HYDROLOGIC REPORT OF THE MINOR GROUNDWATER BASINS IN COMANCHE, COTTON AND TILLMAN COUNTIES

Technical Report 96-3

by

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INTRODUCTION

The hydrogeologic report of the minor alluvial and bedrock groundwater basins in Comanche, Cotton, and Tillman Counties was conducted by the Oklahoma Water Resources Board under the authority of Oklahoma Statutes Title 82, Sections 1020.4 and 1020.5. Section 1020.4 authorizes the Board to conduct hydrologic surveys and investigations of fresh groundwater basins to characterize the availability, extent and natural hydrologic conditions of the resource. The Board is further directed by Section 1020.5, upon completion of the hydrologic survey, to determine the maximum annual yield of fresh water to be produced from each groundwater basin as well as the equal proportionate share of the maximum annual yield to be allocated to each acre of land overlying the basin(s). This determination is to be based on the following criteria:

1) The total land area overlying the basin or subbasin;
2) The amount of water in storage in the basin or subbasin;
3) The rate of recharge to the basin or subbasin and total discharge from the basin or subbasin;
4) Transmissivity of the basin or subbasin; and
5) The possibility of pollution of the basin or subbasin from natural sources.

The maximum annual yield determinations and equal proportionate share results are subject of an accompanying report.

The purpose of this report is to review, assess, and evaluate hydrologic data pertaining to the groundwater resources in the study area. Data sources include records maintained by the Board, existing hydrogeologic reports and references which assess the study area and hydrologic reports or texts which evaluate hydrogeologic settings similar to the study area. In some instances, field measurements may be made to provide support for certain assumptions or estimates about a particular parameter.

This report will provide the hydrologic data necessary to determine or estimate the above criteria which will provide the basis for determining the maximum annual yield and equal proportionate share of the minor groundwater basins within the study area.

A minor groundwater basin is defined as a distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which the groundwater wells yield less than 50 gallons per minute on the average basinwide, if from a bedrock basin, and less than 150 gallons per minute, if from an alluvial and terrace basin.

Two minor alluvial and terrace groundwater basins and two minor bedrock basins were identified within the study area. The alluvial and terrace deposits associated with Deep Red Creek, West Cache Creek and East Cache Creek, as well as their tributary branches, are named the Cache Creek Groundwater Basin (CCGB) and the alluvium associated with Beaver Creek will be named Beaver Creek Groundwater Basin (BCGB). The minor bedrock basins identified in the three counties will be named the Post Oak Groundwater Basin (POGB) and Hennessey-Garber Groundwater Basin (HGGB).

PHYSICAL SETTING

Location

This report will be limited to the minor groundwater basins in Comanche, Cotton and Tillman counties in southwest Oklahoma. The three counties contain approximately 1,650,000 acres or 2,575 square miles.

The alluvial deposits in the study area are associated with the stream systems present in the three counties. The main branch of the Beaver Creek stream system begins in northeastern Comanche County. It flows primarily south until it exits the study area in eastern Cotton County at the upper end of Waurika Lake.

East Cache Creek's headwaters are in the limestone hills area north of the Wichita Mountains in southwest Caddo County. It initially flows northeast out of the hills then bends southeast and eventually south as it enters northeastern Comanche County. East Cache Creek continues this southerly route until its confluence with West Cache Creek, which marks the beginning of Cache Creek in southern Cotton County, about five miles above the Red River confluence.

West Cache Creek's headwaters are in the Wichita Mountains near its crest on the south face of the mountains and flows southeast until its confluence with East Cache Creek. Deep Red Creek originates in southeastern Kiowa County and flows southeast until its confluence with West Cache Creek in southern Cotton County.

The southern boundary of the CCGB is located along Cache Creek approximately two miles above its confluence with the Red River.

Alluvial and terrace deposits adjacent to the North Fork of the Red River and the Red River constitute major groundwater basins and are not considered in this report.

The groundwater resources for the minor bedrock basins were identified primarily in the Post Oak, Hennessey and Garber formations which outcrop in or underlie a majority of Comanche, Cotton and Tillman Counties. The Wellington and Oscar formations outcrop in a small portion of Tillman and Cotton Counties and have also been included.

Major bedrock basins excluded from this report are the Timbered Hills Group and Arbuckle Group outcropping in northwestern and north-central Comanche County. The El Reno and Whitehorse Groups which outcrop in northeastern Comanche County are considered potential major bedrock basins and have also been excluded. The

Wichita Mountain outcrop area, which can exhibit fractured porosity, has not been included in this report due to insufficient documentation regarding groundwater resources. Figure 1 shows the limits of the study area and surface drainage features.

Setting

The land encompassed within Comanche, Cotton, and Tillman Counties is in the Red Bed Plains Region of the southern great plains. With the exception of the Wichita Mountains in northwest Comanche County, the terrain is a gently rolling plain underlain by weakly consolidated reddish clays, shales and sandstones and unconsolidated alluvium. The elevation above mean sea level ranges from 2,479 feet in northwest Comanche County in the Wichita Mountains, to 890 feet in southern Cotton County near the Red River.

Climate

Climate is temperate and continental of the dry subhumid type. The weather is influenced by the alternate movement of warm moist air from the gulf and of either contrasting cooler marine air from the West Coast or colder, dry air from the Arctic. Rapid change is common and results in significant fluctuations of temperature, humidity, wind and precipitation. Seasonal changes are gradational. Winters are mild, cold spells usually last only a few days. Spring is the most variable, bringing the heaviest precipitation and greatest number of severe storms (Mobley and Brinlee, 1967, Comanche County; Ringwald and Lamar, 1963, Cotton County; and Lamar and Rhodes, 1963, Tillman County).

According to National Weather Service rain gauge data, annual precipitation has varied from a low of 15.80 inches to a high of 49.50 inches within the study area (period of record 1942-1992). The mean annual precipitation ranges from 28 inches per year in central Tillman County to 32 inches in northeast Comanche County (OWRB, 1990). The mean annual precipitation for the study area is determined to be 30 inches. Snowfall ranges from about 6 inches per year in Tillman County to 7.5 inches in Comanche County.

Average monthly temperature ranges from 41 degrees in January to 86 degrees in July with an average annual temperature of 63 degrees. Winds generally prevail out of the south with the exception of January and February when northerly winds prevail (Mobley and Brinlee, 1967, Comanche County; Ringwald and Lamar, 1963, Cotton County; and Lamar and Rhodes, 1963, Tillman County).

Regional Geology

Rocks outcropping in the three county area range in age from Cambrian to Quaternary. The oldest rocks are the Cambrian igneous rocks of the Wichita mountains. The three predominant varieties of igneous rocks are gabbros, granites, and rhyolites (Stone, 1977).

