GROUND WATER MANAGEMENT OF THE ISOLATED TERRACE DEPOSIT (GERTY SAND) OF THE CANADIAN RIVER IN GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

By

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GROUND WATER MANAGEMENT OF THE ISOLATED TERRACE
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IN GARVIN, McCLAIN, AND PONTOTOC
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PREFACE

The results of the investigation into the state and federal regulatory statutes was to set up a ground water management strategy for the Isolated Terrace Deposit of Garvin, McClain, and Pontotoc counties, Oklahoma. The intent of this study was to bring to light the relationship of man, land and water for continued economic existence for this region.

Special thanks is extended to my advisor, Dr. Douglas Kent, for his supervision as principle investigator for this project, which was funded by the Oklahoma Water Resource Board. Appreciation is also extended to my committee members, Dr. Joseph Westphall and Dr. Sterling Burks for their review and suggestions.

The author is also indebted to the Oklahoma Water Resource Board personnel in the Ground Water Division for their participation on this project; special thanks is extended to Duane Smith and Bob Thomas for their collaboration throughout the project. Other personnel, too numberous to mention, are also thanked for their support and help.

The economic-social aspect of this study would not be possible without the cooperation and hospitality of the people who lived in the study area including those who lived in or near Stratford, and Byars. Thanks is also extended to Mr. Hucks of Wynnewood, Rural Water District, for his help in data aquisition.

Appreciation is extended to my parents, brothers and sister for their love, support, and encouragement.

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ABSTRACT

The Isolated Terrace Deposit of Garvin, McClain, and Pontotoc Counties, Oklahoma is located in south-central Oklahoma. The Terrace deposit (refered to as the Gerty Sand) is an unconfined aquifer in the Quarternary and Oscar Group sediments. The irrigation and water supply wells are completed in the Terrace deposit.

Developments of ground water protection in Oklahoma is based on the Doctrines of Prior Appropriation to individual basins or subbasins requiring a right to beneficial use designated for agricultural, municipal and industrial purposes. The use of well spacing and the metering of wells is allowed under the auspices of the Oklahoma Water Resource Board and can be considered for management strategies.

The present allocation rate should be modified as is due to the variable climatic, hydrologic, and water quality characteristics of the aquifer. The municipal and rural water district demands should be adjusted to meet the future increase in populace of this area based on the aquifer characterisitics, and in the annual allocations of water rights.

The interrelationship of the aquifer to domestic and municipal uses for economic benefits is vital to the general welfare of this area and should be maintained. A Irrigation Ground Water Management Conservation District should be developed for the protection of the Isolated Terrace (Gerty Sand) deposit. Several ground water management scenerios should be developed to protect the aquifer.

CHAPTER I

INTRODUCTION

General

The objective of this study was to determine the dynamic relationship of ground water consumption for agricultural and municipal uses, and to develop a ground water management strategy for the study area. The first objective is accomplished by describing the Hydrogeology, which is used to determine the maximum annual yield of fresh water that can be produced from the Isolated Terrace Deposit of the Canadian River of Garvin, McClain, and Pontotoc counties, Oklahoma. The second objective is to develop ground water management scenerios using the hydrogeologic data in consumation with information obtained through a literature search and a political survey.

Under title 82 Oklahoma Statutes Annotated, Water and Water Rights, Section 1020.4 and 1020.5 gives the Oklahoma Water Resources Board powers and duties to "make hydrologic surveys and investigations of each fresh ground water basin or subbasin;" and to "make a determination of the maximum annual yield of fresh water to be produced from each ground water basin or subbasin". The determination of the maximum annual yield is based on the following (Okla. Stat. Ann. Tit. 82, Sec. 1020.5, 1987):

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 natural recharge to the basin or subbasin and total discharge from the basin or subbasin;
4. Transmissibility of the basin or subbasin; and
5. The possibility of pollution of the basin or subbasin from natural sources.

The maximum annual yield of each fresh ground water basin or subbasin shall be based upon a minimum basin or subbasin life of twenty (20) years from the effective date of this act.

The annual allocation is determined based on the maximum annual yield and is the number of acre-feet per acre per year that can be produced by the aquifer that will cause one-half of the area of the aquifer to be depleted to five feet or less saturated thickness of water over a 20 year pumping period starting July 1, 1973.

The development of a ground water management strategy was accomplished through literature search of ground water management for the state of Oklahoma, and a review of other state publications. The political survey was modified after the Tillman Terrace Aquifer study in southwestern Oklahoma (March, 1983).

Location

The area of study is located in the south-central part of the state of Oklahoma, in northeastern Garvin, southeastern McClain, and western Pontotoc counties (see figure 1). The Isolated Terrace deposit, the gerty sand, is an unconfined aquifer. The Isolated Terrace Deposit covers approximately 40 square miles (25,600 acres) and is described geologically as a dissected plateau bounded by the Hunton Arch, Arbuckle Mountains, and the Pauls Valley Uplift. The Terrace Deposit is drained by three streams: Big Creek, Spring Brook Creek, and Keel Sandy Creek.

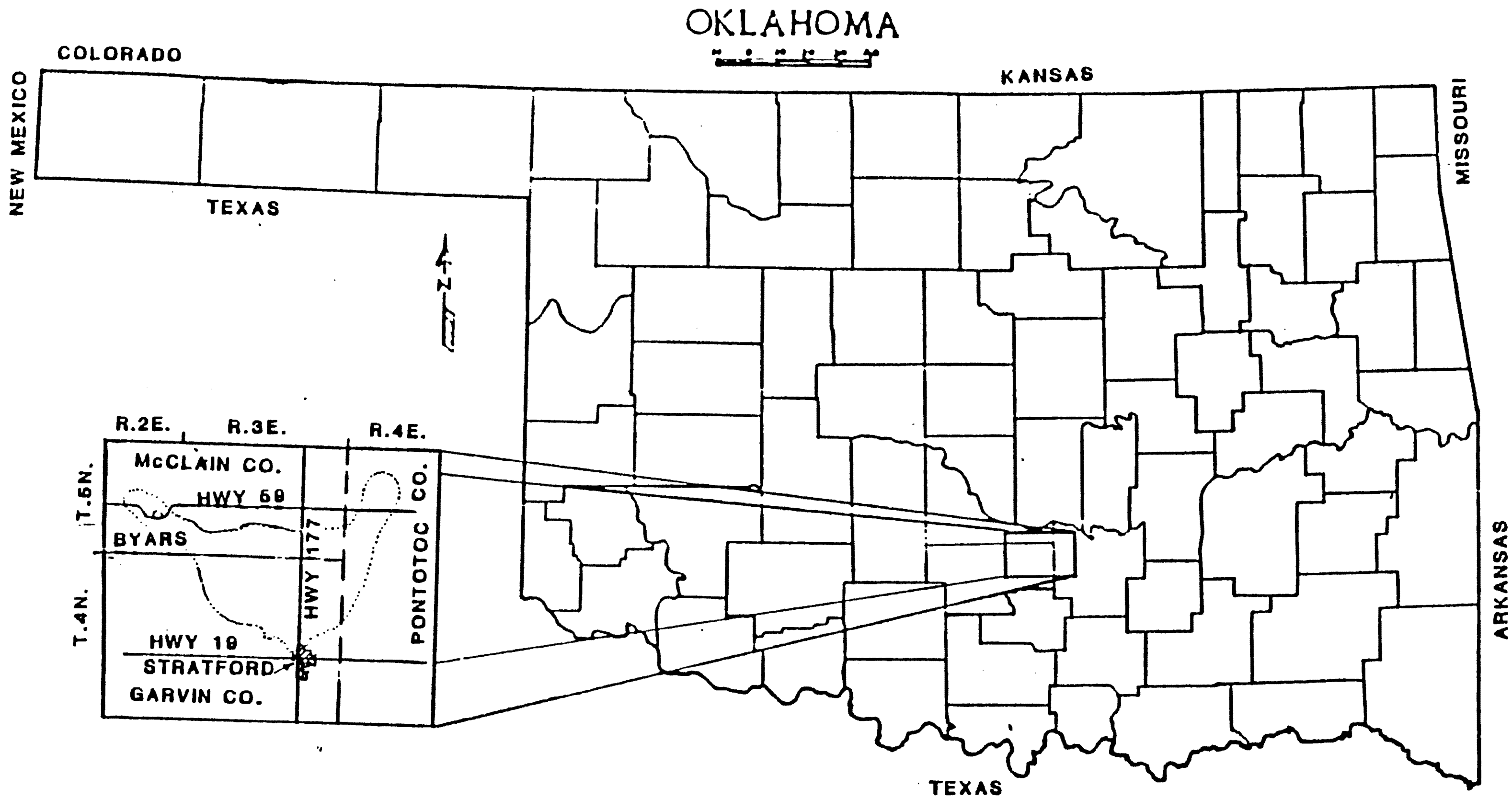

FIGURE 1. LOCATION OF STUDY AREA.

CHAPTER II

PHYSICAL ENVIRONMENT

Geology

General

The study area geology is represented by the formations of the Oscar Group, Pontotoc Terrane, Upper Pennsylvanian in age. The western boundary of the study area is composed of younger sediments of Permian Age called the Wellington Formation. The eastern boundary lies on top of the Vanoss Group, Upper Pennsylvanian in Age (Hart, 1974). The Oscar Group, Stratford Formation is found to be composed of conglomerate sand rock, red-brown shale, and a tan limestone. The Tertiary deposits, commonly found with the Gerty sand, covers a majority of the study area. The Gerty sand is found in the area capping most of the topographic hills. The Gerty sand is found with well rounded rose colored chert quartzite cobbles with some petrified wood on the hills. Quarternary System sediments exposed in the study area include the terrace deposit alluvium, which can be traced and parallels most of the Canadian River. This alluvium is composed of a white to tan, medium to coarse grain, unconsolidated sand. The working of this sand on the erosional surface has a yellow-tan color, medium grained and unconsolidated, different from the white sand exposures. The recent deposits are the dune deposits exposed throughout the study area. These deposits are commonly found in a loess form in stream cuts and may include some of the reworked lower sediments.

The study area is locatd on the western flank of the Hunton arch, on the northern side of the Arbuckle Mountain anticline, and on the northeast side of the Anadarko Basin. Topographically Garvin county is a dissected plateau showing small apparent domes and anticlinal noses (Dott, 1927).

Previous Work

The Gerty Sand was first described in Geology of MacAlester-Lehigh Coal Fields Indian Territory by Taff (1898). The Gerty Sand is described by Taff as:

> . . . recent in geological time an extensive deposit of gravel, sand, and silt . . . . These gravels and sands are not cemented into hard rocks; instead they are incoherent deposits, and resemble recent river or lake sand plains. When the coarse gravel and sand are at the surface they are forest covered, but when they are silted over there is usually a prairie which blends imperceptibly with the general peneplain of the higher valleys. There are indications from its condition that the surface upon which the gravel and sand were deposited was a deserted river channel. The gravel, sand, and silt are spread out in a long somewhat sinuous band. . . . Upon the north side especially this sand plain abuts against the highlands....
>
> The material of the gravel is all foreign to this region. It is composed of brown quartzitic sand, conglomerate, and various shades of red, white, and black quartz, jasper, and chert. The gravel occurs at the base of the deposit, but is not everywhere present there. It is generally most abundant near the center of the area that contains it. Near the border of the basin, and in many places above the coarser sand, a fine yellow sand or silt occurs, and this is found in wells to be stratified with layers of red and yellow clays.

Loomis (1922) described the limestone outcrop of Section 2, T.4N., R.3E. as Pennsylvanian limestone surrounded by Permian red beds, and stated that no Hart limestone can be found further north of this point. Morgan

(1924) studied the geology of the Stratford, Oklahoma area and described the limestone outcrop in Section 2, T.4N., R.3E. and names it as the Hart limestone surrounded by the Gerty Sand. Dott (1927) compiled all of the geology for Garvin County, studied all of the Pennsylvanian Paleogeology, and produced a series of cross-sections of the Hunton Arch in "Pennsylvanian Paleogeology With Special Reference To South-Central Oklahoma". Conkling (1927) studied and described the geology of Pontotoc County as well as the structure and depositional environment of most sediments deposited within the Pontotoc County area. Anderson (1927) made reference to the Gerty sand and recent sand deposition along the Canadian River in "Geology of Cleaveland and McClain Counties". Hendricks (1937) determined the known outcrops of the Gerty Sand extend from the vicinity of Byars in McClain and in northeastern Garvin County eastward across southern Pottawatomie, southern Seminole, northern Pontotoc, southern Hughes, northeastern Coal, Pittsburg, and western Latimer Counties, Oklahoma. Weaver (1954) described the Gerty and how the Gerty received its name: "J. A. Taff named this formation for the town of Gerty in the south-central part of Hughes County, Oklahoma". Weaver also, reported that there was considerable doubt as to whether any of the high terrace deposits in that county should be correlated with the Gerty as they do not lie at the same approximate level and are not similar to the gerty exposures in other adjoining counties. Paine (1958) described the stratigraphy and surface rock exposures as presented in "Subsurface Geology of T.4N., R.5E., Pontotoc County. Lowe (1968) described thge stratigraphy of Silurian to Pennsylvanian System lithologic units and referenced the Quarternary System sediments (Gerty sand) in "Geology of The Ada Area, Pontotoc County". Hart (1974) developed a series of four maps in a form of a Hydrologic Atlas in

"Reconnaissance of Water Resources of the Ardmore and Sherman Quadrangles, Southern Oklahoma". Nofziger, et. al., (1983) worked on characterizing the Konawa soils and determined the hydraulic conductivity of the soils in the vicinity of Stratford, and Stillwater, Oklahoma.

In reference to ground water management modeling, works were done by Kent, et. al., (1984) in "Evaluation of Aquifer Performance and Water Supply Capabilities of the Washita River Alluvium in Oklahoma", Department of Geology, Oklahoma State University. Kent, et. al., (1984) modified the U. S. Geological Survey mathematic model for ground water management modeling purposes. Kent, et. al., (1984) developed a ground water management model of the Washita River alluvium Aquifer in Grady, McClain, Garvin, Murray, Carter, and Johnston Counties in South-Central Oklahoma. Kent, et. al., (1983) used the ground water management model for the Washita River alluvium Aquifer in Roger Mills and custer Counties, Oklahoma. Kent, et. al., (1983) made an assessment of the ground water managemnt model in "Economic, Social, and Institutional Impacts of Ground Water Regulation of the Tillman Terrace Aquifer in Southwestern Oklahoma". Kent et. al., (1982) applied the ground water management model to the "Enid Isolated Terrace Aquifer in Garfield County, Oklahoma". Kent, et. al., (1981) applied a ground water management model to the Elk City Sandstone Aquifer in West-Central, Oklahoma. Kent, et. al., (1981) applied the model of ground water managment to the Enid Isolated Terrace Deposit in North-Central, Oklahoma.

Lithologic Units

Recent Deposits

The recent deposits involve the reworking of the Gerty sand into dune deposits. These deposits are cream white to light gray in color and have a Fine to gritty texture with worm and rodent burrows near the surface where exposed in stream cuts.

Other recent deposits exposed in the study area are composed of the sediments from the Gerty sand. This sand is found exposed in Big Creek river valley sides. The sand is composed of varve like structure cross-bedded, where cut by the river.

Quarternary System

Terrace Deposit. The terrace deposit alluvium overlay the Permian, and the Upper Pennsylvanian sediments. The terrace deposit has been identified as the Gerty sand by Taff (1898), Dott (1930), Weaver (1954), Paine (1958) and Lowe (1968). The terrace deposit sediment is composed of unconsolidated sand, and sands with lenses of silt and clay. The unconsolidated sand is a yellow to tan sand, non cemented, with rounded clear quartz sand grains.

Another sand exposure located in the SW.1/4 of the SW.1/4 of the SW.1/4 of the SE.1/4 of Section 25, T.5N., R.3E., which is a yellow to tan sand with clay and gray silt stringers. The sand grains are fine to medium grained, and well rounded clear quartz of approximately 0.08 to 0.20 millimeters in diameter with little or no cement, and is found with blue-gray clay fragments.

The Terrace Channel sediments is believed to be composed of a white to yellow (tan), medium grained sand with some apparent cross-bedding.

This sand is different from the yellow to tan sands exposed on the surface. The white sand has organic stringers and grades downward into an arkosic conglomerate with shale directly below. The exposure of this sand is located on the north-south road in the W.1/2 of the NW.1/4 of the SW.1/4 of the NW.1/4 of Section 12, T.4N., R.2E..

Tertiary System

Tertiary Deposits. The Tertiary sediments can be found capping the tops of the hills within the study area. The Tertiary sediments are a red to brown, well rounded, chert quartzite cobbles, which are found with some petrified wood. The size of the gravel ranges from one-half inch to four inches in diameter. This appears to represent a remnant of the Ogallala Formation which is underlain by bedrock outliers of the Permian and Upper Pennsylvanian Age.

Permian System

Wellington Formation. The Wellington Formation exposed in the study area can be found west of the city of Byars. This formation is a medium grain sand, with red-brown and white alternating sand stringers. On the eastern boundary the sand is predominately a red-brown sandstone. The Wellington Formation is described as a shale, red-brown, with several 20 to 30 feet of bituminous sandstones at the base (Hart, 1974). Field investigation reveals a mixture of red-brown and white sandstone, medium to fine grained textured sand, well cemented in part.

Upper Pennsylvanian System

Oscar Group. The Oscar Group has been broken down into the Konawa and Stratford Formations. The Konawa Formation is exposed in McClain county on the McClain-Garvin county line. This formation is composed of a series of red shales and sandstones. The shale interval is red-brown, thinly layered with black organic material in between the layers. The sandstone exposure is a red-brown, medium grained well cemented sand. This formation and a portion of the Wellington Formation is found at an outcrop exposure along the east-west road of SW.1/4 of the SW.1/4 of the SW.1/4 of the SE.1/4 of Section 25, T.5N., R.3E.. Other outcrop exposures are found at a site located at the E.1/2 of the E.1/2 of the E.1/2 of Section 23, T.5N., R.3E., which has a strike of N.53°E. and a dip of 4° to the east. This outcrop reveals a syncline structure of the west limb of the Hunton Arch. The last exposure of the Konawa Formation is located in the SW.1/4 of the SW.1/4 of the NW.1/4 of Section 28, T.4N., R.4E., and has a strike of N.78°W., and a dip of 6 to the north. This outcrop confirms warping movement of the sediment due to wave occurrance on the large sandstone blocks, tan to brown, thinly layered in part, noncalcareous, and exposed on the surface. The wave apex is approximately five feet on some blocks.

The Stratford Formation is composed of shale and limestone. Towards the base of this shale, the shale begins to be calcareous. Field measurements were made at a site located in the N.1/2 of the SE.1/4 of the SE.1/4 of Section 2, T.4N., R.3E. on a shale and limestone exposure. The shale has a strike of N.80°W. with a 15° dip to the west. This shale is below the conglomerate and is gradational to the limestone, called the Hart limestone base. The limestone exposed is chemically precipitated. The buff to cream white limestone has patches and stringers of calcite crystals of one-half to two inches in diameter.

Vanoss Group. The Vanoss Group is described as a shale, maroon, arkose, and a limestone conglomeratge (Hart, 1974). Field investigation revealed a shale interval with arkosic sandstone to coarse grain red to dark brown colored conglomerate. The conglomerate material has a thickness of approximately 18 feet. On the smooth surface exposure of the conglomerate has a strike of N.70°W., and a dip of approximately 2° to the west. Paleocurrent measurements of the conglomerate exposed in the SE.1/4 of the SE.1/4 of the NE.1/4 of Section 30, T.5N., R.3E. has a strike of N.65°W., with a dip of 17° to the west. This indicates the source of the conglomerate material is from the Arbuckle Mountain. Near the base of the conglomerate is a shaley, flat quartzite pebbles that are approximately one and a half by four inches long by one to a half inch wide. Fracture measurements of the conglomerate material are N.65° W., N.58°W., N.16°E., and N.20°E.. Also, at this same location is a normal fault with a displacement of approximately 30 feet. North of this outcrop exposure, approximately one mile, in the NW.1/4 of the SW.1/4 of the NW.1/4 of Section 20, T.5N., R.3E. a conglomerate exposure contains solution cavities in certain intervals with coarse grain quartz sand and nodules of approximately six to 10 inches in diameter surrounded by silt.

The generalized stratigraphic section can be seen in figure 2. This section will show the relative age of the formations encountered in the study area, and will show the approximate thickness of each unit. The measured sections of outcrop exposures can be found in the Appendix A. The measured sections will show the elevation of exposures encountered and will have a generalized lithologic description along side the section. The measured sections will show the gradational sequence of the terrace alluvium.

The subsurface geology is represented by the stratigraphic section

GEOLOGIC SECTION

AGE		FORMATION	SECTION	Thickness in Feet
QUARTERNARY		River Sand		0 To 60
		Gerty Sand		88
PERMIAN		Wellington Fm.		100
UPPER PENNSYLVANIAN	OSCAR GROUP	Konawa Fm.		500 (20)
	OSCAR GROUP	Stratford Fm.		400 (30)
		Vanoss Fm.		250 To 900
		Ada Fm.		100
		Vamoosa Fm.		125 To 260
		Hilltop Fm.		70
		Belle City Fm.		30
		Nellie Bly Fm.		200 To 300
		Francis Fm.		500

( ) EROSIONAL SURFACE FIELD MEASURED EXPOSURE FOR GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

FIGURE 2. GENERALIZED STRATEGRAPHIC SECTION.

of the formations measured on the surface exposures. A general hydrogeologic cross-section model was developed Using the measured section elevations and water well driller logs from the Oklahoma Water Resource Board. The general hydrogeologic model cross-section can be seen in figure 3, the east-west; and figure 4, the north-south topographic profile of the Isolated Terrace deposit. The drillers logs were used mostly from irrigation well logs filed with the Oklahoma Water Resource Board for the prior rights allocation and can be seen in Appendix B. A geologic bedrock map was developed using the outcrop exposures, driller logs, and the electrical, D. C. Resistivity method. This map used the red-sandy shale (red bed) as the base and in some areas used the conglomerate material and limestone as the base. The geologic bedrock map can be seen in figure 5. The development of a lithologic facies map was made using driller logs, outcrop exposures, and the resistivity method. Figure 6 shows the lithologic facies map. The lithologic facies map depicts the pinching of the Hart limestone and where the conglomerate interfaces with the shale. A conceptual three dimensional model, using driller logs, shows the interaction of ground water development in the conglomerate and the Gerty sand (see figure 7). This three dimensional map shows the May, 1985 water table level that is interacting and hydrologically connected to the conglomerate material.

Geologic Parameters

Surface elevation or land elevation values were taken from the United States Department of the Interior Geologic Survey, 7.5 minute series topographic quadrangle maps. The quadrangle maps of the Asher, Byars, Stratford, and Wanette, Oklahoma were used to represent the study

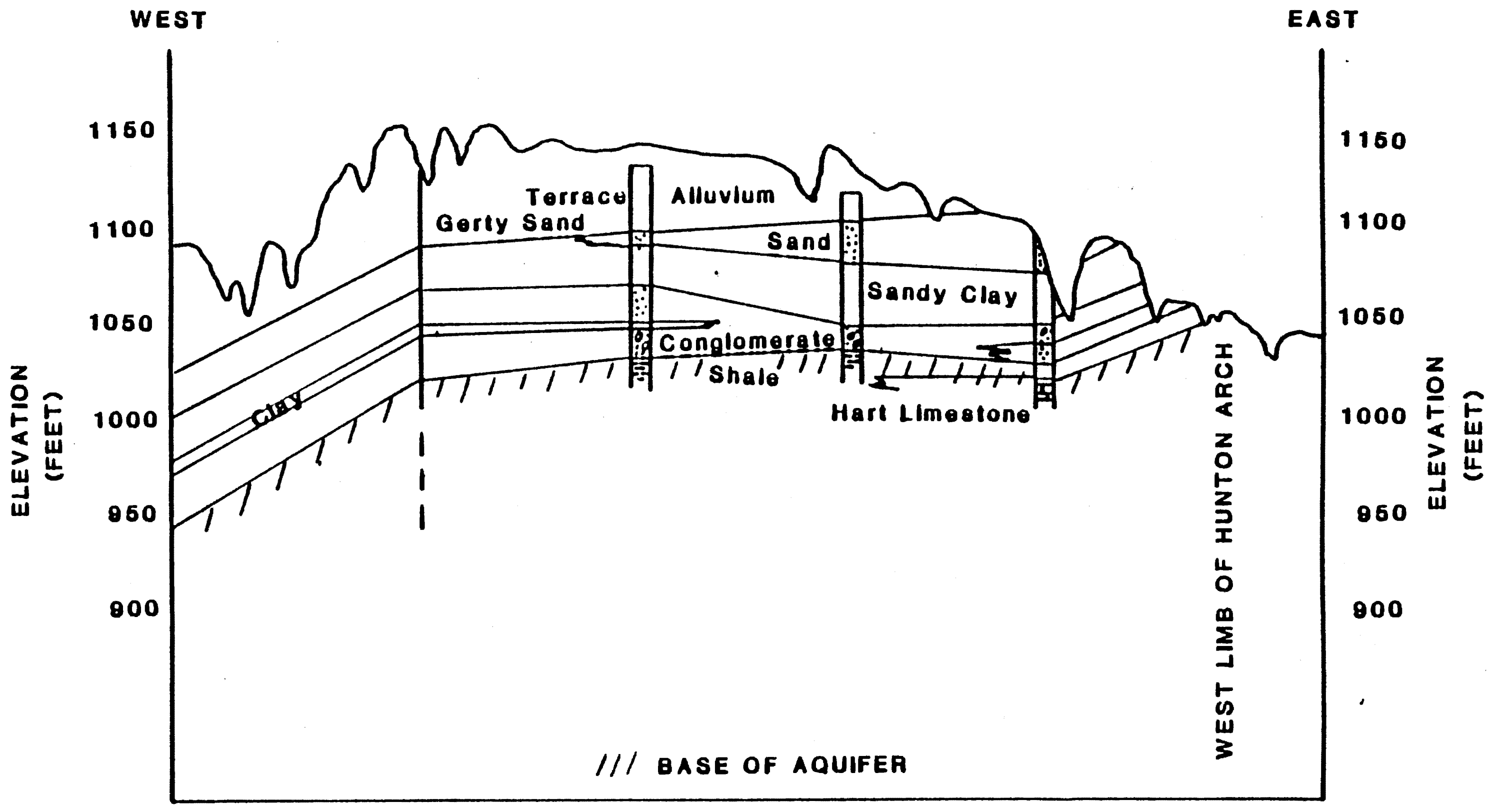

FIGURE 3. GENERAL HYDROGEOLOGIC MODEL OF THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA, EAST-WEST TOPOGRAPHIC PROFILE.

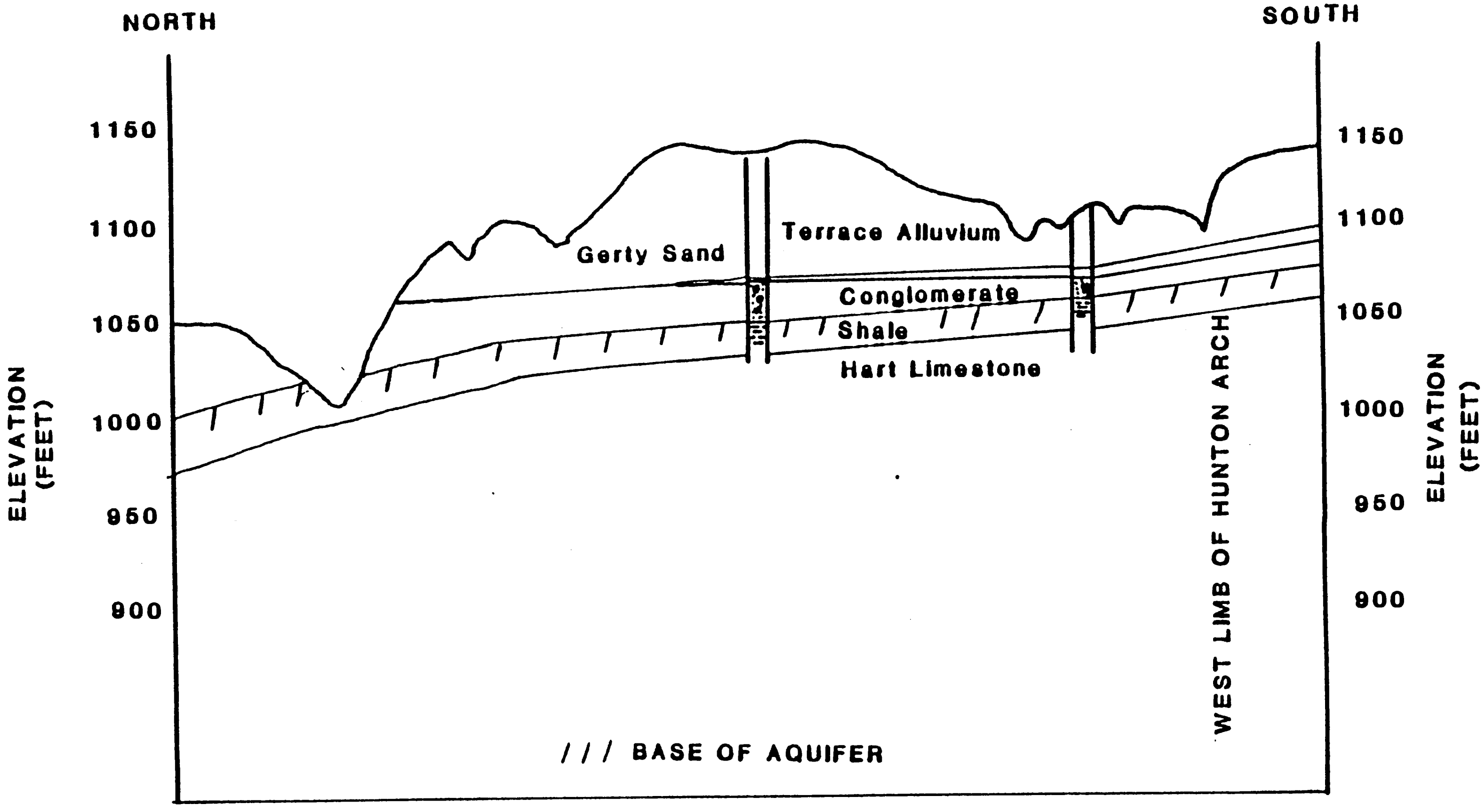

FIGURE 4. GENERAL HYDROGEOLOGIC MODEL OF THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA, NORTH-SOUTH TOPOGRAPHIC PROFILE.

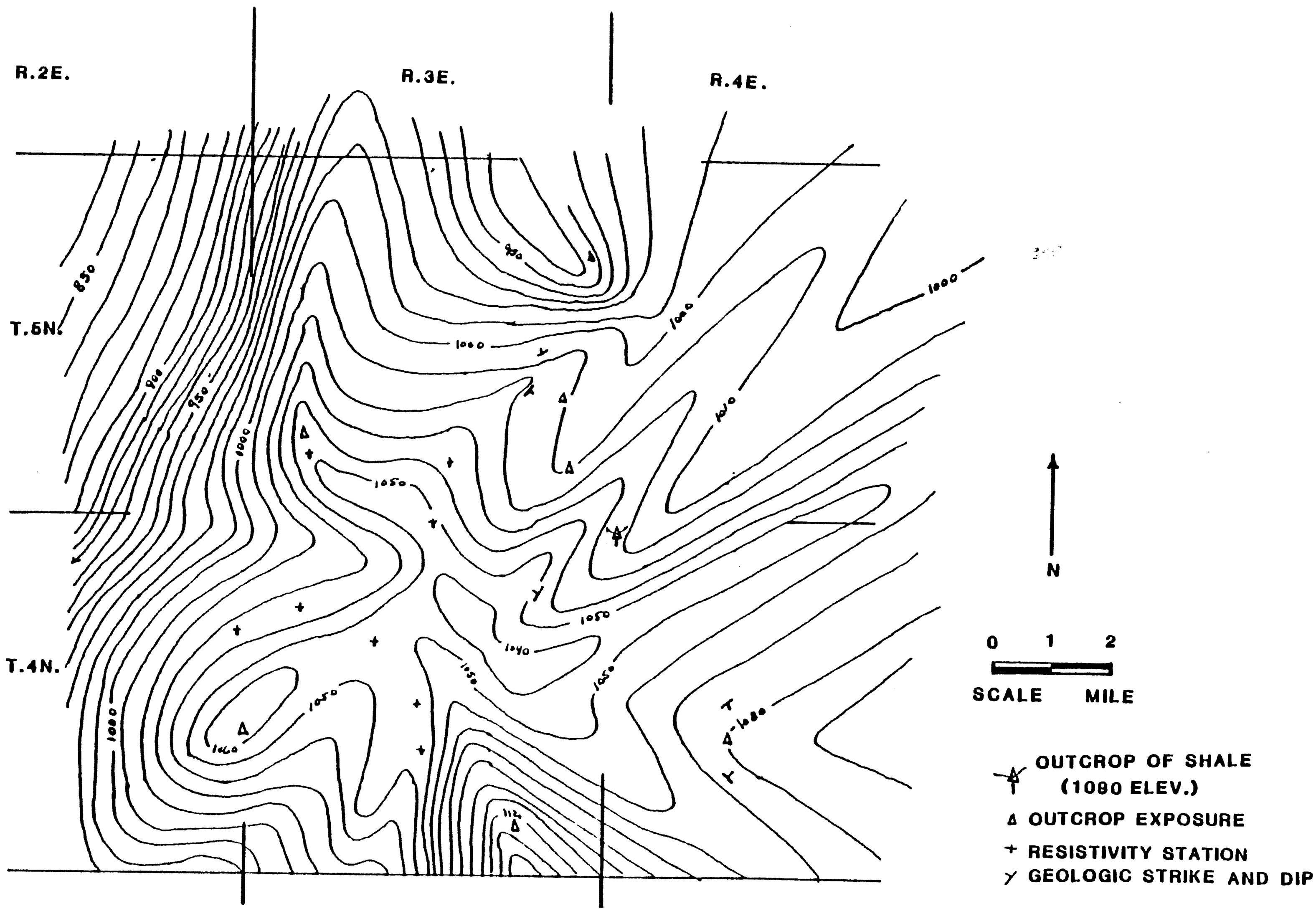

FIGURE 5. CONCEPTURALIZED BEDROCK MAP OF THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

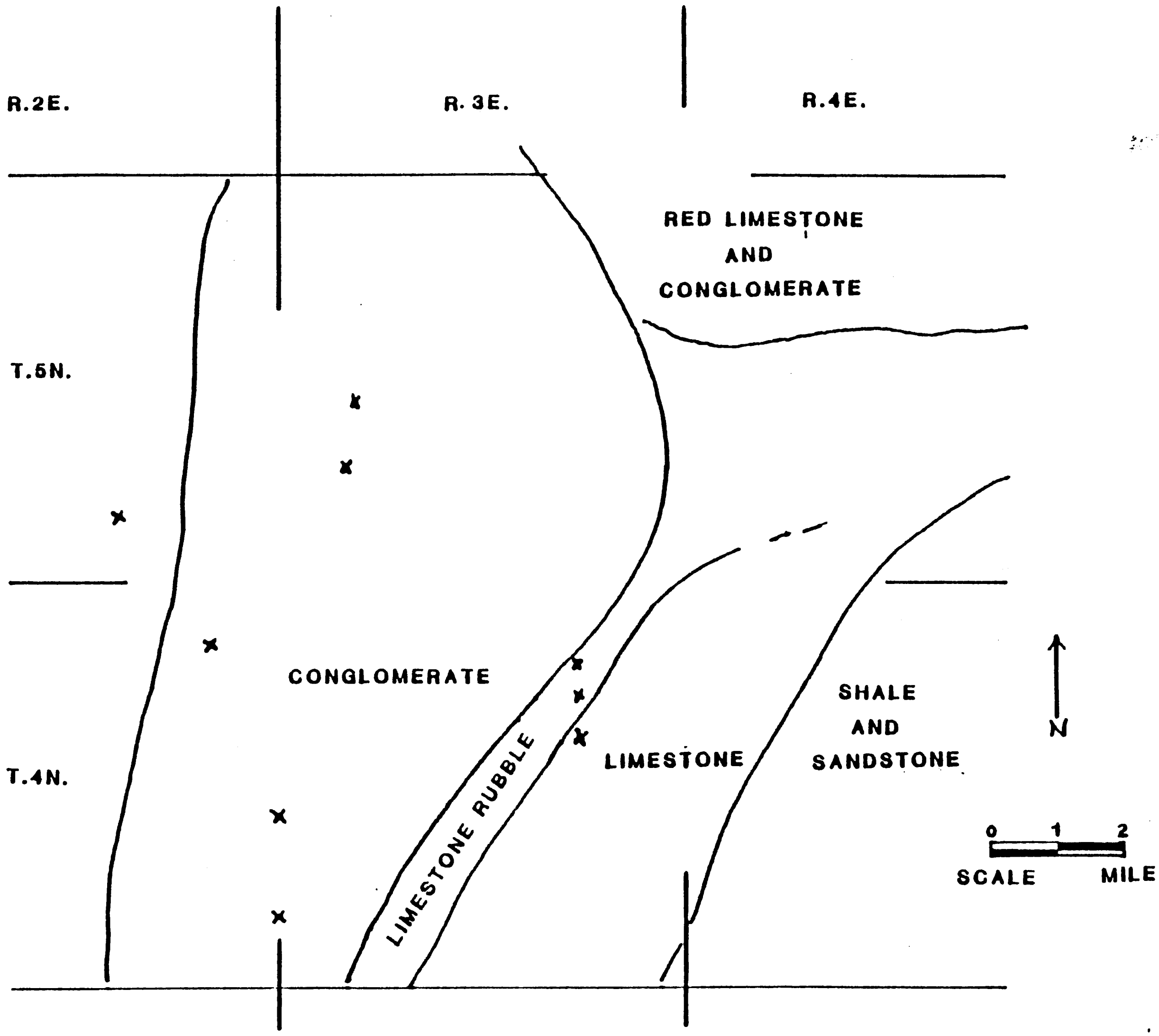

FIGURE 6. LITHOLOGIC FACIES MAP OF THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

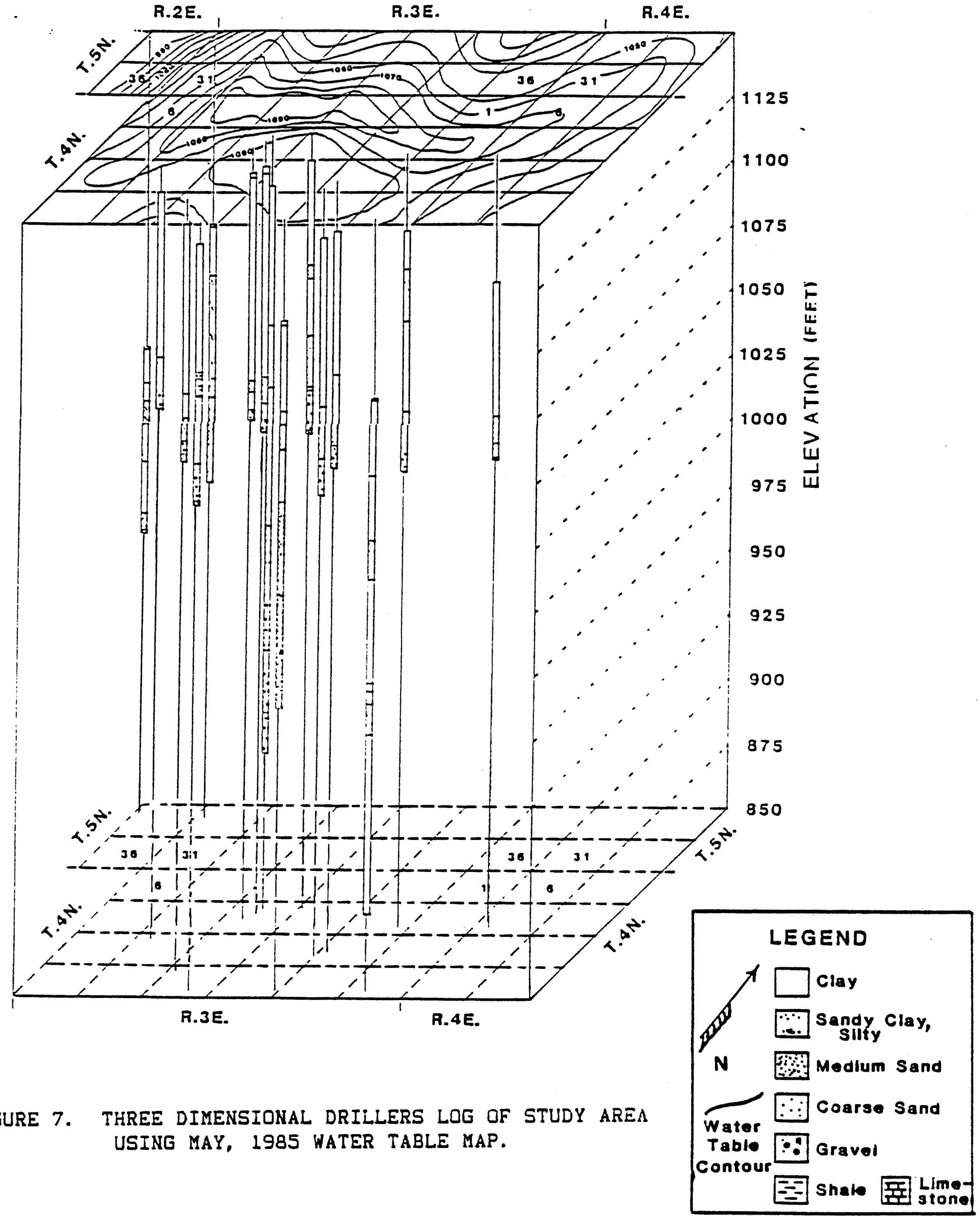

FIGURE 7. THREE DIMENSIONAL DRILLERS LOG OF STUDY AREA USING MAY, 1985 WATER TABLE MAP.

area. Elevations are assigned to driller logs, water level measuring sites, and outcrop exposures.

