of the Trinity Group aquifer currently providing ground water to the WSC wells.

CONCLUSIONS

There exist in the Dripping Springs area essentially two aquifers, the Lower Glen Rose (Deep) aquifer and the Upper Glen Rose (Shallow) aquifer. Also, there can be intermediate or "perched water table" aquifers of limited areal extent. Depending on the land elevations, the depth to water can range from about 85 to 296 feet in the Deep aquifer and from 5 to 91 feet in the Shallow aquifer. Additionally, the Shallow aquifer occurs at the land surface causing waterlogging of soils during wet seasons.

The Lower Glen Rose (Deep) aquifer is susceptible to contamination from the land surface due to the open-hole completion of existing wells. Often, only a few feet of surface casing was installed when a water well was drilled. Below the casing and in the open-hole interval between the casing and the water level, ground water can seep and percolate into the borehole through some of the porous and permeable limestones, thus providing a conduit for water from the land surface to reach deep water-bearing formations. Overall, the Deep aquifer generally has slightly higher concentrations of sulfate, fluoride, and dissolved solids than the Shallow aquifer. While most of the samples are within the Texas Department of Health recommended standards for drinking water, a few exceed them. Unusually high nitrate concentrations detected in the Shallow aquifer were not significantly present in the Deep aquifer.

The main focus of this investigation is on the Upper Glen Rose (Shallow) aquifer, which is the most susceptible to contamination from the land surface. The more densely populated areas are located on or near the outcrop of the Shallow aquifer. Depth to the water table can be less than 10 feet with water-logged soils during wet periods. Even though nitrate concentrations are well within the Texas Department of Health water quality standards, unusually high concentrations of nitrate were detected that indicate nitrate pollution of the Shallow aquifer within the study area. Testing for bacteria was not conclusive even though high counts of fecal coliform and fecal streptococcus above Texas Department of Health standards were found in the standing water in boreholes in the Shallow aquifer. This should warrant future testing of Shallow aquifer wells and springs.

The hydrogeological setting of the Shallow aquifer is the main cause of the waterlogging of soils within the townsite of Dripping Springs during wet periods. Water levels rise and intercept the land surface because the low permeability of the water-bearing rocks of the Shallow aquifer retards ground-water movement toward seeps, springs, and areas of evapotranspiration. This situation is further aggravated by the additional infiltration of wastewater derived from the numerous private septic systems operating in Dripping Springs. It has been estimated that as much as 20,129,928 gallons per year of wastewater from the septic systems may be available as recharge to the Shallow aquifer in the Dripping Springs area. The overall chemical quality of the ground water of the Upper Glen Rose (Shallow) aquifer is better than the overall chemical quality of the ground water of the Lower Glen Rose (Deep) aquifer. However, the Shallow aquifer generally has higher concentrations of nitrate and chloride, while the Deep aquifer has higher concentrations of sulfate, fluoride, and dissolved solids.

Much of the area of Dripping Springs is covered with thin soils where the depth to bedrock is less than 18 inches. Therefore, the septic tank absorption field hazard is severe, making it difficult and costly to meet proper operating standards for septic systems.

Domestic wells continue to be used in the City of Dripping Springs in spite of the availability of a reliable ground-water supply from the wells of the Dripping Springs WSC.

RECOMMENDATIONS

The Texas Water Development Board will establish a ground-water monitoring network in the Dripping Springs area with a focus on the Upper Glen Rose (Shallow) aquifer. Selected wells and springs which have had high bacteria counts or unusually high nitrate concentrations above ambient levels will be considered for future monitoring. Also, a selected number of wells completed in the Lower Glen Rose (Deep) aquifer will be considered for future monitoring as well as a representative well of the Dripping Springs Water Supply Corporation. Because of its statewide efforts, the Texas Water Development Board will be limited to monitoring only a part of the selected wells. Consequently, it is recommended that the City of Dripping Springs or some other interested entity monitor the remaining selected wells.

A procedure to test for bacteria in water wells and springs, especially the Shallow aquifer, should be established. Working with the Texas Department of Health, a sampling methodology should be worked out to achieve more reliable results.

Unused water wells, especially in the Shallow aquifer, should be properly plugged. Future wells completed in the Glen Rose Formation and other underlying water-bearing units of the Trinity Group aquifer should be properly cased and cemented, and open borehole completion, particularly near the land surface, should be avoided.

Because of the thin soils in the study area and the related severe septic tank absorption field hazard, concerted efforts should be made to bring septic tank systems into compliance with established construction and operating standards.

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