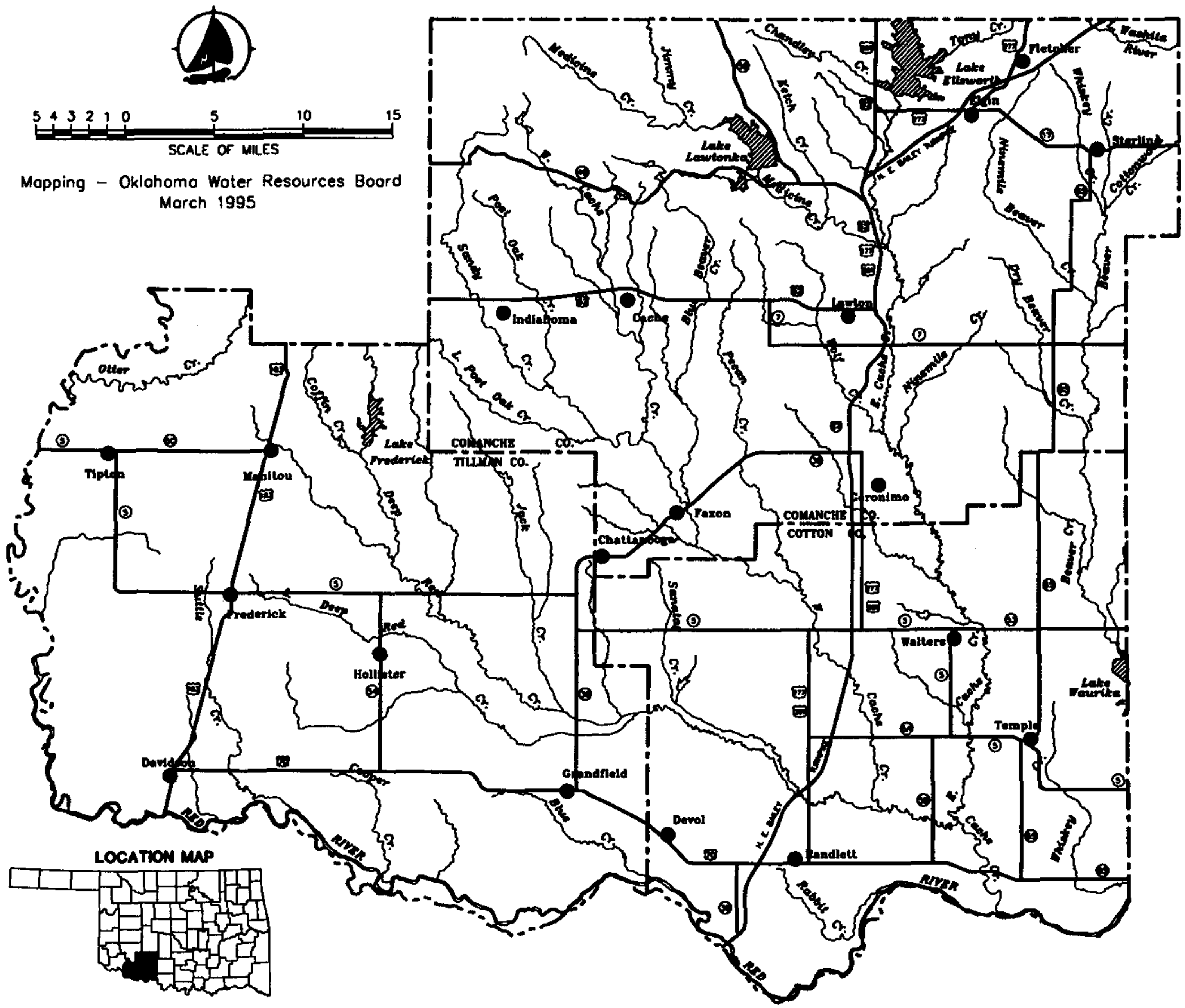

Figure 1. Study Area Showing Surface Drainage Features, Towns and Primary Roadways.

A heavily faulted area of Ordovician and Cambrian limestones and dolomites of the Arbuckle Group outcrop in the Slick Hills north of the mountains. The Permian age Post Oak Conglomerate was deposited by small ephemeral streams that eroded and drained the Wichita Mountains (Al-Shaieb et al, 1977). The Post Oak is principally comprised of limestone, granitic debris and sand. This formation crops out at the base and south of the mountains. Away from the mountains, this formation becomes finer grained and eventually grades into and becomes interfingered with the Permian Hennessey Shale and Garber Sandstone.

Deposition of the Hennessey and Garber formations is believed to be contemporaneous with that of the Post Oak Conglomerate but of a different source, occurring primarily in a shallow sea environment (Pate, 1947). Also exposed in areas near the Red River are sandstones and shales of the Wellington Formation. In the northeast corner of Comanche County, Permian age sandstones and shales of the White Horse Group and El Reno Group outcrop. Quaternary age alluvial deposits occupy the creek valleys. Figure 2 shows the local geology of the region (Havens, 1977).

Kent (1986) described the following relationship of the formations in the subsurface. The Wichita Mountains are a block of igneous rocks bounded by steep faults. Overlying the igneous rocks are the Arbuckle Group of limestones and dolomites. Overlying the Arbuckle Group in the north are the Permian Hennessey Shale, Garber Sandstone, and El Reno and White Horse Groups. The Permian Post Oak Conglomerate, Hennessey Shale, and Garber Sandstone lie on the Arbuckle to the south of the mountains and are undifferentiable in the subsurface. These Permian formations are often referred to as red beds due to their reddish iron oxide staining.

There are several structural features which influence the relief and stratigraphy of the area. From the northeast portion of the study area to the southwest portion exists a series of arches, structurally high areas and sedimentary basins, structural low areas where sediment accumulations are greatest. The structural basins and arches are oriented primarily in a northwest to southeast direction. The succession of primary structural features from northeast to the southwest in the study area are the Meers Fault and associated Limestone Hills, the Wichita Mountains in Comanche County, the Marietta Basin in south-central Comanche and northeast Cotton County, the Waurika-Muenster Arch in central and southeast Cotton County and the Hollis Basin which extends to southeast Tillman County.

GROUNDWATER RESOURCES

Cache Creek and Beaver Creek Groundwater Basins

The CCGB and BCGB comprise approximately 350 square miles of Quaternary deposits that occur as channel and flood plain deposits and unconformably overlie the Permian formations in the area. The alluvium is an unconsolidated deposit which consists of clay, silt,

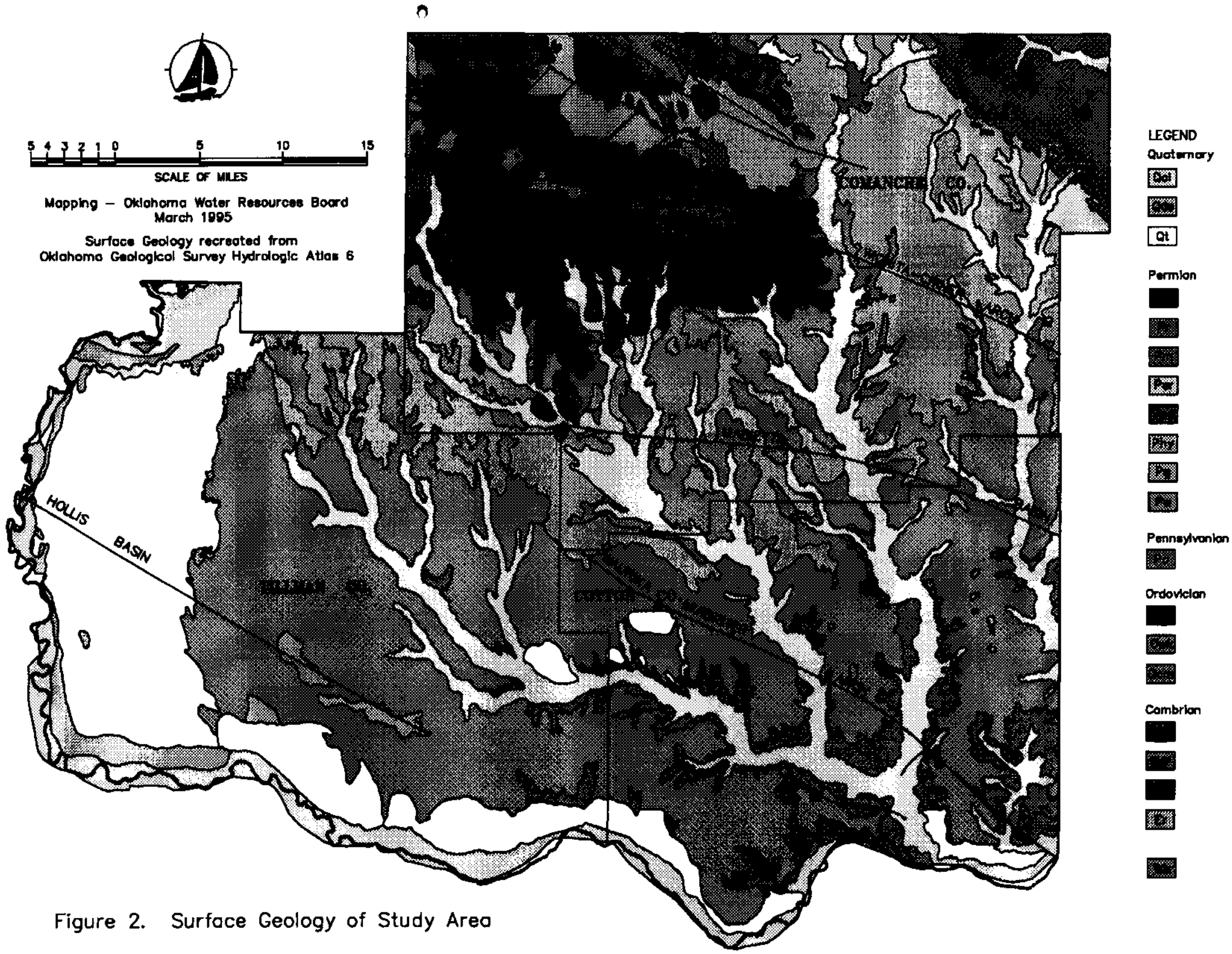

Figure 2. Surface Geology of Study Area

STRATIGRAPHIC NOMENCLATURE

Quaternary

Alluvium; sand, clay and gravel as much as 50 feet thick.