The bedrock elevation values were determined from driller's logs from the Oklahoma Water Resource Board, from geophysical surveys, and outcrop exposures exposed throughout the study area. The plotting and mapping of well log descriptions and outcrop exposures resulted in a bedrock map. The bedrock map reflects the convoluted or deformed erosional surface of the Oscar Group formations measured in the field.

Geophysical Surveys

Field Methods

Geophysical surveys were conducted in the Isolated Terrace deposit inorder to determine the extent of the aquifer. A Bison Earth Resistivity Meter Model 2350 was used to fill gaps in the data, to determine the water table and extent of lithologic units of conglomerate, limestone, gerty and recent sands, inorder to derive a bedrock map for computer modeling purposes. The resistivity method was used as a method to determine shallow subsurface sand and gravel investigations. In this investigation, the surveys were made at a station by moving the four electrodes at four foot, equal, intervals (a-spacing) to reach a depth of approximately 110 feet.

The apparent resistivity was calculated from the following equation (Bison, 1969):

$$Pa - A(2\pi V/I)$$

Where Pa is apparent resistivity in ohm/ft, A is a-spacing in feet, V is voltage in volts, and I is current in milliamperes. Apparent resistivity versus depth were graphed for the 14 stations in a grided fashion across the study area. Two survey stations were correlated closely to drillers irrigation well logs descriptions or geologic logs. Resistivity graphs for the 14 survey stations can be seen in Appendix C. Figure 8 shows the distribution and location of the 14 resistivity stations across the study area. The two resistivity stations closely related to the geologic logs are coded CA and BF. Other resistivity stations, in the close proximity of irrigation wells were correlated to irrigation well logs and outcrop exposures. Table I shows a typical resistivity data for the station of Byars, or code CA. Figure 9 shows the graph of resistivity station CA with the drillers log as a comparison for interpretations. The interpretation of different lithologic units are that sand and gravels will have a high resistivity value. Dry sand and gravels will have a higher apparent resistivity value. The value of resistivity is attributed to the ion free moisture contained in the lithologic unit. Clay and silts will tend to have a lower apparent resistivity value. Also, the greater the depth of investigation will produce a lower apparent resistivity value.

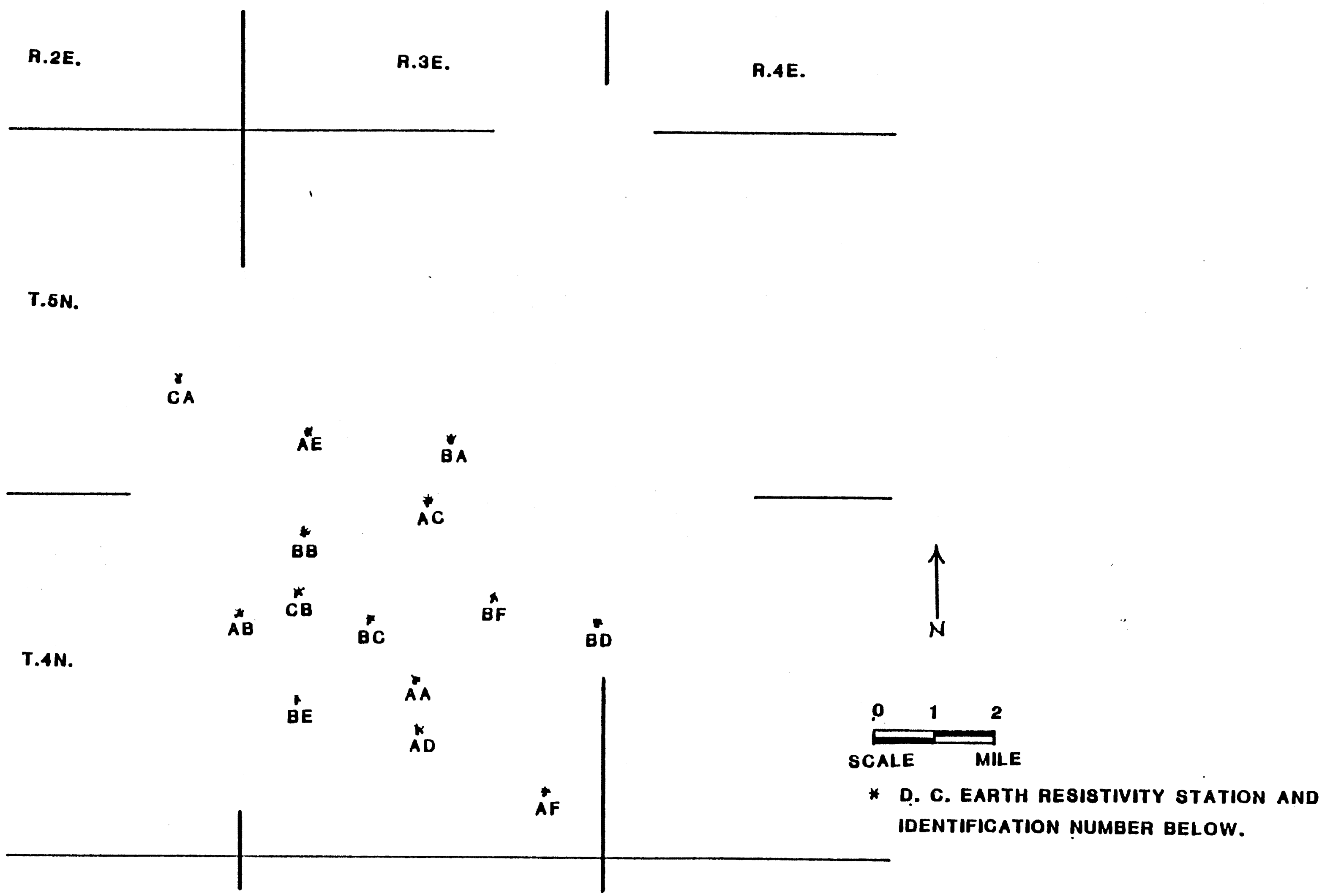

FIGURE 8. D. C. EARTH RESISTIVITY STATION DISTRIBUTION AND LOCATION MAP.

TABLE I

RESISTIVITY DATA FOR STATION CA IN T.5N., R.2E.
IN THE NE.1/4 OF THE NE.1/4 OF THE NE.1/4
OF SECTION 26, E.-W. ROAD.

Electrode Black (P) inner	Electrode Red (I) outer	A-space (feet)	Dial reading (2IIV/I)	Multiplier	Apparent Resistivity (ohm/ft)
2	6	4	782.0	0.01	31.28
4	12	8	430.6	0.01	34.45
6	18	12	400.0	0.01	48.00
8	24	16	327.6	0.01	52.42
10	30	20	346.6	0.01	69.32
12	36	24	256.0	0.01	61.44
14	42	28	266.0	0.01	74.48
16	48	32	263.2	0.01	84.22
18	54	36	240.0	0.01	86.40
20	60	40	231.4	0.01	92.56
22	66	44	204.0	0.01	89.76
24	72	48	202.2	0.01	97.06
26	78	52	162.4	0.01	84.45
28	84	56	191.6	0.01	107.30
30	90	60	179.0	0.01	107.40
32	96	64	233.4	0.01	149.38
34	102	68	288.0	0.01	195.84
36	108	72	133.5	0.01	96.12
38	114	76	935.2	0.001	71.08
40	120	80	145.8	0.01	116.64
42	126	84	176.4	0.01	148.18
44	132	88	102.8	0.01	90.46
46	138	92	163.0	0.01	149.96
48	144	96	151.6	0.01	145.54
50	150	100	876.0	0.001	87.60

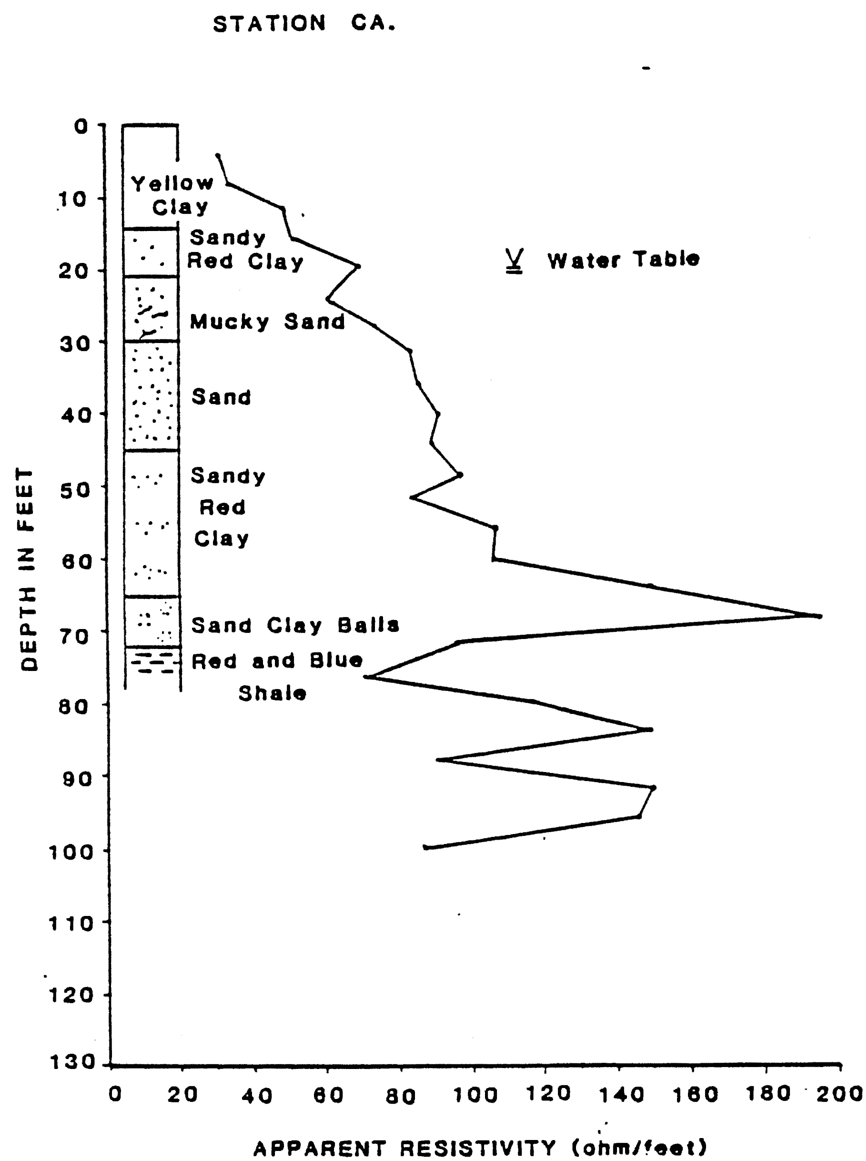

FIGURE 9. D. C. EARTH RESISTIVITY STATION CA GRAPH.

Climate

Precipitation

The Isolated Terrace deposit (Gerty Sand) in McClain, Garvin, and Pontotoc Counties, Oklahoma has a continental type climate. The average annual precipitation for a 35 year period of the study area was characterized for the stations of Ada (39.24), Konawa (38.09), Pauls Valley (33.21), and Purcell (36.67) in inches (see figures 10-13). The mean average annual precipitation over the entire study area is approximately 36.60 inches per year. The monthly distribution of precipitation is highest for the month of May, and January being the driest as can be seen in figures 14-17. The plot of a five year moving average of the annual precipitation for the 35 year period of (1950-1985) depicts a cyclic period of approximately seven years being drier than the mean, and the other seven years being wetter than normal. Appendix D shows the five year moving average of the annual precipitation for Ada, Konawa, Pauls Valley, and Purcell, Oklahoma. The five year moving average for Pauls Valley is not complete due to breaks in the annual reported data.

Evapotranspiration

The evapotranspiration yearly rate of 22.74 percent is estimated over the study area by using the most complete data available from the National Oceanic Atmospheric Administration publication for the recording stations throughout Oklahoma. The recording stations of Altus, Fort Gibson, Canton, Hulah, Great Salt Plains, Fort Supply, Keystone, Broken Bow, Grand River, Tenkiller Perry, Oolagah and Tipton

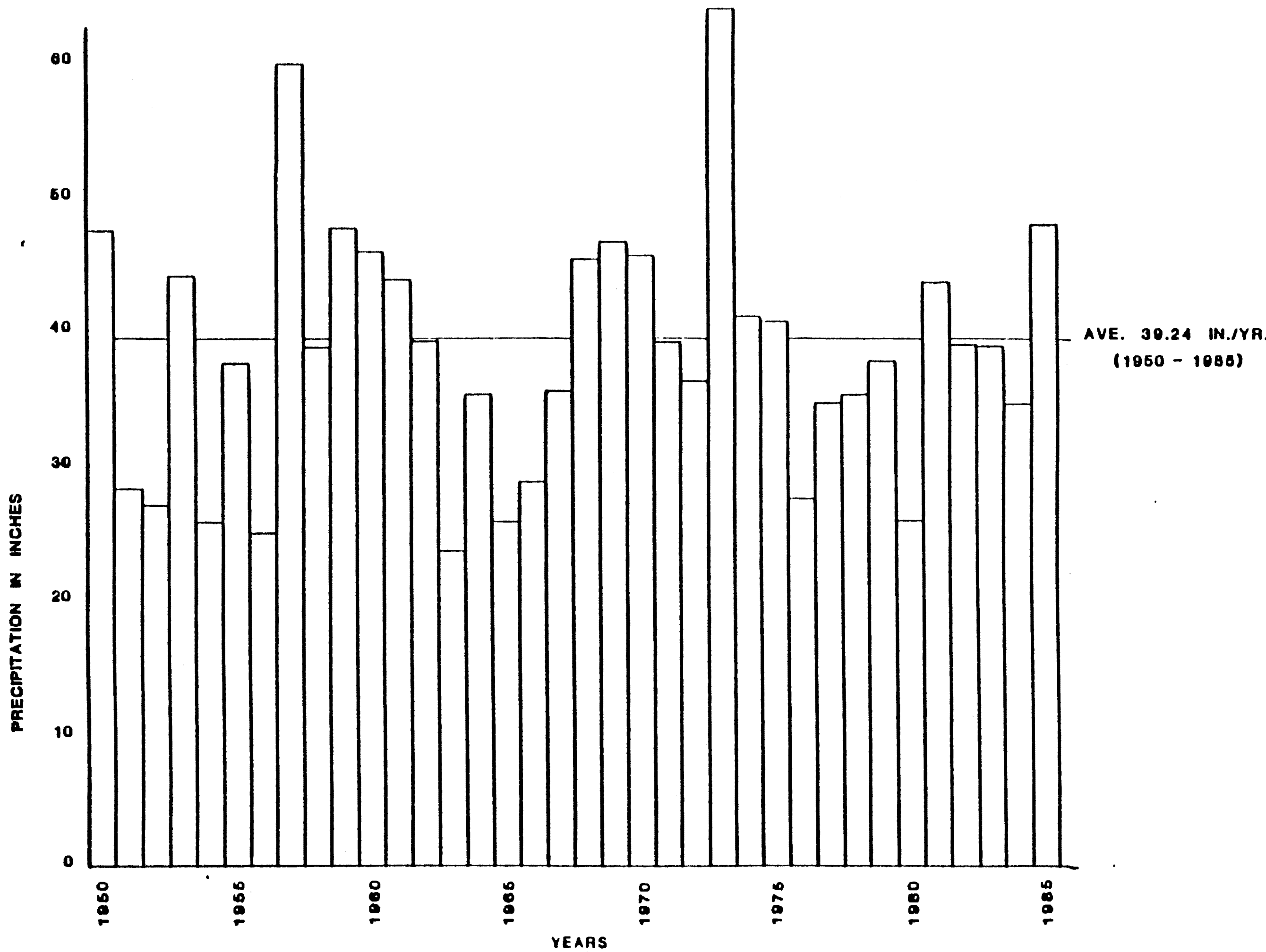

FIGURE 10. ANNUAL PRECIPITATION AT ADA, OKLAHOMA.

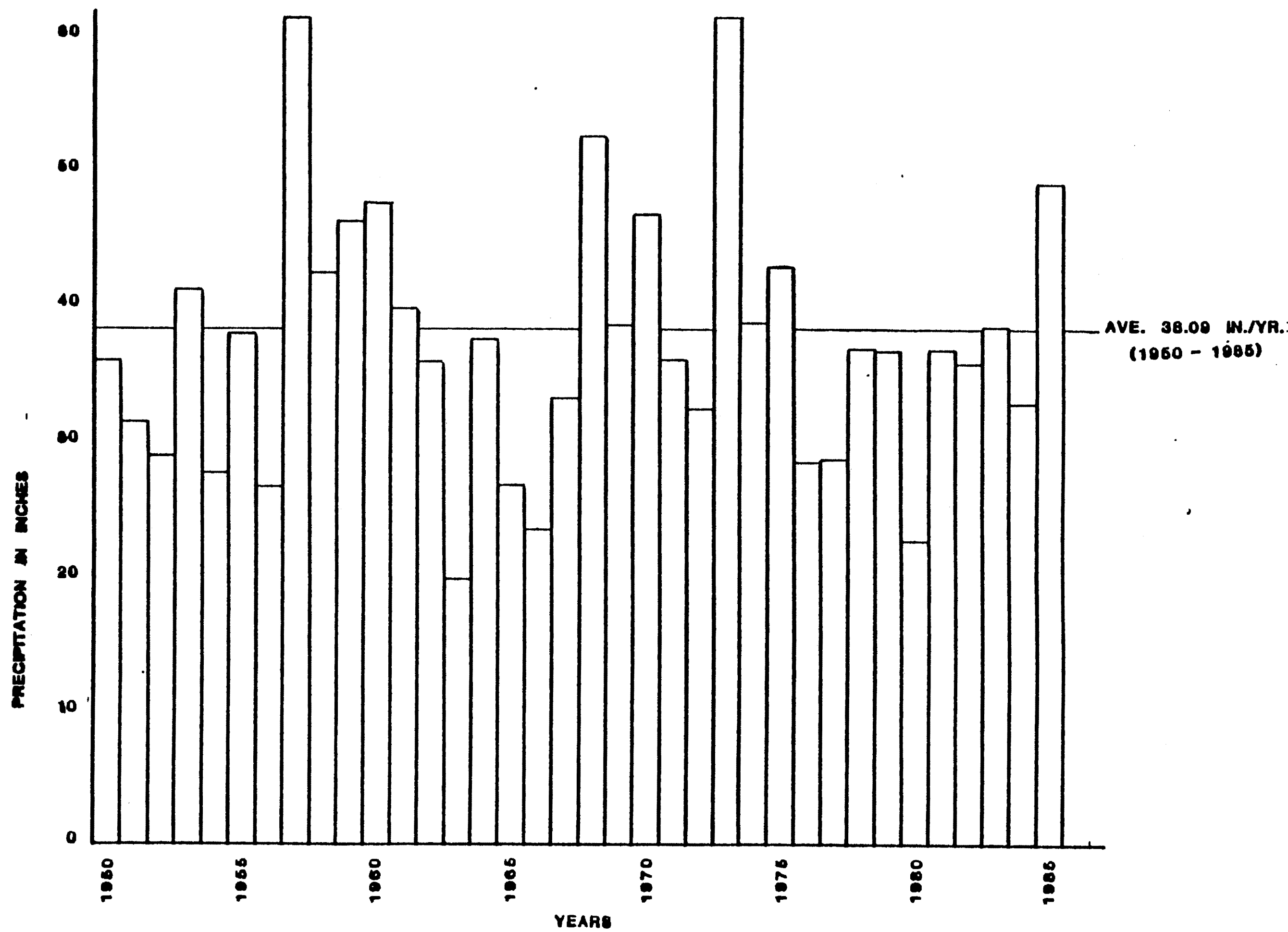

FIGURE 11. ANNUAL PRECIPITATION AT KONAWA, OKLAHOMA.

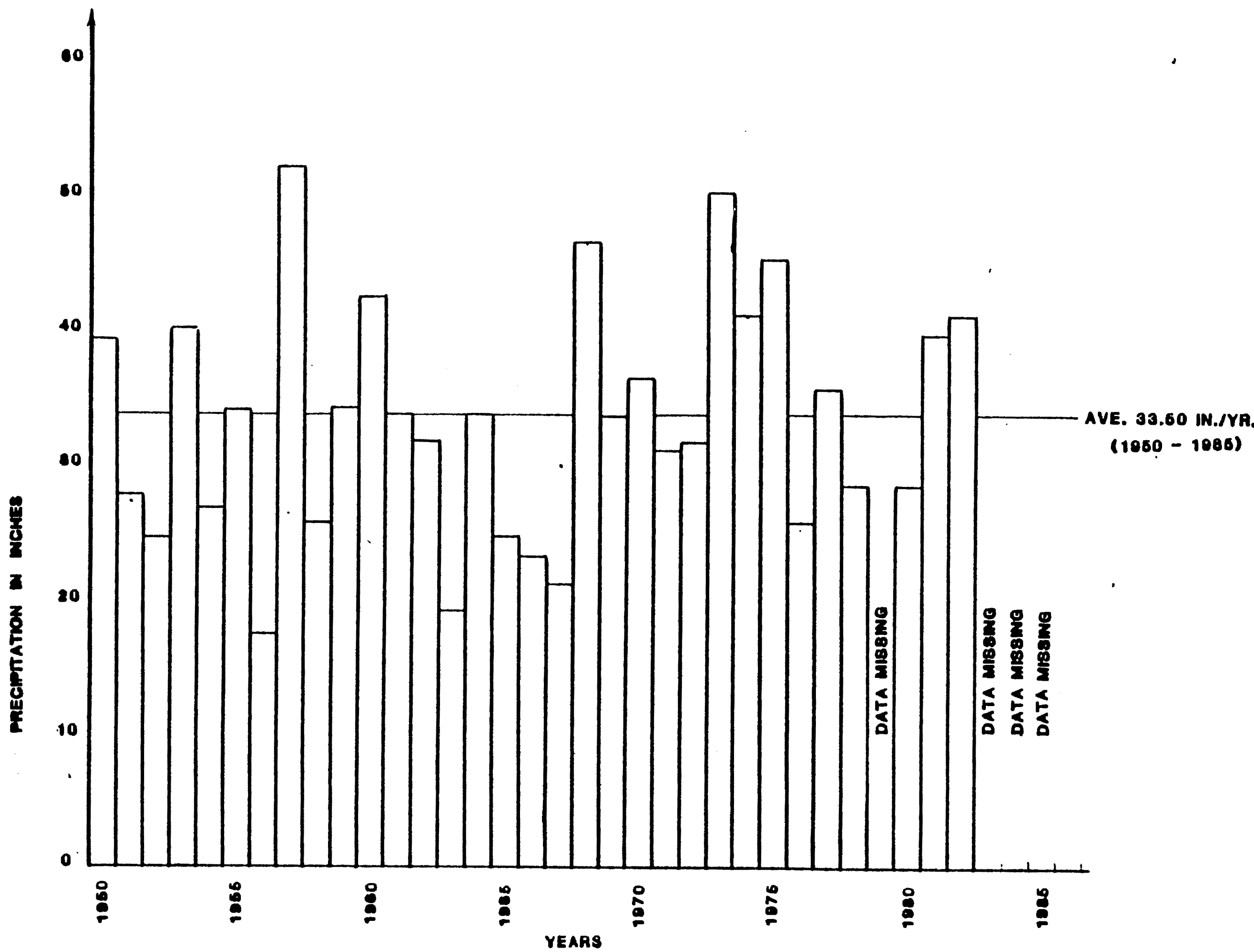

FIGURE 12. ANNUAL PRECIPITATION AT PAULS VALLEY, OKLAHOMA.

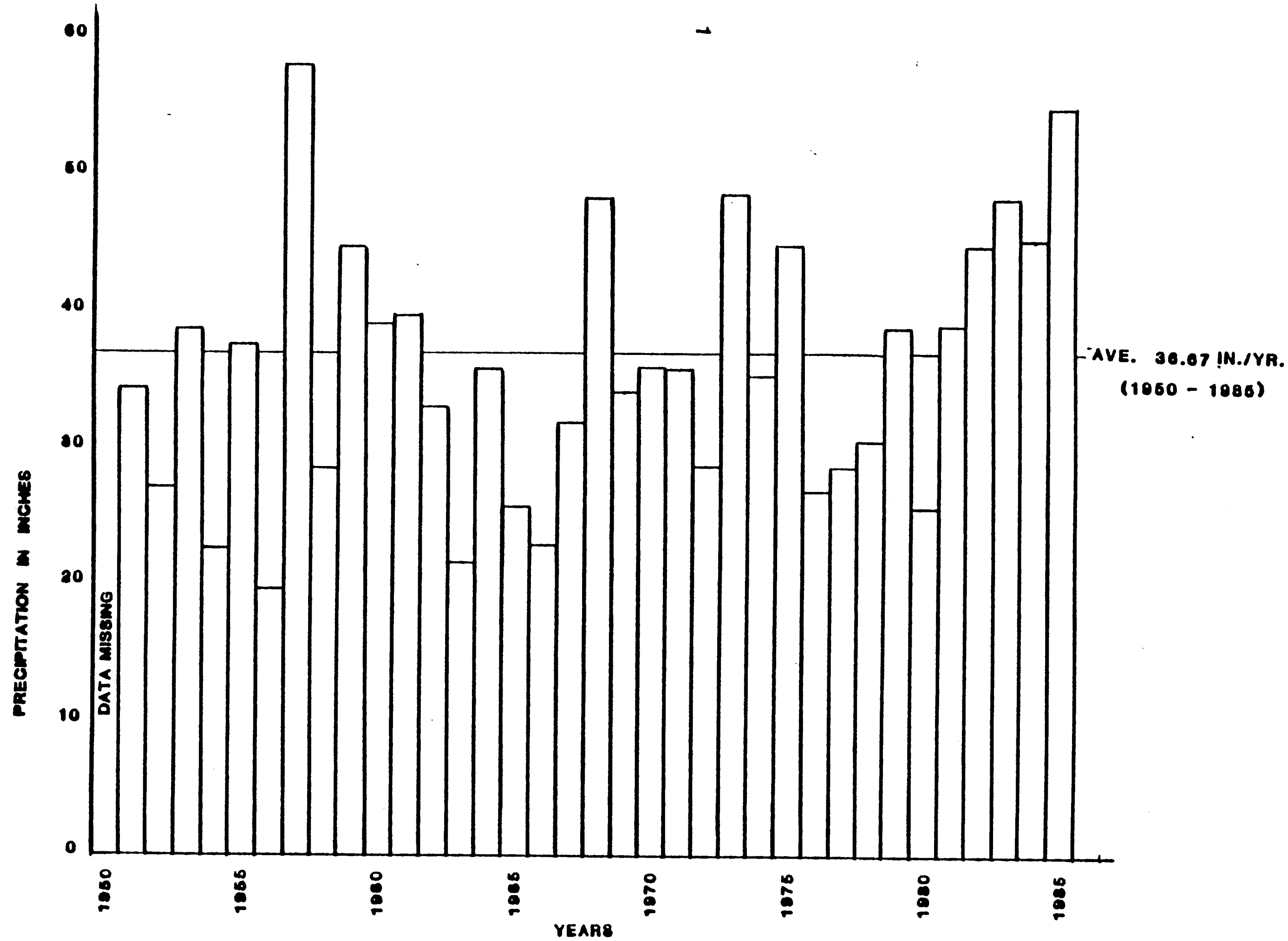

FIGURE 13. ANNUAL PRECIPITATION AT PURCELL, OKLAHOMA.

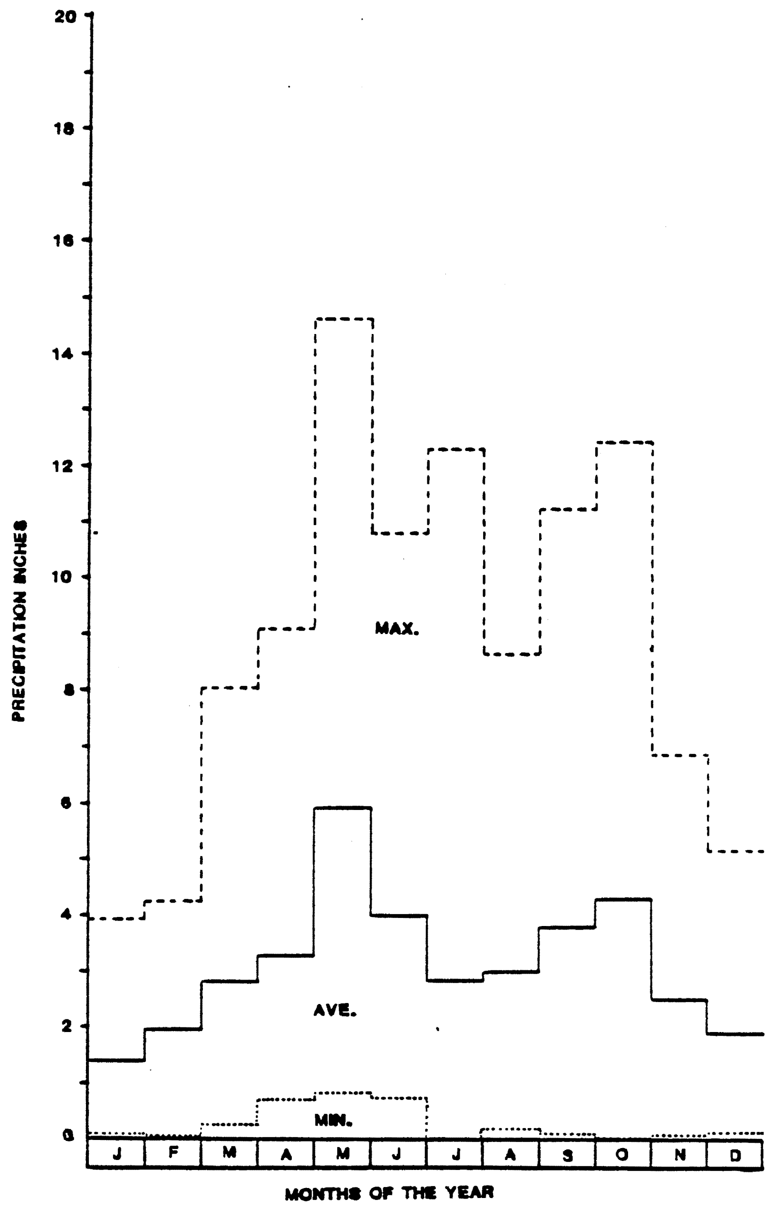

FIGURE 14. MONTHLY PRECIPITATION AT ADA, OKLAHOMA.
(1950-1985)

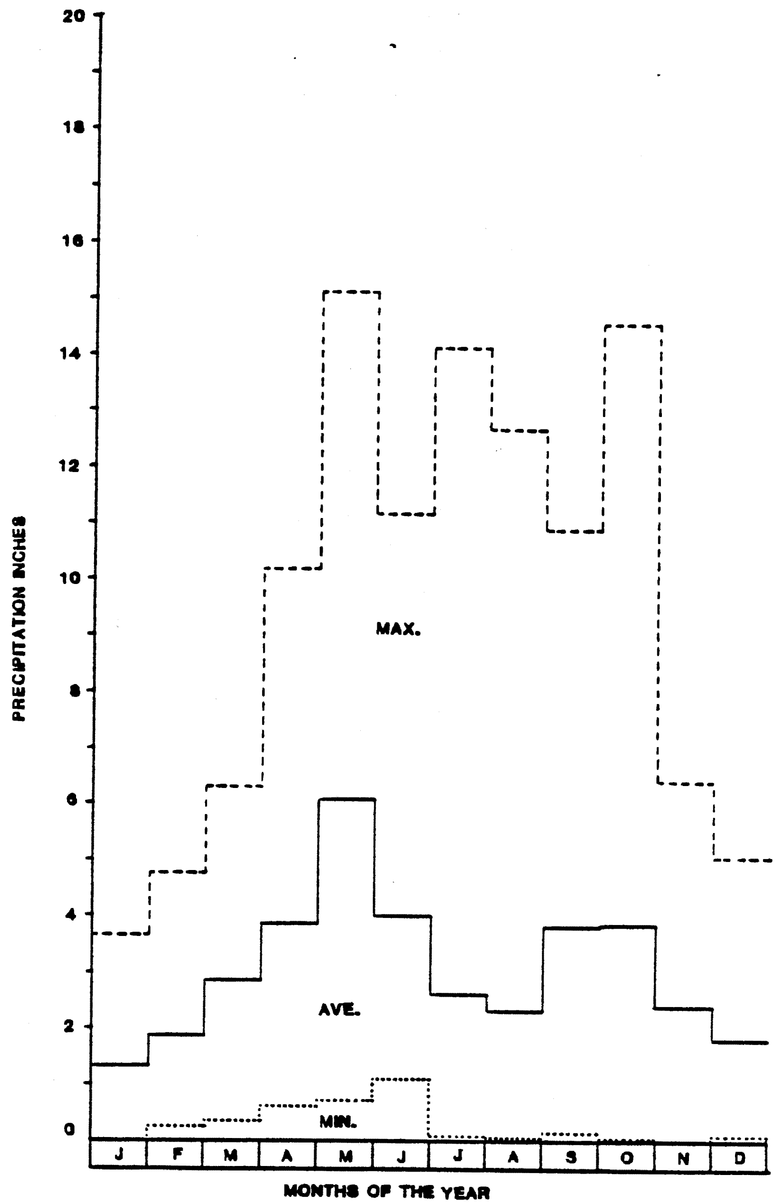

FIGURE 15. MONTHLY PRECIPITATION AT KONAWA, OKLAHOMA. (1950-1985)

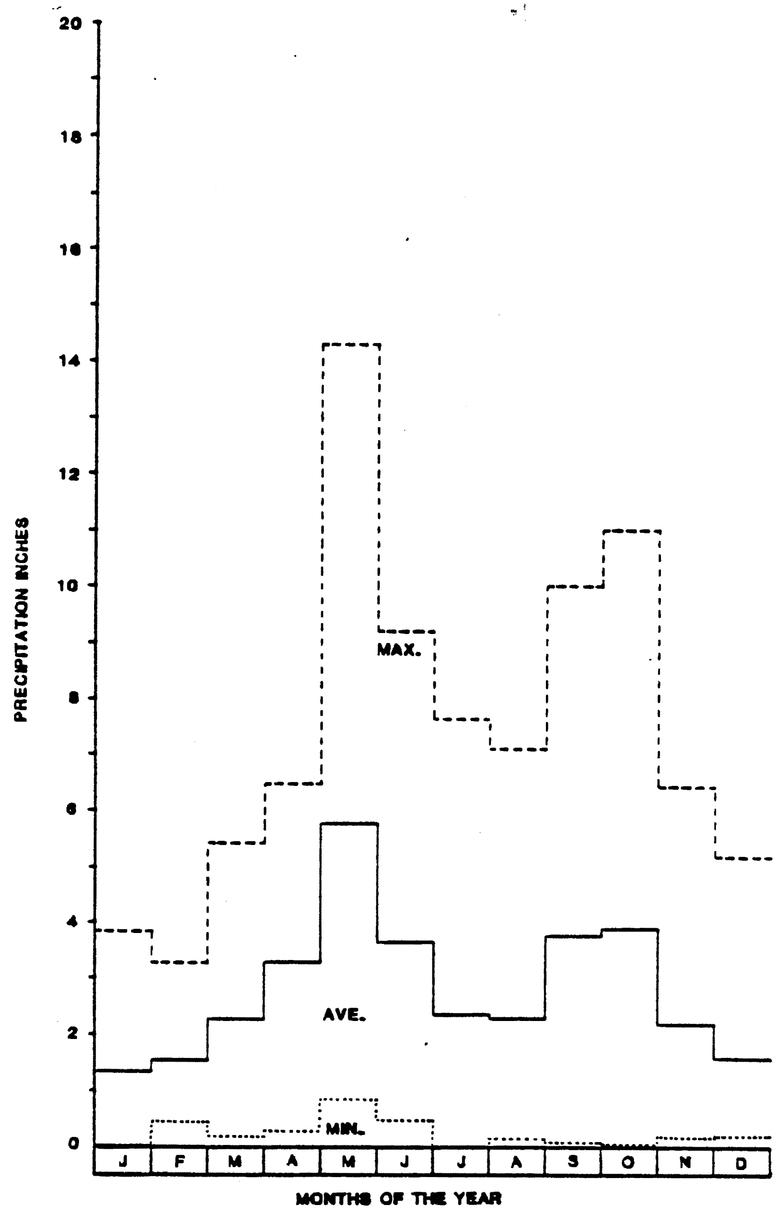

FIGURE 16. MONTHLY PRECIPITATION AT PAULS VALLEY, OKLAHOMA. (1950-1985)

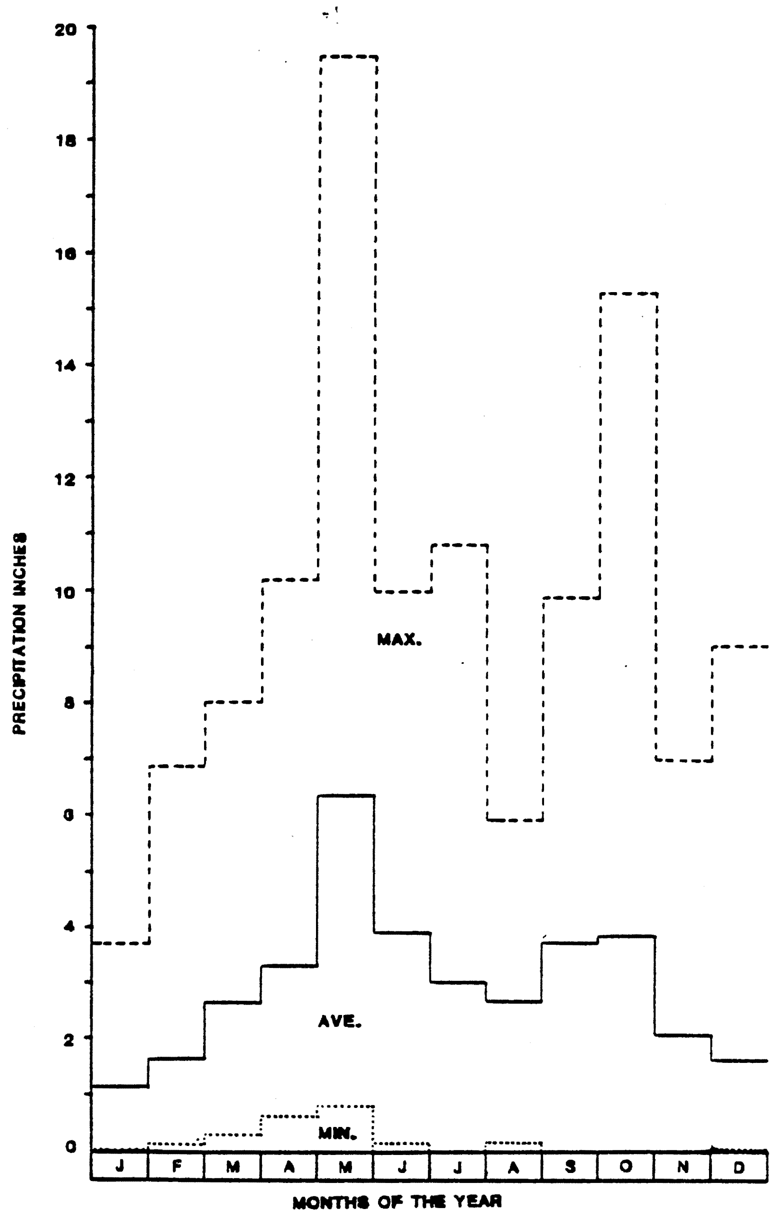

FIGURE 17. MONTHLY PRECIPITATION AT PURCELL, OKLAHOMA. (1950-1985)

Dams, and the Chickasa experiment station. All of these stations use the class A evaporation pan recorders. The majority of the stations data is complete. The evaporation rate distribution over the study area is estimated from a contoured evaporative rate map for the whole state of Oklahoma as shown in figure 18. The class A evaporative pan data is mainly taken during the vegetation growing cycle of May to October. The evaporative rate map for the whole state of Oklahoma for the period of May to October can be seen in figure 19. The evaporative rate on a monthly basis reveals July to be the highest of Approximately 34.5 percent across the study area. The evaporation rate maps on a monthly basis from May to October can be seen in Appendix E.

Temperature

The average monthly temperature for Ada, Pauls Valley, and Purcell, Oklahoma can be seen in Table II.

TABLE II

AVERAGE MONTHLY TEMPERATURE FOR ADA, PAULS VALLEY, AND PURCELL, OKLALHOMA.

Station	J	F	M	A	M	J	J	A	S	O	N	D
Ada	33.2	37.8	55.6	63.5	70.8	77.0	81.9	82.9	75.3	62.9	51.0	37.5
Pauls Valley	-	-	57.3	64.7	71.3	77.2	82.2	83.8	76.1	-	50.5	39.1
Purcell	32.0	38.5	55.8	63.0	70.6	76.7	-	82.9	75.5	62.9	48.7	36.1

Source: Oklahoma Climate Survey, 1985.

The recording station of Ada, Oklahoma has the most complete record and is the closest to the study area.

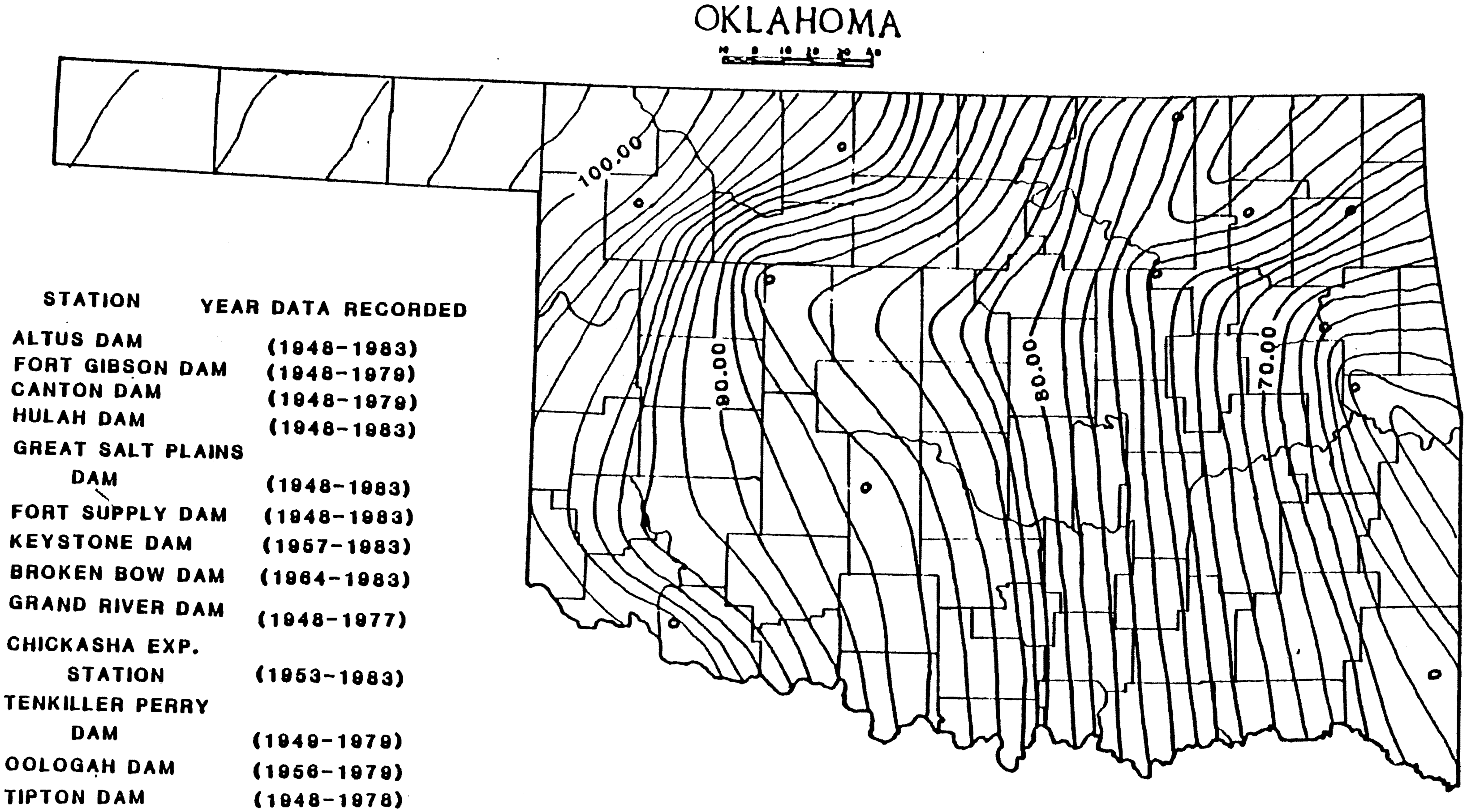

FIGURE 18. JANUARY TO DECEMBER EVAPORATION ISOHYET MAP.
(in inches for years 1948-1983)

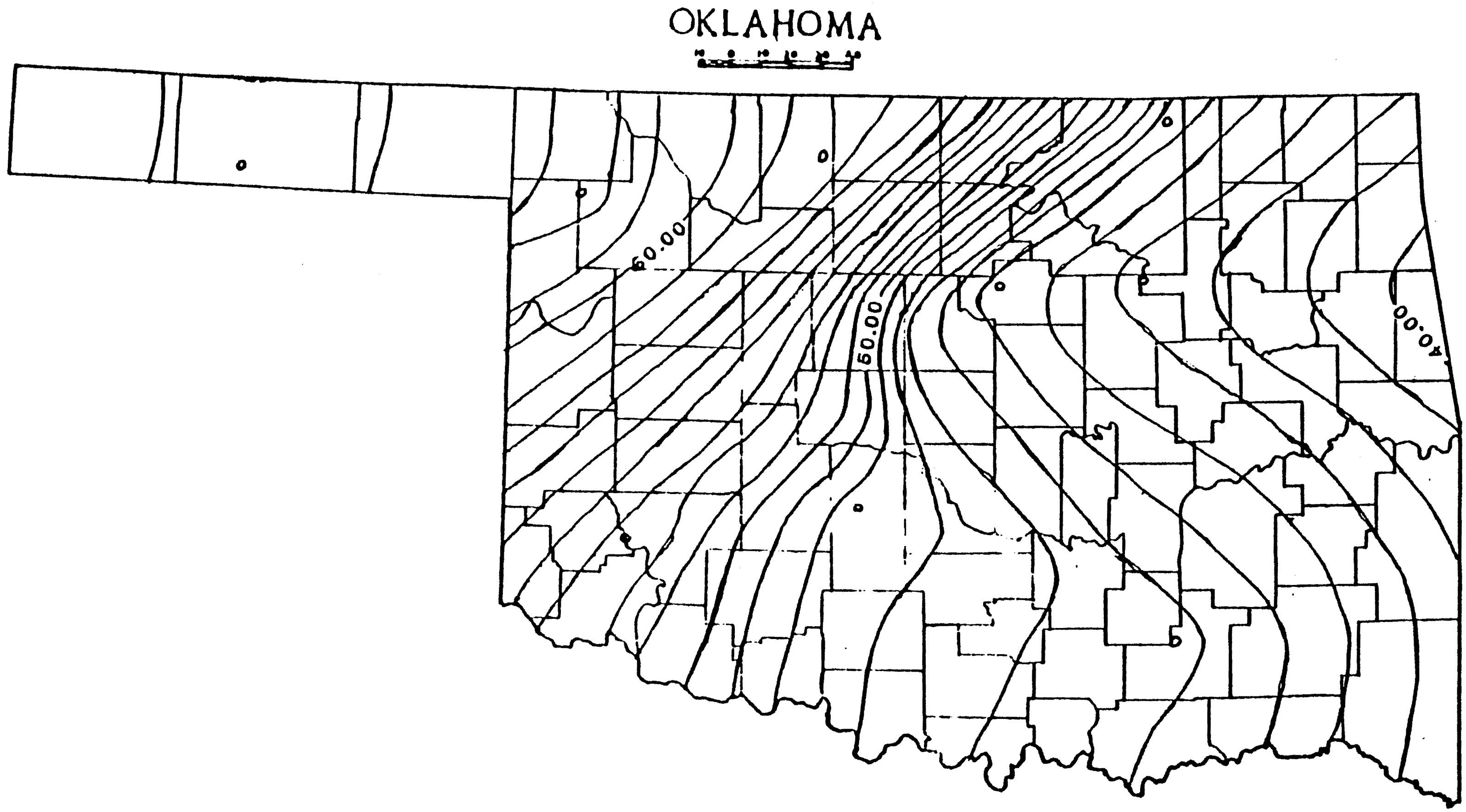

FIGURE 19. MAY TO OCTOBER EVAPORATION ISOHYET MAP.
(in inches for years 1963-1983)

Hydrogeology

Water Table

The Isolated Terrace Deposit is an unconfined aquifer, with some areas being partly confined by clay or shale layers. The development of a water table map was made by plotting water level measurements that were measured in the study area in May, August, November, 1985; and March, 1986 from private domestic wells thoughout the study area. Figure 20 shows the May, August, and November, 1985 and March 1986 water level measuring, water quality, and irrigation well aquifer test site location map. Figures 21-24 shows the water table maps from May to November, 1985 to March, 1986.

Hydrograph

The constant monitoring of water levels was made by installing four hydrograph recorders in the study area. Upkeep and maintenance was done by the Oklahoma Water Resource Board, Ground Water Division. The best maintained hydrograph record is the Aeromotor site located in the W.1/2 of the NW.1/4 of Section 2, T.4N., R.3E.. Figures 25 shows the hydrograph record from May 22,1985 to December 31, 1985 for the Aeromotor hydrograph. Figure 26 shows the Aeromotor hydrograph record from January 1, 1986 to November 1, 1986. Other hydrograph sites are located in the NW.1/4 of the SW.1/4 of Section 11, the SW.1/4 of the NW.1/4 of the NW.1/4 of Section 23, and the SE.1/4 of the SW.1/4 of the SW.1/4 of Section 4, T.4N., R.3E.. Mechanical problems caused some of the hydrograph data to have large broken records. Some of the problems include clock stopping, pen skipping, float or wire catching in the

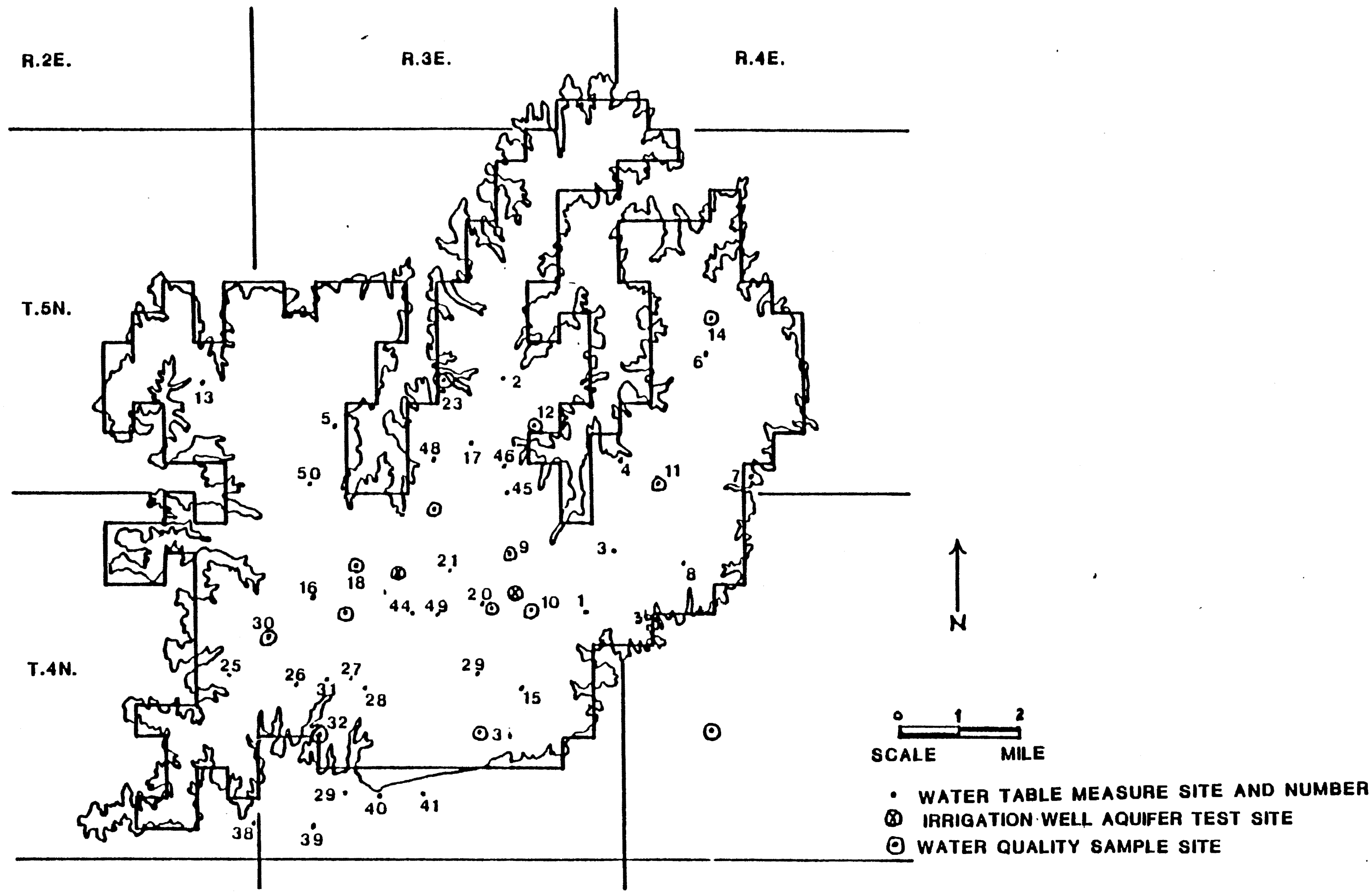

FIGURE 20. MAY, AUGUST, AND NOVEMBER, 1985: AND MARCH, 1986 WATER LEVEL MEASURING, WATER QUALITY, AND IRRIGATION WELL AQUIFER TEST SITE LOCATION MAP.

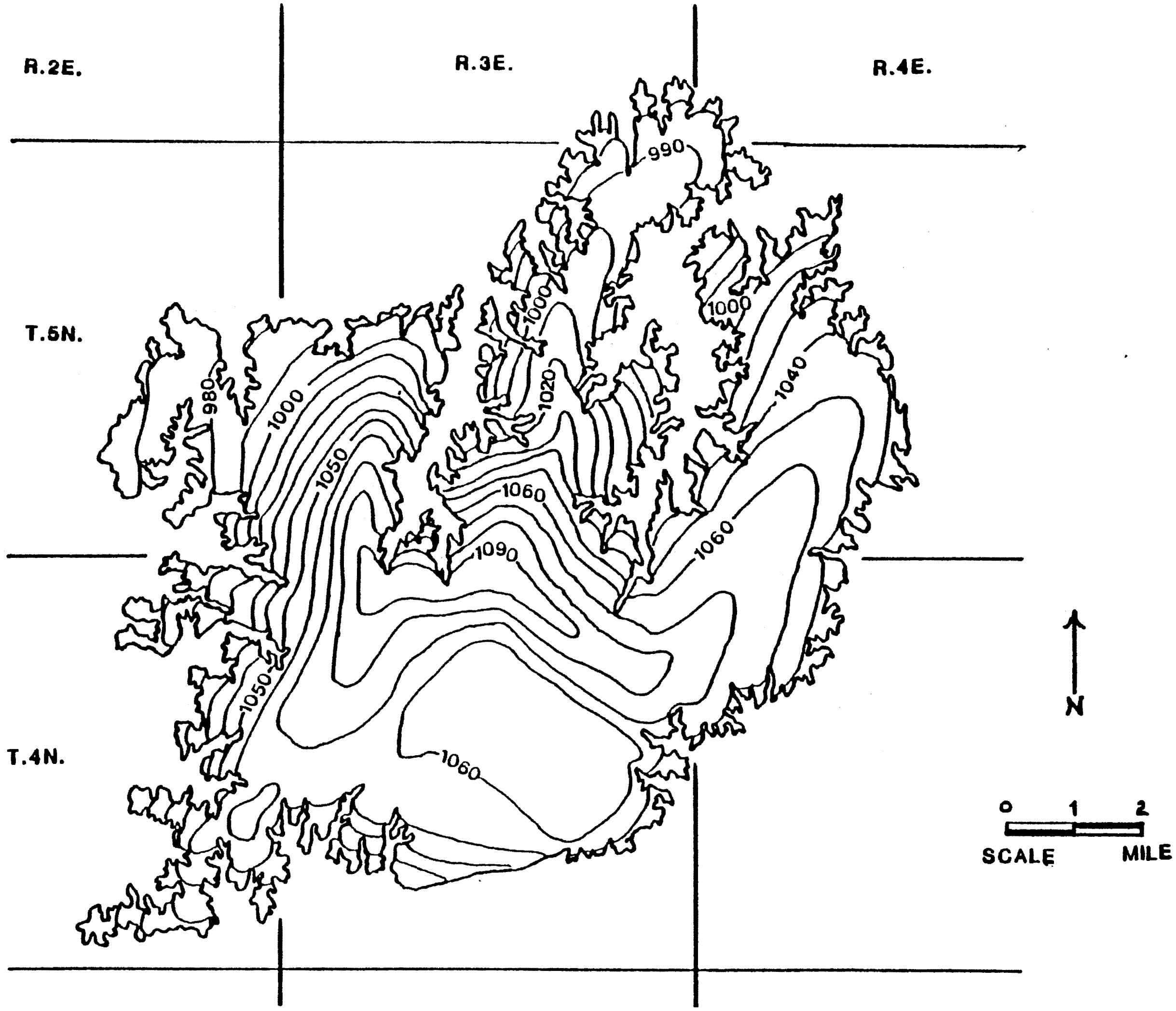

FIGURE 21. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. MAY 21-22, 1985 WATER TABLE MAP.

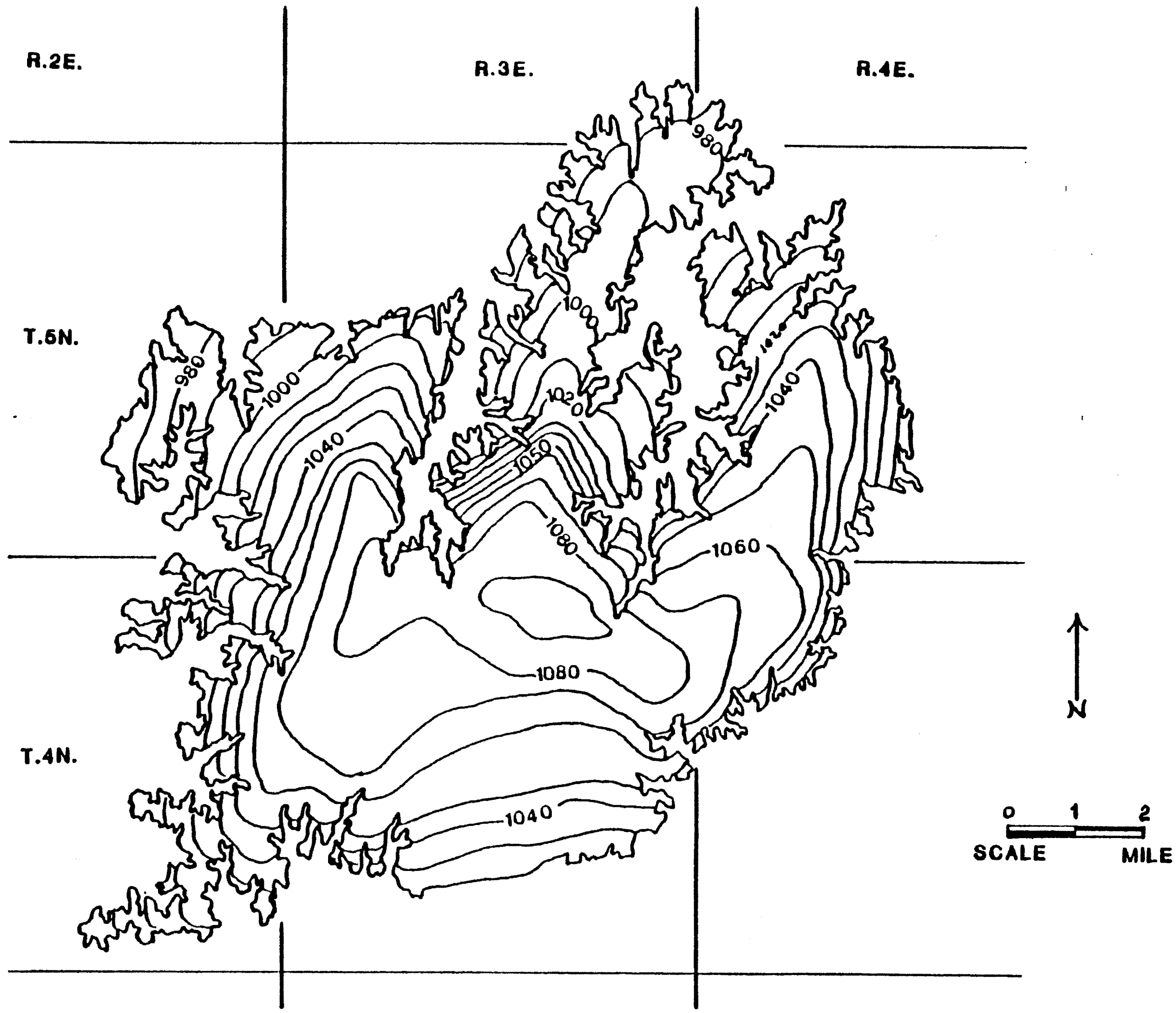

FIGURE 22. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. AUGUST 12, 13, AND 17, 1985 WATER TABLE MAP.

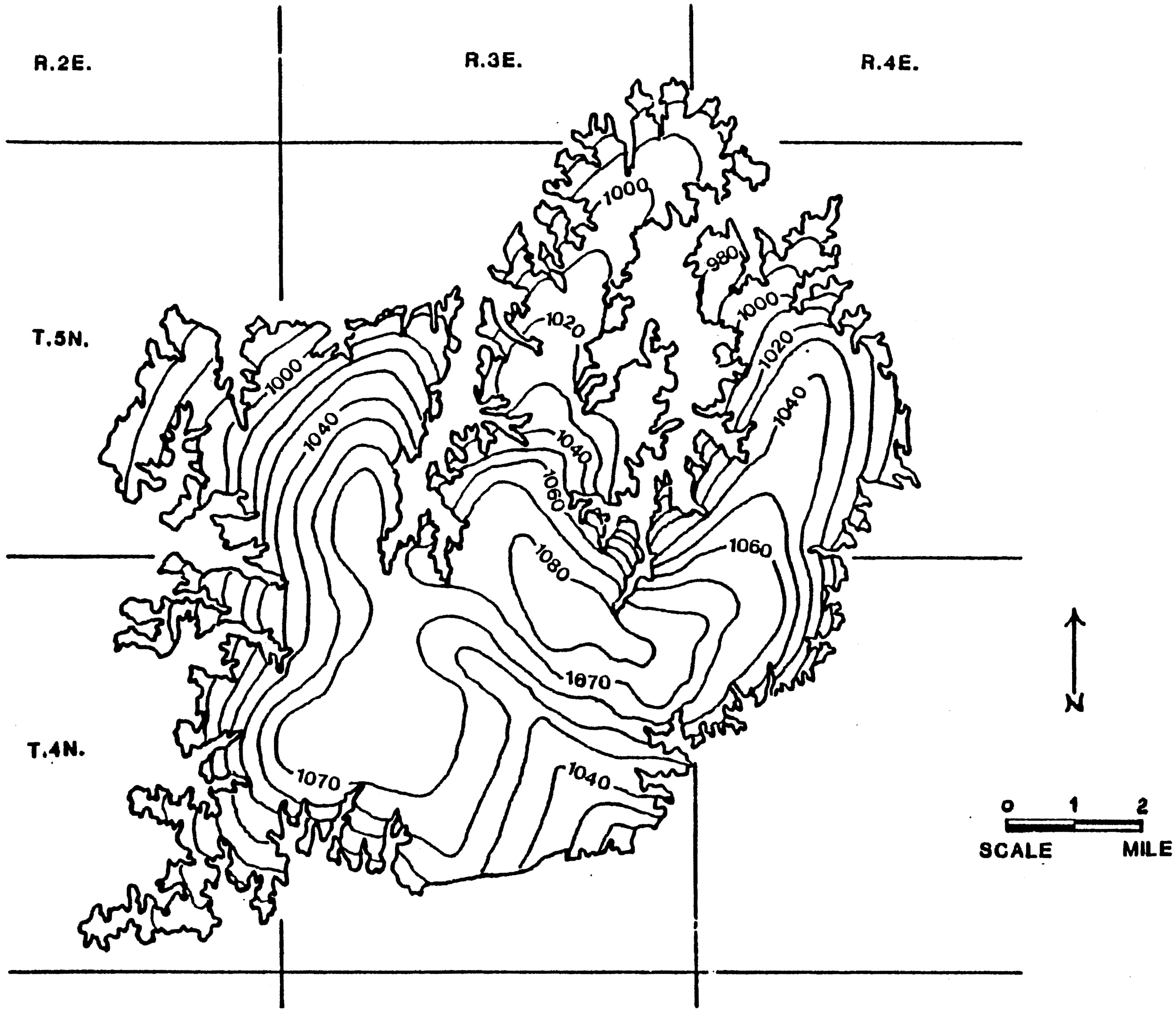

FIGURE 23. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. NOVEMBER 11, AND 19, 1985 WATER TABLE MAP.

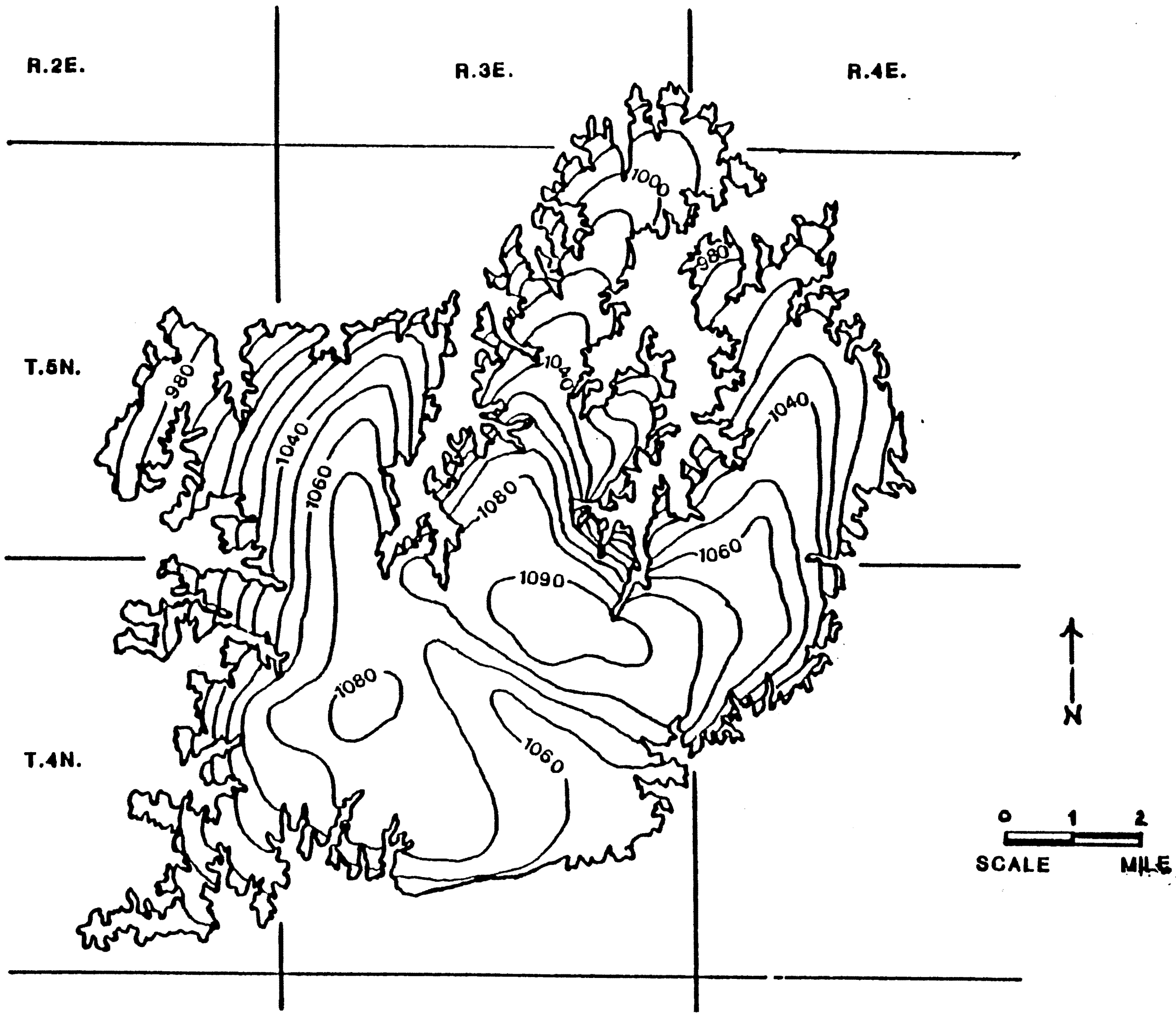

FIGURE 24. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. MARCH 5, AND 6, 1986 WATER TABLE MAP.

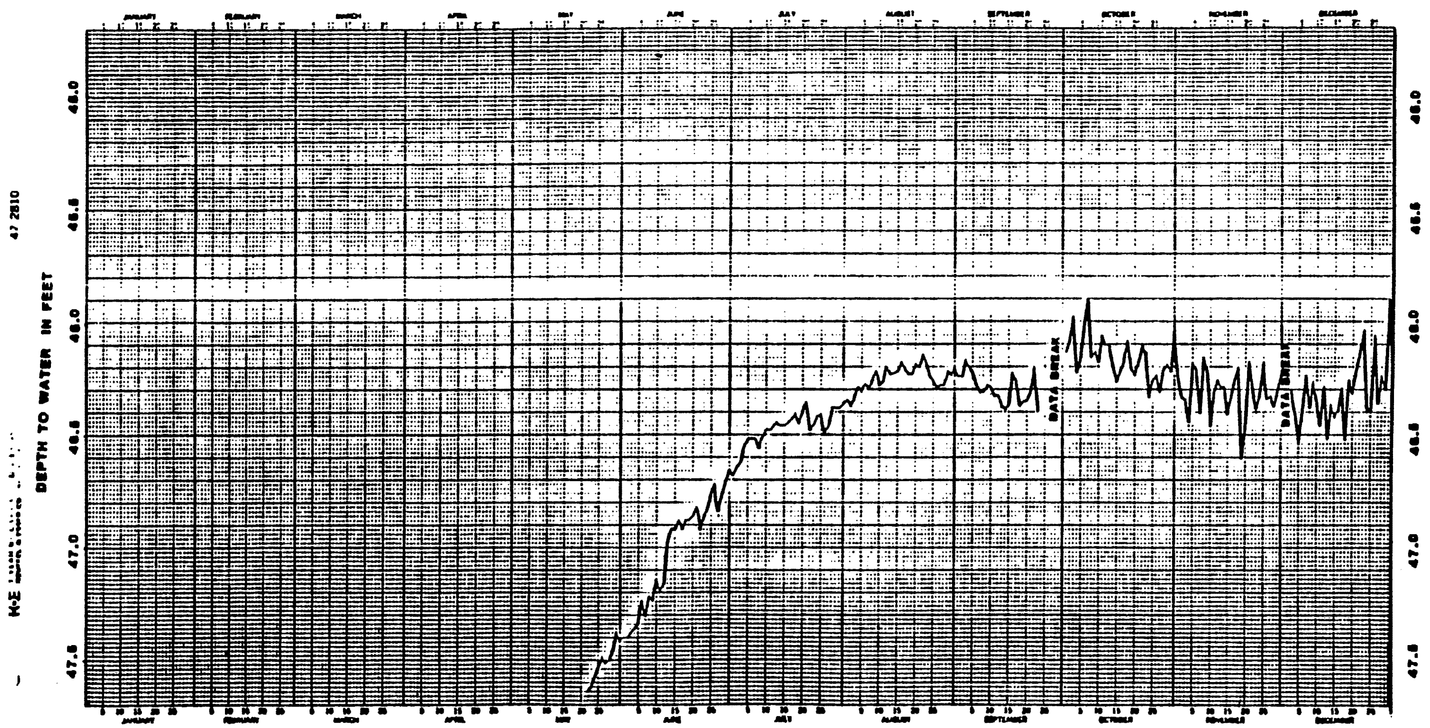

FIGURE 25. AEROMOTOR HYDROGRAPH RECORD FROM MAY 22, 1985 TO DECEMBER 31, 1985.

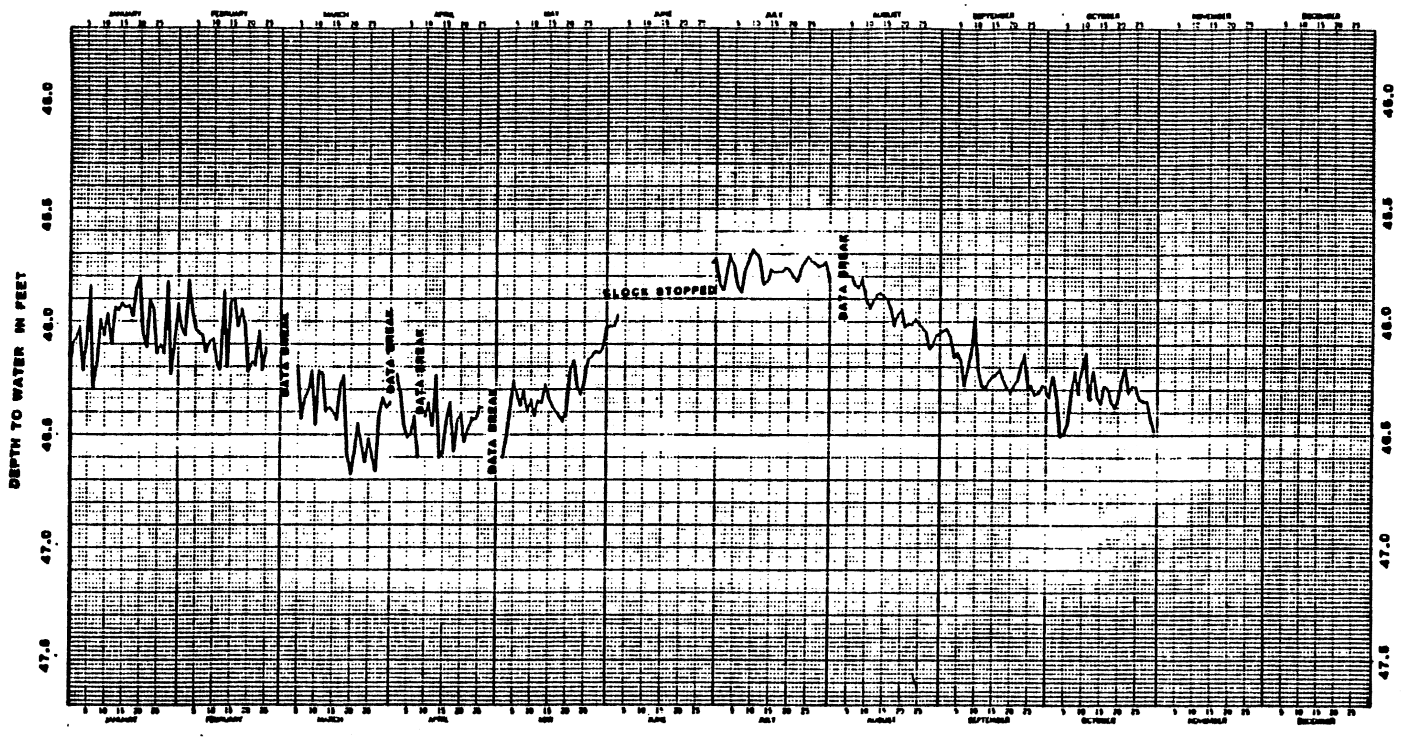

FIGURE 26. AEROMOTOR HYDROGRAPH RECORD FROM JANURARY 1, 1986 TO NOVEMBER 1, 1986.

well, etc.. Overall, each hydrograph reflects approximately the same data. Figure 27 shows the typical hydrograph record for the period of June 29, 1986 to August 5, 1986. One day on the Hydrograph record is approximately three squares. The water level is measured at 45.74 feet from the surface of the ground. The representation of dailey peaks on the hydrograph record is the phreatophytic consumption and evapotranspiration. Studies of these fluctuations has resulted in an equation to calculate the dailey evapotranspiration for a particular period. The phreatophytic consumption and evapotranspiration is calculated during the middle of the month, the week of the 15th.

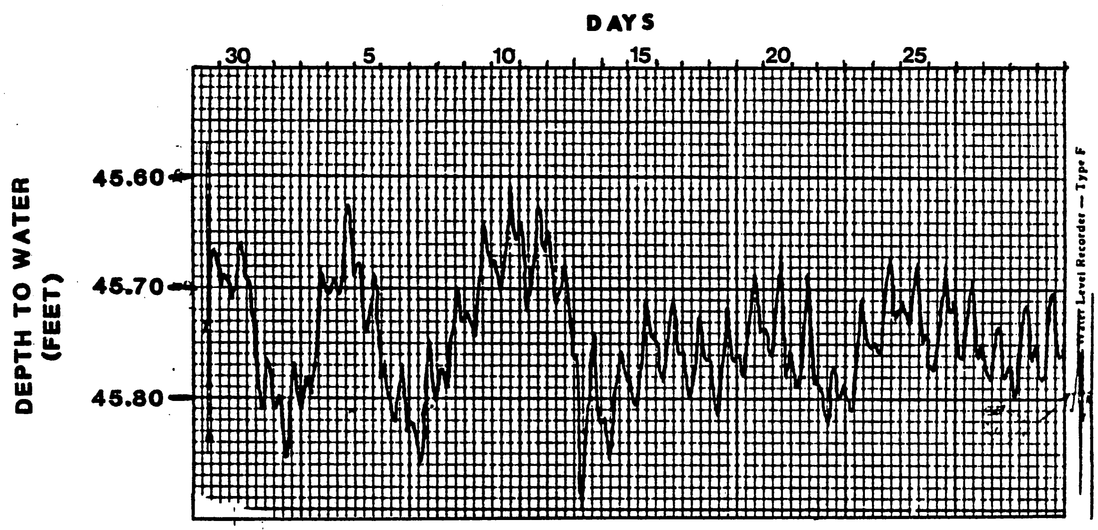

Figure 27. Aeromotor Hydrograph Record from June 29, 1986 to August 5, 1986.

The equation for a 24 hour period as adopted by Freeze, et. al., (1979):

$$E = Sy\ (24r + s)$$

Where E is the actual dailey evapotranspiration (L/Day), Sy is the specific yield of the soil, r is the hourly rate of ground water inflow (L/H), and s is the net rise or fall of the water table during the 24 hour period (L), in inches per month. Table III shows the calculated values of phreatophytic consumption and evapotranspiration from the Aeromotor, Block House, and Smith hydrograph record. These values are calculated only for the growing season of May to October 1985 and 1986. In the equation the Sy value used is 0.10 for the specific yield. The differences in the calculated values is due to the soil texture types and vegetation surrounding the hydrograph location.

TABLE III

PHREATOPHYTIC CONSUMPTION AND EVAPOTRANSPIRATION VALUES FOR THE AEROMOTOR, BLOCK HOUSE, AND HYDROGRAPH DATA FOR 1985 AND 1986.

Site	Year	May	June	July	Aug.	Sept.	Oct.
Aeromotor	1985	-	0.936	0.528	0.940	1.028	0.960
	1986	0.692	-	0.874	1.536	1.008	-
Block house	1985	0.605	0.649	0.648	-	1.080	0.912
	1986	0.576	0.792	0.600	0.672	1.152	1.128
Smith	1985	0.416	-	0.456	0.594	0.480	0.804
	1986	0.632	0.634	0.764	0.768	0.570	-

The Aeromotor hydrograph is located on a medium grained unconsolidated sand with mostly praire grasses. The smith and block hydrograph is located on a sandy loam (Gerty Sand) type soil with seeded pasture grasses or farmland. The large fluctuations seen in the hydrograph record in figure 27 is due to barometric fluctuations, and recharge from precipitation.

The barometric pressure is recorded from weekly series weather maps from the National Oceanic and Atmospheric Administration, recorded in Millibars. Changes in atmospheric pressure produces an inverse relationship in the Isolated Terrace deposit. As barometric pressure increases the water table decreases in an unconfined aquifer (Freeze, et. al., 1979). The barometric efficiency is the ratio of hydraulic head over the change in atmospheric pressure as recorded by Freeze, et. al., (1979):

$$B = \frac{\gamma dh}{dPa}$$

Where B is the barometric efficiency, Pa is the atmospheric pressure, and γdh is the change in hydraulic head. The small fluctuation in an unconfined aquifer of the Isolated Terrace deposit is the effect of the change in pressure on air bubbles in the soil-moisture zone or between the saturated and unsaturated zone. Therefore, as pressure increases soil water replaces the entrapped air space causing the saturated zone of the water table to move upward. The barometric efficiency equation for the Isolated Terrace deposit has a range of 0.027 to 0.045 feet. This is the effective change in the hydraulic head of the water table in the hydrograph well. The rise in the water level may be due to a precipitation event on the same day or about a day in advance. This is the lag time for the water to reach the water table and raise the water table. Figure 28 shows the barometric pressure on a dailey basis for Oklahoma City for the year of 1985, and figure 29 shows the barometeric pressure on a dailey basis for Oklahoma City for the year of 1986. The data is plotted up to November 1, 1986.

The comparisons of the hydrograph and the barometric pressure records will show the apparent relationship of barometric pressure on

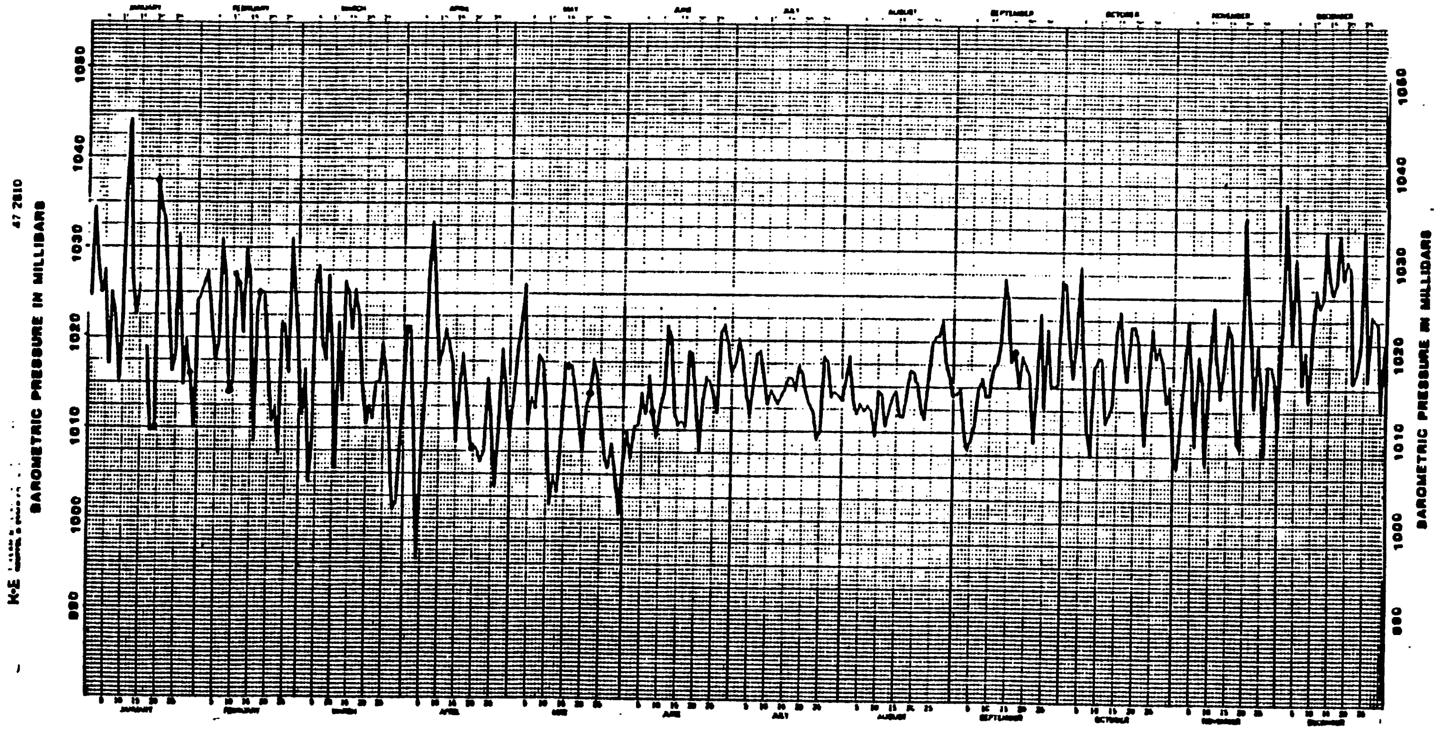

FIGURE 28. BAROMETRIC PRESSURE ON A DAILEY BASIS FOR OKLAHOMA CITY FOR YEAR 1985.