Dune Sand; wind-laid sand as much as 50 feet thick.

Terrace Deposits; sand, clay and gravel as much as 50 feet thick.

Permian

Weatherford Gypsum Bed; gypsum and dolomite as much as 60 feet thick in the upper part of the Rush Springs Sandstone.

Rush Springs Sandstone; fine grained sandstone as much as 300 feet thick.

Marlow Formation; fine grained sandstone with some silty shale as much as 130 feet thick.

El Reno Group; sandstone, siltstone and shale as much as 580 feet thick.

Post Oak Conglomerate; limestone conglomerate interbedded with sand, silt, clay and shale as much as 500 feet thick at surface.

Hennessey Group; red-brown to grey shale with some tan sandstones as much as 200 feet thick.

Garber Sandstone; red-brown, fine-grained sandstone and mudstone conglomerate as much as 210 feet thick.

Wellington Formation; maroon shale as much as 130 feet thick.

Pennsylvanian

Oscar Group; shale, sandstone and arkose as much as 500 feet thick.

Ordovician

Upper part of Arbuckle Group; limestone and dolomite as much as 4,000 feet thick.

West Spring Creek and Kindblade Formations; dolomite, dolomitic sandstone, conglomerate and limestone as much as 2,000 feet thick.

Cool Creek and McKenzie Hill Formations; limestone and conglomerate with abundant quartz sand and cherty zones as much as 2,000 feet thick

Cambrian

Lower Arbuckle and Timbered Hills Groups; limestone, dolomite, siltstone, sandstone, conglomerate and shale ranging from 1,200 to 2,000 feet thick.

Carlton Rhyolite Group; rhyolite flows, tuffs, conglomerate beds and diabase sills as much as 4,500 feet thick.

Wichita Granite Group; 600 to 15,000 feet thick.

Raggedy Mountain Gabbro Group; gabbro, anorthosite and diorite as much as 10,000 feet thick.

sand and gravel. The alluvium forms a band along the streams ranging from approximately 0.125 to nearly 5 miles wide. A few minor terrace deposits associated with Deep Red Creek have been incorporated as part of the CCGB. Terrace deposits are older alluvium which occupy positions topographically higher than recent alluvium and mark the former position of the stream. The distribution of the alluvial and terrace deposits within the study area is shown in Figure 3 and is taken from Havens (1977).

Kent (1986) reported the average thickness of the alluvium to be 40 feet along East Cache Creek, Beaver Creek and the lower portion of West Cache Creek south of Township 1 North in Comanche County. According to Kent (1986), the average thickness of the alluvium in the northern part of West Cache Creek is 30 feet. Kent reported the average saturated thickness of the deposits to be 16 feet. It should be noted that Kent's study did not include Deep Red Creek or the deposits that occur south of Township 2 South in Cotton County.

OWRB well records and data from Havens (1977) indicate that the thickness of the alluvium in southern Cotton County and along Deep Red Creek ranges from 17 to 50 feet and averages approximately 40 feet. From a review of well records for the entire basin, the average total thickness of the alluvium is determined to be 38 feet.

Measurements of the depth to water in 22 wells, taken by the OWRB in the fall of 1993, ranged from 2 to 22 feet below land surface, and averaged 11.5 feet. In most instances, the wells in which water levels were measured fully penetrated the total thickness of the aquifer, terminating a few feet into the underlying bedrock formations. The average saturated thickness, as determined from those field measurements, is 22 feet. This information is summarized in Table 1.

Groundwater in the CCGB and BCGB flows from topographic divides toward the streams under a gentle gradient. There was insufficient distribution of water head data to produce a potentiometric surface map of the basins.

Most of the streams in Comanche County are intermittent and flow only during the wet season. During the dry months the water table in the stream valleys lies below the bottom of the stream channel. In other words, the streams are losing streams in the dry months and gaining streams during the wet periods. Beaver Creek, however, is a perennial stream (except for droughts) and East Cache Creek has its flow sustained by municipal effluent and releases from Lakes Lawtonka and Ellsworth (Hauth et. al, 1984). For most years, Deep Red Creek experiences no flow periods based on stream gauge data near Randlett in Southern Cotton County. This relationship of intermittent stream flow relating to the wet and dry seasons is assumed to be similar for the smaller streams in Cotton County as well.

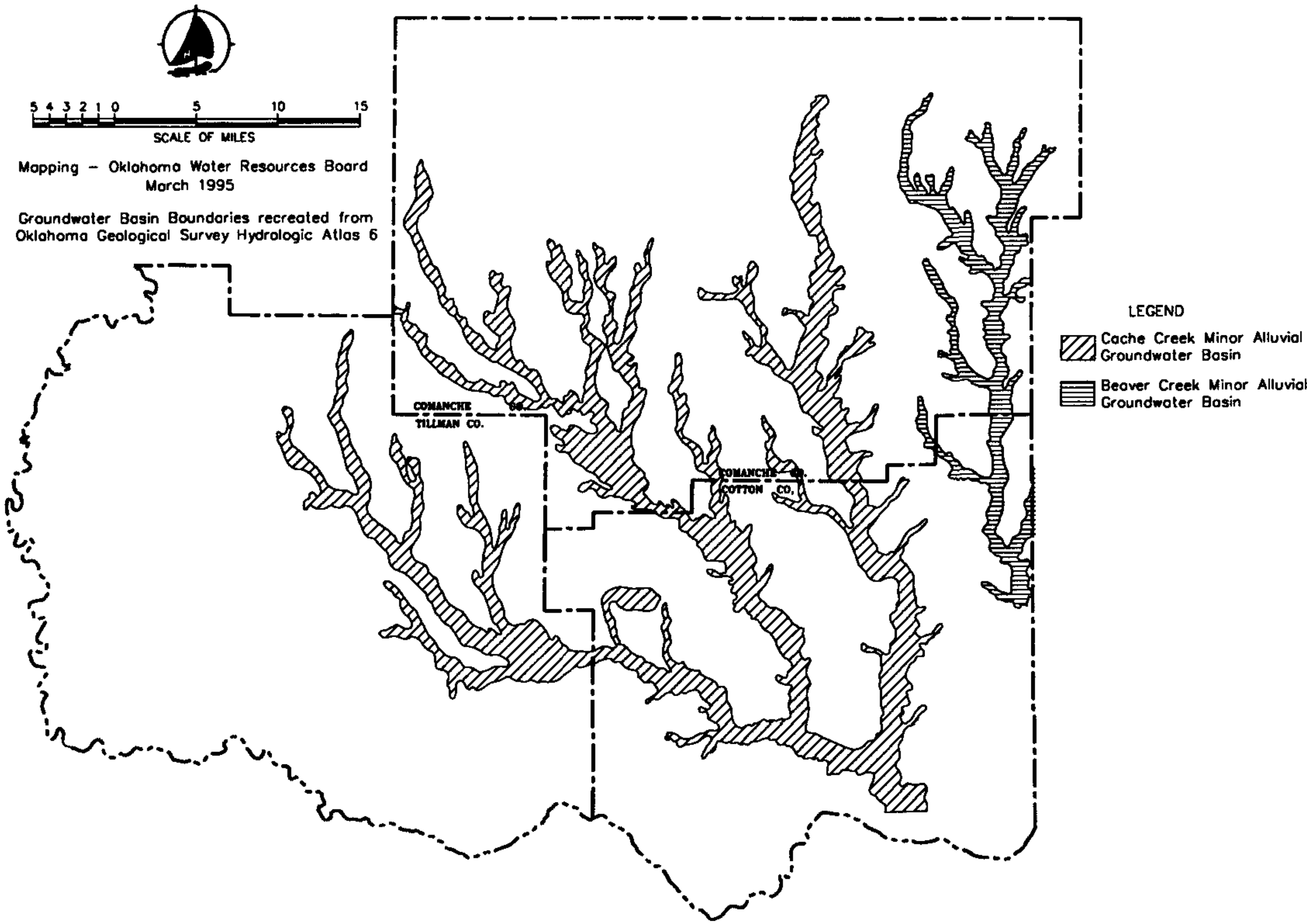

Figure 3. Distribution of Alluvial and Terrace Deposits in Study Area.