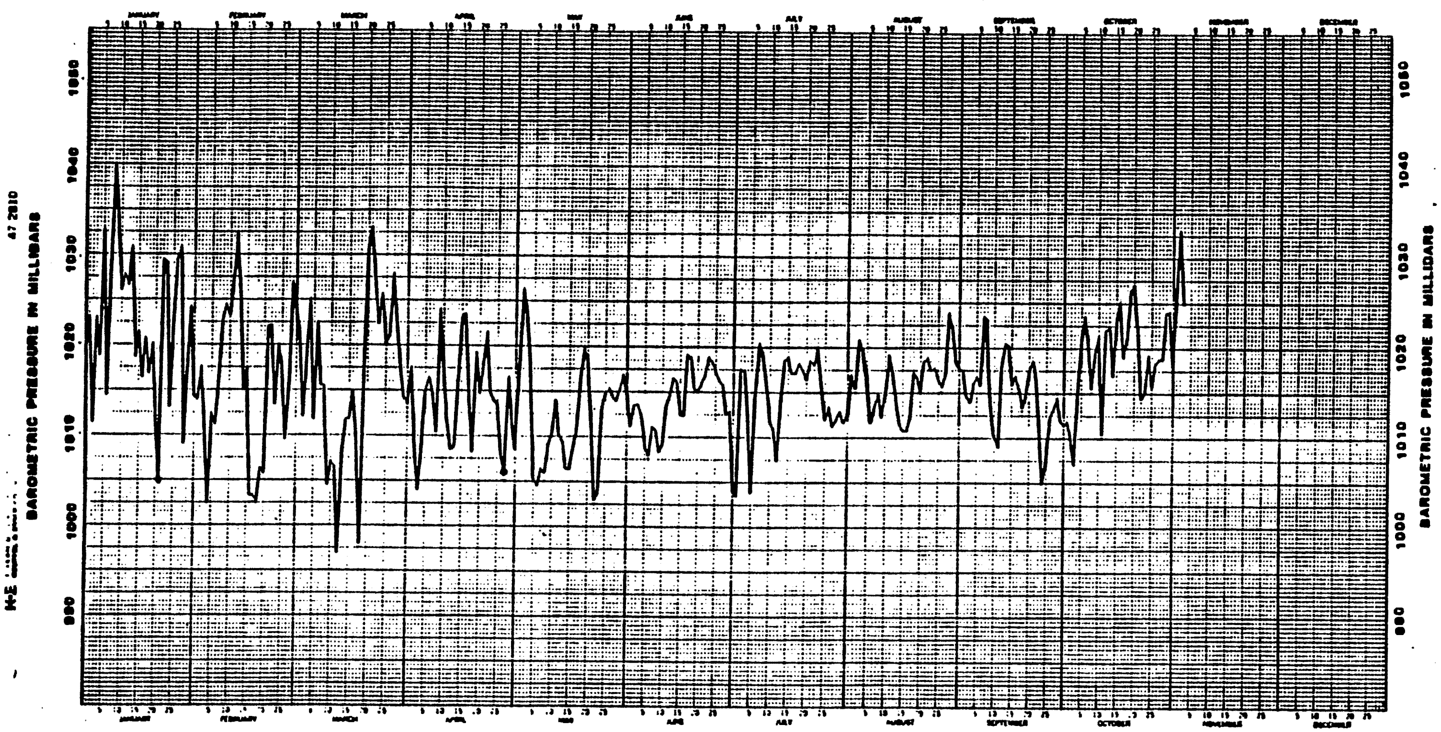

FIGURE 29. BAROMETRIC PRESSURE ON A DAILEY BASIS FOR OKLAHOMA CITY FROM JANUARY 1, 1986 TO NOVEMBER 1, 1986.

the water table. Figure 30 will show the dailey precipitation for the recording stations of Ada, Oklahoma for the year of 1985, and figure 31 will shows the dailey precipitation for the recording station of Ada, Oklahoma for the year of 1986 up to November 1, 1986. The dailey precipitation is recorded from the National Oceanic Atmospheric Administration monthly reports, and from the Oklahoma Climatological Survey of Norman, Oklahoma. The dailey precipitation is recorded a day earlier for Pauls Valley compared to the other stations of Ada, Konawa, and Purcell, Oklahoma. The earlier precipitation event is attributed to the movement of weather fronts to the northeast from the southwest.

Irrigation Well Data

The distribution of irrigation wells was mapped by plotting well logs, prior right well legal descriptions, and by road survey. Figure 32 shows the irrigation well location and distribution map. Some of the irrigation well logs contain good lithologic descriptions and pertinent pump test results that were suppplied by local well drillers to the Oklahoma Water Resource Board. The well log pump test data for irrigation wells are listed in Table IV. Table IV will show the date of well completion, location, static water level, to pump ratings and type, and the power source initially proposed. The majority of the irrigation wells have electricity as a power source to pump the water. The variations in pump yield is due to changes in the composition of the terrace deposit, to changes in bedrock, and to the different well completions. The majority of the irrigation wells are located in a predominately flat sloped farm land. Towards the outer boundary of the terrace deposit is a few irrigation wells that have been abandoned due to the marginal characteristics of the farm land. The marginal land is

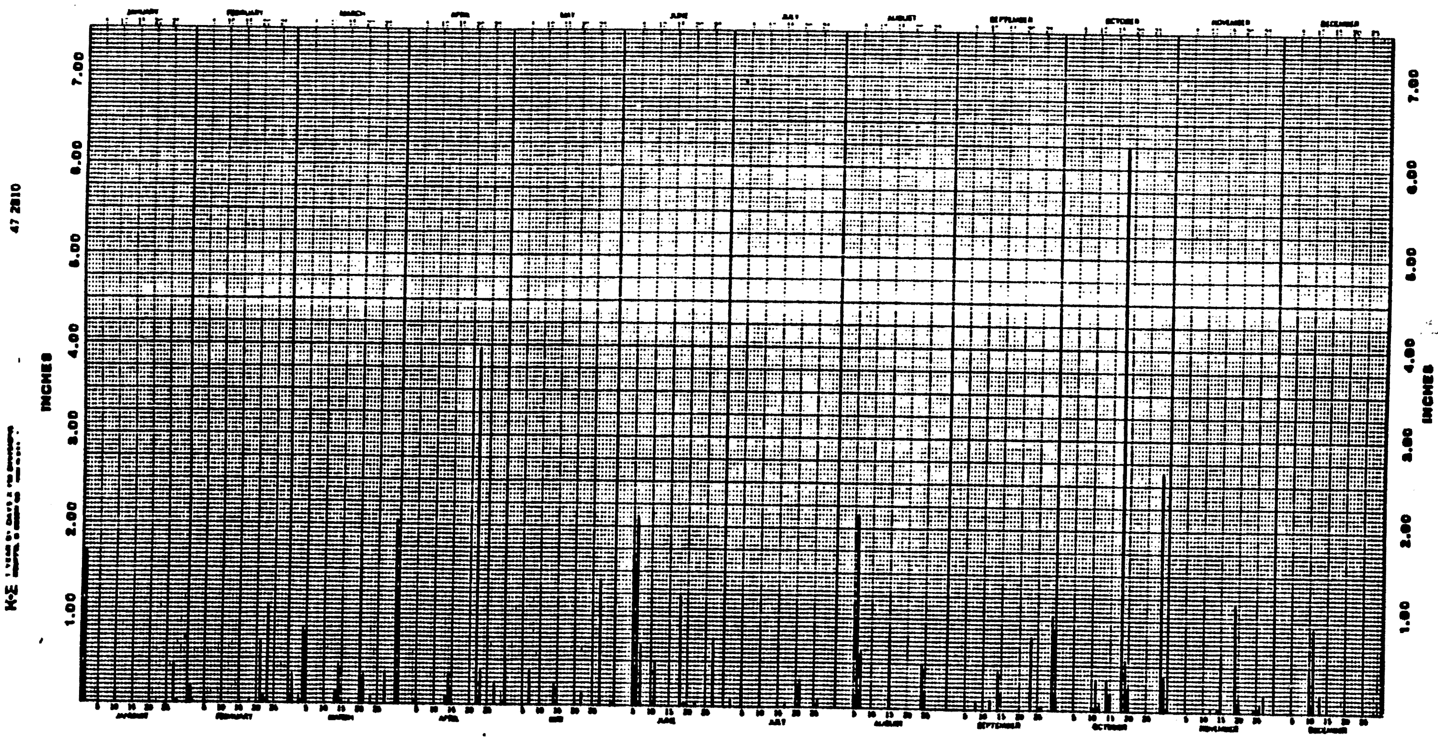

FIGURE 30. DAILEY PRECIPITATION FOR ADA, OKLAHOMA FOR YEAR 1985.

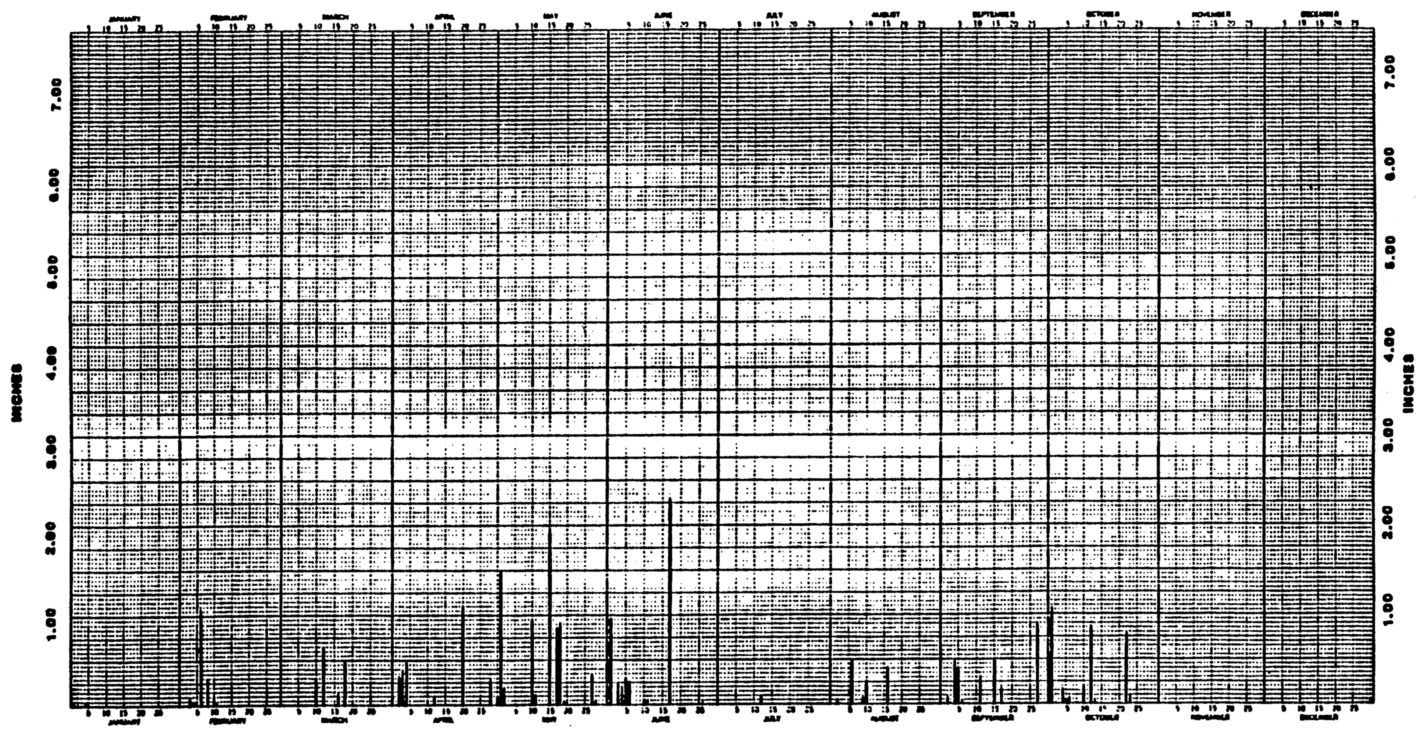

FIGURE 31. DAILEY PRECIPITATION FOR ADA, OKLAHOMA FROM JANUARY 1, 1986 TO NOVEMBER 1, 1986.

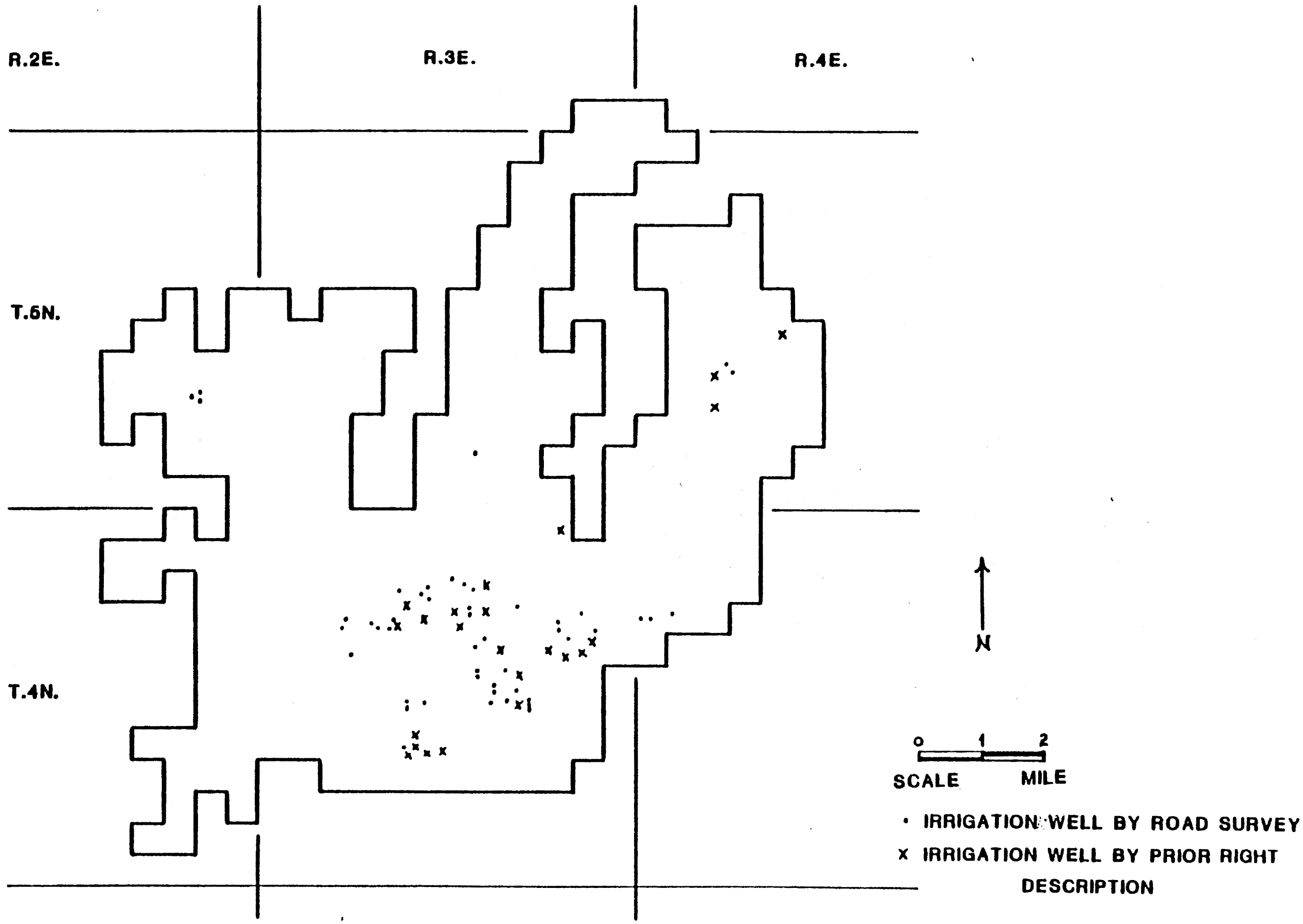

FIGURE 32. IRRIGATION WELL LOCATION AND DISTRIBUTION MAP.

TABLE IV

WELL LOG PUMP TEST DATA FOR IRRIGATION WELLS.

Date	Location	SWL (ft)	Diameter of Hole (inches)	Total Depth (ft)	Gravel Pack (Ton/Yd)	Yield of Well (gpm)	Observed Drawdown (ft)	Pumping Duration (hrs)	Pump Rating (gpm)	Type of Pump	Power Source
6/29/53	SW NE NW 23 4N 3E	55	36	92	27	110	15	12	110	Turbine	5 Hp Elec.
6/29/53	W NE NW 23 4N 3E	52	36	90	28	110	22	12	110	Turbine	5 Hp Elec.
6/29/53	NW NE NW 23 4N 3E	53	36	88	28	115	23	12	115	Turbine	5 Hp Elec.
8/ /56	SE NW 11 4N 3E	20	30	60	12	200	56	5	200	Turbine	15 Hp Elec.
10/10/57	SE SE 21 4N 3E	65	30	96	16	-	-	-	-	-	-
1/ 2/59	NW SW 11 4N 3E	42	30	80	21	450	-	-	450	Turbine	-
8/ /61	NE SE 9 4N 3E	56	30	93	-	425	37	8	425	Turbine	48 Hp LPG
3/26/63	SW NE 9 4N 3E	154	28	220	-	800	54	48	800	Turbine	413 Chrys.
3/28/63	NE NE NE 22 4N 3E	53	30	94	15	-	-	-	-	-	-
9/ 7/63	SW SE 21 4N 3E	79	30	101	20	350	22	8	350	Turbine	65 Hp Gas.
10/31/63	NW NW 23 4N 3E	53	30	74	8	450	-	-	450	-	-
1/17/64	NE NW NW 21 4N 3E	66	30	94	-	166	20	30	160	Turbine	25 Hp Inter.
1/21/64	NE SE 9 4N 3E	55	30	94	-	450	35	8	450	Turbine	LPG
1/22/64	N SE 7 4N 4E	33	30	60	7	125	-	8	125	Turbine	75 Hp Propane
1/24/64	SW SW SE 11 4N 3E	65	24	95	5	250	25	24	250	Turbine	Gasoline
1/24/64	S SE 10 4N 3E	54	30	97	16	650	-	11	650	West.	40 Hp LPG
2/10/64	9 4N 3E	69	30	102	18	475	-	-	475	Turbine	Gasoline
2/15/64	NW NW 10 4N 3E	60	30	106	-	465	40	9	465	-	LPG
2/26/64	NW SW 14 4N 3E	56	30	92	11	525	88	14	500	Turbine	LPG
5/28/64	NE NW 17 4N 3E	64	32	86	-	420	20	36	420	Turbine	Propane
9/27/64	NE SE 15 4N 3E	55	30	90	15	595	-	8	595	Turbine	40 Hp Gas.
10/ 2/64	SW SW 14 4N 3E	50	30	99	16	850	-	6	850	Turbine	Gasoline
11/21/64	S SW 7 4N 4E	34	30	68	8	135	-	8	135	Turbine	Propane
5/ 3/65	SE 23 4N 3E	68	30	94	20	625	85	5	625	Turbine	LPG
4/ 1/66	SW SW SE 11 4N 3E	65	30	88	5	150	25	24	150	Turbine	Gasoline
6/20/66	NW SE NE 2 4N 3E	15	20	58	7	340	-	5	340	Rotary	60 Hp Gas.
10/25/66	S SW 7 4N 4E	34	30	68	8	-	-	-	-	-	-
8/ /72	10 4N 3E	40	12	95	3	-	-	3	375	Turbine	25 Hp Elec.
3/17/73	NW SE SE 11 4N 3E	65	22	93	5	-	25	25	250	Turbine	Gasoline
11/ 7/77	NW NE SW 9 4N 3E	72	24	96	2	220	16	4	215	Turbine	Elec.
12/ 8/77	NE SE NW 9 4N 3E	74	24	103	2	250	20	4	245	Turbine	Elec.
1/10/79	SE SE SE 22 4N 3E	20	9	150	-	4	110	2	4	-	-

used mostly as pasture or range land, which is attributed to the amount of silts and clays associated with the terrace alluvium.

Hydraulic Conductivity

The variations in yield is termed the hydraulic conductivity (K) or permeability. The "permeability is the capacity of an aquifer to transmit in a unit time, a unit volume of water at the prevailing viscosity through a cross-sectional unit area, measured at right angles to the direction of flow, under a hydraulic gradient of unit change in head through a unit length of flow" (Freeze, et. al., 1979).

The permeability (K) from specific capacity data was determined from information found in the drillers logs. A wells specific capacity data, gallons per minute per foot of drawdown, is calculated through the equation adopted after Walton (1970):

$$T = \frac{Q}{s}\,264 \operatorname{Log}\left(\frac{Tt}{2693\,rw^2S}\right) - 65.5$$

Where Q/s is the specific capacity in gpm/ft, Q is the discharge in gpm, and s is the drawdown in feet. The coefficient of transmissivity is T in gpm/ft. The coefficient of storage is S, a fraction. The nominal annulus (radius of the well) is represented by rw squared in feet. The time after pumping started is represented by t, in minutes. The well log pump test data used in this equation can be seen by refering to the above Table IV. The values of Storage range from 0.10 to 0.30 (Freeze, et. al., 1979). In the calculation those values for 0.10 and 0.20 were used in the equation. Table V shows the basic and calculated data for those irrigation wells used in the specific capacity calculations.

The second method was to use the lithologic descriptions from

TABLE V

BASIC AND CALCULATED DATA FOR IRRIGATION WELLS SPECIFIC CAPACITY, TRANSMISSIVITY, GEOLOGIC LOG PERMEABILITY, AND AQUIFER TEST DATA.

	Basic Data							Calculated Data									
Location	Total Depth (ft)	Static water level (ft)	Test Yield (gpm)	Pumping Duration (hrs)	Drawdown (ft)	Saturated Thickness (ft)	Specific Capacity (gpm/ft)	Transmissivity from S. C. C.10	Transmissivity from S. C. C.20	Permeability from S. C. 0.10	Permeability from S. C. 0.20	Geologic log perm. Lower	Geologic log perm. Upper	Average Permeability Using S. C. 0.20 Lower	Average Permeability Using S. C. 0.20 Upper	Aquifer Data Using Jacob Method Lower	Aquifer Data Using Jacob Method Upper
SW NE 9 4N 3E	220	154	800	48	54	158	14.8	19,034	17,737	120	112	153	371	133	242		
NE NW NW 21 4N 3E	92	66	166	30	20	13	8.3	9,562	8,865	735	682	403	1,018	543	850		
NE NE 17 4N 3E	86	64	420	36	20	23	21.0	26,202	24,962	1,165	1,085	957	2,439	1,021	1,762		
SE NW 11 4N 3E	60	20	200	5	56	30	8.9	2,891	2,557	96	85	334	853	210	469		
SW SW SE 11 4N 3E	95	65	250	24	25	50	10.0	12,041	11,159	219	203	54	117	129	160		
SW SW SE 11 4N 3E	88	65	150	24	25	55	6.0	6,493	5,957	130	119	59	128	89	124		
NW SW 14 4N 3E	92	56	525	14	88	14	6.0	6,093	5,499	402	393	515	1,305	454	849		
NE SE 9 4N 3E	93	56	425	8	37	-	11.5	11,765	10,731	-	-	-	-	-	-		
NW NW 10 4N 3E	106	60	465	9	40	45	11.6	12,101	11,057	-	-	-	-	-	-		
W NE NW 23 4N 3E	92	55	110	12	15	-	7.3	7,124	6,458	-	-	-	-	-	-		
W NE NW 23 4N 3E	88	53	115	12	23	-	5.0	4,608	4,150	-	-	-	-	-	-		
W NE NW 23 4N 3E	90	52	110	12	22	-	5.0	4,608	4,150	-	-	-	-	-	-		
NE SE 9 4N 3E	94	55	450	8	35	-	12.9	13,356	12,200	-	-	-	-	-	-		
NW NE SW 9 4N 3E	96	72	215	4	16	26	13.9	13,607	12,395	523	477	197	484	337	481	395	513
NE SE NW 9 4N 3E	103	74	245	4	20	33	12.3	12,258	11,152	371	388	186	461	262	400		
NW SW 11 4N 3E	80	56	450	-	-	24	-	-	-	-	-	-	-	-	-	370	490
						AVERAGE PERMEABILITY				403	374	323	811	-	-		

1 Site of aquifer test Jarrel well.
2 Site of aquifer test Watt well.

driller logs to determine permeability. This method was developed by Kent, et. al., (1973), who subdivided different grain sizes into permeability classes. The grain sizes found in the study area is found in the sand and conglomerate material. The coarser material found in the conglomerate material is larger than the very coarse sand grains and is termed gravel. The coefficient of permeability versus grain size envelope can be seen in figure 33. The different classes are presented below and subdivided into low, middle, and high ranges. The lithologies of the saturated thickness form each geologic log were subdivided into their respective ranges by percentages. The saturated thickness of each range was divided by overall percentage and multiplied by the permeability of each of the respective range values. The four range values for the lower, middle, and upper lithologies are: range 1, clay with values of 1, 1.5, and 5; range 2, very fine sand and clay with vlaues of 30, 40, and 60; range 3, fine to medium sand with values of 140, 210, and 300; range 4, coarse to very coarse sand with values of 1,000, 1,600, and 2,550. Appendix F will show the calculation from the available geologic well log lithologic permeabilities. The saturated thickness interval was determined from water table contour maps for the well location and averaged over that quarter section. The surface elevation for the respective well was determined from the topographic maps.

Permeability values were determined through data derived from two aquifer test sites within the study area. The first aquifer test site was performed on May 21-22, 1985 in the N.1/2 of the SE.1/4 of the NW.1/4 of Section 9, T.4N., R.3E.. The basic operating procedure was to record the pump test data and the static water level in the irrigation well and in the observation well, which is located 200 feet from the

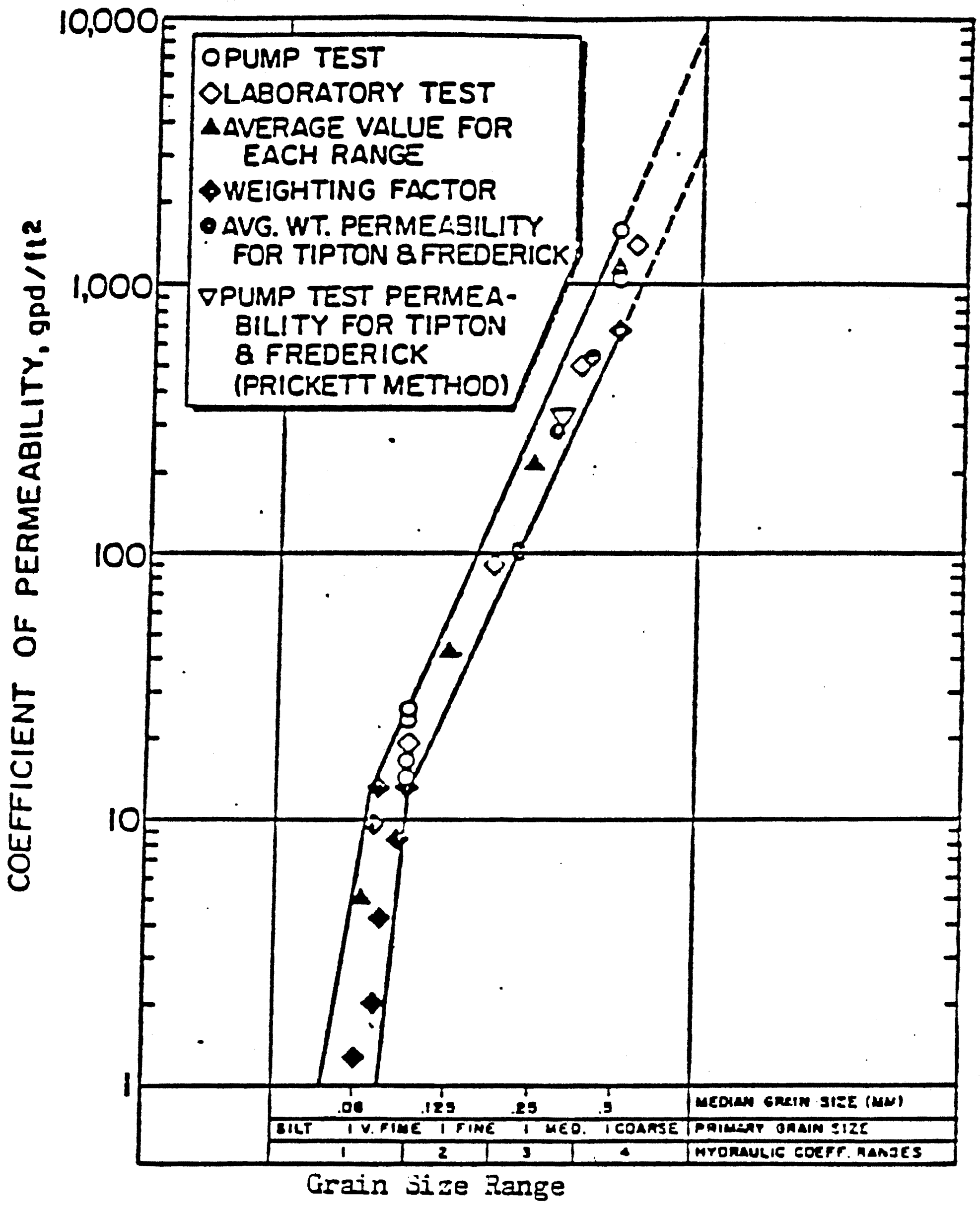

FIGURE 33. COEFFICIENT OF PERMEABILITY VS. GRAIN SIZE ENVELOPE.

pumping well. The pump discharge per time is recorded and the depth to water is monitored in the observation well. A transmissivity value can be determined using the Jacob, Theise, or Hantush methods. At this pump test site, the Jacob method was used for the Jarrell well located in Section 9, T.4N., R.3E.. The Jacob equation is a follows by Johnson (1975):

$$T = 264\ Q/S$$

Where T is transmissivity, in gallon per day per feet; Q is discharge rate in gallon per minute; and S is the residual drawdown per one log cycle in feet. The permeability can be calculated by the following equation:

$$K = T/b$$

Where K is permeability in gallon per day per foot squared; T is transmissivity in gallon per day per foot; and b is saturated thickness interval in feet. The average transmissivity calculated for the irrigation well in Section 9, T.4N., R.3E. is 11,900 gpd/ft and the permeability is approximately 745 gpd per foot squared. Appendix G shows the aquifer production test data calculations and graphs.

The second aquifer test was conducted on August 17, 1985 in the SE.1/4 of the NW.1/4 of the SW.1/4 of Section 11, T.4N., R.3E.. This production test site was conducted using an irrigation well flow meter to determine the outflow from the well. Also, an observation well was monitored at 392 feet from the pumping well. The depth to water was monitored in the pumping well and a reading from the meter was taken at a specific time interval. The recovery of the well was monitored at the end of the pumping period. The recovery of the well reflects the rise in the water level in the well after the pumping period for a particular time interval. The irrigation pump is rated at 450 gallons per minute according to the well log. Using the Jacob equation as stated above, a transmissivity value of 11,760 gpd/foot squared was calculated. A permeability was calculated at 675 gpd/ft. (see Appendix G for aquifer procution test data for Jarrell, and Watt irrigation well data, calculations, and graphs).

The aquifer test data for the Watt irrigation well shows that recharge is almost immediate after the well has been pumped. Inorder for full recharge to be complete, it takes approximately 13 days for the cone of depression to be fully recovered. The pump, after approximately 40 minutes of pumping begins to surge. The surge is that the water table is below the well casing and air is drawn into the pump turbine causing the pump to almost lose its prime. (see graph in Appendix G on pump gpm versus Time). The transmissivity and permeability value may be higher than the total aquifer in question due to the lithologic nature of the aquifer at this particular location. The well is completed in the Tertiary sands and the limestone rubble of the Oscar Group. The effect of vacuum in the irrigaiton well casing from the pumping seems to draw more water from the aquifer into the well casing, which helps to keep the turbine filled with water. The aquifer can produce only the amount of water that it can yield. Two other methods were used to determine the aquifer transmissivity and permeability values, the Thiese and Hantush methods, but no concise values could be reached.

Water Quality

The ground water quality or water quality sampling was conducted on May 21-22, 1985 in groups of three for five locations within and outside of the gerty sand terrace alluvium boundary. In the field, pH and field conductance was measured at most locations of water quality sampling (see figure 20). The pH is reflected by those wells completed within the gerty sand, which has a pH of approximately neutral. Those wells completed in deeper lithologic units have a more alkaline pH of approximately 9.0. Figure 34 shows the water quality sampling site identification number, and pH values. At the water quality sampling site, samples were taken in plastic pint bottles and fixed with H So and HNo to keep the common elements in solution. Water quality samples were tested by the Oklahoma Department of Health. Table VI shows the mean water quality analysis values. Appendix H contains the water quality analysis for each sampling site and the identification number to correlate to locations in figure 34.

The total hardness present in the Terrace alluvium is classed as moderately hard; 150 - 300 MG/L is hard; and greater than 300 MG/L is very hard. Total mean hardness is 136 MG/L. The terrace alluvium water is considered to be moderately hard.

The quantity of mineral elements dissolved in the Terrace alluvium aquifer is the total dissolved solids (TDS). The total dissolved solids mean value is 418 MG/L. The U. S. Environmental Protection Agency recommends a maximum value of 500 MG/L for drinking water total dissolved solids. The sulfate concentration has a mean value of 30.67 MG/L, which is thought to occur due to the organic material in the terrace alluvium. The chloride concentration has a mean value of 55.25

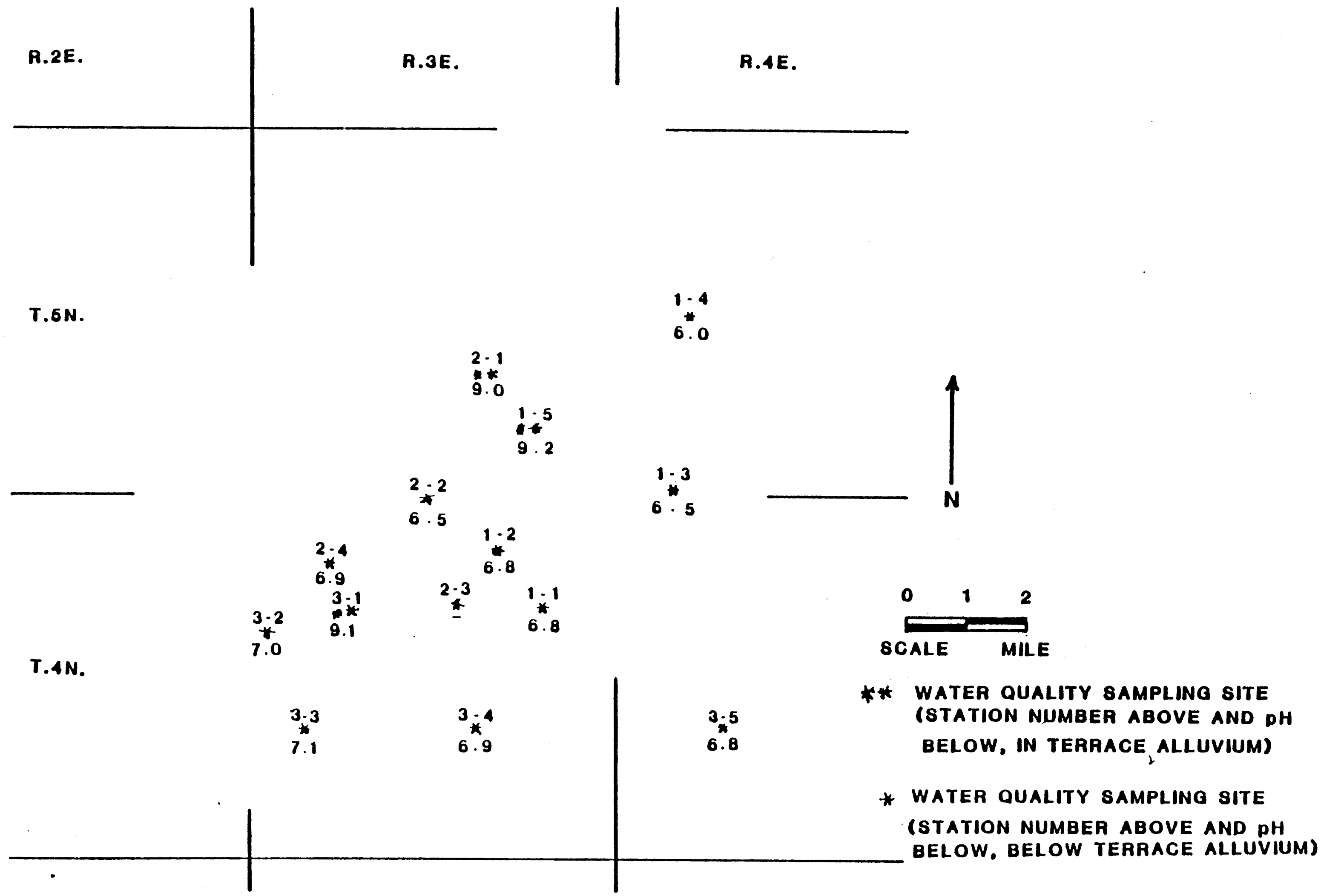

FIGURE 34. WATER QUALITY SAMPLING MAP.

MG/L, which is a common element of ground water. Both sulfate and chloride are below the U. S. Department of Health recommended rejection limit of 250 MG/L. The elements of manganese, arsenic, cadnium, chromium, and selenium are below the detection limits. Overall, the water quality of the Terrace alluvium is good.

TABLE VI

MEAN WATER QUALITY ANALYSIS FOR THE ISOLATED TERRACE DEPOSIT (GERTY SAND) OF GARVIN, McCLAIN AND PONTOTOC COUNTIES OKLAHOMA.

parameter	remarks	mean value	Max values	Min	Total value	Units	No. of samples above MDL
Chloride		55.25	283.00	12.00	884.00	MG/L	14
Nitrite-Nitrate as N		2.92	6.10	0.50	26.30	MG/L	9
Specific conductance		937.69	3,100.00	230.00	12,190.00	UMHOS/OM	14
Solids, Tot. Diss.		418.36	1,108.00	186.00	5,857.00	MG/L	14
Hardness, Total		136.75	639.00	< 10.00	1,499.00	MG/L	11
Barium		368.75	540.00	<200.00	2,950.00	UG/L	8
Calcium		43.71	125.00	1.00	612.00	MG/L	14
Copper		30.50	150.00	5.00	427.00	UG/L	14
Lead		20.78	31.00	< 20.00	291.00	UG/L	14
Manganese	<	20.00	< 20.00	< 20.00	-	UG/L	14
Sodium		114.43	540.00	32.00	1,602.00	MG/L	14
Floride		0.53	2.40	0.21	7.40	MG/L	14
pH		6.76	9.20	6.00	94.60	STD	13
Sulfate		30.67	46.00	< 20.00	184.00	MG/L	6
Alkalinity		330.93	704.00	137.00	4,633.00	MG/L	14
Arsenic	<	10.00	-	-	-	UG/L	14
Cadnium	<	2.00	-	-	-	UG/L	14
Chromium	<	10.00	-	-	-	UG/L	14
Iron		375.00	500.00	<100.00	750.00	UG/L	2
Magnesium		12.75	56.00	< 1.00	152.00	MG/L	11
Selenium	<	5.00	-	-	-	UG/L	14
Zinc		132.90	920.00	< 4.00	1,329.00	UG/L	10
Water Temp.		15.31	-	-	-	C	13

< less than detection limits.
MDL Minimum Dectection Limit

The possible contamination from the agricultural industries is not a problem or concern for ground water pollution. the only possible source of contamination could be from pesticide applications, but seems to be handled appropriately by the users. Oil well drilling activities does not apprear to be causing any serious problems in the Terrace alluvium. Only, old abandoned drilled oil wells from the 1930 to 1960 period should be checked for possible leakage.

Recharge

The determination of recharge values for modeling purposes, suggest the available amount of water as inflow into the aquifer system. The direct inflow from precipitation and some upward leakage through the underlying bedrock less the water loss by evapotranspiration would be an idealized undeveloped aquifer. The developd aquifer system suggest net recharge and ground water discharge (base flow) plus the amount of ground water discharged from pumping would be an idealized steady-state system today.

The determination of the amount of recharge distributed across the study area included two classes of soil infiltration for a single rainfall intensity-runoff relationship based on the Soil Conservation Service method (SCS). The classes of soil infiltration are farmland, with a curve number of 70; and forest, dune, and sand area with a curve number of 30. Figure 35 will show a typical sand exposure and a loam soil distribution map across the study area. The loam soil is considered farm land in the calculations.