Table 1. Water Level Measurements, October 1993

Legal Location	Co.	TD	DTW	Surface Elev.	Water Head Elev.	Sat. Thick.	Creek Alluvium
NWNWNE05T2NR9W	16	36	12.50	1100	1087.50	23.50	Beaver
SENENE08T2NR9W	16	36	14.80	1110	1095.20	21.10	Beaver
NENESE15T1NR10W	16	30	1.90	1070	1068.10	28.10	Beaver
SWSWSW12T2NR10W	16	36	8.00	1095	1087.00	28.00	Beaver
SENWSW33T1SR9W	17	31	10.50	980	969.50	20.50	Beaver
SWSESE19T1NR11W	16	35	12.90	1040	1027.10	22.10	ECACK
SESENE03T1SR11W	16	N/A	8.20	1105	1096.80	---	ECACK
NWNENE30T3SR10W	17	42	8.00	930	922.00	34.00	ECACK
SWSWSW19T2NR14W	16	37	14.40	1280	1265.60	22.60	WCACK
NWSWSW23T2NR14W	16	28	8.00	1245	1237.00	20.00	WCACK
NESENE01T1SR13W	16	35	7.70	1130	1122.30	27.30	WCACK
NENESE20T1SR13W	16	30	18.50	1102	1083.50	11.50	WCACK
SWSESW02T1SR14W	16	40	11.50	1155	1143.50	28.50	WCACK
NESESE03T1SR14W	16	39	10.20	1160	1149.80	28.80	WCACK
SESESE08T2SR12W	17	42	20.20	1035	1014.80	21.80	WCACK
NWNWNW17T2SR12W	17	N/A	22.20	1050	1027.80	---	WCACK
NWNWNW21T2SR12W	17	38	18.65	1036	1017.35	19.35	WCACK
SESESE28T2SR12W	17	40	15.00	995	980.00	25.00	WCACK
NWSWSW30T3SR11W	17	18	4.00	950	946.00	14.00	WCACK
NESWNW02T3SR12W	17	19	9.35	980	970.65	9.65	WCACK
NWNWNW24T3SR14W	71	26	12.40	1000	987.60	13.60	DPRCK
SWSWSW31T4SR10W	17	10	4.20	890	885.80	---	CACK
Mean Values		33	11.50			22.07	

County Codes: 16 - Comanche, 17 - Cotton, 71 - Tillman
TD: Total Depth of the Well in feet to red bed
DTW: Depth to Water shown in feet below land surface
Surface elevation & water head elevation shown in feet above Mean Sea Level.
Sat. Thick. - Saturated thickness of aquifer at the well head in feet.
Creek Alluvium Codes : ECACK - East Cache Creek, WCACK - West Cache Creek, CACK - Cache Creek, DPRCK - Deep Red Creek

Aquifer Parameters

Aquifer parameters were determined by field measurements, analysis of well acceptance tests, grain size evaluations and existing references and reports that evaluated aquifer properties for similar type aquifer media.

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be defined in terms of storage coefficient and transmissivity. For unconfined aquifers, storage coefficient and specific yield are nearly equivalent.

Kent, et al, (1986) estimated the permeability, or hydraulic conductivity (K), of the alluvial sediments using a relationship between grain size and permeability developed by Kent and others (1973). Kent generated four ranges of hydraulic conductivity for alluvial materials based on research involving field and laboratory permeability testing. Saturated lithologies presented on well logs are assigned to one of the following grain size classes. Each class has associated with it an average permeability value corresponding to the median grain size of that range. The following grain size classes along with their median grain size and K value are shown in Table 2.

Table 2. Hydraulic Conductivity (K) Classes used to assign permeability values to saturated lithologies on well logs.

	Silt - V. Fine Sand	V. Fine Sand- Fine Sand	Fine Sand- Medium Sand	Medium Sand- Coarse Sand
	Class 1	Class 2	Class 3	Class 4
Median Grain Size (mm)	0.06	0.125	0.25	0.5
K Values in Ft/day	0.70	6.00	27.00	167.00

For each log, a weighted permeability can be obtained for the entire saturated section of the lithologic record by multiplying the average K value associated with the assigned grain size class with the thickness of that interval, then summing the total for all classes divided by the total saturated feet of the well.

Using this method, Kent derived an average K value of 132 ft/day for the alluvium. Using the same method but looking at a different subset of well logs completed in the CCGB and BCGB, a K value of 101 ft/day was estimated for this study.

Another method to calculate K and transmissivity (T) is available if well acceptance tests (short duration pump tests) have been conducted. As a means to compare the estimated T and K values derived from the grain size analysis, data from fourteen wells with well acceptance tests were input into the OWRB's TOT computer program, which calculates K and T (OWRB, 1992). K and T values derived from this method were two to three times greater than those derived from the grain size analysis. These extrapolated values were obtained from well acceptance tests conducted in areas of known high yield wells and may not be representative of the majority of the CCGB and BCGB. A summary of the estimated aquifer parameters and their sources is shown in Table 3.

Table 3. Aquifer parameters.

Source	Hydraulic Conductivity Ft/day	Transmissivity Ft^2/day	Specific Yield	Aquifer Saturated Thickness (ft)
OWRB, TOT	300	6270		
Kent, 1986	132	2112	.02	16
OWRB, 1994	101	2222	.15	22
Stacy, 1958	134		.15	

For the purposes of estimating the T (product of the aquifer saturated thickness and K) for the CCGB and BCGB, an average of the values for K and saturated thickness derived from Kent (1986) and OWRB well log analysis and water level measurements were used. The average saturated thickness is estimated to be 19 feet and the average K value to be 117 ft/day. T is estimated to be 2,200 ft^2/day.

Kent estimated the specific yield to be 0.02, a conservatively low value for management purposes. For this study a specific yield ranging from 0.15-0.20 compares favorably with other studies and hydrogeologic texts involving these types of aquifer materials (Stacy, 1958, Driscoll, 1986 and Havens, 1989).

The amount of annual recharge to the basins is estimated to be 12 percent of the average annual precipitation, or approximately 3.6 inches per year. This percentage of recharge was estimated by Barclay and Burton (1953) for the alluvial and terrace deposits in Tillman County.

Aquifer Storage and Yield Capabilities

Aquifer storage is calculated as the product of the land acreage overlying the basin, and the specific yield and saturated thickness of the basin. From the preceding discussion, specific yield ranges from 0.15 to 0.20 and the saturated thickness varies from 16 to 22 feet. The CCGB and BCGB are overlain by 184,870 acres and 37,325 acres of land respectively.

Determination of the initial storage for the basins was estimated using the average of the range of values for specific yield and saturated thickness (0.17 and 19 feet respectively). Consequently, initial storage of CCGB and BCGB was estimated to be 597,100 acre-feet and 120,600 acre-feet respectively.

Wells completed in the CCGB and BCGB yield from 5 to 500 gpm. Stone (1981) reported that most wells completed in the alluvium yield from 5 to 50 gpm, but may locally yield 500 gpm. Kent (1986) reported the typical well yield as being 77 gpm.

Water use

Groundwater is not heavily relied on to supply agricultural crop water. Dry-land farming is prevalent in eastern Tillman, Comanche and Cotton Counties relying upon rainfall to provide the necessary moisture for crops (Hounslow and Back, 1986; field observations, 1993; OWRB, 1983). This contrasts with the western Tillman County area which is underlain by the Tillman Terrace, a major groundwater basin where over 4 billion gallons of water per year are withdrawn from irrigation wells and applied to crop land (OWRB, 1983).

While only limited quantities of groundwater are pumped for irrigation, groundwater is an important source of water for some rural water districts and smaller communities in the area. Also, individuals in outlying areas not served by rural water systems rely on the basin for domestic and stock water use.

Reported groundwater use for 1993 from permit holders within the two basins was 253 million gallons or 776 acre-feet. 177 million gallons or 543 acre-feet supplied rural water districts and towns and 76 million gallons or 233 acre-feet were used for irrigation. A majority of the groundwater currently pumped from the basins is obtained from the alluvium of West Cache Creek. Groundwater rights and water use data for 1993 are summarized in Table 4.

Table 4. Water Rights and Water Use Summary for CCGB and BCGB.

Purpose	Number of Permits	Permitted Amount	Reported Water Use
Irrigation	16*	1,374 A.F.	233 A.F.
Public Water Supply	8*	1,576 A.F.	543 A.F.
Totals	23*	2,950 A.F.	776 A.F.

* - Includes Prior Groundwater Rights

Prior Groundwater Rights

Groundwater rights established within the CCGB basin prior to July 1, 1973, and recognized by Board Order total 2,070 acre-feet. No prior groundwater rights were established as of July 1, 1973, for the BCGB.

Post Oak Groundwater Basin

The surficial boundary of the Post Oak Groundwater Basin (POGB) is defined as that area which is substantially contained within the outcrop area of the Post Oak Conglomerate on the south side of the Wichita Mountains in Comanche County. The subsurface boundary for the POGB is located at the base of the Post Oak Conglomerate at the contact with the underlying Arbuckle Group. The total surface area of the POGB was determined to be 85,120 acres (133 mi^2).

The Post Oak Conglomerate is unconfined (Kent, 1986) and is approximately 500 feet thick (Havens, 1977). The Post Oak, which overlies the Arbuckle Group, is described by Havens as a limestone conglomerate interbedded with sand, silt, clay and shale.

Kent reported that Stone (1977) mapped patterns of grain sizes and found evidence of ancient stream channels within the Post Oak Conglomerate in areas of coarse mean grain size. Adjacent to these areas, finer grained sediment and rock exist. As a result of this, Kent (1986) separated the Post Oak aquifer into two zones based on permeability, transmissivity and well yield differences. Kent estimated the hydraulic conductivity and transmissivity for each zone from well log data and the grain-size envelope. Kent's analysis was limited to well completions that were typically 50 feet in total depth, and he considered 20 feet (average saturated thickness) to be the effective thickness of the Post Oak Aquifer.

The average thickness of the POGB is determined to be 500 feet in concurrence with Havens (1977). Based on an average depth to water estimated at 30 feet, the average saturated thickness is determined to be 470 feet.

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be described in terms of storage coefficient and transmissivity. For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. For this study, specific yield was estimated to be 0.05; this compares favorably for reported values for sediments similar to those in the POGB (Kent, 1986).

This report incorporates Kent's values for aquifer parameters for the upper 50 feet of the Post Oak aquifer with those estimated from wells completed at 500 feet in order to estimate a mean value for the entire thickness of the POGB for hydraulic conductivity and transmissivity.

Kent estimated hydraulic conductivity (K) within the upper 50 feet for the coarse grained sediments occurring in Stone's ancient stream channels and the finer grained sediments occurring outside their boundaries. The K values derived for Kent's coarse and fine-grained zones were 107 ft/day and 27 ft/day respectively.

The OWRB examined drillers' logs of water wells completed through the total thickness of the POGB. It was estimated that approximately 35% of the interval consisted of sand, sandstones, limestone conglomerates and granite wash and are considered to be equivalent in nature to Kent's fine-grained zone with respect to permeability. The balance of the lithologic section consisted primarily of claystone, siltstone, limestone and dolomite interbeds and have been interpreted as having significantly lower permeability.

The hydraulic conductivity of the claystone/carbonate interval was assigned a value of 0.001 ft/day. This falls within a range of K values assigned to rocks described by Heath (1983) as unfractured shales. Based on professional judgment, the claystone/carbonate zone in the POGB, for the purposes of estimating a K value, has been equivocated with Heath's unfractured shales. To obtain a weighted or proportional estimate of this property and transmissivity for the entire thickness of the basin, the grain size envelope method (Kent, 1973) was utilized. The hydraulic conductivity of the POGB is determined to be 13 ft/day and the transmissivity is 6100 ft^2/day (See Table 5).

Table 5. Estimated hydraulic conductivity and transmissivity for the POGB.

Grain Size/ Media Type	Hydraulic Conductivity	Sat. Interval in feet	K for POGB	T for POGB
Medium-Coarse Sand	107 ft/day	20 feet		
Fine Sand	27 ft/day	157 feet		
Claystone & Limestone	.001 ft/day	293 feet		
Weighted Results			13 ft/day	6100 ft^2/day

The amount of annual recharge to the POGB is estimated to be 3.6 inches per year, which is 12 percent of the average annual precipitation. This percentage for recharge was selected by comparing the POGB with recharge estimates from previous basin studies conducted by Havens (1977).

The regional groundwater gradient for the POGB trends southeast, generally following the topography. Directly south of the Wichita

Mountains, the groundwater gradient is relatively steep, ranging from 5 to 8 ft/mi. Further south the gradient levels off to approximately 1 ft/mi (Hounslow and Back, 1986).

Aquifer Storage and Yield Capabilities

Determination of the initial storage of the basin was calculated by multiplying the area of the basin by the specific yield and the average saturated thickness of the basin. The initial storage for the POGB was estimated at approximately 2,000,000 acre-feet.

Wells completed in the POGB may yield as much as 110 gallons per minute Kent et al (1986). This type of production would probably be limited to wells which intersect coarser sediments within Stone's ancient stream channels. The typical yield of well completed in the POGB is estimated to be less than 50 gallons per minute.

Water use

The POGB is not heavily relied on to supply agricultural crop water. Dry-land farming is prevalent in eastern Tillman, Comanche and Cotton Counties, relying upon rainfall to provide the necessary moisture for crops (Hounslow and Back, 1986; field observations, 1993; OWRB, 1983). Groundwater from the POGB is an important source of water for domestic and stock water use for individuals in outlying areas not served by rural water systems.

Reported water use for 1993 by permit holders within the POGB totaled 19.2 million gallons, or 58.9 acre-feet (OWRB, 1993). Groundwater withdrawals were reported for irrigation and commercial purposes (See Table 6).

Table 6. Permit and Water Use Information for POGB during 1993

Purpose	Number of Permits	Permitted Amount	Reported Use
Irrigation	8*	3001 acre-feet	39.0 acre-feet
Commercial	6*	1698 acre-feet	19.9 acre-feet
Totals	14*	4699 acre-feet	58.9 acre-feet

* - Includes Prior Rights

Prior Groundwater Rights

Groundwater rights established within the POGB prior to July 1, 1973 and recognized by Board Order total 40 acre-feet. The prior rights established in the POGB are limited to Comanche County.

Hennessey-Garber Groundwater Basin

The HGGB, for the purpose of this report, primarily includes the outcrop area of the Hennessey and the Garber formations. Minor outcrops of the Wellington and Oscar formations in Cotton and Tillman Counties have also been included. The HGGB consists of approximately 1,376,000 acres (2150 mi^2) of Permian deposits that occur primarily as conglomerates, sandstones and shales. Kent et al (1986) reported that these formations can attain a thickness greater than 2,000 feet in the subsurface. The upper boundary of HGGB, where it is overlain by the Tillman Terrace major groundwater basin is at the contact between the Tillman Terrace and the Garber-Hennessey Formations.