The annual amount of precipitation distributed over the study area is 36.60 inches per year. The average rainfall available for recharge is estimated by multiplying precipitation times evapotranspiration (%)

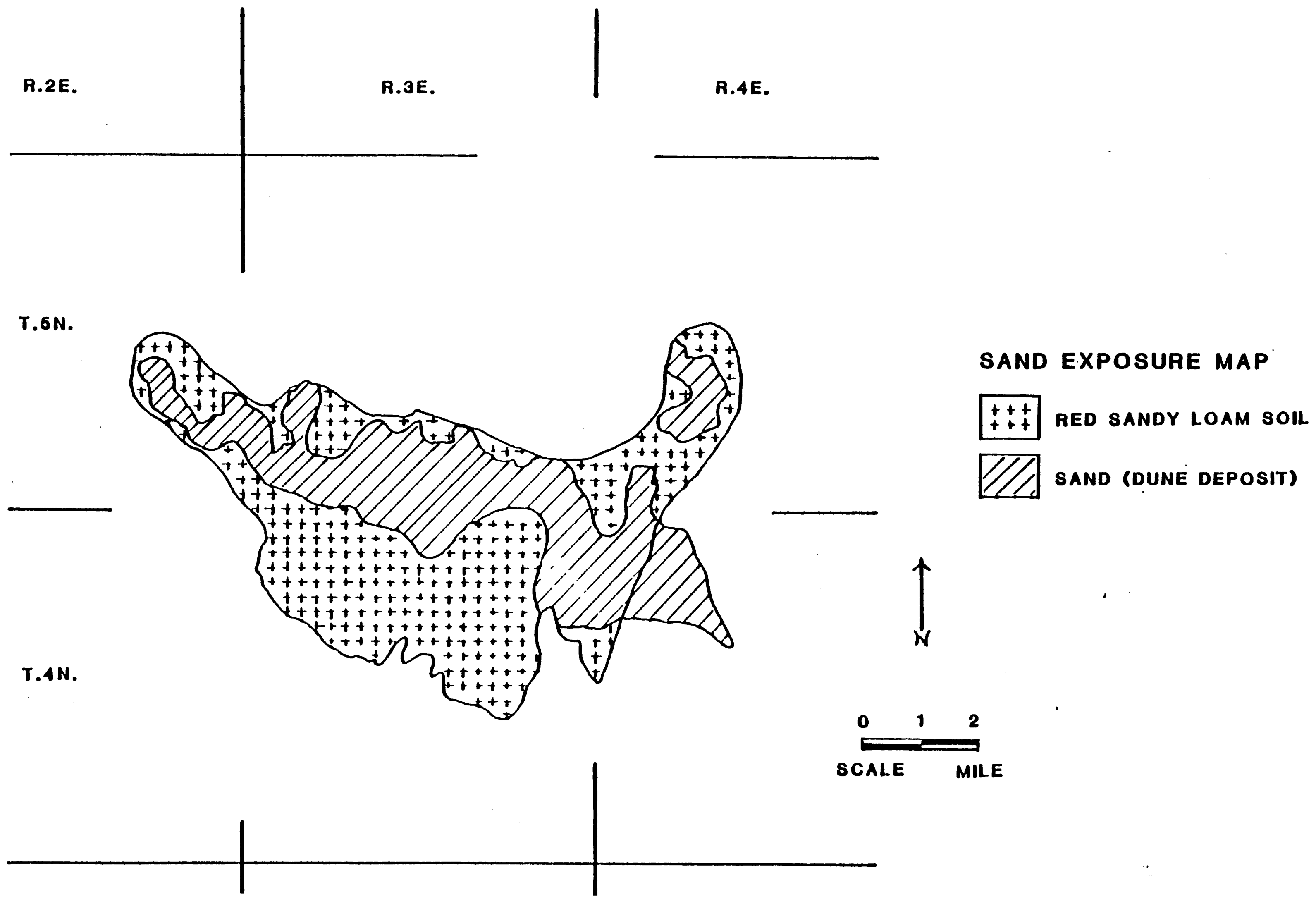

FIGURE 35. SAND EXPOSURE MAP DISTRIBUTION FOR THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA USED AS RECHARGE.

percentage to obtain the total precipitation available in inches per year. The total precipitation available as rainfall and checked with the specific curve number on the SCS method chart obtains the amount of direct runoff (Q) in inches. The total precipitation minus direct runoff gives a estimated value of rechage in inches per year over the study area. Table VII will show the calculations for the diffuse recharge for the recording stations of Ada, Konawa, Pauls Valley, and Purcell, Oklahoma.

TABLE VII

CALCULATIONS OF DIFFUSE RECHARGE OVER THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN AND PONTOTOC COUNTIES, OKLAHOMA.

Station	Annual Precipitation (in/yr)	Evapo- Transpiration (percentage)	Total Precipitation (in/yr)	Farmland Runoff (Q, in.)	Forest, etc. Runoff (Q, in.)
Ada	39.24	22.67	8.90	5.00	0.60
Konawa	38.08	"	8.64	"	"
Pauls Valley	33.50	"	7.60	"	"
Purcell	36.67	"	8.31	"	"
Average	36.50	"	8.27	"	"
Total Recharge of average (in/yr):				3.27	7.75

Aquifer Development

Land-Use

The aquifer development is shown in the land-use of the Isolated terrace deposit aquifer which is predominately agricultural. The crops grown are alfalfa, wheat, corn, soybean, peanut, milo, cotton, and orchard (peaches). A majority of the farm land is under irrigation. Some farm operations are cash crop, dairy, and retail sales. Retail sales include Watt Peanut Farm and Smith Brothers Catfish Farm. A further analysis of farming practices include dry-land farming operations that are located within and mostly on the boundary of the terrace deposit. Towards the outer boundary of the study area is mostly woodlands and pasture lands. The land-use of the Isolated Terrace deposit is closely related to the aquifer, and the aquifer characteristics described earlier in this chapter. Orchards are grown on the recent sand exposures on the northern to middle portion of the study area.

Prior Rights and Priority of Land Owners

The prior rights and priority of rights of landowners within the study area was mapped and categorized based on the date of priority and legal description for Garvin, McClain, and Pontotoc Counties, Oklahoma. The allocation of acre-feet divided by the number of acres to be irrigated gave a weighted average of acre-feet per acre for each of the owners of prior rights. The general allocation is determined by the Oklahoma Water Resources Board, which can be two acre-feet per acre. Appendix I has the prior rights allocation for Garvin, McClain, and Pontotoc Counties, Oklahoma. The summary of prior right annual allocations can be seen for each county in Table VIII. The legal description of prior rights annual allocation will show specific property under irrigation (see figure 36). Most property owners with prior rights have irrigation wells in use. The use of prior rights by an appropriator to put water allocated to a beneficial use is within the confines of the law, especially if transferred or sold to some other party for some beneficial use. Such an example is the sale of an

TABLE VIII

PRIOR RIGHT ANNUAL ALLOCATION FOR GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

Garvin County: Date	Priority by date	Type	Name	Annual Allocation Ac/ft	Acre	AF/A
6/30/54	1	Municipal	Stratford, City	392	-	-
12/28/56	2	Irrigation	Mercer, connie T.	63	40	1.58
12/30/60	3	Irrigation	Jarrell, Jim L.	130	150	0.86
5/22/63	4	Irrigation	Smith, Royce	234	130	1.80
6/14/63	5	Irrigation	Jarrell, Kenneth	103	80	1.29
10/ 7/63	6	Irrigation	Easter, M. T.	60	30	2.00
11/ 1/63	7	Irrigation	Bryant, Lydia R.	153	80	1.91
12/16/63	** 8	Irrigation	Smith, Royce	120	100	1.20
1/ 1/64	9	Irrigation	Watt, Willie	150	85	1.76
1/ 1/64	10	Irrigation	Watt, Willie	72	120	0.60
2/26/64	11	Irrigation	Christ, Paul	138	157	0.88
3/16/64	12	Irrigation	Smith, charles	160	80	2.00
3/23/64	13	Irrigation	Crosby, S. R.	192	131	1.47
3/27/64	14	Irrigation	Freeman, W. L.	172	110	1.56
4/ 2/64	15	Irrigation	Watt, Donald	80	60	1.33
4/13/64	16	Irrigation	Gallup, J. G.	243	200	1.22
2/ 8/66	17	Irrigation	Gray, Baxter	37	50	0.74
4/25/66	18	Irrigation	Slaughter, W. P.	40	210	0.19
7/21/66	19	Irrigation	Eldred, Jimmy D.	52	63	0.83
8/19/66	20	Irrigation	Baker, L. B.	70	102	0.69
2/ 9/67	21	Irrigation	Jarrell, Kenneth	59	80	0.74
7/ 7/67	22	Irrigation	Gray, Gus	12.5	21.4	0.58
7/ 7/67	23	Irrigation	Jarrell, Jim L.	42.2	72.6	0.58
9/28/67	24	Irrigation	Townsend, Kenneth	85	100	0.85
2/14/68	25	Irrigation	Smith, Wm. E.	136	80	1.70
3/ 5/73	26	Irrigation	Russ, Albert J.	97	170	0.57
4/10/73	27	Irrigation	Brundridge, Ben	150	130	1.15
Pontotoc County:						
7/28/66	1	Irrigation	Wood, Wallace	160	45	3.56
8/ 8/66	2	Irrigation	Wood, J. B.	40	40	1.00
9/20/66	3	Irrigation	Opitz, June	167	120	1.39
8/17/67	4	Irrigation	Herndon, James F.	80	160	0.50
8/17/67	5	Irrigation	Herndon, James F.	3	40	0.08
8/25/67	6	Irrigation	Attom, Jim	56	35	1.24
McClain County:						
12/ 9/64	1	Irrigation	Younger, Les	45	80	0.56
4/25/66	2	Irrigation	Slaughter, W. O. or Billie	40	20	2.00

** Currently used as a rural water supply for Wynnewood, Oklahoma.

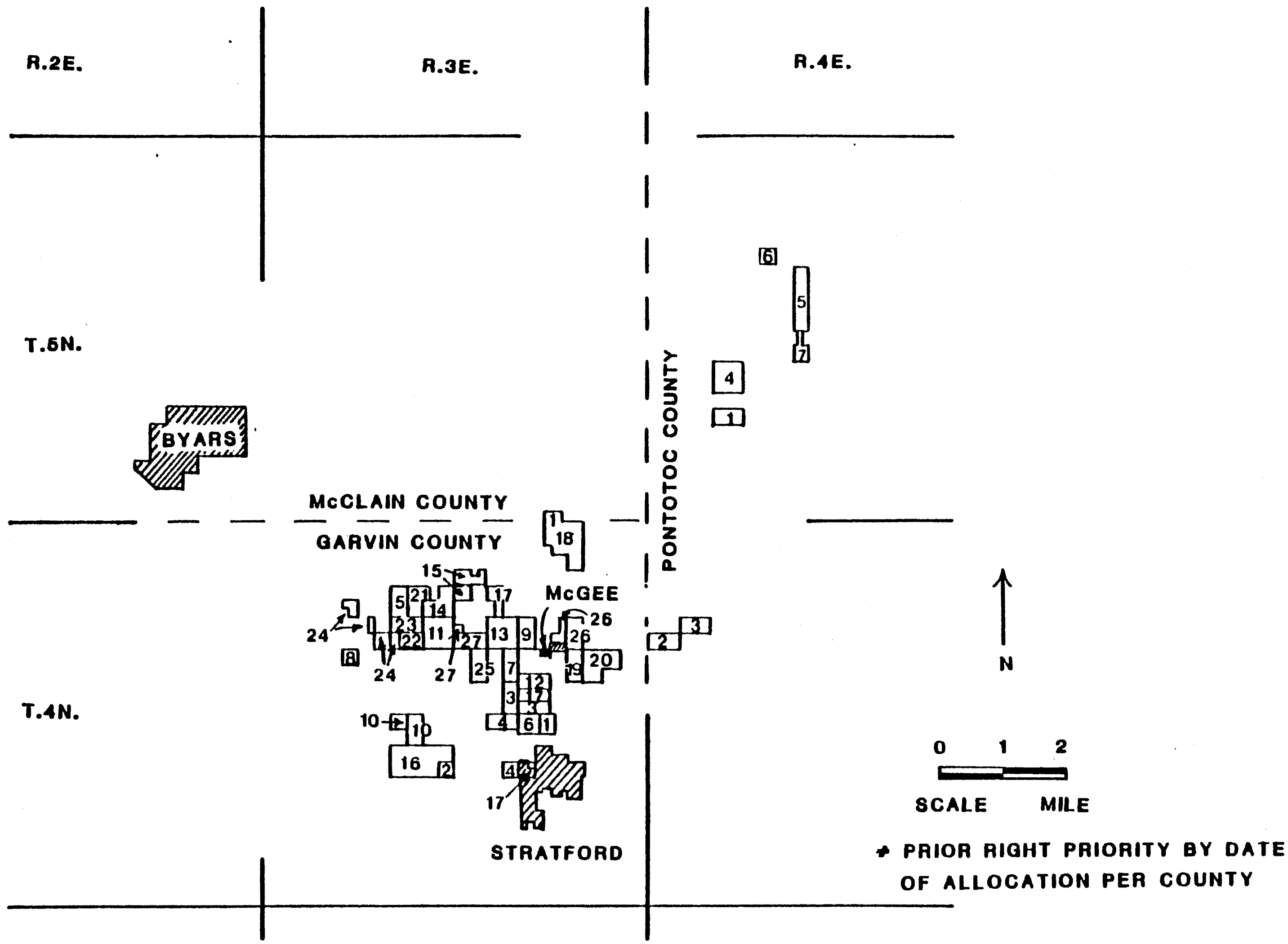

FIGURE 36. PRIOR RIGHTS PRIORITY DISTRIBUTION MAP PER COUNTY FOR GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

appropriators prior rights to a rural water district for a beneficial use. The prior right allocations are given priority on a county basis. Each county has more prior right applicants, only those applicants within the study area are listed in the Table. Some of the prior right applicants may have moved to town and leased their prior right to the renter of the property, or have passed on their prior right (transferred) to relatives or sold the right with the property.

Rural Water District

The rural water district of Wynnewood, Oklahoma has a large rural customer service pipeline network that extends up to and south of Stratford, Oklahoma. Figure 37 shows the rural water district pipeline map of Wynnewood, Pauls Valley, Rosedale, Byars, Stratford, and a part of Ada, Oklahoma (Rural water Systems in Oklahoma, 1980). the rural water district obtains the water for the water district from numerous wells along the pipeline network. The City of Wynnewood, Oklahoma Rural Water District Well that is located within the study area is in the N.1/2 of Section 17, T.4N., R.3E.. This well was an existing irrigation well converted to a municipal rural water district well. The process involved installing a new well casing, hooking up to the rural water district pipeline, and installing a flow meter onto the pumping well. the pumped water is stored in a storage tank located in the SW.1/4 of the SW.1/4 of the SW.1/4 of Section 24, T.4N., R.2E.. The water tower helps to maintain water pressure within the pipeline network. The rural water district well within the study area was put into operation in August of 1984. Table IX shows the meter reading and gallons used for the well located in Section 17, T.4N., R.3E. Generally, the meter

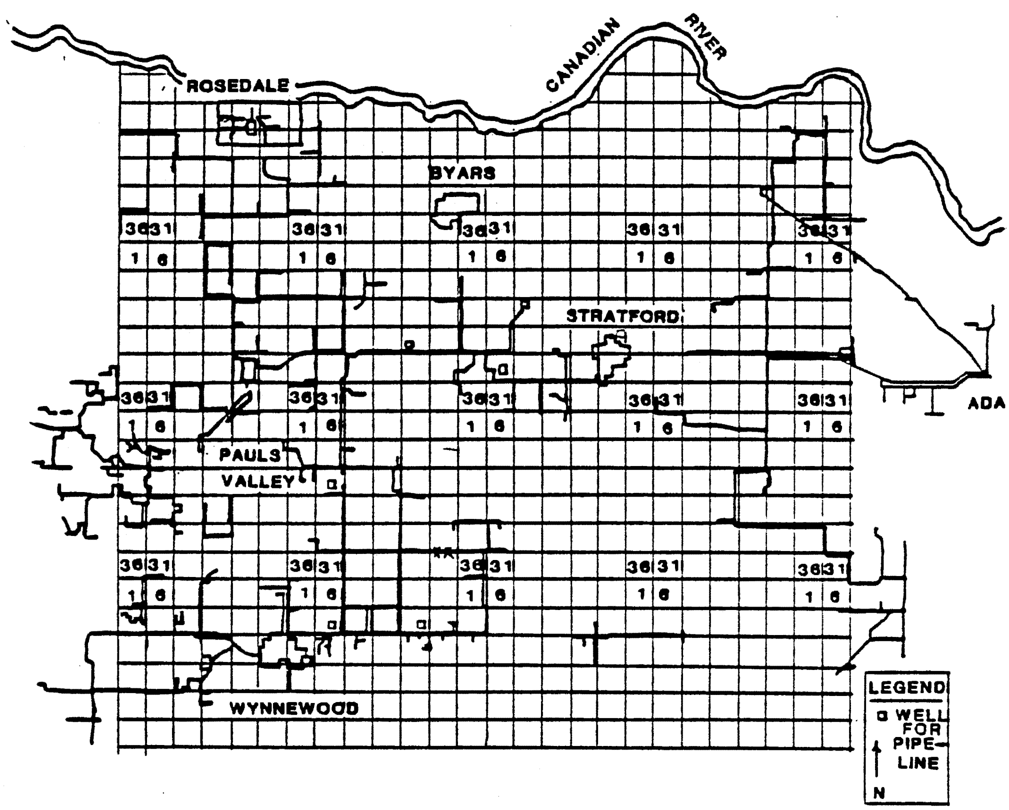

FIGURE 37. RURAL WATER DISTRICT PIPELINE MAP FOR ISOLATED TERRACE DEPOSIT. (Modified After Rural Water Systems in Oklahoma, 1980)

readings were taken at the middle of the month.

The future demand for water from the area is continually increasing every year. At this time, the exact number of new residents needing to be hooked up to the rural water district is not known. However, the increase in populace of this area is begining to be seen in the increasing demand for water, and the increasing need of the rural public to be hooked up to a water district pipeline network.

TABLE IX

WYNNEWOOD OKLAHOMA RRURAL WATER DISTRICT WELL
LOCATED IN N.1/2 OF SECTION 17, T.4N., R.3E.

Date	Meter Reading	Gallons Used
8/14/84	0	-
9/14/84	1,050,000	1,050,000
10/15/84	3,766,000	2,716,000
11/13/84	5,877,000	2,111,000
12/17/84	7,700,000	1,823,000
1/15/85	9,987,000	2,287,000
2/15/85	12,710,000	2,723,000
3/15/85	14,329,000	1,619,000
4/16/85	16,523,000	2,194,000
5/15/85	18,020,000	1,497,000
6/14/85	19,122,000	1,102,000
7/15/85	20,911,000	1,789,000
8/15/85	23,420,000	2,509,000
9/15/85	25,888,000	2,468,000
10/16/85	27,749,000	1,861,000
11/15/85	29,660,000	1,911,000
12/17/85	31,542,000	1,882,000
1/15/86	33,375,000	1,883,000
2/14/86	35,440,000	2,065,000
3/14/86	37,358,000	1,945,000
4/16/86	39,741,000	2,383,000
5/14/86	41,686,000	1,945,000
6/13/86	43,768,000	2,082,000
7/15/86	46,460,000	2,692,000
8/15/86	49,829,000	3,369,000
9/16/86	53,777,000	2,948,000
10/15/86	54,840,000	1,063,000
11/14/86	57,045,000	2,205,000

Municipal Water Usage

The municipal demand for the City of Stratford and Byars is reflected in the increase in municipal wells being planned and put into operation. The population of Stratford, Oklahoma is currently 1462, and the population of the City of Byars, Oklahoma is 353 from the 1980 census. The tentative per capital water use figures adopted by the Arkansas, Red and White Basins Inter-Agency Committee for the cities within the state lying east of the 100 degree meridian for the year 2000 is 155 gallons per day for 1,000 to 10,000 persons (Oklahoma Long Range Water Program, 1954). The municipal demands for water for the city of Stratford, Oklahoma currently utilizes four wells. Three of the wells are rated at 75 gallons per minute and the fourth is rated at 600 gallons per minute to meet the consumptive demand of 96,875 gallons in five hours (Delaney, 1969). The 600 gallon per minute well is used mostly for fire protection as recommended by the National Board of Fire Underwriters, which require 1,500 G. P. M. for five hours (Delaney, 1969). The 600 g.p.m. well does not represent a long term pumping rate, but reflects the short term pumping demand as placed on the municipal wells. Table X shows the monthly water usage for the city of Stratford, Oklahoma. The number of wells in use during the months of May to October is four. The fourth well, the 600 gpm well, is not pumped continuously. The well is used to fill the city of Stratford's water tower. The average total hours a pump is in use may not reflect the total city's consumptive usage. A well may be run continuously for a period of time and then shut down for minor repairs, parts, or untill demand calls for the pump to be turned on.

TABLE X

MONTHLY WATER USAGE FOR THE CITY OF STRATFORD, OKLAHOMA.

Date/ Month 1985	Water Pumped 1,000 gallons per day	No of wells in use	Ave. total hours in use
January	8,218,700	2	48
Febuary	7,286,300	2	46
March	8,142,600	2	44
April	10,060,500	3	59
May	11,380,500	3	64
June	14,488,400	3	67
July	12,781,800	4	71
August	12,896,800	4	71
September	12,264,100	4	71
October	11,451,300	3	65
November	10,992,300	3	65
December	8,563,800	3	48
1986			
January	11,177,000	3	63
Febuary	9,882,700	3	58
March	10,981,200	4	62
April	10,721,700	3	61
May	11,001,000	3	62
June	11,027,100	3	64
July	13,470,600	4	72
August	12,983,700	4	72
September	10,540,800	4	60
October	-	-	-
November	10,744,500	3	63
December	10,499,400	3	59

CHAPTER III

LEGAL, INSTITUTIONAL AND ECONOMIC ENVIRONMENT

Legal and Institutional Dimension of Ground Water Management

The management of ground water requires attention of both issues of quality and quantity. Management options are used to assure that an adequate quantity of water is available and that the quality is adequate for the uses encountered.

Federal legislation regarding the environment were enacted in the 1970's to protect ground water quality using various state laws and common (tort) principles of negligence and nuisance. These laws, aimed at protecting ground water quality, provide only fragmented control mechanisms. The control mechanisms have most emphasis on ground water quality and some emphasis on ground water quantity (water rights). The protection of ground water quality is accomplished through six environmental laws administered by the Environmental Protection Agency. These laws were directed at surface water quality protection but, contain certain aspects of ground water protection.

The Safe Drinking Water Act (P. L. 93-523) serves to protect public drinking water supplies. The Environmental Protection Agency is to have authority to set maximum contaminant levels for the public drinking water supplies (Section 1412). EPA is to have authority in the underground injection control program under Subtitle C, and to administer the sole source aquifer provion under Subsection 1424 (e) to protect ground water (Feliciano, 1984).

The Clean Water Act of 1977 (P. L. 95-217) enacted in 1972 as the Federal Water Pollution Control Act under P. L. 92-500, authorized EPA to protect both surface and ground water. Section 208 of the Clean Water Act required states to plan for area-wide waste management to protect ground water (Synder, 1979). Section 303 authorized EPA to set water quality standards, and Section 402 required a permit system to control point-source discharges into surface waters (Feliciano, 1984).

The Resource Conservation and Recovery Act (P. L. 94-580) authorized EPA to regulate the disposal of municipal solid waste and hazardous wastes that may have adverse effects on public health and the environment. the RCRA provision for ground water protection is under Subtitle C, which establishes a mechanism for the handling of hazardous waste, including performance standards, and a permit system for facilities storing hazardous waste. Also, under Subtitle D, of the act established a mechanism for the development of municipal solid waste disposal facilities (Feliciano, 1984).

The Comprehensive Environmental Response, Compensation, and Liability Act (P. L. 96-510) authorized the federal government to respond to discharges of hazardous substances and to help clean up contaminated sites if necessary. The primary objectives of this act, better known as "Superfund", was to prevent toxic chemicals in hazardous waste sites from leaching into ground water supplies. Subsection 101 (8) of the act's definition of "Environment" included ground water and drinking water supplies (Feliciano, 1984).

The Toxic Substance Control Act (P. L. 94-469) and the Federal Insecticide, Fungicide, and Rodentcide Act (P. L. 92-516) established a system of environmental controls for toxic and pesticide substances. The environmental controls for the toxic and pesticide substances is accomplished by screening various chemicals prior to manufacture and use. Within the Act, the screening of the chemicals for possible environmental harm to prevent or minimize ground water contamination is not the main objective (Feliciano, 1984).

The analysis of water laws by state, within different regions of the country, assures ground water quantity through the system of water laws. Eastern states generally have adopted the Riparian system of water law, and the western states have developed the Prior Appropriative system. The riparian right itself is jure-naturae, land abutting water and land by nature receives benefits and increased value by reason of the waters in the water course. The Appropriative rights are statutory in origin based on legislative enactments establishing rights in those who put water to a beneficial use, first. Arkansas and California have ground water mining problems but neither has any current restrictions on the use of ground water for irrigation. Arizona, Colorado, Idaho, Kansas, Nebraska, and New Mexico do regulate use and have legislation aimed directly at ground water mining. Florida, Oklahoma, and Texas regulate use, but have no special legislation dealing with ground water mining. The state of Florida, within the Florida Water Resources Act of 1972, calls for a closer relationship between land and water management to accomodate rapid draining of wetlands to facilitate agricultural and residential land-use (Maloney, et. al., 1978).

Ground water rights, concerning use, are rights to abstraction based on the common law rule, reasonable use, and correlative rights. Moreover, the Doctrine of Mutual Prescription is gained by use in the ground water right law. The English Common Law Rule (93 C. J. S.

Section 93, 1956) of absolute ownership provided that the owner of the land surface could appropriate any and all of the underlying percolating waters for whatever purposes he pleases. This rule holds that the right to capture, use or sell the percolating waters exist in each and every landowner absolutely. The injury to his neighbor is dumnum absque injuria: a land owner takes so much water that his neighbor is adversely affected and can demand no compensation from the landowner who extracted the water (Reinke, et. al., 1978). The exceptions are to not maliciously take water and not willfully waste the water for the sole purpose of injuring his neighbor. Under the common law rule, conservation is discouraged resulting in rapid development and exploitation of available ground water.

The Reasonable Use Doctrine or the American Common Law Doctrine of Reasonable Use (93 C. J. S. Section 93, 1956), provides a surface owner to be entitled to use water under his property. A use is reasonable if made in connection with overlying land, even if it causes harm to an adjacent owner. Water can be withdrawn for transportation and sale off the land provided no injury is done to adjacent owners. Where other owners are not affected, each landowner still has the right to extract and use all percolating water that can be withdrawn from his land for whatever purposes he pleases, absent want on and willfull waste (Reinke, et. al., 1978).

The Correlative Rights Rule (93 C. J. S. Section 93, 1956) required that the uses of water must be reasonable and that such uses of water must consider the priority of all land owners be equitable considered. Under this rule, if the supply is insufficient for competing uses, no owner may extract and use more than his fair share of the available water. However, no restrictions are placed upon excessive withdrawls of ground water by surface owners collectively (Reinke, et. al., 1978).

The Prescriptive Right Rule (93 C. J. S. Section 93, 1956) is analagous to the adverse possession of land which is a presumption of a grant, and is gained by use, without permission and for at least five years of water rightfully belonging to some other person. The Prescriptive right applies only when a rightful owner fails to act to protect his rights against injury by the prescripter, and is designed to promote productive use of societies resources. The Prescriptive Right comes into play when a basin is being overdraft, and pumping by the prescriptor is presumed to injure every overlying owner and appropriator. This doctrine divides available ground water in accordance with how much has historically been used rather than by time of appropriation or some other means (Helwig, et. al., 1978).

The way mining problems are handled can be seen by analysing the way various states attack the problem. In California, surface waters fall under two categories of water law: the Colorado and the California Doctrines. California's ground water rights laws, in the case of Action Vs Blundell of 1843, uses the English Rule of Absolute Ownership (common law rule). In this case it was "predicated on the notion that the nature and movement of percolating ground water were not capable of being understood, and was developed in response to humid conditions, were abundant ground water was often a nuisance to be disposed of" (Helwig, et. al., 1978). In 1903, the California supreme court in the case of Katz Vs Walkinshaw, rejected the common law rule because it was inappropriate for arid regions, and considered that ground water is a precious resource (Helwig, et. al., 1978). The court in 1903 also recognized that withdrawing to much ground water would affect streams and the underground aquifer system. This court case established the

Doctrine of Correlative Rights analagous to the Riparian and Appropriative Doctrines. The Riparian analogy is that it gave everyone bordering a body of water a proportional share. The analogy to the appropriative doctrine is that it limited the use of water of overlying owners to reasonable beneficial uses on the overlying land. A later case of Pasadena Vs Alhambra of 1949, the courts said overlying land was limited to land within the ground water basin (Helwig, et. al., 1978).

According to the California Doctrine, the appropriative right to pump ground water for beneficial use is not limited to the land overlying a ground water basin or by some person other than the owner of the land on which the well is located (Helwig, et. al., 1978). Also, in California, one does not have to file a permit or other documentation to appropriate ground water. "Overlying rights have priority over Appropriative rights" (Helwig, et. al., 1978). California's ground water law is influenced by court decisions which is not of a legislative nature, and does not specifically put restrictions on the use of ground water for irrigation except that it must be a reasonable and beneficial use.

Nebraska's water law regulates use and has legislation aimed directly at ground water mining. Early development of irrigation in Nebraska started with surface water and eventually moved to ground water irrigation in the early 1960's. Nebraska, "followed a laissez-faire ground water control policy, in part, because the relative abundance of ground water fostered the belief that supplies would always be plentiful" (Aiken, et. al., 1978). Prior to the 1969 legislation, local landowners had to petition to form ground water conservation districts. The Nebraska legislature in 1969 provided for the reorganization of soil and water conservation districts, and a variety of watershed districts into larger, more comprehensive Natural Resource Districts (Aiken, et. al., 1978). The reorganization combined 150 single purpose districts into 24 natural resource districts in 1972. Later, public concerns about declining ground water levels lead to the Nebraska Ground Water Management Act of 1975, which established ground water control areas on the local level to be viewed by the NRD. Under the Act, to establish the ground water control areas, the Department of Water Resources Director must find at least one of the following conditions as recorded by Aiken, et. al., (1978):

> 1) conflicts between users are occuring or may be reasonably anticipated;
>
> 2) substantial economic hardships exists or are forseeable as a direct result of current or anticipated ground water declines; or
>
> 3) other conditions exist that indicate the inadequacy of the ground water supply or that require the area to be designated as a control area for protection of the public welfare.

Once a control area has been designated a decision of what alternative ground water regulation is needed as authorized by the Ground Water Management Act. The Ground Water Management Act alternative controls are 1) well spacing restrictions, 2) rotation or pumping restrictions, 3) allocation of ground water, and 4) moratoria on well drilling (Aiken, et. al., 1978). Other alternative controls may be adopted for a particular site by the NRD not specifically authorized by the Act, such as allocation of ground water use. Nebraska regulates ground water use on a local level and legislation under the Ground Water Management Act of 1975 is aimed at controlling ground water mining.

Oklahoma Ground Water Law

The development of Oklahoma's water law system of Prior Appropriation was governed by the American Rule of Reasonable use in the original Oklahoma Territorial Statute of 1890 (Hutchins, 1960). The Territorial Acts of 1890 use the dual system of Prior Appropriation and Riparian Doctrines of water law. The Riparian system of water law is predominately applied to water coarses of rivers and streams. Whereas, the Appropriative system is a right of benefical use specifically designated for irrigation purposes based on the priority of right separate of any water coarse. The Territorial Oklahoma Statutes of 1890, Section 4162 divides ground water into those waters flowing in definite underground streams and those waters not flowing in definite underground streams (Hutchins, 1960). Those waters not flowing in definite underground streams (percolating waters) was subjected to English Common Law Rule as recorded in the case of Canada Vs Shawnee of 1936. The ruling of the supreme court in the case of Stillwater Vs Cundiff of 1939 said the correlative rights rule in rivers and streams to be applied to ground water (Hutchins, 1960). In 1949, Oklahoma Ground Water Law was enacted outlining procedures by which water would be allocated among competing users (Hutchins, 1960). This was amended in 1961 and 1962 establishing a system of Prior Appropriations (Okla. Stat. Ann. Title 60, Section 60, 1971). Provisions of Oklahoma Ground Water Law will issue a permit to anyone intending to make a beneficial use of ground water by applying to the Oklahoma Water Resource Board. The OWRB will allocate an applicant his proportionate share of water based on the maximum annual yield of the basin or subbasin, which is equal to the percentage of land overlying the fresh ground water basin.

Prior to the effective date of the Ground Water Act of July 1, 1973 any person having a right to put ground water to a beneficial use has the right to bring this use under the provisions of current law (Okla. Stat. Ann. Title 82, Section 1020.14, 1987). Prior rights according to early Oklahoma Ground Water Law dated August 26, 1949 had to be put to a beneficial use within two years with the board (Kent, et. al., 1983). Later, an amendment of July 5, 1961 of the Oklahoma Ground Water Act required a user to put water to a beneficial use within five years (Kent, et. al., 1983). An amendment of July 1, 1973 required a permit be filed with the Oklahoma Water Resource Board by application, and to put the water to a beneficial use within five years (Okla. Stat. Ann. Title 82, Section 1013, 1987). Oklahoma Prior Appropriation system follows two doctrines of Relation and Diligence. The doctrine of Relation is the legal principle in the application upon the completion of the last act of a series necessary to complete the act, put back to the date at which time the first act was performed (Hutchins, 1960). The doctrine of Diligence is a principle pertaining to the date of priority of the right and its position of the right in relation to other appropriative rights that attach to the same source of supply (Hutchins, 1960).

Oklahoma laws include management strategies of well spacing and the metering of wells by the Oklahoma Water Resource Board (Okla. Stat. Ann. Title 82, Section 1020.17 and 1020.19, 1987). The Oklahoma Water Resource Board is responsible for managing the states ground water resource, and determining prior ground water rights by reviewing new and existing applications. The Oklahoma Water Resource Board with the United States Geological Survey maintains a well survey in the state to determine whether water levels are rising or declining in each county.

Opinion Survey

Purpose

A political survey was conducted in person in the Isolated Terrace Deposit of Garvin, McClain and Pontotoc counties, Oklahoma. The purpose of the survey was conducted to gain insight into ideas of the area residents on current water related issues. The issues addressed political, land-use, and water consumption factors.

Method

The method used to survey respondents was based on a grided base map and to survey those respondents closest to a grid line (see figure 38). More than one survey trip was conducted due to many of the area residents worked during the day at nearby cities, and many of the farmers were busy harvesting crops or working the fields. The survey questions were broken down into three categories: general, water use, and political. The general section of the survey was aimed at understanding how long respondents lived in there community, from where they derive most of the income, the size of their households, and the water consuming conveniences the respondents utilized in their homes. The water usage section was to determine the respondents source of water and an estimate of how much water their households used per month. The water use section integrated agricultural questions of crops grown whether irrigated or nonirrigated and the amount of fertilizer and pesticides used. The water useage section asked questions about the number of irrigation wells used, source of power, and acres under

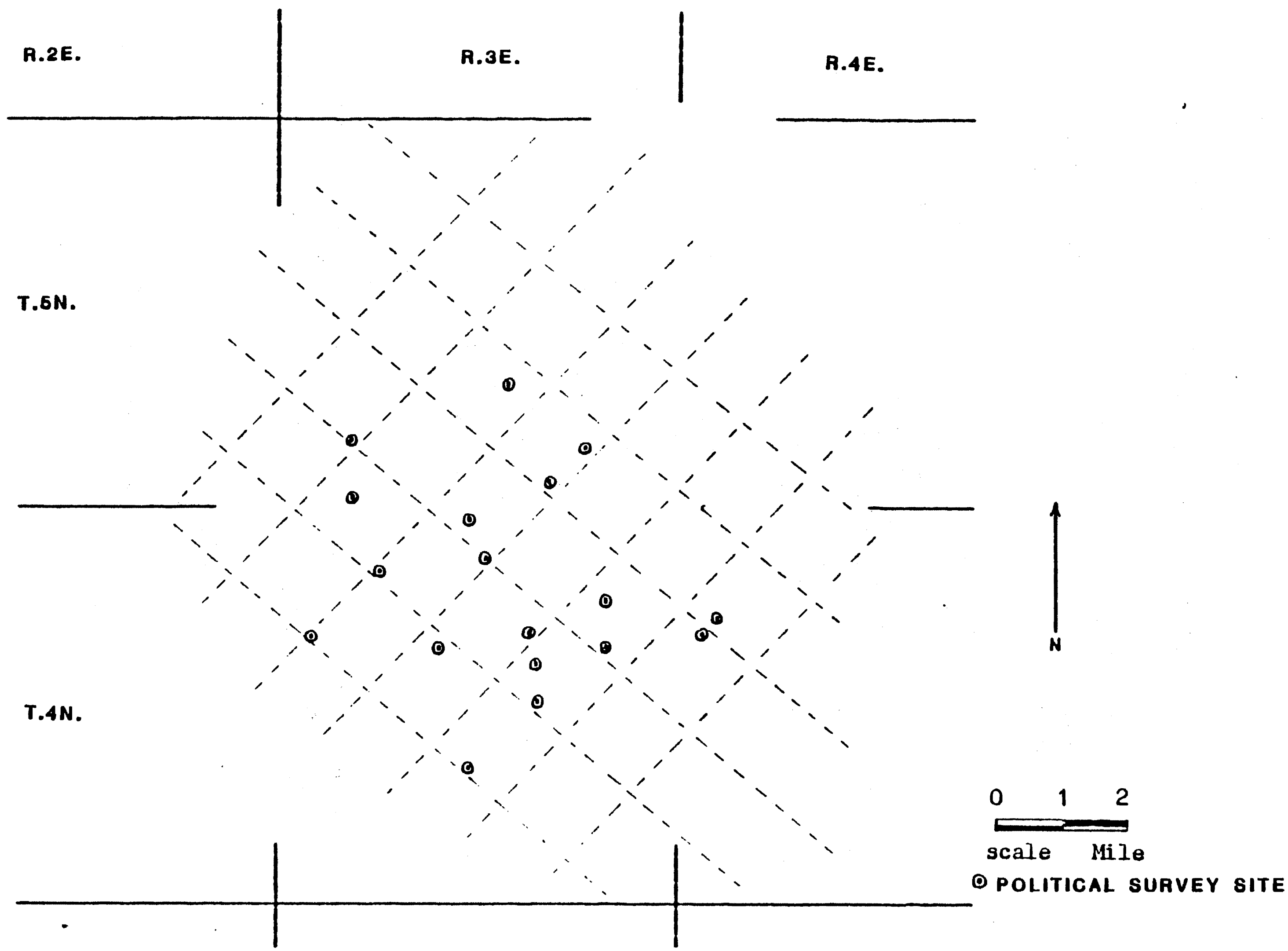

FIGURE 38. POLITICAL SURVEY GRID AND DISTRIBUTION MAP.

irrigation. These questions will be analysed in the agricultural economics section. The political questions are aimed at current ground water issues of management and issues of water rights affecting natural resources. The survey analysis of questions weight each question in a percent histogram. This method was used due to it is easier to see how the majority of the respondents answered the questions (see Appendix J, for survey issues, and histogram percentage for each question). The results of this survey are used only for background information and to verify certain assumptions regarding water use in the aquifer. However, due to the small sampling size, we cannot generalize to the population.

Results

The results of the political survey analysis shows that a majority of the respondents lived greater than 10 years in the study area. Most respondents receive income from agricultural crop (32%), and livestock production (29%). Income from other sources was reported at 24 percent. Of those respondents surveyed, 94 percent live in the rural area. The average household size was four. Conveniences utilized in most households are automatic dishwasher (26%), washing machine (34%), and central air conditioning (18%). All respondents get their source of water from a private (domestic) well. Monthly consumptive use of water is estimated at 5,000 to 10,000 gallons at 56 percent. A majority of the respondents (94%) have not experienced a water shortage in their community. No decision could be reached on the issue that if water supplies became scarce water rates would be implemented for a rural water district. The average farm size is 440 acres with a minimum of 10 acres to a maximum of 1,500 acres. The four major crops grown in the study area are alfalfa (13%), Wheat (15%), Corn (10%), and peanut (15%).

A crop rotation scheme is used by 56 percent of the respondents. In crop production, 67 percent use fertilizers, 44 percent use herbicide, and 50 percent use insecticide. A minimum of one irrigation well and a maximum of seven irrigation wells are used by the area farmers with a total of 29 well listed in the survey. An average of approximately 67 acres per well is under irrigation. A majority of the farmers have irrigated more than six years as as minimum and a maximum of 26 years with the average being 19 years. Some farmers (33%) have added irrigation wells to their operation due to putting more land into production and the need for more water. The furrow irrigation system is used mostly at 39 percent. The turbine irrigation pump is used at 44 percent. The fuel source used to pump the water for irrigation is electricity (39%), and L. P. natural gas (22%). Respondents were in favor of installing a meter on their irrigation well (22%). Some suggestions area farmers had if water supplies for irrigation became scarce would be: change crops to dry-land; change crop operation; dig more wells; use more surface water; never go back to irrigation; and there is no need to change if human consumption along with increased production costs would be reflected in commodity price for agricultural production costs. Changes in energy costs has affected 44 percent of the respondents to change the crops they grow. The concern of how respondents felt towards the current water supply in their area is described as adequate by 61 percent.

The measures necessary for ground water management of well spacing was accepted by 50 percent and of those surveyed 33 percent strongly favored this method. The use of meters was strongly disagreed upon by 39 percent. The management requirement of allocation and rotation was strongly disagreed upon by 61 percent of the respondents. The management scheme of taxes on agricultural users was strongly disagreed upon by 78 percent of the respondents. The management scheme of changing crops was agreed upon by 44 percent of the respondents. Many of the respondents (50%) felt they already pay too much in land taxes. A electric load management scheme was strongly disagreed upon by 56 percent of the respondents.