The thickness of the HGGB was determined to be 200 feet on the basis of the deepest wells known to exist within the basin. A water quality parameter mapped by the Oklahoma Corporation Commission (OCC) provides support that the selection of this thickness is reasonable and representative of a maximum thickness for the basin. That parameter, described as the base of treatable water is defined by that depth in which the concentration of total dissolved solids in the groundwater exceeds 10,000 mg/l (OCC Base of Treatable Water Maps, 1982).

Aquifer Parameters

Hydraulic conductivity and transmissivity were estimated from lithologies of wells completed at depths around 200 feet. Using the same methodology for the HGGB as was used for the POGB, the hydraulic conductivity is estimated at 2.7 ft/day and the transmissivity is estimated at 472 ft^2/day. A specific yield of 0.02 was estimated for the HGGB based on the percentages of shales to sand as represented on the well completion reports. A summary of the data is shown in Table 7.

The amount of annual recharge to the HGGB is estimated to be 2.7 inches per year, which is 9 percent of the average annual precipitation. This percentage for recharge was selected by comparing the HGGB with recharge estimates from previous basin studies conducted by Havens (1977).

The regional groundwater gradient trends southeast, generally following the topography. South of the Wichita Mountains, the gradient levels off to approximately one ft/mi (Hounslow and Back, 1986).

Table 7. Estimated hydraulic conductivity and transmissivity for the HGGB.

Grain Size	Hydraulic Conductivity	Saturated Interval	K for HGGB	T for HGGB
Fine Sand	27 ft/day	17.5 feet		
Unfractured Shales	.001 ft/day	157.5 feet		
Weighted Results			2.7 ft/day	472 ft^2/day

Aquifer Storage and Yield Capabilities

Determination of the initial storage of the basin was calculated by multiplying the area of the basin by the specific yield and the average saturated thickness of the basin. The initial storage of the HGGB was determined to be approximately 4,800,000 acre-feet. Wells completed in the HGGB yield on the average 30 gallons per minute (Kent et al, 1986).

Water Use

Groundwater from the HGGB is not heavily relied on to supply agricultural crop water. A small amount of groundwater is used from the basin for public water supply. Also, individuals in outlying areas not served by rural water systems rely on the basin for domestic and stock water use.

Reported water use for 1993 by permit holders within the HGGB totaled 15.3 million gallons or 47 acre-feet (OWRB, 1993). The entire amount was utilized by one rural water district. No water use was reported for irrigation. Table 8 summarizes the permit and water use data for the basin.

Table 8. Permit and Water Use Information for HGGB during 1993

Purpose	Number of Permits	Permitted Amount	Reported Water Use
Irrigation	3*	60 acre-feet	No Reported Use
Public Water Supply	2*	182 acre-feet	47.1 acre-feet
Totals	5*	242 acre-feet	47.1 acre-feet

* - Includes Prior Rights

Prior Groundwater Rights

Groundwater rights established within this basin prior to July 1, 1973, and recognized by Board Order total 245 acre-feet. This includes 167 acre-feet in Comanche County, 60 acre-feet in Tillman County and 18.0 acre-feet in Cotton County.

GROUNDWATER QUALITY

Cache Creek and Beaver Creek Groundwater Basins

Investigations of groundwater quality within the CCGB and BCGB have dealt primarily with the Comanche County area. Most of the following discussion relates to that portion of the basin. Stone (1981) reported the quality of the water in the alluvium as being extremely variable but generally is of acceptable quality except where nitrate pollution has occurred. Elevated levels of nitrogen occur within the CCGB within a few areas that are intensively farmed and where large quantities of nitrogen-based fertilizers are applied (Hounslow and Back, 1986). Locally, high levels of fluoride in the underlying Post Oak aquifer in Comanche County could degrade the quality of groundwater in the CCGB. In some instances, high levels of dissolved solids in the CCGB and BCGB may limit the use of the groundwater for some purposes.

The ramifications of man-made contaminants (nitrates) present in the groundwater are beyond the scope and purpose of this report. The following discussion pertains to the impact, if any, of naturally occurring mineral constituents on the basin's water quality.

Fluoride

Levels of fluoride in the groundwater in the Post Oak Conglomerate Formation underlying portions of the CCGB have been found as high as 35 mg/l (Hounslow and Back, 1986). Fluoride levels as high as 17 mg/l have been identified in the Arbuckle Group (Havens, 1983). In areas where the Post Oak water contains elevated levels of fluoride and is overlain by the CCGB, care should be taken when constructing shallow alluvial wells so as not to commingle the Post Oak waters with the alluvial waters. The upper end of the West Cache Creek segment of the basin appears to be the most vulnerable to contamination from fluoride.

Excessive fluoride levels can lead to tooth mottling and deterioration of the skeletal structure. The Environmental Protection Agency's (EPA) secondary drinking water standard for fluoride is 1.6 mg/l.

Dissolved Solids

Total dissolved solids (TDS) are described as the solid residue remaining after evaporation of a water sample during analysis. TDS denotes the concentration of mineral constituents dissolved in water. The maximum TDS recommended for public water supplies is 500 mg/l. The recommended limit for TDS is based mainly on taste thresholds and not physiological effects. Water that greatly exceeds (several thousand mg/l TDS) the 500 mg/l threshold is generally not palatable. The overall usefulness of the water supply should be judged on the concentration of individual ions rather than the total concentration of all substances (Pettyjohn, 1983).

Most of the potable groundwater in the study area is high in TDS, with many water wells and even some municipal water systems regularly exceeding 1000 mg/l (Stone, 1981). TDS reported by Havens (1977) for the CCGB and BCGB range from 210 mg/l to 2200 mg/l.

Table 9 is a summary of selected anions and cations sampled and analyzed from thirteen wells within the CCGB and BCGB (Havens, 1977). The table shows average concentrations for the parameters and EPA's maximum concentration levels (MCL's) for drinking water where applicable.

Table 9. Anion and Cations in the CCGB and BCGB

Parameters	**Concentration in mg/l**	**EPA MCL's**
Total Dissolved Solids	960	500
Sodium/Potassium	266	N/A
*Nitrate	8	10
Chloride	274	250
Hardness	271	N/A
Bicarbonate	433	N/A
Sulfate	127	250

* - represents average concentration for nitrate for wells completed in alluvium for entire Lawton Quadrangle (Havens 1977).

In summary, except in localized areas, the water quality of CCGB and BCGB is probably suitable for all beneficial uses. The major natural source of pollution in the area that might impact some portions of the CCGB comes from the fluoride that exists in the adjacent and underlying Post Oak Conglomerate. High TDS concentrations may limit the use of groundwater for some purposes.

However, with proper well completion techniques (completing wells above the Post Oak and sealing the annular space between the surface casing and bore hole with cement grout to a minimum depth of 10 feet), water quality sampling and analysis, negative health affects can be mitigated.

Post Oak and Hennessey-Garber Groundwater Basins

Havens (1977) reported chemical analyses of water samples for 16 wells from minor groundwater basins within the study area. These analyses were made by the U.S. Geological Survey and State and private agencies. Other investigations of groundwater quality within the POGB and HGGB have also been conducted primarily in the Comanche County area. Water quality concerns documented for the POGB and HGGB areas include fluoride and dissolved solids.

Fluoride

Levels of fluoride in the groundwater in the Post Oak have been found as high as 35 mg/l (Hounslow and Back, 1986). The fluoride source originates from the dissolution of riebeckite, a fluoride bearing amphibole contained in the Quanah granite of the Wichita Mountains. Post Oak formation samples have been analyzed by Green and Al-Shaieb (1981) and the analytical results indicate the Post Oak Conglomerate as the fluoride source rock.

The fluoride-rich waters are prevalent in a wide belt, beginning approximately 12 miles south of the Wichita Mountains and trending east-west (Hounslow and Back, 1986). The high levels begin in the west near the Tillman county line and diminish in the east near Lawton. Fluoride concentrations in waters directly south of the Wichitas are less than 1 mg/l.

Excessive fluoride levels can lead to tooth mottling and deterioration of the skeletal structure. The Environmental Protection Agency's (EPA) secondary drinking water standard for fluoride is 1.6 mg/l.

Dissolved Solids

The dissolved solids reported by Havens (1977) are described as the solid residue remaining after evaporation of a water sample during analysis. Water containing 500 mg/l or less of dissolved solids is generally considered satisfactory for most domestic uses. Havens reported that the water quality is so variable in the Lawton quadrangle area that it is impossible to delineate quality by geographical area. Dissolved solids for the POGB and the HGGB were reported to range from 272 mg/l to 5290 mg/l, with the average being 1881 mg/l.

Table 10 summarizes the data for selected anions and cations from 16 wells within the POGB and HGGB (Havens, 1977). The table shows average concentrations for the parameters and EPA's maximum concentration levels (MCL's) for drinking water where applicable.

Table 10. Anion and Cations in the POGB and HGGB from 16 selected wells (Havens, 1977)

Parameters	Concentration in mg/l (average)	EPA MCL's
Total Dissolved Solids	1881	500
Sodium/Potassium	489	N/A
Nitrate*	10	10
Chloride	544	250
Hardness	363	N/A
Bicarbonate	326	N/A
Sulfate	314	250

* - represents average concentration for nitrate for wells completed in minor basins for entire Lawton Quadrangle

In summary, except in localized areas, the water quality of the POGB and HGGB is probably suitable for all beneficial uses. The major natural source of pollution in the area is the fluoride that exists in the Post Oak Conglomerate. Also, localized water quality problems exist from high total dissolved solids. Pollution of the basin from these parameters can be minimized with proper well construction, treatment, and water quality testing.

SUMMARY

Cache Creek Groundwater Basin

The following data on Cache Creek Groundwater Basin were derived in order to calculate and determine the MAY and EPS of the basin:

1) The total land area overlying the basin is 184,870 acres;
2) The amount of water in storage in the basin on July 1, 1995 was approximately 597,000 acre-feet;
3) The average rate of recharge was estimated to be 3.6 inches or 12 percent of the average annual precipitation with 1,110,000 acre-feet of recharge over the life of the basin. The total amount of groundwater established under prior rights is 2,070 acre-feet with a total discharge determined to be 41,400 acre-feet over the life of the basin;
4) The transmissivity of the basin is estimated at 2,200 ft^2/day;
5) The possibility of pollution of the basin from natural sources such as fluoride, which occurs in portions of the adjacent and underlying Post Oak Conglomerate, can be minimized by proper well construction techniques and water quality testing and analysis;

Beaver Creek Groundwater Basin

The following data on the Beaver Creek Groundwater Basin were derived in order to calculate and determine the MAY and EPS of the basin:

1) The total land area overlying the basin is 37,325 acres;
2) The amount of water in storage in the basin on July 1, 1995 was approximately 120,600 acre-feet;
3) The average rate of recharge was estimated to 3.6 inches or 12 percent of the average annual precipitation with 224,000 acre-feet of recharge over the life of the basin. The total amount of groundwater established under prior rights is 0 acre-feet with a total discharge determined to be 0 acre-feet over the life of the basin.
4) The transmissivity of the basin is estimated at 2,200 ft^2/day;
5) The possibility of pollution of the basin from natural sources is considered to be negligible.

The maximum annual yield and equal proportionate share results are provided in an accompanying report entitled Maximum Annual Yield Determination for Cache Creek and Beaver Creek Minor Groundwater Basins.

Figure 4 shows the boundaries of the respective groundwater basins superimposed on the public land survey system in Comanche, Cotton and Tillman Counties.

Post Oak Groundwater Basin

The following data on Post Oak Minor Groundwater Basin were derived in order to satisfy the requirements of Oklahoma Groundwater Law:

1) Total land overlying the basin was determined to be 85,120 acres;
2) The amount of water in storage in the basin was determined to be 2,000,000 acre-feet;
3) The rate of recharge was estimated to be 3.6 inches per year with 511,000 acre-feet of recharge over the life of the basin. The total amount of groundwater established under prior rights is 40 acre feet per year with a total discharge determined to be 800 acre-feet over the life of the basin;
4) Average transmissivity of the basin was determined to be 6100 ft^2/day;
5) Natural sources of pollution in the basin include fluoride and total dissolved solids. Pollution of the basin can be minimized by proper well construction, treatment, and water quality testing and analysis;

Hennessey-Garber Groundwater Basin

The following data on Hennessey-Garber Minor Groundwater Basin were derived in order to satisfy the requirements of Oklahoma Groundwater Law:

1) Total land area overlying the basin was determined to be 1,376,000 acres;
2) The amount of water in storage in the basin was determined to be 4,800,000 acre-feet;
3) The rate of recharge was estimated to be 2.7 inches per year with 6,200,000 acre-feet of recharge over the life of the basin. The total amount of groundwater established under prior rights is 245 acre-feet per year with a total discharge determined to be 4900 acre-feet over the life of the basin;
4) Average transmissivity of the basin was determined to be 472 ft^2/day;
5) Natural sources of pollution in the basin include fluoride and total dissolved solids. Pollution of the basin can be minimized by proper well construction, treatment, and water quality testing and analysis;

The maximum annual yield and equal proportionate share results are provided in an accompanying report entitled Maximum Annual Yield Determination for Hennessey-Garber and Post Oak Minor Groundwater Basins.

Figure 5 shows the boundaries of the respective groundwater basins superimposed on the public land survey system in Comanche, Cotton and Tillman Counties.