The views of respondents towards the present ground water laws in Oklahoma seemed to disagree with the law. The views are agree (28%), strongly agree (11%), neutral (22%), and disagree (33%). Agreement seemed to be reached with the statement that managing ground water would be performed by a single state agency. The views are strongly agree (6%), Agree (39%), neutral (6%), disagree (28%), and strongly disagree (17%). The issue of water conservation as the best alternative for meeting water needs was strongly agreed upon (11%) and agreed upon (50%) of the respondents. The return to dry-land farming techniques was agreed upon by 61 percent and strongly agreed upon by 11 percent of the respondents. The issue of the state is to establish a ground water management district was viewed by the respondents who disagreed by 56 percent. The issue concerning ground water management district is to have powers to enforce rules and impose controls was strongly agreed on (28%), and agreed upon (39%) of the respondents. The issue on the establishment of a ground water management system by local county and townships was agreed (44%) and strongly agreed (22%) of the respondents.

Concerning the issue that ground water should be considered public property rather than private property, respondents disagreed (39%), and strongly disagreed (44%). The issue concerning that water for irrigation should be a higher priority than industrial use was viewed by the respondents as strongly agree (50%), and agreed (17%). Concerning the statement that ground water is a renewable resource, 50 percent of the respondents agreed. Concerning the issue that the state should be divided into ground water districts, 61 percent of the respondents agreed. The statement that by the year 2000 ground water in this country will be depleted was viewed by 56 percent of the respondents who disagreed with the statement. Concerning the issue that Oklahoma Ground Water Law is adequate to solve problems of shortages in the future was disagreed upon by 44 percent of the respondents. The issue of using a graduated tax per unit of irrigation water pumped as a management option was strongly disagreed (33%) and disagreed upon (33%) of the respondents.

The environmental and natural resources issues was viewed by respon dents based on how serious the issues are in the state. Air pollution was viewed as no problem (44%) by the respondents. Water pollution was viewed as serious (33%) by the respondents. Commodity farm prices was viewed as very serious (33%) and serious (39%) of the respondents surveyed. Drought was viewed as serious (39%) of the respondents surveyed. Population growth and coal strip mining was viewed as no problem by 44 percent of the respondents. Water shortages was split between serious and not problem by 39 percent of the respondents. Soil erosion was viewed as a serious problem (44%) by the respondents. Flooding was viewed as no problem (33%) of the respondents. Energy costs was considered a very serious problem (50%) of the respondents. Soil depletion was viewed to be serious problem (50%) of the respondents. Ground water depletion was viewed as being serious (39%) of the respondents. Waste disposal was viewed as a very serious problem (44%)

of the respondents.

The general comments of some of the respondents surveyed were to develop a comprehensive water program and laws that are enforceable; to develop state water laws to protect individual landowners; and to help farmers with cost and production of products to meet future supply and demand for the state of Oklahoma and the Nation.

Agricultural Economics

General

The analysis of agricultural economics encompasses mainly the crops grown under irrigation and dry-land farming practices. Data is obtained from the political survey questions number 11, 12, 17, 21, 22, and 27 (see Appendix J). The total number of working irrigation wells in the study area counted by road survey is 38. One irrigation well is used for a catfish farm. The other is a irrigation will with no pump on which is located in section 34, T.5N., R.3E.. The municipal wells for the city of Stratford and the city of Byars are not considered. Another irrigation well in section 17, T.4N., R.3E. is used for the rural water district of Wynnewood, and is not considered. The rest of the irrigation wells have operational pumps.

Agricultural Crops Grown

The crops grown in the study area are alfalfa, wheat, corn, soybean, peanut, milo, cotton, and orchard (peaches). Analysing six farmers surveyed and their total acreage in farm operation owned or leased under irrigation will give some indication of net returns as a benefit of irrigation Vs dry-land farming practices. The result of the survey shows that approximately 4,500 acres is farmed, and approximately 1,300 acres were under irrigation in the 1985 growing season. The amount of irrigated crops were 325 acres of alfalfa, 180 acres of corn, 40 acres of soybean, 370 acres of peanut, and 40 acres of milo. Evaluation of crop yields are taken from the Oklahoma Agricultural Statistics, 1985. These crop yield per acre values are considered for dry-land and irrigation farming practices for Garvin county and not for McClain and Pontotoc counties. Since McClain and Pontotoc counties did not have many of the acres reported in the political surveys. The crops of alfalfa (hay), corn, soybean, oat, and barley did not report any acres under irrigation. A trend of crop prices from 1960 to 1985 reveals a steady increase in crop prices to 1984, with 1985 showing a decline in commodity prices.

Irrigation Benefits Vs Dry-Land

Considering the benefits of irrigation Vs dry-land farming practices an assumption that if no irrigation, all crops would have to be dry-land crops. Therefore, analysis of the total acres for irrigation for the crop of peanut grown over the same number of acres for dry-land crop should reveal a net benefit for irrigation. A net benefit of 1.14 : 1 cents per pound for peanut can be realized for utilizing an irrigation practice. Table XI shows the dry-land Vs irrigation net returns for the various crops grown in the study area. The dry-land crop yield is the south-central counties average reported yield. The irrigation crop yield value is high for the Garvin county estimate. Therefore, speculation that yields reported included irrigated acreage was incorporated into the dry-land crop yield value. The total net returns of dry-land Vs irrigated crops shows a benefit ratio of 1.21 : 1 for those irrigated crop acreage surveyed.

TABLE XI

DRY-LAND VERSUS IRRIGATION NET RETURNS

crop	Dry-land yield/acre	acre	price	total	Irrigation yield/acre	price	total
alfala	3.72 ton	325	$81.40*	98,412.60	5.00 ton+	$81.40	132,275.00
corn	89.72 bu.	180	2.70	43,603.92	105.00 bu.	2.70	51,030.00
soybean	26.00 bu.	40	4.70	4,888.00	32.60 bu.	4.70	6,128.80
peanut	2,230.00 lbs.	370	0.263	217,001.30	2,540.00 bu.	0.263	247,167.40
milo	44.30 bu.	40	3.90	6,910.80	73.00 bu.	3.90	11,434.80
	TOTAL NET RETURN			$370,816.62			$448,036.00

\+ Value from area farmer yield per acre estimate.
* Value taken from Agricultural Prices, 1985 Summary, USDA, June 1986.
__ Value used is state average for south-central, Oklahoma.

Source: Oklahoma Agricultural Statistics, 1985, OK. Dept. Of Agriculture.

Further analysis of crop net returns under irrigation need to consider the type of irrigation system utilized and the fuel source cost values. Furrow irrigation is the sytem mostly used in the study area. The fuel source mostly used is electricity and L. P. gas. Fertilizers applied to the crops varied from 200 to 400 pounds per acre. The state of Oklahoma cost per KWH for the years of 1984 and 1985 for electricity are 7.2 and 7.5 cents, respectively (Ag. Prices, 1985 Summary, 1986). Table XII shows the monthly L. P. gas price paid for by the state of Oklahoma, and the average yearly trend of L. P. gas prices of the United States in dollars per gallon. The analysis of the other fuel types used within the study area are gasoline and diesel. Table XIII shows the monthly gasoline prices paid for by the state of Oklahoma and the average yearly trend of gasoline prices of the United States in dollars per gallon. The gasoline engines used to pump the water generally are water cooled. However, air cooled engines can be used.

TABLE XII

L. P. GAS PRICES PAID BY MONTH FOR OKLAHOMA AND 1980 TO 1985 UNITED STATES TREND.

LPG	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oklahoma	$0.70	.70	.69	.69	.69	.67	.64	.63	.63	.65	.67	.72
YEAR					United States							
1985	$0.743	.739	.735	.733	.730	.725	.719	.699	.703	.699	.722	.764
1984	.773	.777	.772	.768	.763	.754	.747	.747	.749	.754	.758	.761
1983	.784	.770	.767	.733	.722	.771	.772	.773	.767	.772	.768	.760
1982	.711	.696	.673	.658	.655	.652	.656	.674	.729	.769	.804	.800
1981	.671	.686	.696	.701	.701	.703	.699	.697	.696	.701	.705	.706
1980	.678	.603	.609	.614	.618	.620	.617	.621	.623	.628	.640	.656

Source: Agricultural Prices, 1985 Summary, USDA, NASS, June 1986.

Planting and harvesting equipment may use tractors to pull the implement and are powered by the fuels of either gasoline or diesel fuel, or the implements may be self propelled. For practical purposes

TABLE XIII

GASOLINE PRICES PAID BY MONTH FOR OKLAHOMA AND 1980 AND 1985 UNITED STATES TREND.

Gasoline	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oklahoma	$1.01	0.98	1.02	1.07	1.12	1.10	1.17	1.16	1.14	1.10	1.11	1.14
YEAR					United States							
1985	1.09	1.07	1.10	1.15	1.17	1.18	1.19	1.19	1.18	1.16	1.17	1.17
1984	1.16	1.16	1.16	1.17	1.18	1.17	1.15	1.14	1.15	1.15	1.15	1.13
1983	1.17	1.13	1.08	1.15	1.19	1.21	1.22	1.23	1.22	1.21	1.19	1.18
1982	1.28	1.26	1.20	1.14	1.17	1.25	1.27	1.26	1.25	1.24	1.23	1.20
1981	1.21	1.29	1.32	1.32	1.32	1.31	1.30	1.29	1.29	1.29	1.29	1.29
1980	1.01	1.09	1.14	1.16	1.17	1.18	1.18	1.17	1.17	1.16	1.17	1.18

Source: Agricultural Prices, 1985 Summary, USDA, NASS, June 1986.

these fuels will not be considered except to realize a trend of prices paid by farmers within the study area.

Table XIV will show the monthly diesel fuel prices paid for by the state of Oklahoma, and the average yearly trend of diesel fuel prices of the United States in dollars per gallon. The irrigation costs considered the initial cost, operational costs and the return over costs. Table XV shows irrigation system selection chart, which reviews different equipment selections. The system of irrigation used in the study area is furrow irrigation.

TABLE XIV

DIESEL FUEL PRICES PAID BY MONTH FOR OKLAHOMA AND 1980 AND 1985 UNITED STATES TREND.

Diesel	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Oklahoma	$0.98	0.95	0.96	1.00	1.03	0.98	0.98	0.96	0.96	1.01	1.03	1.05
YEAR					United States							
1985	0.96	0.95	0.94	0.97	0.98	0.97	0.94	0.93	0.95	0.97	1.02	1.04
1984	1.00	1.04	1.02	1.00	1.00	1.01	1.00	0.99	0.98	0.99	0.99	0.98
1983	1.09	1.04	0.96	0.96	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.00
1982	1.16	1.15	1.11	1.07	1.07	1.11	1.12	1.10	1.11	1.11	1.14	1.12
1981	1.06	1.13	1.16	1.18	1.18	1.17	1.18	1.17	1.17	1.17	1.17	1.18
1980	0.90	0.95	0.98	1.00	1.00	1.00	1.01	0.99	0.99	1.00	1.01	1.03

Source: Agricultural Prices, 1985 Summary, USDA, NASS, June 1986.

This system requires land leveling as an initial costs. This system utilizes gated pipe to irrigate every or every other furrow. Also, this system is most adaptable to approximately level 1 (%) percent slopes. The majority of the labor occurs over moving the pipes to irrigate a particular field. The operation and maintenance costs associated for different types of engines can be seen in Table XVI. Electric motors are the most efficient per operating hour used. The determination of the estimated relative cost per horse power-hour can be derived from the following formulas:

Diesel: $\text{Cost/hp-hr} = \dfrac{\text{Cost/Gallon}^{1}}{15}$

Propane: $\text{Cost/hp-hr} = \dfrac{\text{Cost/Gallon}^{1}}{9}$

Natural Gas: $\text{Cost/hp-hr} = \dfrac{\text{Cost/MCF}^{1}}{81}$ (MCF= 1,000 cubic feet)

Electricity: 2 $\text{Cost/hp-hr} = \dfrac{\text{cost/KWHR}^{1}}{1.2}$

1 Cost used should be average expected cost over the life of the investment.

2 If demand, or standby charges, are assessed, then demand cost/hp-hr should be calculated as shown below and added to the energy cost/hp-hr to obtain the total cost/hp-hr.

$$\text{Demand Cost/hp-hr} = \frac{\text{Annual Demand Cost}}{(\text{Annual KWHR})(1.2)}$$

Source: Dekalb Research Notes No. 16, 1982.

TABLE XV

IRRIGATION SYSTEM SELECTION CHART

Equipment Description	Cost ($/Ac.)	Labor Req'd. * (Hr./Irrig. Ac.)	Pump Operation (Percentage %)	Requirement and Limitations
Gated Pipe	150	0.6	75	Relatively level application site. Undesirable condition for operating personnel.
Tow Line	210	0.2-0.4	85	Rectangular fields desirable. Pull strips required.
Side Wheel Roll	220	0.2-0.6	85	Rectangular field required. Low crop clearance. Recommend for use on relatively flat terrain.
Traveling Big Gun	240	0.2-0.4	85	Operating land required. High operating pressure. Applicable for irregular shaped fields.
Center Pivot	270	0.05-0.3	99	Most cost effective on square fields. Increased cost to irrigate corners. Moderately adaptable to small irregular shaped fields.
Solid Set	900	0.5-1.0	99	Applicable to irregular shaped fields. adaptable to most crops susceptible to damage by harvesting equipment and animals.

* Wide range in values due to system management as well as equipment variations within the general category. For example, electric drive center pivots would be expected to require substantially less labor than water drive hydraulic center pivots.

Source: Modified after the Dekalb Research Notes No. 16, 1982.

TABLE XVI

OPERATION AND MAINTENANCE COSTS FOR PUMPING UNIT PER 1000 HOURS ASSUMING OPERTATING 1000 HOURS PER YEAR OR MORE.

Type of Engine	Lube	Labor	Repairs	Total
Air cooled-gasoline	$3.80	$4.50	$5.50	$13.80
Water cooled-gasoline	3.20	4.20	4.00	11.40
Water cooled-natural gas	3.50	4.20	3.80	11.50
Water cooled-diesel	3.32	4.17	7.85	15.34
Electric	0.67	--	0.33	1.00

Source: Dekalb Research Notes No. 16, 1982.

The general monthly estimated electric rates area farmers pay is calculated at $300.00. This value is determined using the above equations. The average irrigation motor is rated at 20 horse power, and is run for an average time period of 12 to 24 hours to irrigate a 80 acre plot. The general irrigating time per month is every three days in some cases depending upon the crop demands (consumptive use requirements). The suggested depreciation period associated with different components of irrigation systems are seen in Table XVII.

The equipment used is turbine electric motors, and surface gated pipes. The land leveling costs has been paid for by most irrigators due to many of the irrigation systems have been in existence for more than 20 years. The depreciation, inflation rate, and interest will affect the various costs for equipment mentioned.

The economic parameters for agricultural maximum crop yield should include irrigation scheduling schemes related to the amount of water applied per application and the dollar return. The hydrologic connection depends on the well development costs and the number of wells required to pump the allocatd water for a specific crop. The drilling and completion cost of a total penetrating well, which has an average depth of 94 feet, and is completed with a 12-inch diameter steel casing with a two foot thick gravel pack, is estimated at 30 dollars per foot (in 1983 dollars) or $2,820 per well (Kent, et. al., 1982).

TABLE XVII

SUGGESTED DEPRECIATION PERIOD FOR COMPONENTS OF AN IRRIGATION SYSTEM.

Component	Depreciation period Hours	or	Years
Well and Casing			20
Pump plant housing			20
Pump, turbine:			
Bowl (about 50% of cost of pump unit)	16,000	or	8
Column, etc.	32,000	or	16
Pump, centrifugal	32,000	or	16
Power transmission:			
Gear head	30,000	or	15
V-belt	6,000	or	3
Flat belt, rubber and fabric	10,000	or	5
Flat belt, leather	20,000	or	10
Power Units:			
Electric motor	50,000	or	25
Diesel engine	28,000	or	14
Gasoline engine			
Air-cooled	8,000	or	4
Water-cooled	18,000	or	9
Propane engine	28,000	or	14
Pipe, asbestos cement and P.V.C.			40
Pipe, surface, gated			10
Pipe, aluminum, sprinkler use			15
Pipe, steel galvanized, surface only			8
Sprinkler heads			None
Land grading *			None
Reservoirs **			
Mechanical Move Sprinkler System (example: Center Pivot)			15
Continuously Moving Sprinkler System (example: Traveler)			10

* Some sources depreciate land leveling in 7 to 20 years, however, if proper annual maintenance is practiced, figure only interest on the leveling costs. Use interest on capital invested in water right purchase.

** Except where silting from watershed will fill reservoir in an estimated period of years.

Source: Dekalb Research Notes No. 16, 1982.

Models exist to calculate the cost to lift water when an aquifer is depleted. The model, at this time, is not accessible from other disciplines and will not be addressed further. Another agricultural economic element to consider is the sale or transfer of water rights. At present, the prior rights allocation is generally for two acre feet per farmer prior right allocation. Due to increased energy, labor costs, and farm related problems, it becomes apparent the allocated prior right sometimes is not used.

A way a farmer can realize a benefit for the prior right is by sale of water allocated to municipal, industrial, or rural water districts. At present the income generated for sale of water to a rural water district is approximately \$0.60 per 1,000 gallons of water used. The farmer pays for the initial well and pump installation. This can generate an income of approximately \$1,500 dollars per month for a farm operation. This can have a benefit for a farmer who feels he can not use his full allocation to a beneficial use. Chapter II describes the prior right allocation for the study area, and a description of the rural water district of Wynnewood, Oklahoma. At this time, the rural water district of Wynnewood, Oklahoma has a demand for more water for the rural water district pipe line service to residents within the area.

Another agricultural economic element to be addressed is the industrial future for the Isolated Terrace Deposit. The sale of orchard crops is mostly done by road side on highway 177, north of Stratford, Oklahoma. It would seem some benefit can be realized by implementing an industrial plant to process the perishable products produced in the study area. This can help to stabilize the economy by creating employment opportunities for the area residents, and help farmers realize economic benefits to their farm operations. The feasibility of such a plan would depend upon the aquifer characteristics of the Isolated Terrace Deposit. Chapter II describes the aquifer characteristics for such a plan.

Consumptive Use of Crops

General

Irrigation scheduling techniques have been developed to reduce irrigation applications while improving or maintaining crop yields. Irrigation scheduling techniques are of the following types of hydrological, and physiological. The hydrological technique is concerned with estimating soil mositure either directly or by the water balance approach. The physiological technique assesses the need for water from plant measurements such as stomata resistance, leaf water potential, growth stage or canopy temperature (Kanemasu, et. al., 1983).

The water balance or a field can be defined as:

$$SM = SM + Pe + I - D - ET$$

Where SM is the soil moisture on a given day, SM is the initial soil moisture, Pe is the effective precipitation, I is irrigation, D is drainage below the root zone, and ET is evapotranspiration (Kanemasu, et. al., 1983).

Irrigating by soil moisture status is most favored by growers as energy and other irrigation costs increase. This method is based on crop needs and the available soil moisture, which will tell irrigators when to apply more water. Three soil moisture properties include the field holding capacity, available soil moisture, and permanent wilting point. Measuring soil moisture can be done by using tensiometers, electrical resistance meters, neutron probes, and the feel process. A detailed description of the working principles of each of these methods will follow.

Hydrological Methods

The tensiometer is an air tight, water-filled tube with porous ceramic tips at the bottom and a vacuum gauge at the top. Generally, two different depths of tensiometers are installed, one shallow at 10 to 12 inches, and the other at 24 to 30 inches. The shallow tensiometer is used to evaluate when to begin irrigation. The deeper used to evaluate infiltration to check for under or over irrigation. Table XVIII relates vacuum gauge readings with a brief interpretation (Dekalb Research Notes, 1982). Tensiometer reading should be taken at about the same time every day to get a better idea of soil moisture status change each day.

The electrical resistance meter operation measures a change in soil moisture content produces a change in electrical conductivity. Electrodes are mounted in blocks of known electrical resistant materials such as gypsum, nylon, fiberglass, or plastic. The basic operating principle is as the soil dries, the resistant block dries and electrical conductivity is reduced. If soil becomes wetter, the resistance block absorbs moisture and electrical conductivity increases. Table XIX is an interpretation of electrical resistance meters as related to soil moisture tension. Many of the resistance blocks have different calibrations. The frequencies should not be greater than ten to 15 centibars because of the changes in soil water tension. Thus, if irrigators apply water more than once a week a reading should be taken on a dailey basis.

TABLE XVIII

INTERPRETING TENSIOMETER READING.

Guage reading	Position of Tensiometer 10 - 12 inch depth	 24 - 30 inch depth
0 - 10	saturated soil one day after a rain.	over irrig. or very slow rain has occured leaching
10 - 20	Field capacity. Young corn (8 leaf emergence could be over-watered if guage stays in this position.	Field capacity irrigation should be stopped. Any further irrig. will cause water loss and nutrient loss if not already started.
30 - 60	Range for starting irrigation. If corn is in the 9 leaf or pre-tassel, start irrig. when vacuum stage reads at 45 at this depth.	Range for starting irrigation. Start before readings at this depth reaches 55 if corn is at pre-tassel or later.
70 or higher	Corn is stressed if corn is young. Older corn with roots below this depth may not show signs.	Corn is suffering yield losses if advanced beyond 9 leaf, corn old enough for roots to extend to this depth show stress.

Source: Dekalb Research Notes, No. 16, 1983.

Another method to measure soil moisture is the neutron probes. This method uses a radioactive source which emits neutrons at a desired soil depth. It works on the principle that when neutrons hit hydrogen ions in soil water zone they bounce back at a slower rate or velocity. An electrical scanner measures the number of these slower neutrons and the readings are converted to soil moisture content. The instrument as yet is not used by farmers, but by Dekalb Researchers, University and commercial researchers (Dekalb Research Notes, No. 16, 1983).

The last method for determining soil moisture is feel. This method amounts to taking a soil probe and boring to various depths to get a

TABLE XIX

INTERPRETATION OF READINGS ON ELECTRICAL RESISTANCE METERS AS RELATED TO SOIL MOISTURE TENSION.

Terms	Bars Tension	Meter Reading	Interpretation
Nearly saturated	< 0.20	200 to 180	Nearly sat. soil, occurs for a few hours following a rain or irrigation
Field capacity	0.20 to 0.32	180 to 160	Field capacity, discontinue irrigation in this range
Irrigation range	0.65 to 1.20	140 to 100	Usual range for starting irrigation. Starting irrigation is this range insures maintaining readily available soil moisture at all times.
Dry	1.6	< 60	Stress range for most soils and crops. Some soil moisture present but dangerously low for maximum plant growth and production.

< less than

Source: Dekalb Research Notes, No. 16, 1983.

soil sample. The condition of the soil is determined by rubbing the soil sample through the fingers. Table XX shows a list of interpretations of soil moisture by soil texture types.

Physiological method

Irrigation scheduling based on consumptive use of crops such as corn can be done using the calendar method, by crop appearance method, and Irrigating by growth stages. The calendar method considers the growth stage of the hybrid, the date of planting, soil characteristics and the capacity of the irrigation system. Studies in Kansas, using limited irrigation, timed to coincide with the critical stages of corn growth was more significant in increasing yields than the calendar date of irrigation (Dekalb Research Notes, No. 16, 1983).

TABLE XX

INTERPRETATION CHART: AVAILABLE SOIL MOISTURE IN PERCENT FOR VARIOUS SOIL TEXTURES USING THE FEEL PROCESS AND CORRESPONDING AVAILABLE WATER IN INCHES PER FOOT

AVAILABLE MOISTURE IN SOIL	FEEL OR APPEARANCE OF SOIL			
	COARSE SANDY LOAM Coarse-textured soils	SANDY LOAM Moderately coarse-textured soils	SILT LOAM Medium-textured soils	SILTY CLAY LOAM Fine and very fine textured soils
0 percent	Dry, loose and single-grained; flows through fingers (0-.1)*	Dry and loose; flows through fingers (0-.2)	Powdery dry; in some places slightly crusted but breaks down easily into powder (0-.3)	Hard, baked and cracked; has loose crumbs on surface in some places (0-.4)
25 to 50 percent	Appears to be dry; does not form a ball under pressure' (.2-.25)	Appears to be dry; does not form a ball under pressure (.3-.4)	Somewhat crumbly but holds together under pressure' (.4-.5)	Somewhat pliable; balls under pressure' (.5-.7)
50 to 75 percent	Appears to be dry; does not form a ball under pressure (.4-.5)	Appears to be dry; does not form a ball under pressure (.6-.8)	Forms a ball under pressure; somewhat plastic; slicks slightly under pressure (.8-1)	Forms a ball; ribbons out between thumb and forefinger (.9-1.3)
75 percent to field capacity	Sticks together slightly; may form a very weak ball under pressure (.6-.8)	Forms a weak ball that breaks easily; does not slick (.9-1.2)	Forms ball; very pliable; slicks readily if relatively high in clay (1.3-1.5)	Ribbons out between fingers easily; has a slick feeling (1.4-1.9)
At field capacity (100 percent)	On squeezing, no free water appears on soil, but wet outline is left on hand (.8-1)	Same as for coarse-textured soils at field capacity (1.2-1.5)	Same as for coarse-textured soils at field capacity (1.5-2.0)	Same as for coarse-textured soils at field capacity (1.9-2.5)
Above field capacity	Free water appears when soil is bounced in hand	Free water is released with kneading	Free water can be squeezed out	Puddles; free water forms on surface

' Ball is formed by squeezing a handful of soil very firmly.
* Values in parentheses are available water per foot in inches at that texture.

USDA

Source: Dekalb Research Notes, No. 16, 1983.

Irrigating by growth stages such as corn is based on the water use pattern requirement for various stages of corn growth. Table XXI shows the dailey water use rates for corn growth stages.

These water use rates will vary from area to area, but should illustrate the need to consider the growth stage in irrigation programs. Kansas research based on crop critical yield for irrigation scheduling has obtained good yields and results.

TABLE XXI

DAILEY WATER USE RATES BY CORN GROWTH STAGE.

(Water use rates are approximate depending on temperature, wind, and soil. Values represent water use rates under favorable moisture conditions in the High Plains.)

Growth Stage	Dailey Water Use Rate (inches)
2 leaves fully emerged (14 days after planting*)	.025
4 leaves fully emerged (21 days after planting*)	.040
6 leaves fully emerged (28 days after planting*)	.055
8 leaves fully emerged (35 days after planting*)	.085
10 leaves fully emerged (42 days after planting*)	.100
12 leaves fully emerged (50 days after planting*)	.180
14 leaves fully emerged (pre-tassel)	.220
16 leaves fully emerged (tassel showing)	.270
Pollination (tassel and silks fully emerged)	.320
Blister stage (silks browning)	.350
Milk stage (kernals are colored)	.310
Dough stage (24 days after pollination*)	.250
Begining dent (36 days after pollination*)	.180
Full dent (48 days after pollination*)	.095
Physiological maturity (60 days after pollination*)	.020

* Number of days to each growth stage will vary with hybrid and climate.

Source: Dekalb Research Notes, No. 16, 1983).

Irrigation Scheduling Literature in Oklahoma

Research on irrigation scheduling has not specifically been done here in Oklahoma. Only experiment station test sites were used to analyze crop yields under dry-land and irrigation practices. Consumptive use of crops in Oklahoma can be estimated using the consumptive use formula. This formula correlates existing consumptive use data from other western states to, in our case, various agricultural crops grown here in Oklahoma. The Blaney and Criddle formula uses monthly temperature, percent of daytime hours and precipitation data for the frost free period, or irrigation season. The consumptive use formula is expressed mathematically as recorded by Garton, et. al., (1955).

U = KF = Sum of kf where:

U = Consumptive use of crop (or evapotranspiration) in inches for any period.
F = Sum of the monthly consumptive use factors for the period. (Sum of the products of mean monthly temperature and monthly percent of annual daytime hours.)
K = Empirical consumptive use coefficient (irrigation season or growing period) determined from experiments at various locations (different value for each crop).
t = Mean monthly temperature, in degree fahrenheit.
P = Monthly consumptive use factor $\left(\frac{t \times p}{100}\right)$.
k = Monthly consumptive use coefficient.
U = kf = Monthly consumptive use in inches.

The consumptive use coefficients used are for the most important crops grown here in Oklahoma. Table XXII shows some of the irrigated crop classifications and the consumptive use coefficient for the growing season. The total irrigation water requirement of crops in any area is the quantity of water needed for the various crops. Table XXIII shows the range of consumptive use and net irrigation water requirements.

The percentage of annual daytime hours for the study area can be derived from Table XXIV. The study area is located at approximately 34.8 degrees latitude north of the equator. This value is taken from the geologic map of Oklahoma, the Hydrologic Atlas in Reconnaissance of Water Resources of the Ardmore and Sherman Quadrangles, Southern Oklahoma (Hart, 1974).

The consumptive use formula varies with the temperature, daytime hours, and available moisture; which can be in the form of precipitation or from ground water sources.

TABLE XXII

COEFFICIENTS USED IN COMPUTING CONSUMPTIVE USE OF WATER IN OKLAHOMA.

Classification	Growing season or period	Consumptive Use coefficient Growing period
Irrigated Crop		
Alfalfa	Frost-free period	0.85
Corn	Apr. 15 - Aug. 15	0.80
Cotton	May 1 - Oct. 31	0.70
Early truck	3 months from last spring frost	0.60
Grass pasture	Frost-free period	0.80
Sorghum	May 1 - Sept. 1	0.70

Source: After Garton, et. al., 1955.

TABLE XXIII

RANGE OF THE CALCULATED CONSUMPTIVE USE AND NET IRRIGATION REQUIREMENT VALUES OF CROPS IN THE STATE OF OKLAHOMA FOR NORMAL RAINFALL.

Crop	Consumptive Use (inches)	Net Irrigation Requirement * (inches)
Alfalfa	33.9 - 43.4	8 - 22
Pasture	31.1 - 40.8	7 - 20
Cotton	26.1 - 29.8	4 - 15
Sorghum	19.6 - 21.8	4 - 11
Corn	21.5 - 23.9	7 - 13
Truck	11.2 - 12.6	0 - 5

* To obtain the gross irrigation water requirements divide the net irrigation requirements by the Irrigation Efficiency.

Source: After Garton, et. al., 1955.

The consumptive use equation uses the mean monthly temperature for a area of study. The mean monthly temperature can be found in Chapter II under the section labeled climate. The monthly consumptive use data are useful in determining the irrigation requirements of crops, frequency of irrigation, disposition of precipitation and its contribution to the ground water supply, safe yields of ground waster basins (Blaney, et. al., 1960).

TABLE XXIV

MONTHLY PERCENTAGE OF ANNUAL DAYTIME HOURS FOR LATITUDES 30 TO 40 DEGREES NORTH OF EQUATOR.

Month	Latitudes in degrees north of equator *							
	31	32	33	34	35	36	37	38
	Percent							
January	7.25	7.20	7.15	7.10	7.05	6.99	6.93	6.87
February	6.99	6.97	6.94	6.91	6.88	6.86	6.82	6.79
March	8.37	8.37	8.36	8.36	8.35	8.35	8.35	8.34
April	8.74	8.74	8.78	8.80	8.83	8.85	8.87	8.90
May	9.58	9.63	9.68	9.72	9.76	9.81	9.87	9.92
June	9.55	9.60	9.64	9.70	9.77	9.83	9.89	9.95
July	9.72	9.77	9.83	9.88	9.93	9.99	10.05	10.10
August	9.25	9.28	9.31	9.33	9.37	9.40	9.44	9.47
September	8.34	8.34	8.34	8.36	8.36	8.36	8.37	8.38
October	7.96	7.93	7.92	7.90	7.87	7.85	7.82	7.80
November	7.15	7.11	7.06	7.02	6.97	6.92	6.87	6.82
December	7.10	7.05	6.99	6.92	6.86	6.79	6.72	6.66
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Computed from "Sunshine Table," U. S. Weather Bureau Bulletin 805, 1905 ed.

* Source: Modified after publication of Garton, et. al., 1955.

A simple method of irrigation scheduling which uses the maximum air temperature, long-term average solar radiation and crop growth stages is the checkbook method (Lundstrom, et. al., 1981). The checkbook method is widely used in the upper mid-western states during rapid irrigation developments. Figure 39 shows the checkbook method, balance sheet, evaluation form (Werner, 1979). The scheduling method records crop rooting depth, available water in root zone, pumping capacity, rainfall and irrigation, and the soil water balance. These factors are balanced just as a checkbook might be balanced. The checkbook system provides irrigators with a easy method to schedule his own irrigations with a reasonable level of accuracy for the specific crops he grows. Comparisons of other methods to schedule water, tensiometers, evaporation pan, and crop coefficient methods, showed the checkbook method to give the highest yield and required slightly more water than the other methods (lundstrom, et. al., 1981).

Week after emergence	Date	Soil water reading		Maximum temperature	Withdrawal	Deposits		Soil water balance	
					Crop water use	Rainfall	Net irrigation		
		A	B					A	B

Figure 39. Checkbook Method, Balance Sheet, Evaluation Form. (After Werner, 1979).

The evaluation of the various methods for the management of farm irrigation systems utilized within the study area can be evaluated appropriately by using irrigation system forms. The irrigation evaluation forms can be useful in determining the amount of water applied across the fields. Appendix K shows irrigation evaluation forms (Merriam, et. al., 1978).

Ground Water Management Strategy

The ground water management strategies may include such systems of electric load management, well spacing, metering of irrigation wells, moritorium of irrigation wells, allocation and rotation of wells, taxes on agricultural users of ground water to the changing of crops to be more suitable for the particular climate encountered. The system of electric load management utilizes irrigation scheduling based on consumptive use of crops grown and time associated with peak electrical demands from rural electric power suppliers. Such a system regulates the irrigation pump motor from the cooperating power suppliers, as is an example in Nebraska. The integration of power management to irrigation scheduling puts the irrigation motor under contract for time control during an irrigation season (Stetson, 1981).

The strategies of well spacing, moritoria and metering of irrigation well, and allocation and rotation of wells can be analysed as to their effectiveness based on Nebraska's Ground Water Management Act. The well spacing strategy in certain control areas can affect the density and location of new wells. Well spacing is a "relatively efficient, equitable and easily administered method of reducing well interference but not an effective method for reducing ground water withdrawls" (Aiken, et. al., 1978). Problems associated with this method is that it could preclude development where early developers get the water while those who have not developed yet are denied the anticipation for development (Aiken, et. al., 1978). The moritorium of irrigation wells is a method based on controlling the ground water to protect the public interest. This is an extreme measure in which no drilling within all or part of a control area needs to have approval from the Natural Resources Department and the Department of Water Resources. Drilling moritoria is a long-term ground water management mechanism which is managed for the benefit of those who caused the problem - the present users (Aiken, et. al., 1978). The metering of irrigation wells is a method to control the amount of flow a user is taking from an aquifer inorder to irrigate his crops. With this method, a user can determine the amount of water that is being put on his crop. Inequities result when no one is around to monitor the amount of water used. Additional costs for this method result by putting a meter on the wells being used at a particular time. Simply, the meters costs money and the time associated with a person putting or switching a meter on a well could be costly.

The ground water management strategy involving rotation and allocation is a control mechanism for when a well can be pumped and limits the amount of water to be pumped by the ground water users, respectively. The rotation method could be adopted for a dailey, weekly, monthly, yearly, or some combination of pumping (Aiken, et. al., 1978). A rotation schedule could be one out of four days or every other year. The water quantity impact could be substantial. The administration to enforce these requirements would include spotters and constant monitoring for a irrigation season. Enforcement during the week or dailey basis would be difficult, but if found by spot check could result in stiff penalties (Aiken, et. al., 1978). The rotation method would seem to be inefficient, inequitable, and difficult to administer during an irrigation season. However, the allocation method seems to be more promising by limiting the quantity of water pumped by ground water users. The ground water allocation could take many forms as recorded by Aiken, et. al., (1978):

1. Allocation of ground water for different bases;
2. per well, per irrigated acre, per irrigable acre, or per crop;
3. allocation by time period of one or several years;
4. could either be uniform or vary according to crop needs or aquifer conditions;
5. could restrict where water is used; and
6. could be established at different quantity levels.

The allocation per well and per irrigable acre is inequitable and difficult to administer. The allocation for irrigated acre would be the most desirable. Time period allocation of a single or several years could be advantageous by allowing carryover of unused allocation permitted for future years use. This allows a ground water user to use his allocation when needed the most and could prevent exhaustion of the allocation before the end of his allocated period. Uniform or varied aquifer conditions could be based on crop needs to provide incentives for those areas with less water to grow crops that require less water (Aiken, et. al., 1978). The restriction of use of ground water would allow irrigators to use water where it is the most productive by pooling allocations and using ground water transfers, limiting interference of nearby wells (Aiken, et. al., 1978). The different quantity levels selected could be a safe yield approach, as in ground water mining, or the intermediate approach, where economic, hydrologic, geographic and political factors of each ground water control area is considered (Aiken, et. al., 1978).

The management strategy of placing taxes on agricultural users could be set up on the basis of the amount of water used, or a tax on the number of acres irrigated. The taxing of agricultural users of ground water could be difficult to determine. The amount of tax to be applied could be proportional to the prior rights allocation. Difficulties occur in determining the relative value of water for irrigation and a fair proportional tax to be levied on such a resource.

The last management strategy is a last resort effort when all other management practices and methods fail, the changing of crops grown to be more suited to a particular climate. Such examples would be to grow small grain crops with shorter growing seasons as winter or spring wheat, rye, and oats. Resorting to growing drought resistant crops such as sunflowers, or cotton. Also, the use of double cropping methods may be dropped as an agricultural practice in Oklahoma by setting up a soil conservation practice similar to PIK (payment in kind) payments to farmers to leave land lay idol after one crop has been harvested.

The aspects of ground water managment will integrate the ground water wants and needs of the public at Stratford, Oklahoma. The political survey results indicate that a majority of the respondents want ground water management to be set up within the state. Also, the development of a comprehensive water program involving water useage for irrigation and integrating agricultural supply and demand economics. The ground water management strategies would allow the state to set up districts, but allow the local governmental agencies to manage or regulate the ground water management systems.

Further development of ground water management should include a type of irrigation scheduling. This is accomplished as a direct result of respondents claim that energy costs has an effect on the type of crops grown, and that the water supply is of concern so irrigation and the municipal uses can be sustained. The transferring of irrigation prior rights to municipal use or rural water districts, as a direct result of a progressively bad farm economy, has benefits in that prior right holders can put the water to a beneficial use for the amount of allocation. The water law system of prior appropriations claims that the transferring of water is legal from one basin to another as long as water allocation is used for a beneficial and reasonable use. The management of water in various basins should be set up for the future supply and demand characteristics of an aquifer. Therefore, this area should develop a Irrigation Ground Water Management Conservation District for the Isolated Terrace deposit water resources planning and management. Oklahoma's legislature should provide and promote a specific claim to water resources planning and management. This chapter was set up to review the management strategies and systems developed in other states with water resource allocation problems.

CHAPTER IV

RESULTS AND CONCLUSION

Hydrogeology

The Isolated Terrace Deposit of Garvin, McClain, and Pontotoc counties, Oklahoma is located in south-central Oklahoma, and is bounded by the Hunton Arch, Arbuckle Mountains, and the Pauls Valley uplift. A hydrogeologic study of the aquifer was to determine the maximum annual yield of fresh water to be produced for each ground water basin or subbasin.

The Isolated Terrace Deposit is an unconfined aquifer. The Isolated Terrace Deposit sediments are refered to as the Gerty sand and are composed of a medium to coarse grain sands, which represent a recharge area on the Garvin-McClain County line; and a gradational sequence of yellow to tan sand with silt and clay stringer at the top, to a white sand, medium grained, with black organic stringers at the base. The Oscar group, Upper Pennsylvanian in Age, sediments of the Stratford Formation is the shale and limestone. The Vanoss Formation, the conglomerate material, is in hydrologic continuity with the Terrace deposit.

Aquifer test data shows the average permeability to be 460 gpd/ft. squared. The aquifer characteristics shows that recharge is almost immediate. Full recharge takes approximately 13 days. Irrigation wells within the study area begin to surge at 40 minutes into the pumping period. Total thickness of the aquifer is 18 feet. The surging may indicate that the pump is overrated for the aquifer characteristics or leakage of turbine pump casing. The irrigation wells are completed into the Upper Pennsylvanian sediments of the Oscar Group, and into the Vanoss Formation, of conglomerate. The Isolated Terrace alluvium is located higher in the stratigraphic section and is a key source for recharge in the aquifer system.

The mean annual precipitation is 36.60 inches per year. A cyclic period of every seven years being wetter than normal can be expected. The average evapotranspiration rate is 22.74 percent over the study area. The relationship of barometeric pressure upon the water table aquifer is an inverse relationship.

The water quality of the Isolated Terrace Deposit is good, with a pH near neutral. Alkaline pH samples were taken from deeper lithologic units below the base of the aquifer.

Institutional Dimensions

The regulatory legislation is found in six environmental laws enacted at the federal level, which were directed at surface water quality, but contain certain aspects of ground water protection. Early developments of state water laws used the Riparian, in abundant water supply areas, and the Prior Appropriation system in arid regions where ground water mining occurs.

The development of Oklahoma's water law system follows the Riparian and Prior Appropriation Doctrines. The Riparian Doctrine deals with surface waters in streams and lakes, and the Prior Appropriation Doctrine is applied to individual basins or subbasins requiring a right of beneficial use designated for agricultural purposes.

A comparision has been made of ground water management strategies in various states, is problemmatical. Oklahoma law, in conjuction with allocation which allows for well spacing and the metering of wells by the Oklahoma Water Resource Board as management strategies. The progressive development of ground water management strategies are: well spacing, rotation and allocation or pumping restrictions, moritorium on well drilling, metering of wells, electric load management, taxes on agricultural users, and the changing of crops to be more suited to a particular climate encountered. The feasibility of these management strategies as adopted in other states may be easily administered but have certain problems in their adaptability.

Legal Institutional Aspects (Political Survey)

A political survey was conducted in the Isolated Terrace Deposit to determine current water related issues. Respondents, in selecting a ground water management strategy, would accept well spacing, and the changing of crops to dry-land farming practices as a last resort effort. There was a dissagreement on management strategies. Respondents were in favor of establishing a ground water management district to be controlled on the local level as developed by a single state agency. The residents wanted to have a ground water management district set up, and to be managed on a local county and township levels. The Water Resource Board is the single state agency with the powers and duties to manage ground water basins or subbasins. The development of a ground water management district has not been fully developed in Oklahoma. The panhandle counties of Oklahoma have irrigation and water resource associations and in other areas of the state, there are conservancy districts that mostly deal with stream and lake drainage systems.