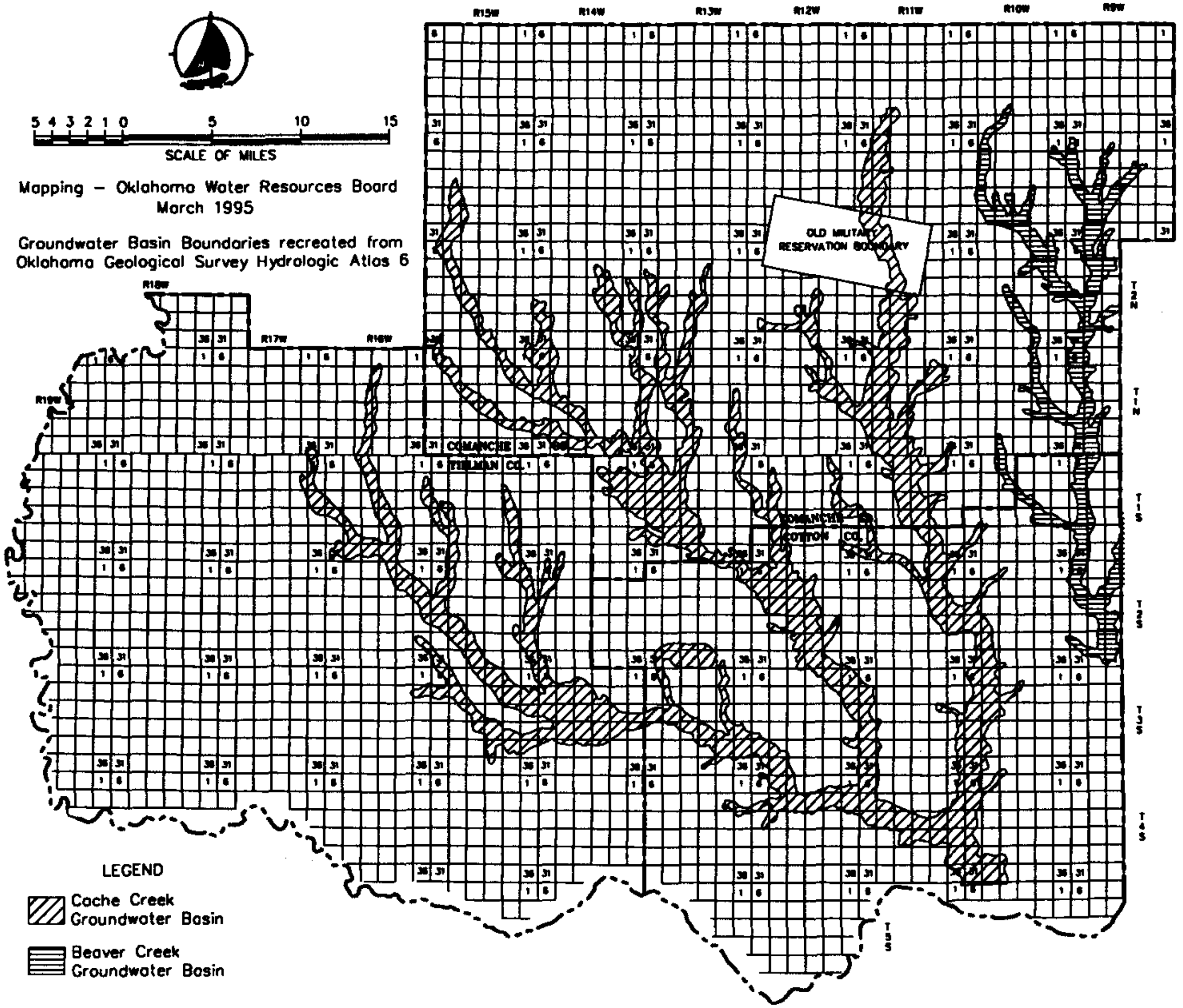

Figure 4. Physical Boundaries of the Cache Creek and Beaver Creek Groundwater Basins.

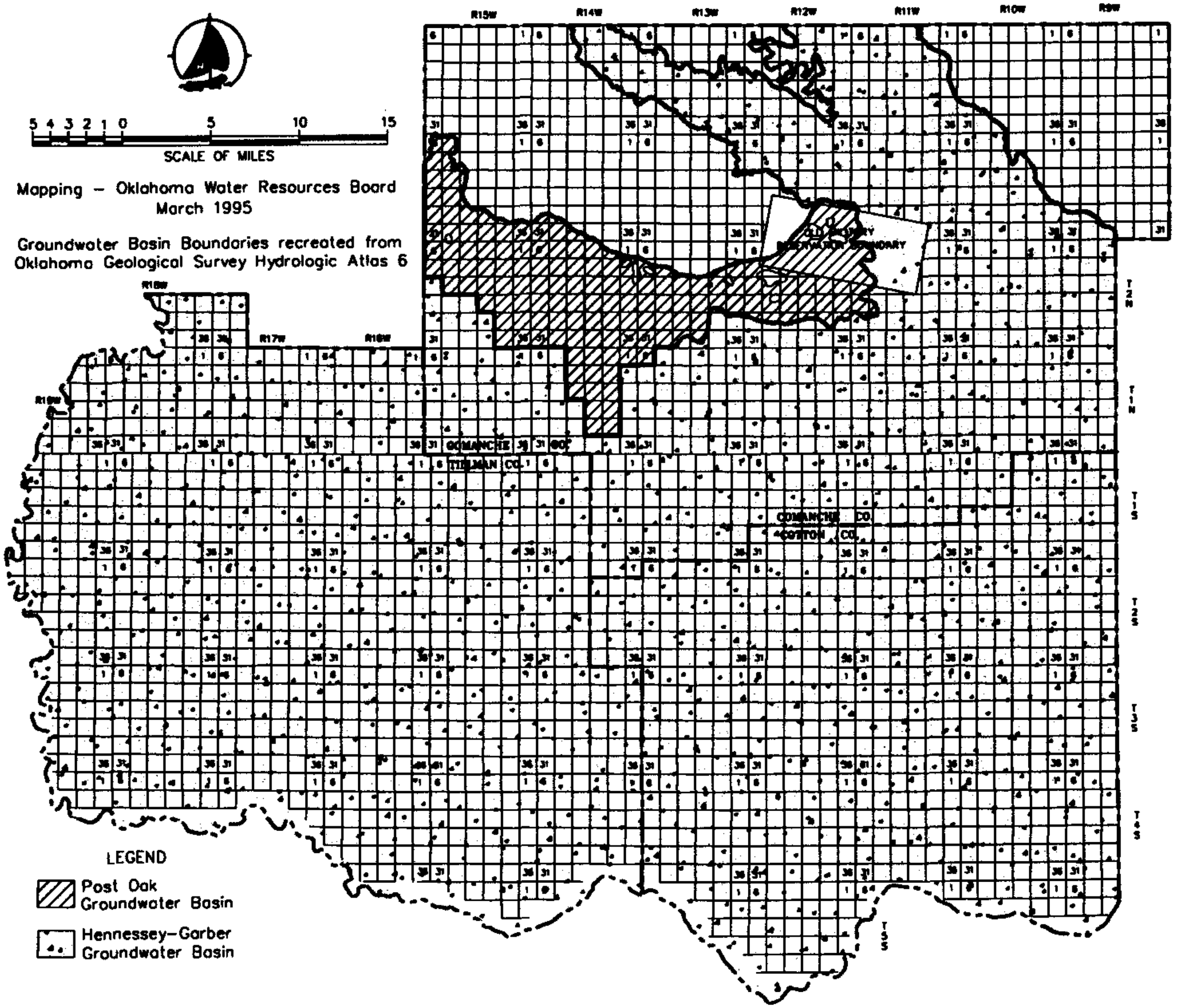

Figure 5. Physical Boundaries of the Post Oak and Hennessey-Garber Groundwater Basins.

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GLOSSARY

Alluvium
A general term for clay, silt, sand, and gravel, or similar unconsolidated material deposited during comparatively recent geologic time by stream or other body of running water as a sorted or partially sorted sediment in the bed of the stream or on its flood plain or delta, or as a cone or fan at the base of a mountain slope.

Aquifer
A formation, group of formations, or a part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Equal Proportionate Share
That portion of the maximum annual yield of water from a groundwater basin which shall be allocated to each acre of land overlying such basin.

Groundwater
Fresh water under the surface of the earth regardless of the geologic structure in which it is standing or moving outside the cut beds or banks of any definite stream.

Groundwater Basin
A distinct underground body of water overlain by contiguous land having substantially the same geological and hydrological characteristics and yield capabilities. The areal boundaries of a basin can be determined by political boundaries, geological, hydrological, or other reasonable physical boundaries.

Hydraulic Conductivity
The volume of water that will move through a medium in a unit of time under a unit hydraulic gradient through a unit area measured perpendicular to the direction of flow.

Life of a Groundwater Basin
That period of time during which pumping of the maximum annual yield for a minimum twenty year life of such basin will result in the complete depletion of the basin with the exception of maintaining five feet of saturated thickness in alluvium and terrace aquifers and fifteen feet of saturated thickness in bedrock aquifers for domestic use.

Major Groundwater Basin
A distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which groundwater wells yield at least fifty gallons per minute on the average basinwide, if from a bedrock aquifer and at least one hundred fifty gallons per minute on the average basinwide, if from an alluvium and terrace aquifer, or as otherwise designated by

the Oklahoma Water Resources Board.

Maximum Annual Yield
A determination by the Board of the total amount of fresh groundwater that can be produced each year from each basin, allowing a minimum twenty year life of such basin.

Permeability
The property of a porous medium to transmit fluids under a hydraulic gradient.

Porosity
The ratio, usually expressed as a percentage, of the total volume of voids of a given porous medium to the total volume of the porous medium.

Prior Groundwater Right
The right to use groundwater established by compliance with the laws in effect prior to July 1, 1973, the effective date of the Groundwater Act.

Specific Yield
The ratio of the volume of water which the porous medium after being saturated, will yield by gravity to the volume of the porous medium.

Storage Coefficient
The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (virtually equal to the specific yield in an unconfined aquifer).

Total Discharge from the Basin
Shall include but may not be limited to the amount of fresh groundwater withdrawn and placed to beneficial use prior to July 1, 1973, which amount shall be determined from the applicable final orders of the Board determining prior groundwater rights.

Transmissivity
The rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.