The district to be used in the Isolated Terrace Deposit of Garvin, McClain, and Pontotoc counties, Oklahoma should develop an irrigation ground water conservation district. The extent of the Isolated Terrace Deposit aquifer limits the district to an isolated basin topographically dissected from the main river and stream networks. The irrigation ground water conservation district would be given powers and duties to investigate into irrigation scheduling practices, and electric load management strategies to help eleviate some of the excessive costs irrigators have to pay. Oklahoma water law allows a watermaster for each district to be given duties to regulate and control the waters to prevent waste. Watermasters and assistants would be paid by the counties inwhich the district lies; and would be paid from a lien (tax) on the property of water users. In this district, well spacing should be adopted to within the Oklahoma Water Resource Board limit of 600 feet. The ground water managment district should protect recharge areas from encroachment of wells to allow the aquifer to be replenished at its full length. The ground water management district should plan for development of ponds in the recharge area of the aquifer. Such pond developments could be constructed with the Soil and Water Conservation Districts. The irrigation ground water conservation district should work to incorportate or specialize in a particular crop for irrigation.

Agricultural Economics

The agricultural economic variables reflect allocation and the survey results. The agricultural economic benefits realized from irrigation practices is dependent upon the aquifer characteristics. The prices farmer pay for fuels, fertilizers, and equipment for irrigation is an added cost. The revenue generated for commodity sales is reflected in the increase yields with irrigation as compared to dry-land farming practices. The commodity crops grown in the study area are alfalfa, wheat, corn, soybean, peanut, milo, cotton, and orchard (peaches). In comparison of irrigation vs dry-land farming practices a benefit ratio of 1.21 : 1 is realized for using irrigation over dry-land farming. The costs associated with selecting a particular irrigation system, and the costs associated with fuels to produce these crops under irrigation is quite expensive. The hidden costs associated with aquifer depletion, or the additional cost to lift water for irrigation would need to be studied further, and these costs are born by the users of the ground water resource.

An irrigation scheduling practice should be adopted to obtain the maximum crop yield for the maximum dollar return, which would seem to help in reducing additional costs born by the irrigator. Irrigation scheduling, based on consumptive use of crops, are the calendar method, crop appearance, and by growth stages of crops. The checkbook method, as developed in the upper midwestern states, should be applied to irrigation scheduling in Oklahoma. Such irrigation scheduling schemes might include the checkbook method as modified for Oklahoma crops, and the use of farm irrigation system evaluation forms. These methods can help to determine the amounts of water applied to a crop, and can help to reduce energy and additional costs born by the irrigators.

The additional revenue realized for the sale or transfer of water rights can be usefull to irrigators. Some prior right allocations, due to bad farming economy, will not be used. The sale or lease of water right allocation to a municipal, industrial, or rural water district will make use of the allocation and should be used.

Ground Water Allocation

The ground water allocation limits set by the Oklahoma Water Resource Board for respective basins or subbasins are related to the physical environment of the aquifer. The relationship of the geology to the ground water availability (hydrologic) factors is reflected in the social economic developments in the Isolated Terrace Deposit. A preliminary estimate of aquifer yield was made prior to modeling. The allocated irrigation acreage is 3,100 acres, which may be equivalent to 55,800 acre-feet of water. The estimated yield as allocated for withdrawl from the aquifer, based on prior rights allocation for irrigation in the study area is 48,200 acre-feet of water. The remaining 7,600 acre-feet of water would be used for distribution for the various other (domestic) uses encountered in the study area. It is estimated that less than half of the water allocated (2,450 acre-feet) is used according to the prior right allocations.

The amount of water used for rural water districts is 0.638 acre-feet per month per 100 acres of the allocation sold. This means the prior right applicant has only used half of his allocated share of appropriated water. The municipal demands for the city of Stratford, Oklahoma is 14,400,000 gallons per month or 44.2 acre-feet per month per allocation. This is an allocation rate of 1.105 acre-feet per month per 40 acres.

Model Results

The amount of water available in the Isolated Terrace Deposit, as modeled by Kent, et. al., (1987), can be used as the effective allocation for the study area. The model results are submitted to the Oklahoma Water Resource Board as a Final Report on the "Evaluation of The Isolated Terrace Aquifer (Gerty Sand) of The Canadain River of Garvin, McClain, and Pontotoc Counties, Oklahoma". Model results were not completed in time for the results to be incorporated into this thesis by the Author.

Recommendation For Future Work

The recommendation for future work should include:

- Change existing water law to encompass Isolated water supplying basins.
- Develop an Irrigation Ground Water Conservation District for the Isolated Terrace deposit of Garvin, McClain, and Pontotoc Counties, Oklahoma.
- To carefully analyse and model commodity crops producted under irrigation and dry-land farming practices.
- To model the aquifer characteristics to determine the effect of aquifer mining effect on pumping costs.
- To develop a feasibility plan for using ground water as a water supply for an industrial plant to process the perisable products produced in the study area.
- Evaluate an irrigation scheduling (checkbook) system to be used by irrigators inorder to reduce excessive irrigation water usage and to reduce the costs born by the irrigators.
- Evaluate the feasibility of electric load management as an irrigation scheduling sytem.

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APPENDIXES

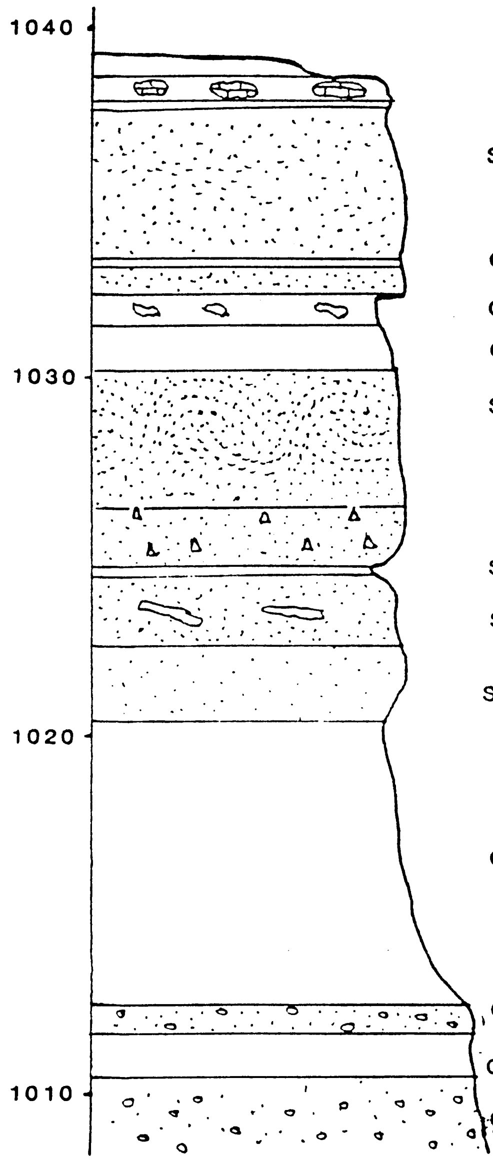
APPENDIX A

GEOLOGIC MEASURED SECTION

MEASURED SECTION

N.-S. ROAD EXPOSURE BETWEEN SECTIONS 13 and 14, T.4N., R.2E.

ELEVATION (Feet) SECTION DESCRIPTION



Soil, Brown, B-Horizon

Clay, Dark Brown, With Limestone Nodules, Calcareous With Black Organic Matter.

Sandstone, White To Light Brown, Medium Sand, Calcareous, Slightly Crossbedded, Friable, Sand Rock Towards Base.

Clay, Gray To Brown.

Clay, Dark Brown To Black, With Nodules.

Clay, Yellow To Gray.

Sandstone, Yellow To Tan, Medium Grained, Crossbedded Slightly, Calcareous At Base With Feldspar Fragments.

Shale, Dark Brown To Black, With Nodules.

Sandstone, Yellow To Tan, Medium To Coarse Grained With Gray Clay Lenses.

Sandstone, Yellow To Tan, Medium To Coarse Grained.

Clay, Blue To Gray.

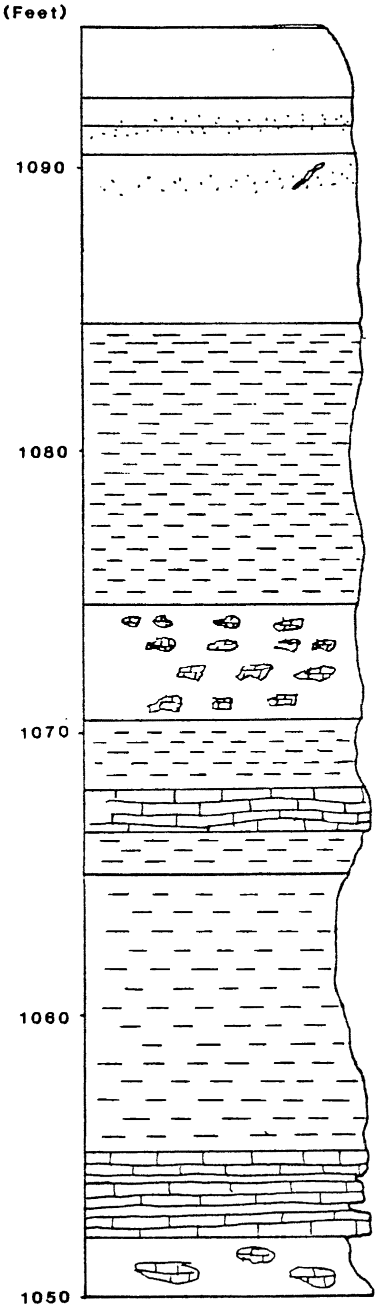
Conglomerate, Dark Gray To Dark Brown, Medium To Coarse Grained.

Clay, Gray To Light Gray.

Conglomerate Coarse Grained.

MEASURED SECTION
W.1/2 OF SE.1/4 OF SE.1/4 OF SECTION 2, T.4N., R.3E.

ELEVATION (Feet) SECTION DESCRIPTION



Soil

A-Horizon

B-Horizon

C-Horizon

Silt, Buff To Cream White, With Worm and Rodent Burrows.

Silt, Buff To Dark Tan, Friable Material.

Shale, Red To Dark Brown, Sandy Clay Texture.

Limestone, White To Gray, Clay (Kaolinite) With Limestone Rubble.

Shale, Red To Dark Brown, Sandy, Calcareous, Clay Texture.

Limestone, Cream To Gray, Cellular Texture, Calcareous.

Shale, Red To Dark Brown, and Blue To Gray Layered Shale, Sandy Clay Texture.

Shale, Red To Dark Brown, Sandy Clay Texture.

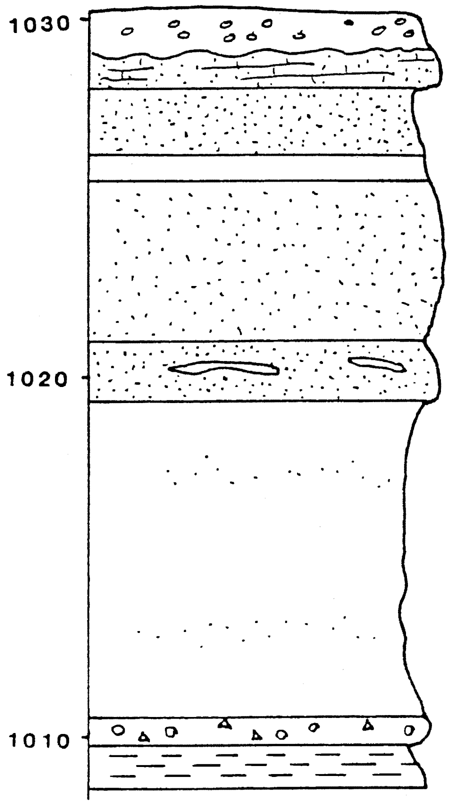
Limestone, Cream To Gray, Three Layered With Clay.

Limestone, Cream To Gray, Limestone Rubble With Clay, Covered With Recent River Sand.

MEASURED SECTION

E.-W. ROAD EXPOSURE BETWEEN SECTIONS 25 and 36, T,5N., R.3E.

ELEVATION (Feet) SECTION DESCRIPTION



Chert Cobbles, Rose To Red Brown, Quartz and Chert.

Sandstone, Red To Brown, Medium Grained, limy, Layered

Sandstone, Tan To Red Brown, Medium Grained. Friable.

Clay, Gray.

Sandstone, White To Buff, Fine To Medium Grained, Slightly Crossbeded, With Solution Cavities.

Sandstone, Cream To Tan, Fine To Medium Sand With Clay Fragments (Lenses).

Clay, Tan To Gray, Sandy Texture.

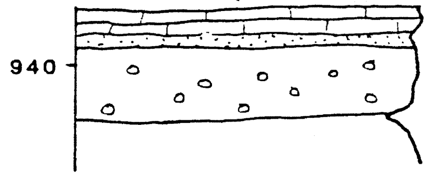
Conglomerate, Tan To Arkose (Gray To Black), With Coarse Grain Quartz and Chert Fragments.

Shale, Gray To Black, Clay Material With Organic Matter.

MEASURED SECTION

NW.1/4 OF SE.1/4 OF SECTION 12, T.5N., R.3E.

ELEVATION (Feet) SECTION DESCRIPTION



Limestone, Tan To Brown.

Sandstone, Red Iron Stained, Medium To Cqarse Grained, Thin Laminated.

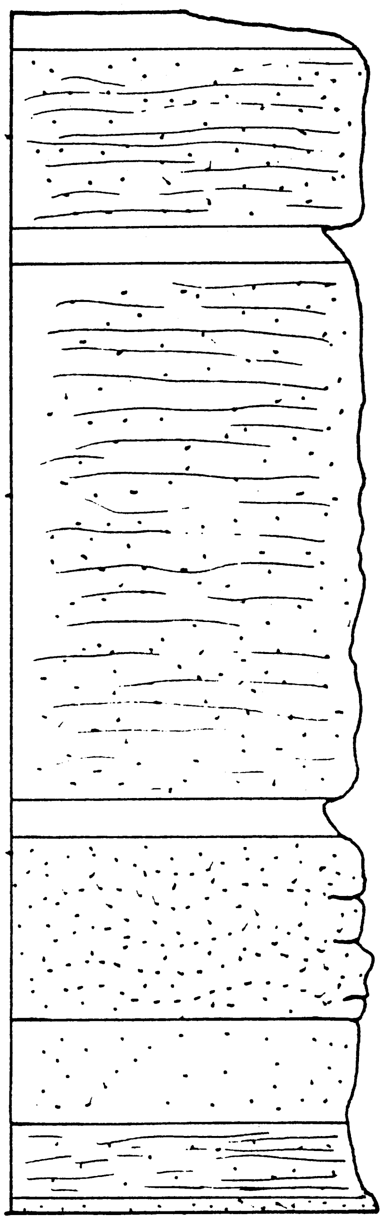
Conglomerate, Red, Quartzite Cobbles.

Clay, Brown.

MEASURED SECTION

N.-S. ROAD EXPOSURE BETWEEN SECTIONS 28 and 29, T.4N., R.4E.

ELEVATION (Feet) | SECTION | DESCRIPTION



Soil A-C Horizon.

Sandstone, Tan To Brown, Thin Laminated, Medium To Coarse Grained, Noncalcareous.

1110

Clay, Gray, Thin Layered.

Sandstone, Tan To Brown, Thin Laminated, Medium To Coarse Grained, Noncalcareous.

1100

Clay, Gray, Thin Layered.

1090

Sandstone, Tan To Brown, Thin Laminated To Blocky, Waive At Weathered Surface, Noncalcareous.

Sandstone, Tan To Light Brown, Coarse Grained.

Sandstone, Tan To Brown, Thin Laminated, Medium To Coarse Grained, Noncalcareous.

1080

Sandstone, Tan To Brown, Coarse Grained, Massive.

APPENDIX B

IRRIGATION DRILLERS LOGS

OWNER Lowell Caskey ADDRESS Rt. Stratford, Okla
LEGAL DESCRIPTION OF WELL NE.1/4 OF SE.1/4 of Section 15, Twp. 4N Rge. 3E
COUNTY Garvin DRILLER Ewbank & Sons ADDRESS Fairview, OK

LOG		
Material	From	To
Clay	0	60
Fine sand	60	72
Gravel	72	81

SOURCE OF INFORMATION WRA
RECORDED BY John Payne DATE 12-10, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED Sept. 27, 1964
WATER ENCOUNTERED AT 55'
STATIC WATER LEVEL 55'
REPORTED Oct. 2, 1964
DIAMETER OF HOLE 30 Inches
TOTAL DEPTH 90 feet
CASED WITH 12 inch CASING TO 84 feet
WELL FINISHED 6' of 12" screen
PACKED WITH 15 yd OF GRAVEL
WATER TO BE USED FOR AMOUNT REQUIRED PER YEAR
YIELD OF WELL 595 G.P.M. OBSERVED DRAWDOWN Max
FEET AFTER 8 HOURS PUMPING AT 595 G.P.M.
TYPE OF PUMP Turbine CAPACITY 710 POWERED BY gasoline 40 hp.

OWNER Charles D. Caskey ADDRESS 405 Medora Rd. Linthicum MD
LEGAL DESCRIPTION OF WELL SW.1/4 OF SW.1/4 of Sec. 14 Twp. 4N Rge. 3E
COUNTY Garvin DRILLER Ewbank & Sons ADDRESS Fairview, OK

LOG		
Material	From	To
clay & fine sand mix	0	66
fine sand	66	86
gravel	86	100

SOURCE OF INFORMATION W.R.A.
RECORDED BY John Payne DATE 12-14, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED Feb. 15, 1964
WATER ENCOUNTERED AT 50 feet
STATIC WATER LEVEL 50
REPORTED Oct. 2, 1964
DIAMETER OF HOLE 30 inches
TOTAL DEPTH 99 feet
CASED WITH 12" CASING TO 84 feet
WELL FINISHED 10' of 0.0100 screen
PACKED WITH 16 yds. OF GRAVEL
WATER TO BE USED FOR AMOUNT REQUIRED PER YEAR
YIELD OF WELL 850 G.P.M. OBSERVED DRAWDOWN Max
FEET AFTER 6 HOURS PUMPING AT 850 G.P.M.
TYPE OF PUMP Turbine CAPACITY 800 POWERED BY Gasoline

OWNER Claude Freeman ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL SW.1/4 OF NE.1/4 of Sec. 9, Twn. 4N, Rge. 3E
COUNTY Garvin DRILLER Ewbanks & Sons ADDRESS Fairview, OK

LOG		
Material	From	To
clay & shale	0	54
clay & ss.	54	78
sandy clay	78	132
sand	132	142
clay	142	146
sand & gravel	146	178
clay	178	180
sand & gravel	180	204
gravel	204	220

SOURCE OF INFORMATION W.R.A.
RECORDED BY Max Moeller DATE 5-28, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED 3-26, 1963
WATER ENCOUNTERED AT 154 TO 220
STATIC WATER LEVEL 154
REPORTED 3-26, 1963
DIAMETER OF HOLE 28 inches
TOTAL DEPTH 220 feet
CASED WITH 16" CASING TO 220 feet
WELL FINISHED Perf. 154-220 ft
PACKED WITH - OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 800 G.P.M. OBSERVED DRAWDOWN 54
FEET AFTER 48 HOURS PUMPING AT 800 G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY 413 Chrysler

OWNER Claud Freeman ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL Sec. 9, Twp. 4N, Rge. 3E
COUNTY Garvin DRILLER Phil Eubank ADDRESS Fairview, OK

LOG		
Material	From	To
(NO LOG REPORTED)		

SOURCE OF INFORMATION W.R.A.
RECORDED BY Letha Vinita DATE 6-3, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED 2-10, 1964
WATER ENCOUNTERED AT 69 feet
STATIC WATER LEVEL 69'
DIAMETER OF HOLE 30 inches
TOTAL DEPTH 102 feet
CASED WITH 12" CASING TO 92 feet
WELL FINISHED
PACKED WITH 18 yds OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 475 G.P.M. OBSERVED DRAWDOWN -
FEET AFTER - HOURS PUMPING AT - G.P.M.
TYPE OF PUMP Turbine CAPACITY 500 POWERED BY Gasoline Motor

OWNER E. L. Gamble ADDRESS Maysville, Oklahoma
LEGAL DESCRIPTION OF WELL SE.1/4 of NW.1/4 of Sec. 11, Twp. 4N, Rge. 3E.
COUNTY Garvin DRILLER R. D. Sawyer ADDRESS Chickasha, OK

LOG		
Material	From	To
clay	0	50
sand & gravel	50	60
shale	(TD)	60

SOURCE OF INFORMATION W.R.A.
RECORDED BY D. E. Spiser DATE 4-10, 1958
METHOD OF DRILLING Rotary
DATE COMPLETED 8- , 1956
WATER ENCOUNTERED AT 50 TO 60'
STATIC WATER LEVEL 20'
REPORTED/MEASURED
DIAMETER OF HOLE 30 inches TO 60 feet
TOTAL DEPTH 60 feet
CASED WITH 8" CASING TO 53 feet
WELL FINISH Ironsite Screen 10"I.D. x 7'
PACKED WITH 12 tons OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 200 G.P.M. OBSERVED DRAWDOWN 56'
FEET AFTER 5 HOURS PUMPING AT 200 G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY 15 Hp. Elec. Motor

OWNER W. O. Henry ADDRESS Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL SE.1/4 of Sec. 23, Twp. 4N, Rge. 3E.
COUNTY Garvin DRILLER Charles Ewbank ADDRESS Fairview, OK

LOG
Material From To
(NO LOG REPORTED)

SOURCE OF INFORMATION W.R.A.
RECORDED BY W. E. DATE 6-3, 1966
METHOD OF DRILLING Rev. Cir.
DATE COMPLETED 5-3, 1965
WATER ENCOUNTERED AT 50 TO 90 feet
STATIC WATER LEVEL 68 feet
DIAMETER OF HOLE 30 inches
TOTAL DEPTH 94 feet
CASED WITH 12 3/4" CASING TO 90 feet
WELL FINISHED Johnson Screen
PACKED WITH 20 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 625 G.P.M. OBSERVED DRAWDOWN 85
FEET AFTER 5 HOURS PUMPING AT 625 G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY L.P.G.

OWNER Jim L. Jarrell ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of NE.1/4 ~f SW.1/4 of Sec. 9, T4N.,R3E.
COUNTY Garvin DRILLER J. R. Meyer ADDRESS Rte. 5, Norman, Ok

LOG			SOURCE OF INFORMATION
Material	From	To	RECORDED BY J. R. Meyer DATE 11-7,1977
soil	0	2	METHOD OF DRILLING Rev. Rotary
clay	2	81	DATE COMPLETED 11-7, 1977
fine sand	81	85	WATER ENCOUNTERED AT
course sand	85	92	STATIC WATER LEVEL 72 feet
course sand &			DIAMETER OF HOLE 24 inch
gravel	92	96	TOTAL DEPTH 96 feet
			CASED WITH 10" CASING TO 96 feet
			WELL FINISHED
			PACKED WITH 1 3/4 yd OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 220 G.P.M. OBSERVED DRAWDOWN 16
FEET AFTER 4 HOURS PUMPING AT 215 G.P.M.
TYPE OF PUMP Turbine CAPACITY 220 G.P.M. POWERED BY Engine

OWNER Kenneth Jarrell ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NE.1/4 of SE.1/4 of NW.1/4 of Sec. 9, T4N, R3E.
COUNTY Garvin DRILLER J. R. Meyer ADDRESS Rte. 5, Norman, OK

LOG			SOURCE OF INFORMATION
Material	From	To	RECORD BY J. R. Meyer DATE 12-8, 1977
soil	0	3	METHOD OF DRILLING Rev. Cir.
clay	3	82	DATE COMPLETED 12-8, 1977
fine sand	82	92	WATER ENCOUNTERED AT
course sand	92	98	STATIC WATER LEVEL 74 feet
gravel	98	103	DIAMETER OF HOLE 24 inches
			TOTAL DEPTH 103 feet
			CASED WITH 10" CASING TO 103 feet
			WELL FINISHED
			PACKED WITH 2 yd OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 250 G.P.M. OBSERVED DRAWDOWN 20
FEET AFTER 4 HOURS PUMPING AT 245 G.P.M.
TYPE OF PUMP Turbine CAPACITY POWERED BY Electric

OWNER Albert J. Russ ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL SW.1/4 of SW.1/4 of SE.1/4 of Sec. 11, T4N, R3E.
COUNTY Garvin DRILLER Box Cox ADDRESS Rte. 1, Stonewall, OK

LOG		
Material	From	To
clay	0	15
sand	15	35
clay	35	70
quick sand & coarse sand	70	87
clay	87	95

SOURCE OF INFORMATION Well Info.
RECORD BY Vikki Schwarz DATE 4-23, 1973
METHOD OF DRILLING Rotary
DATE COMPLETED 1-24, 1964
WATER ENCOUNTERED AT 65 feet
STATIC WATER LEVEL 65 feet
DIAMETER OF HOLE 24 inches
TOTAL DEPTH 95 feet
CASED WITH 10" CASING TO 95 feet
WELL FINISHED
PACKED WITH 5 yds. OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL G.P.M. OBSERVED DRAWDOWN 25
FEET AFTER 24 HOURS PUMPING AT 250 G.P.M.
TYPE OF PUMP Turbine CAPACITY POWERED BY Gasoline
QUALITY OF WATER Good SAMPLE Yes/No DATE 4-6, 1973

OWNER Allen Phillips ADDRESS Rte. 2, Byars, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of NW.1/4 of Sec. 10, T4N, R3E.
COUNTY Garvin DRILLER Ewbanks & Sons ADDRESS Fairview, OK

LOG		
Material	From	To
soil	0	41
dry sand	41	46
clay	46	68
quicksand	68	88
clay	88	89
gravel	89	105
red bed	105	106

SOURCE OF INFORMATION W.R.A.
RECORD BY M.M. DATE 5-26, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED 2-15, 1964
WATER ENCOUNTERED AT 60 feet
STATIC WATER LEVEL 60 feet
REPORTED 2-15, 1964
DIAMETER OF HOLE 30 INCHES TO 106 feet
TOTAL DEPTH 106 feet
CASED WITH 12 5/8" CASING TO 96 feet
WELL FINISH
PACKED WITH yds./tons OF GRAVEL

WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 465 G.P.M. OBSERVED DRAWDOWN 40
FEET AFTER 9 HOURS PUMPING AT 465 G.P.M.
TYPE OF PUMP CAPACITY POWERED BY L. P. Gas

OWNER Albert J. Russ ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL SW.1/4 of SW.1/4 of SE.1/4 of Sec. 11, T4N, R3E.
COUNTY Garvin DRILLER Ewbank Inc. ADDRESS Fairview, OK

LOG		
Material	From	To
clay & sand	0	65
sand	65	70
coarse sand & gravel	70	88

SOURCE OF INFORMATION Well Info.
RECORD BY Vikki Schwarz DATE 4-23, 1973
METHOD OF DRILLING Rotary
DATE COMPLETED 4-1, 1966
WATER ENCOUNTERED AT 65 feet
STATIC WATER LEVEL 65 feet
DIAMETER OF HOLE 30 inches
TOTAL DEPTH 88 feet
CASED WITH 12" CASING TO 80 FEET
WELL FINISHED
PACKED WITH 5 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL G.P.M. OBSERVED DRAWDOWN 25
FEET AFTER 24 HOURS PUMPING AT 150 G.P.M.
TYPE OF PUMP Turbine CAPACITY 150 POWERED BY Gasoline Motor
QUALITY OF WATER Good SAMPLE yes/no DATE 4-6, 1973

OWNER Albert J. Russ ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of SE.1/4 of SE.1/4 of Sec. 11, T4N, R3E.
COUNTY Garvin DRILLER Ewbank, Inc.. ADDRESS Fairview, OK

LOG		
Material	From	To
clay	0	15
sand	15	35
clay	35	70
sand & coarse sand	70	93

SOURCE OF INFORMATION Well Info.
RECORD BY Vikki Schwarz DATE 4-23, 1973
METHOD OF DRILLING Rotary
DATE COMPLETED 3-17, 1973
WATER ENCOUNTERED AT 65 feet
STATIC WATER LEVEL 65 feet
DIAMETER OF HOLE 22 inches
TOTAL DEPTH 93 feet
CASED WITH 10" CASING TO 88 feet
WELL FINISH
PACKED WITH 5 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL G.P.M. OBSERVED DRAWDOWN 25
FEET AFTER 25 HOURS PUMPING AT 250 G.P.M.
TYPE OF PUMP Turbine CAPACITY 300 POWERED BY Gasoline
QUALITY OF WATER Good SAMPLE yes/no DATE 4-6, 1973

OWNER C. B. Smith ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of SW.1/4 of Sec. 14, T4N, R3E.
COUNTY Garvin DRILLER C. Ewbanks ADDRESS Fairview, OK

LOG		
Material	From	To
clay	0	56
fine sand	56	83
coarse gravel	83	90
red bed	90	92

SOURCE OF INFORMATION W.R.A.
RECORD BY Letha Vinita DATE 6-10, 1964
METHOD OF DRILLING Rev. Cir.
DATE COMPLETED 2-26, 1964
WATER ENCOUNTERED AT 56 feet
STATIC WATER LEVEL 56 feet
DIAMETER OF HOLE 30 inches
TOTAL DEPTH 92 feet
CASED WTIH 12 1/2" CASING TO 82 feet
WELL FINISH
PACKED WITH 11 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 525 G.P.M. OBSERVED DRAWDOWN 88
FEET AFTER 14 HOURS PUMPING AT 500 G.P.M.
TYPE OF PUMP Turbine CAPACITY 525 GPM POWERED BY L.P. Gas

OWNER C. B. Smith ADDRESS Rte. 1, Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NE.1/4 of NW.1/4 of Sec. 17, T4N, R3E.
COUNTY Garvin DRILLER Ewbanks ADDRESS Fairview, OK

LOG		
Material	From	To
clay	0	64
gravel	64	86

SOURCE OF INFORMATION W.R.A
RECORD BY Max Moeller DATE 5-28,1964
METHOD OF DRILLING Rotary
DATE COMPLETED
WATER ENCOUNTERED AT 64 feet
STATIC WATER LEVEL 64 feet
REPORTED
DIAMETER OF HOLE 32 inches TO 86 feet
TOTAL DEPTH 86 feet
CASED WITH 12" CASING TO 86 feet
WELL FINISH 10 foot screen
PACKED WTIH - yds./tons OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 420 G.P.M. OBSERVED DRAWDOWN 20
FEET AFTER 36 HOURS PUMPING AT 420 G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY Propane 28 Hp.

OWNER W. A. Watts ADDRESS Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of NW.1/4 of Sec. 21, T4N, R3E.
COUNTY Garvin DRILLER Ewbanks & Sons ADDRESS Fairview, OK

LOG			
Material	From	To	SOURCE OF INFORMATION W.R.A.
			RECORD BY Max Moeller DATE 5-25, 1964
clay	0	66	METHOD OF DRILLING Rotary
sandy clay	66	75	DATE COMPLETED 1-17, 1964
fine sand	75	84	WATER ENCOUNTERED AT 66 feet
gravel	84	89	STATIC WATER LEVEL 66 feet
red bed	89	92	REPORTED 1-17, 1964

DIAMETER OF HOLE 30 inches TO 94 feet
TOTAL DEPTH 94 feet
CASED WITH 12 3/4" CASING TO 94 feet
WELL FINISH 10' Slot Casing
PACKED WITH - yds./ton OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 166 G.P.M. OBSERVED DRAWDOWN 20
FEET AFTER 30 HOURS PUMPING AT 160 G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY International 25 HP

OWNER City of Byars ADDRESS Byars, Oklahoma
LEGAL DESCRIPTION OF WELL NW.1/4 of NW.1/4 of NW.1/4 of Sec. 25, T5N, R2E.
COUNTY McClain DRILLER John H. Welch, Inc. ADDRESS Stratford, OK

LOG			
Material	From	To	SOURCE OF INFORMATION
			RECORDED BY Jerry Berry DATE
Top Soil	0	1	METHOD OF DRILLING Air Lift
Yellow Clay	1	14	DATE COMPLETED Nov. 17, 1983
Sandy Red Clay	14	21	WATER ENCOUNTERED AT
Mucky Sand	21	30	STATIC WATER LEVEL
Sand	30	45	REPORTED
Sandy Red Clay	45	65	DIAMETER 9 Inches
Sand Clay Balls	65	72	TOTAL DEPTH 100 Feet
Red & Blue Shale	72	100	CASED WITH 5" 200# Inch CASING TO 100 feet

WELL FINISHED Slit from 35 to 45 feet
PACKED WITH 2 yds OF GRAVEL
WATER TO BE USED FOR Munic. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 15 gpm OBSERVED DRAWDOWN -
FEET AFTER - HOURS PUMPING AT - G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY -

OWNER Fred Shivers ADDRESS Stratford, Oklahoma
LEGAL DESCRIPTION OF WELL SE.1/4 of SE.1/4 of SE.1/4 of Sec. 22, T4N, R3E.
COUNTY Garvin DRILLER John H. Welch, Inc. ADDRESS Stratford, OK

LOG			SOURCE OF INFORMATION
Material	From	To	RECORDED BY Larry Watson
Top Soil	0	2	METHOD OF DRILLING Rotary
Red Clay	2	35	DATE COMPLETED Jan. 10, 1979
Blue Clay	35	40	WATER ENCOUNTERED AT 20 feet
Coarse Sand			STATIC WATER LEVEL 20'
Clay Particles	40	50	DIAMETER OF HOLE 9 Inch
Red Shale	50	70	TOTAL DEPTH 150 Feet
Blue Shale	70	108	CASED WITH 5"-160# PVC CASING TO 150 Feet
Red Shale	108	150	WELL FINISHED
			PACKED WITH 65 cu. ft. OF GRAVEL

WATER TO BE USED FOR Ind. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 4 G.P.M. OBSERVED DRAWDOWN 110
FEET AFTER 2 HOURS PUMPING AT 4 G.P.M.
TYPE OF PUMP - CAPACITY - POWERED BY -

OWNER H. L. Ledford ADDRESS 331 S. W. 31 St. Oklahoma City, OK 73119
LEGAL DESCRIPTION OF WELL SE.1/4 of SW.1/4 of NW.1/4 of Sec. 30, T5N, 52E.
COUNTY McClain DRILLER Jerry Berry ADDRESS Stratford, OK

LOG			SOURCE OF INFORMATION
Material	From	To	RECORDED BY John H. Welch DATE 6/10/83
Top Soil	0	1	METHOD OF DRILLING Rotary
Mucky Sand	1	20	DATE COMPLETED 5/19/83
Fine Dirty Sand	20	60	WATER ENCOUNTERED AT
Med. Fine Sand	60	67	STATIC WATER LEVEL
Blue Shale	67	100	DIAMETER OF HOLE 9 Inch
			TOTAL DEPTH 100 feet
			CASED WITH 5-20# PVC CASING TO 100 feet
			WELL FINISHED
			PACKED WITH 2 yd.

WATER TO BE USED FOR Dom. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 5 G.P.M. OBSERVED DRAWDOWN -
FEET AFTER - HOURS OF PUMPING AT - G.P.M.
TYPE OF PUMP - CAPACITY - POWERED BY -

OWNER Clarence Essary ADDRESS Rte. 3 Stratford, OK
LEGAL DESCRIPTION OF WELL SW.1/4 of SE.1/4 of Sec. 21, T4N, R3E.
COUNTY Garvin DRILLER Ewbanks & Sons ADDRESS Stratford, OK

LOG

Material	From	To
Clay	0	50
3 Layer Rock	50	60
Clay	60	86
Sand & Gravel	86	100
Red Bed	100	101

SOURCE OF INFORMATION WRA
RECORDED BY Wayne F Watt DATE May 26, 1964
METHOD OF DRILLING Rotary
DATE COMPLETED 9/7/1963
WATER ENCOUNTERED AT 79 feet
STATIC WATER LEVEL 79 feet
DIAMETER OF HOLE 30 Inch
TOTAL DEPTH 101 feet
CASED WITH - CASING TO -
WELL FINISHED -
PACKED WITH 20 Yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR -
YIELD OF WELL 350 G.P.M. OBSERVED DRAWDOWN 22
FEET AFTER 8 HOURS PUMPING AT 350 G.P.M.
TYPE OF PUMP Turbine CAPACITY 500 POWERED BY Gasoline Motor 65 HP.

OWNER L. B. Wood ADDRESS Rte. 1, Stratford, OK
LEGAL DESCRIPTION OF WELL N.1/2 of SE.1/4 of Sec. 7, T4N, R4E
COUNTY Garvin DRILLER Ewbanks and Son ADDRESS Fairview, OK

LOG

Material From To
(NO LOG REPORTED)

SOURCE OF INFORMATION WRA
RECORDED BY W. E. DATE 10/25/1964
METHOD OF DRILLING Rotary
DATE COMPLETED 1/22/ 1964
WATER ENCOUNTERED AT 27 feet
STATIC WATER LEVEL 33 feet
DIAMETER OF HOLE 30 Inch
TOTAL DEPTH 60 feet
CASED WITH - CASING TO - feet
WELL FINISHED 5' # 100 Slot Johnson
PACKED WITH 7 1/8 yd. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 125 G.P.M. OBSERVED DRAWDOWN -
FEET AFTER 8 HOURS PUMPING AT - G.P.M.
TYPE OF PUMP Turbine CAPACITY - POWERED BY Propane 75 HP

OWNER Wallace Wood ADDRESS Rte. 1, Stratford, OK
LEGAL DESCRIPTION OF WELL S.1/2 of SW.1/4 of Sec. 7, T4N, R4E
COUNTY Pontotoc DRILLER Ewbank and Son ADDRESS Fairview, OK
Well # 1

LOG		
Material	From	To
Clay	0	52
Med. Sand & Mixed Gravel	52	62
Med. Sand	62	68
Red Bed	68	

SOURCE OF INFORMATION WRA
RECORDED BY W. E. DATE 10/25/1966
METHOD OF DRILLING Rev. Circulation
DATE COMPLETED 11/21/1964
WATER ENCOUNTERED AT 52 feet
STATIC WATER LEVEL 34 feet
DIAMETER OF HOLE 30 Inches
TOTAL DEPTH 68 feet
CASED WITH 12 3/4 " CASING TO - Feet
WELL FINISHED # 100 Johnson Irrigation
PACKED WITH 7 1/2 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR -
YIELD OF WELL 135 G.P.M. OBSERVED DRAWDOWN -
FEET AFTER 8 HOURS PUMPING AT - G.P.M.
TYPE OF PUMP Turbine CAPACITY 4" POWERED BY Propane

OWNER Wallace Wood ADDRESS Rte. 1, Stratford, Okla.
LEGAL DESCRIPTION OF WELL S.1/2 of SW.1/4 of Sec. 7, T4N, R4E.
COUNTY Pontotoc DRILLER Ewbank and Son ADDRESS Fairview, OK
Well # 2

LOG		
Material	From	To
Clay	0	52
Med. Sand	52	62
Med. Sand	62	68
Red Bed	68	

SOURCE OF INFORMATION WRA
RECORDED BY W. E. DATE 10/25/1966
METHOD OF DRILLING Rev. Circulation
DATE COMPLETED -
WATER ENCOUNTERED AT 52 feet
STATIC WATER LEVEL 34 feet
DIAMETER OF HOLE 30 Inches
TOTAL DEPTH 68 feet
CASED WITH 7" CASING TO 68 feet
WELL FINISHED 5' Johnson Irrigation Screen
PACKED WITH 8 yds. OF GRAVEL
WATER TO BE USED FOR Irrig. AMOUNT REQUIRED PER YEAR -
YIELD OF WELL - G.P.M. OBSERVED DRAWDOWN
FEET AFTER - HOURS PUMPING AT - G.P.M.
TYPE OF PUMP - CAPACITY - POWERED BY -

OWNER Town of Stratford ADDRESS Stratford, OK
LEGAL DESCRIPTION OF WELL SW.1/4 of NE.1/4 of NW.1/4 of Sec. 23, T4N,R3E.
COUNTY Garvin DRILLER R. D. Sawyer ADDRESS Chickasha, OK
Well # 1

LOG
Material From To
(NO LOG REPORTED)

SOURCE OF INFORMATION WRA
RECORDED BY H. Ford DATE 7/2/1954
METHOD OF DRILLING Rotary
DATE COMPLETED 5/20/1953
WATER ENCOUNTERED AT 80 feet
STATIC WATER LEVEL 55 feet
DIAMETER OF HOLE 36 Inches
TOTAL DEPTH 92 feet
CASED WITH 8" CASING TO 86 feet
WELL FINISHED 30" Surf. Csg. to 10'-cement
Stainless Steel Screen 8" x 6'
PACKED WITH 27 Tons OF GRAVEL

WATER TO BE USED FOR Munic. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 110 G.P.M. OBSERVED DRAWDOWN 15
FEET AFTER 12 HOURS PUMPING AT 110 G.P.M.
TYPE OF PUMP Turbine CAPACITY 75 G.P.M. POWERED BY 5 HP. Electric

OWNER Town of Stratford ADDRESS Stratford, OKlahoma
LEGAL DESCRIPTION OF WELL W.1/2 of NE.1/4 of NW.1/4 of Sec. 23, T4N,R3E.
COUNTY Garvin DRILLER R. D. Sawyer ADDRESS Chickasha, OK
Well # 2

LOG
Material From To
(NO LOG REPORTED)

SOURCE OF INFORMATION WRA
RECORDED BY H. Ford DATE 7/2/1954
METHOD OF DRILLING Rotary
DATE COMPLETED 10/12/1953
WATER ENCOUNTERED AT 78 feet
STATIC WATER LEVEL 52 feet
DIAMETER OF HOLE 36 Inches
TOTAL DEPTH 90 feet
CASED WITH 8" CASING TO 84 feet
WELL FINISHED 30" Surf. Csg. to 10' cement
Stainless Steel Screen 8" x 6'
PACKED WITH 28 Tons OF GRAVEL

WATER TO BE USED FOR Munic. AMOUNT REQUIRED PER YEAR
YIELD OF WELL 110 G.P.M. OBSERVED DRAWDOWN 22
FEET AFTER 12 HOURS PUMPING AT 110 G.P.M.
TYPE OF PUMP Turbine CAPACITY 75 G.P.M. POWERED BY 5 HP. Electric

OWNER Town of Stratford ADDRESS Stratford, OK
LEGAL DESCRIPTION OF WELL NW.1/4 of NE.1/4 of NW.1/4 of Sec. 23, T4N, R3E.
COUNTY Garvin DRILLER R. D. Sawyer ADDRESS Chickasha, OKla.
Well # 3

LOG
Material From To
(NO LOG REPORTED)

SOURCE OF INFORMATION WRA
RECORDED BY H. Ford DATE 7/2/1954
METHOD OF DRILLING Rotary
DATE COMPLETED 10/20/1953
WATER ENCOUNTERED AT -
STATIC WATER LEVEL 53' REPORTED 6/24/1954
DIAMETER OF HOLE 36 Inches
TOTAL DEPTH 88 feet
CASED WITH 8" CASING TO 84 feet
WELL FINISHED 30" Surf. Csg. to 10'-Cement
Stainless Steel Screen 8" x 6'
PACKED WITH 28 Tons OF GRAVEL
AMOUNT REQUIRED PER YEAR -
OBSERVED DRAWDOWN 23

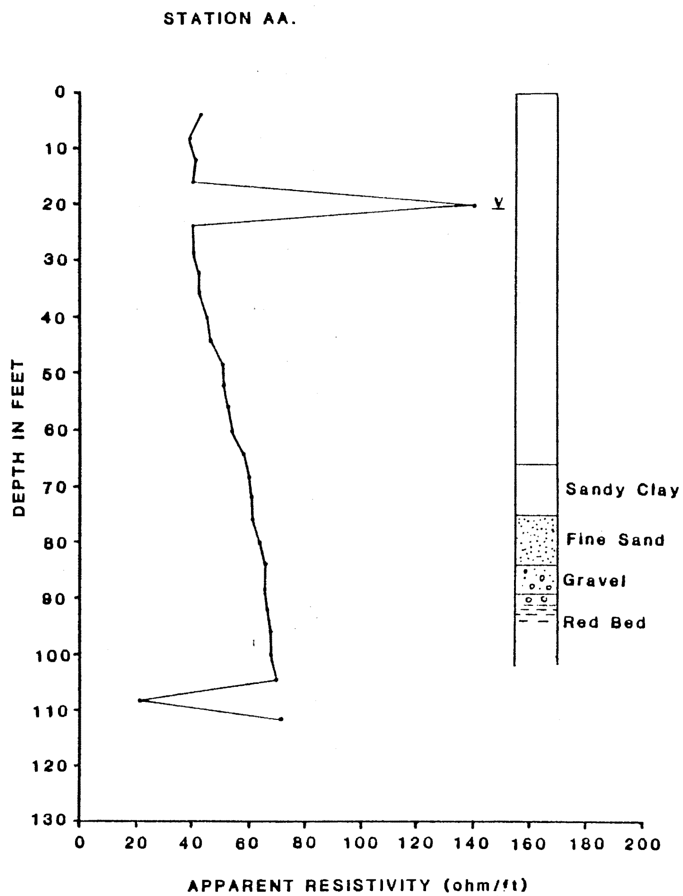
WATER TO BE USED FOR Munic.
YIELD OF WELL 115 G.P.M.
FEET AFTER 12 HOURS PUMPING AT 115 G.P.M.
TYPE OF PUMP Turbine CAPACITY 75 G.P.M. POWERED BY 5 HP. Electric

APPENDIX C

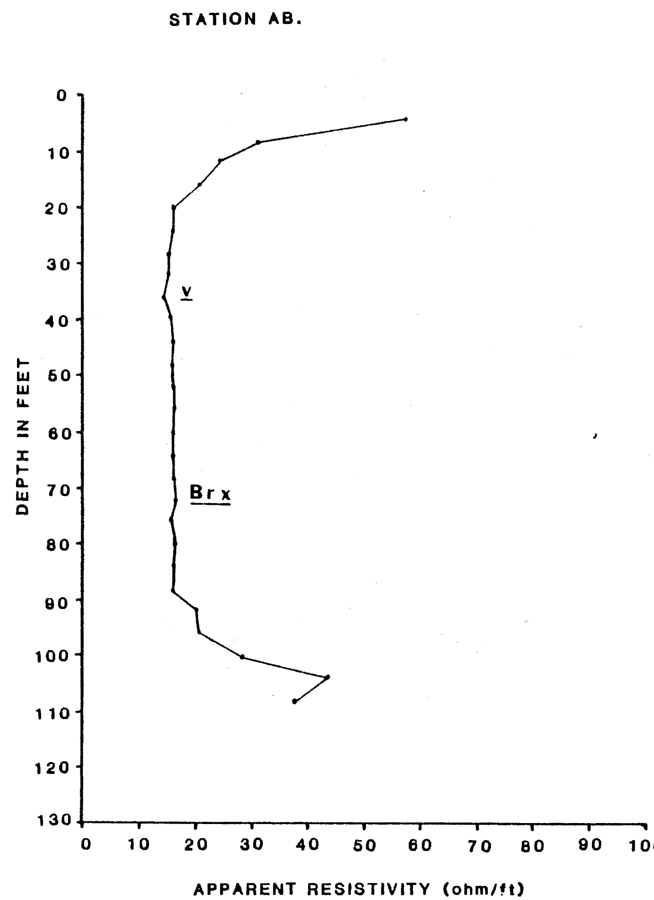
GEOPHYSICAL EARTH RESISTIVITY GRAPHS

STATION	LOCATION
AA	NE1/4 of NE1/4 of NE1/4 of NE1/4 of Section 21, T.4N., R.3E.
AB	SE1/4 of SE1/4 of SE1/4 of SE1/4 of Section 12, T.4N., R.2E.
AC	N1/2 of NW1/4 of NW1/4 of NW1/4 of Section 3, T.4N., R.3E.
AD	SE1/4 of SE1/4 of SE1/4 of SE1/4 of Section 21, T.4N., R.3E.
AE	SW1/4 of SW1/4 of SW1/4 of SW1/4 of Section 29, T.5N., R.3E.
AF	W1/2 of SW1/4 of SW1/4 of Section 25, T.4N., R.3E.
BA	N1/2 of NE1/4 of NE1/4 of NW1/4 of Section 34, T.5N., R.3E.
BB	W1/2 of NW1/4 of NW1/4 of Section 5, T.4N., R.3E.
BC	N1/2 of NW1/4 of NW1/4 of Section 16, T.4N., R.3E.
BD	W1/2 of NE1/4 of NE1/4 of NE1/4 of Section 13, T.4N., R.3E.
BE	E1/2 of SE1/4 of NE1/4 of Section 19, T.4N., R.3E.
BF	SE1/4 of NW1/4 of SW1/4 of Section 11, T.4N., R.3E.
CA	NE1/4 of NE1/4 of NE1/4 of Section 26, T.5N., R.2E.
CB	NE1/4 of NE1/4 of SE1/4 of Section 7, T.4N., R.3E.

STATION	DRILLER LOG INTERPRETATION LOCATION
AA	NW1/4 of NW1/4 of Section 21, T.4N., R.3E.
AB	
AC	
AD	SW1/4 of SE1/4 of Section 21, T.4N., R.3E.
AE	SE1/4 of SW1/4 of NW1/4 of Section 30, T.5N., R.2E.
AF	
BA	
BB	
BC	NE1/4 of NE1/4 of SW1/4 of Section 9, T.4N., R.3E.
BD	S1/2 of SW1/4 of Section 7, T.4N., R.3E.
BE	
BF	SE1/4 of NW1/4 of Section 11, T.4N., R.3E.
CA	NW1/4 of NW1/4 of NW1/4 of Section 25, T.5N., R.3E.

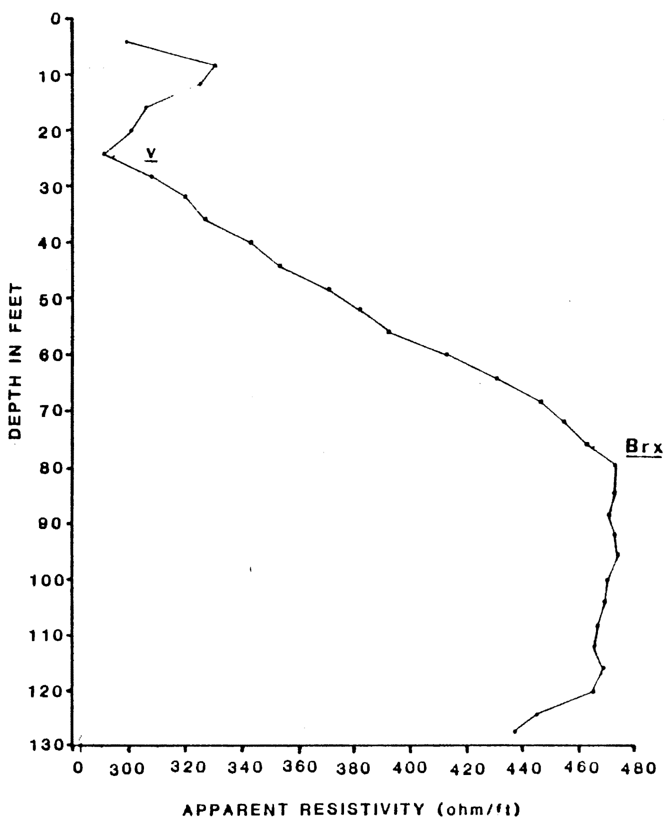


STATION AA.
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
90
100
110
120
130
V
Sandy Clay
Fine Sand
Gravel
Red Bed
0 20 40 60 80 100 120 140 160 180 200
APPARENT RESISTIVITY (ohm/ft)

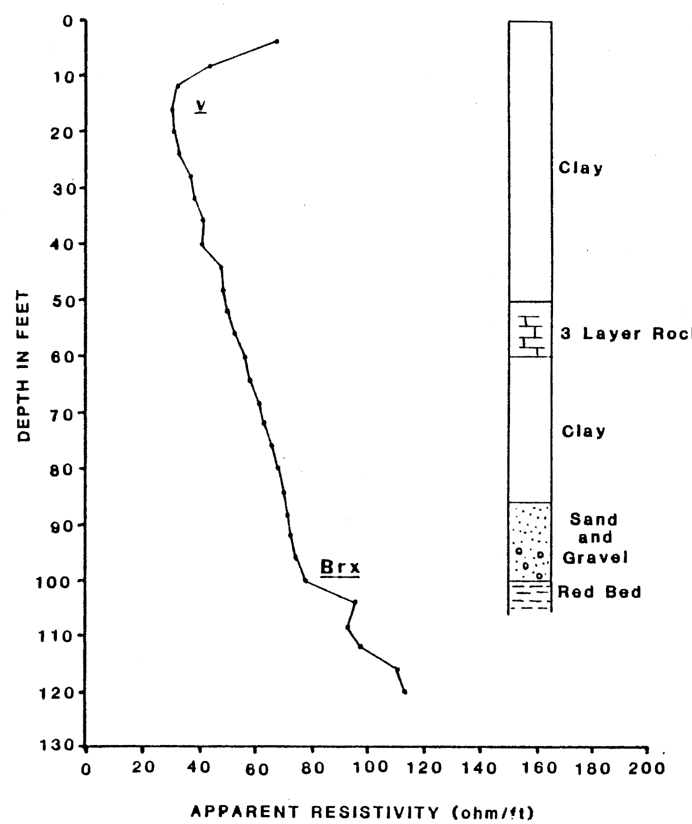


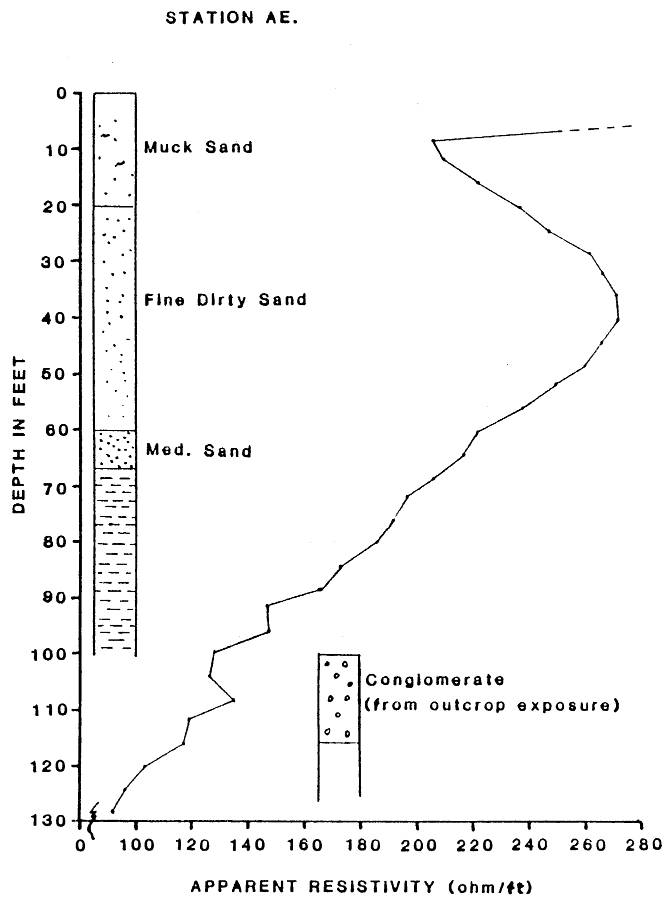
STATION AB.
DEPTH IN FEET
0
10
20
30
40
50
60
70
80
90
100
110
120
130
V
Brx
0 10 20 30 40 50 60 70 80 90 100
APPARENT RESISTIVITY (ohm/ft)

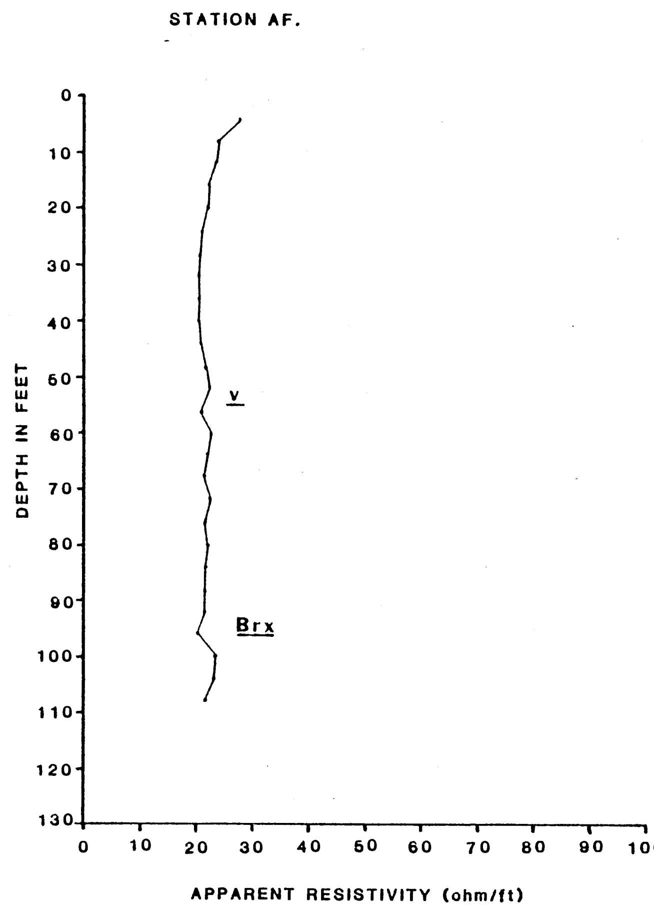
STATION AC.



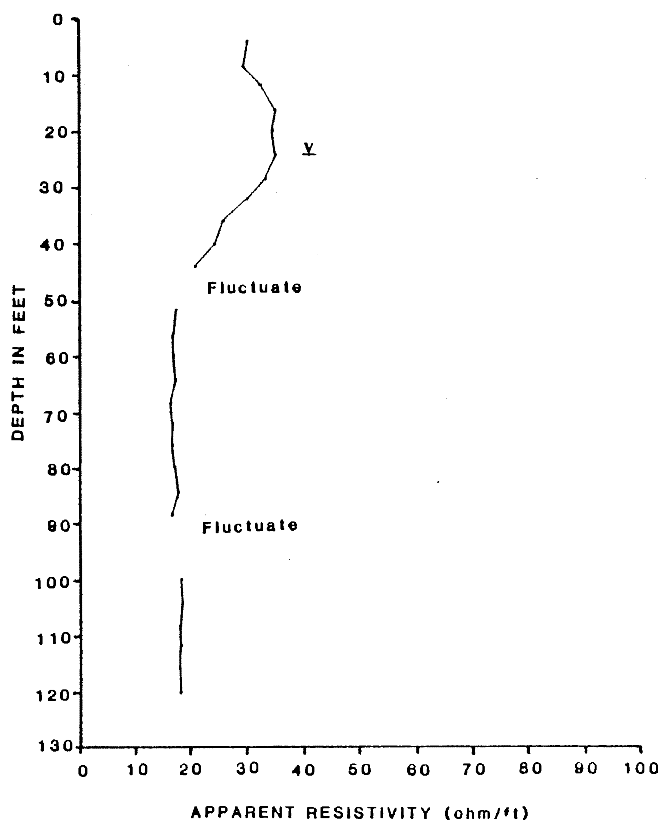
STATION AD.



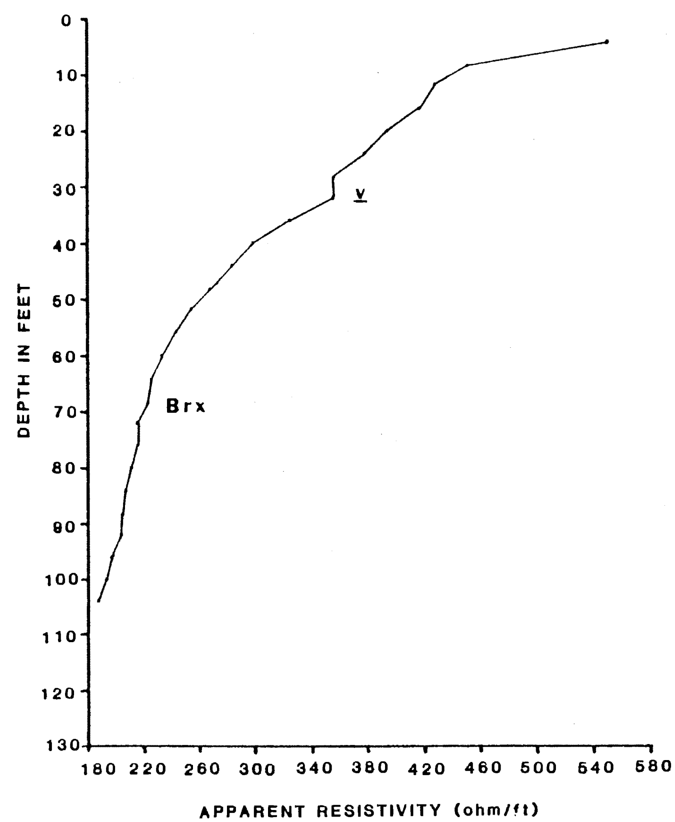

STATION AE.
DEPTH IN FEET
Muck Sand
Fine Dirty Sand
Med. Sand
Conglomerate
(from outcrop exposure)
APPARENT RESISTIVITY (ohm/ft)


STATION AF.
DEPTH IN FEET
V
Brx
APPARENT RESISTIVITY (ohm/ft)

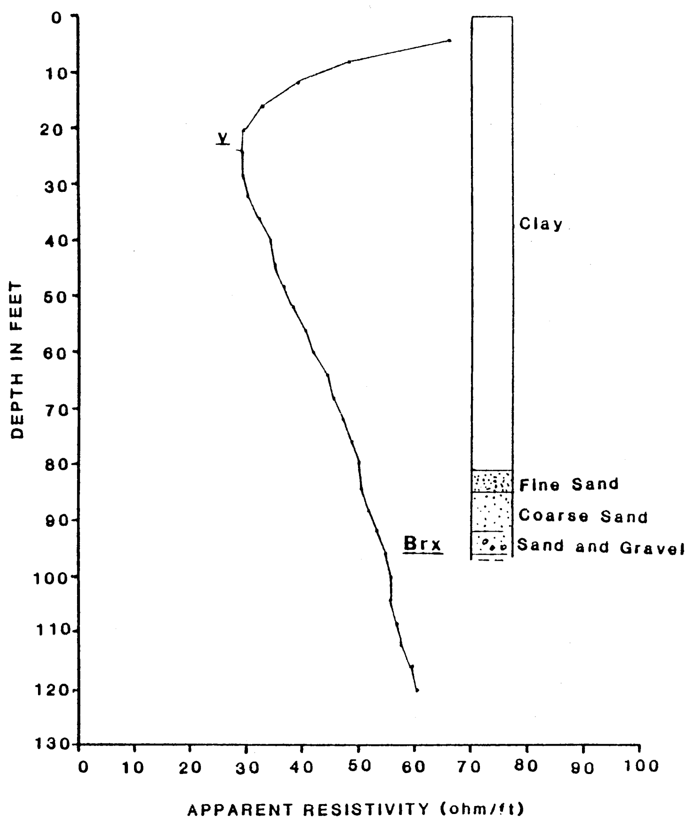
STATION BB.



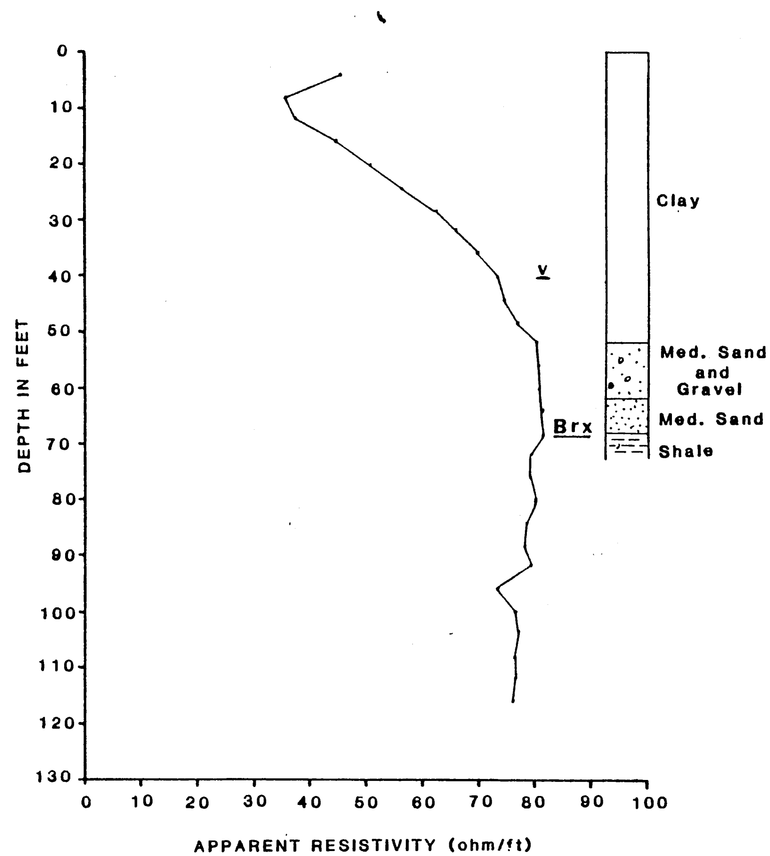
STATION BA.



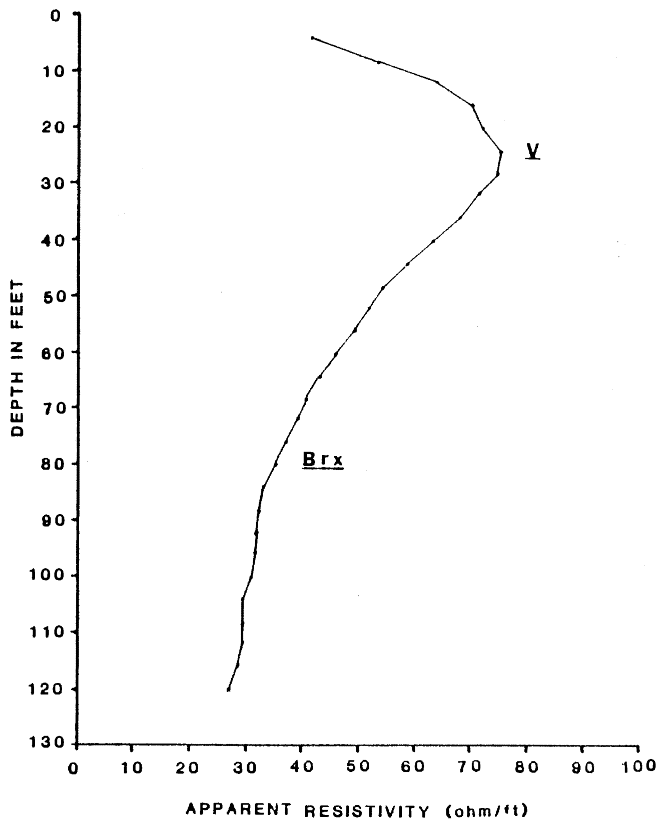
STATION BC.



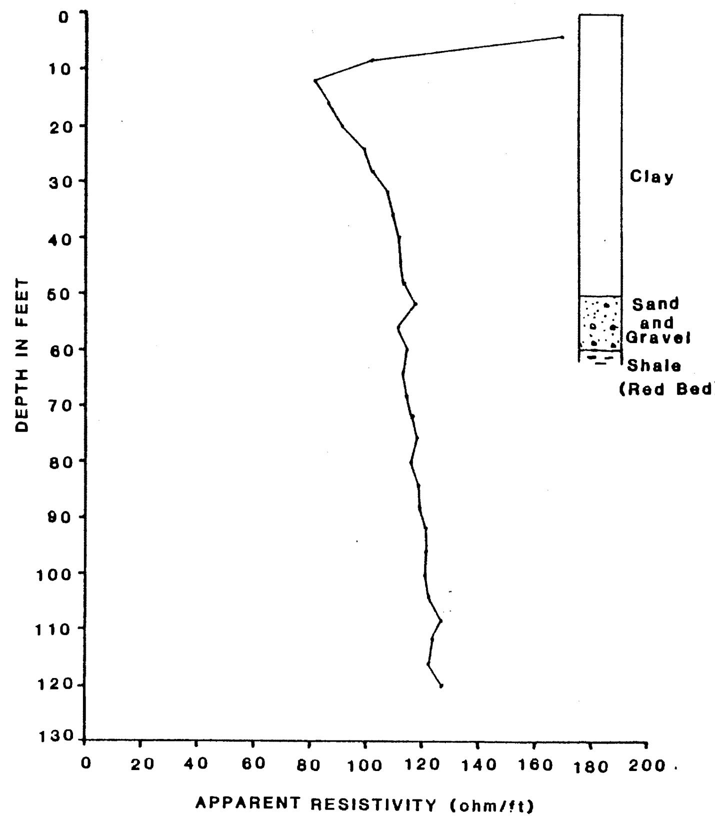
STATION BD.



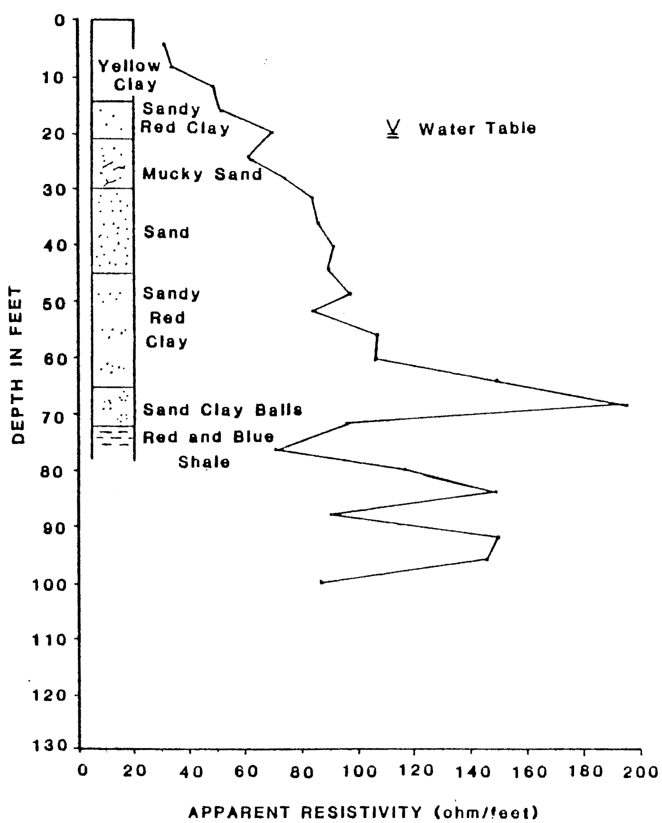
STATION BE.



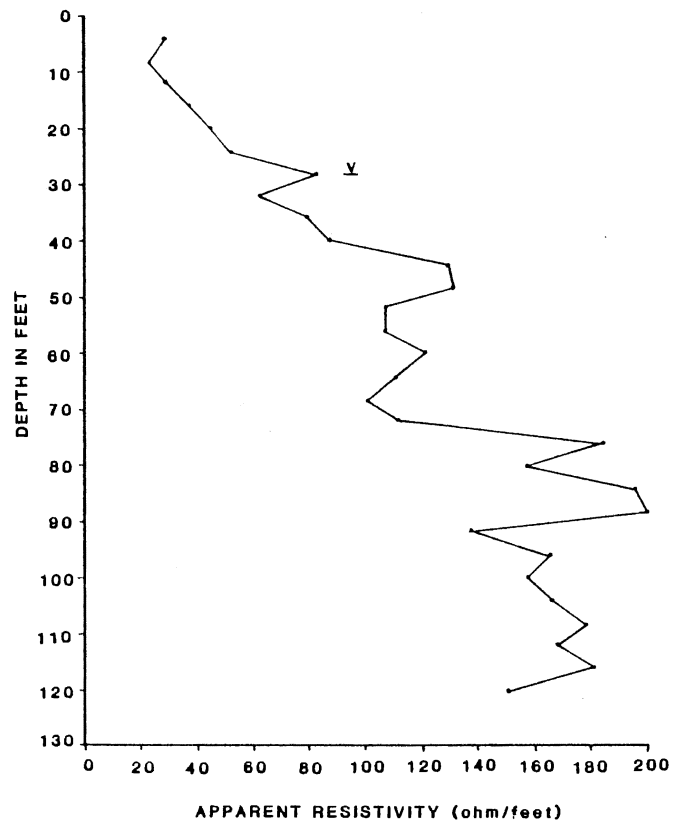
STATION BF.



STATION CA.



STATION CB.

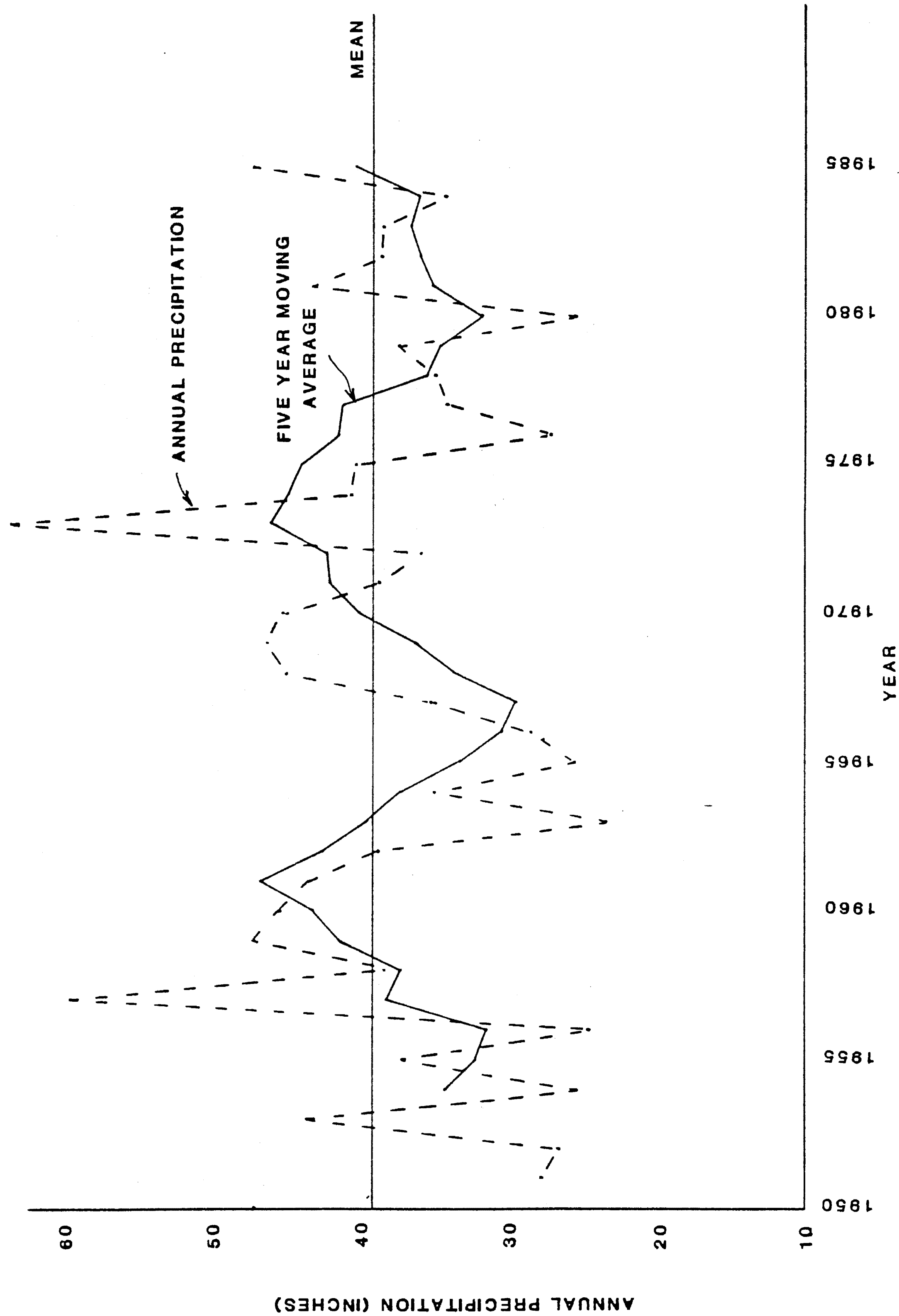


APPENDIX D

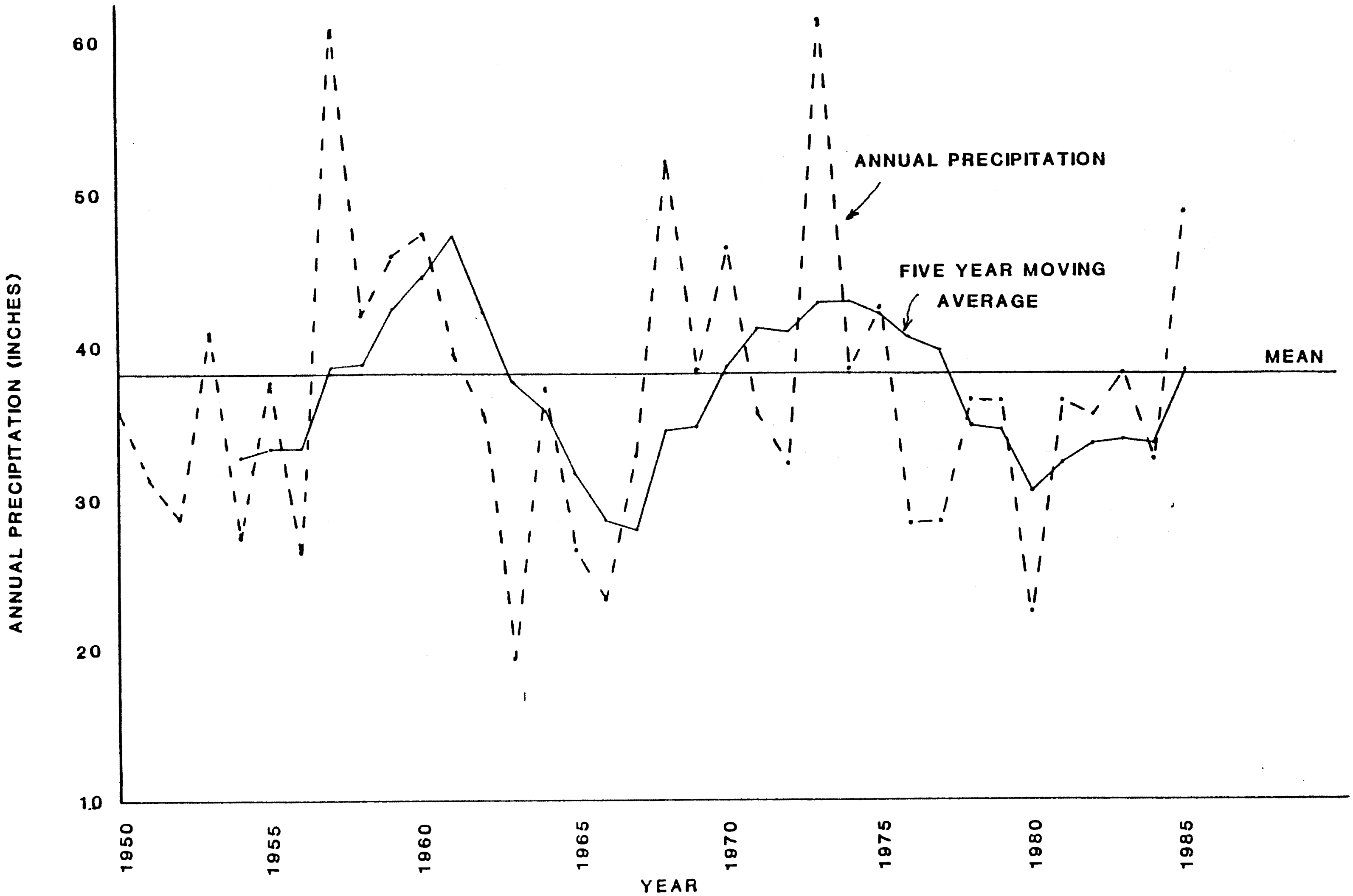
FIVE YEAR MOVING AVERAGE OF ANNUAL PRECIPITATION FOR

ADA, KONAWA, PAULS VALLEY, AND PURCELL, OKLAHOMA

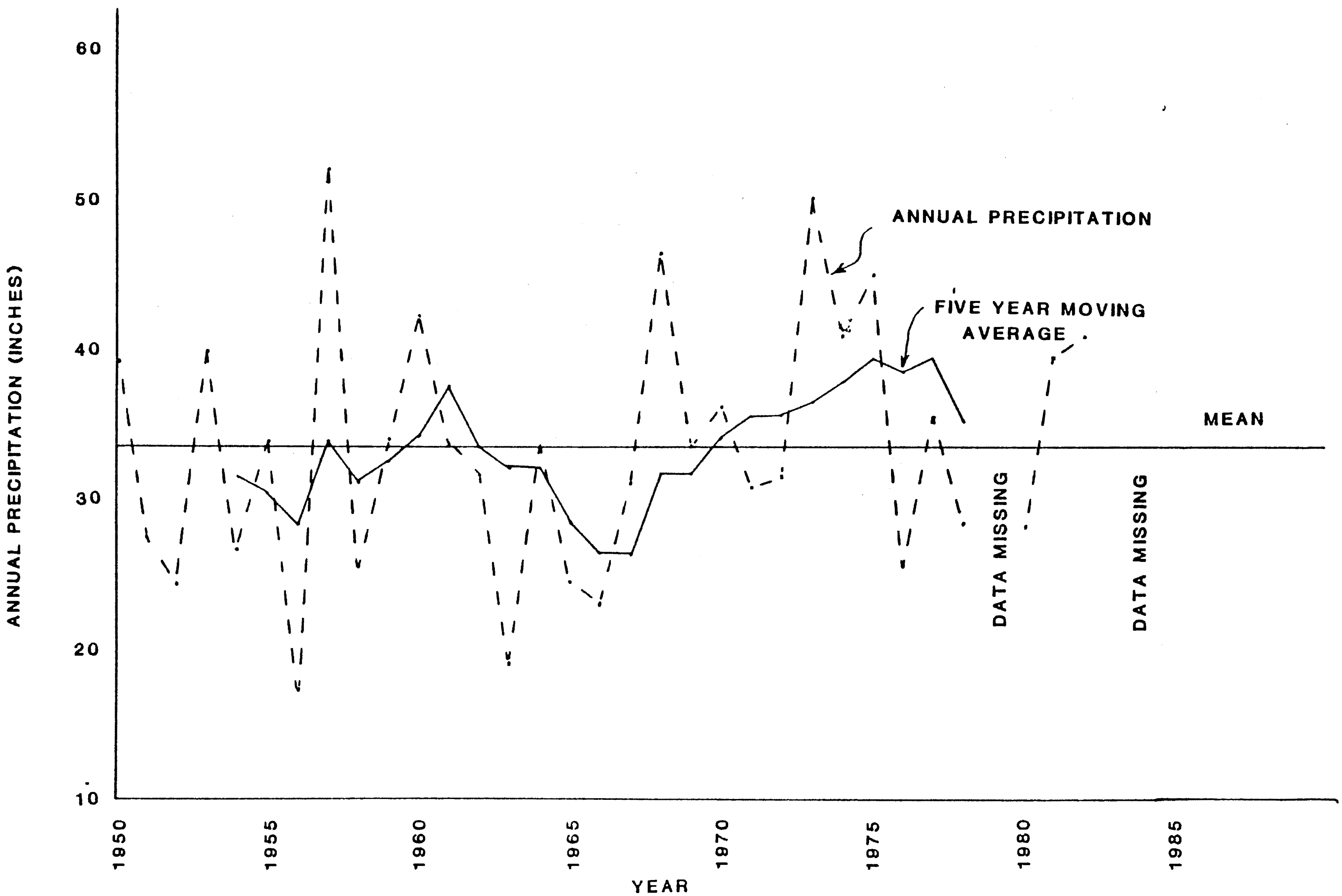
ADA, OKLAHOMA ANNUAL PRECIPITATION AND FIVE YEAR MOVING AVERAGE.



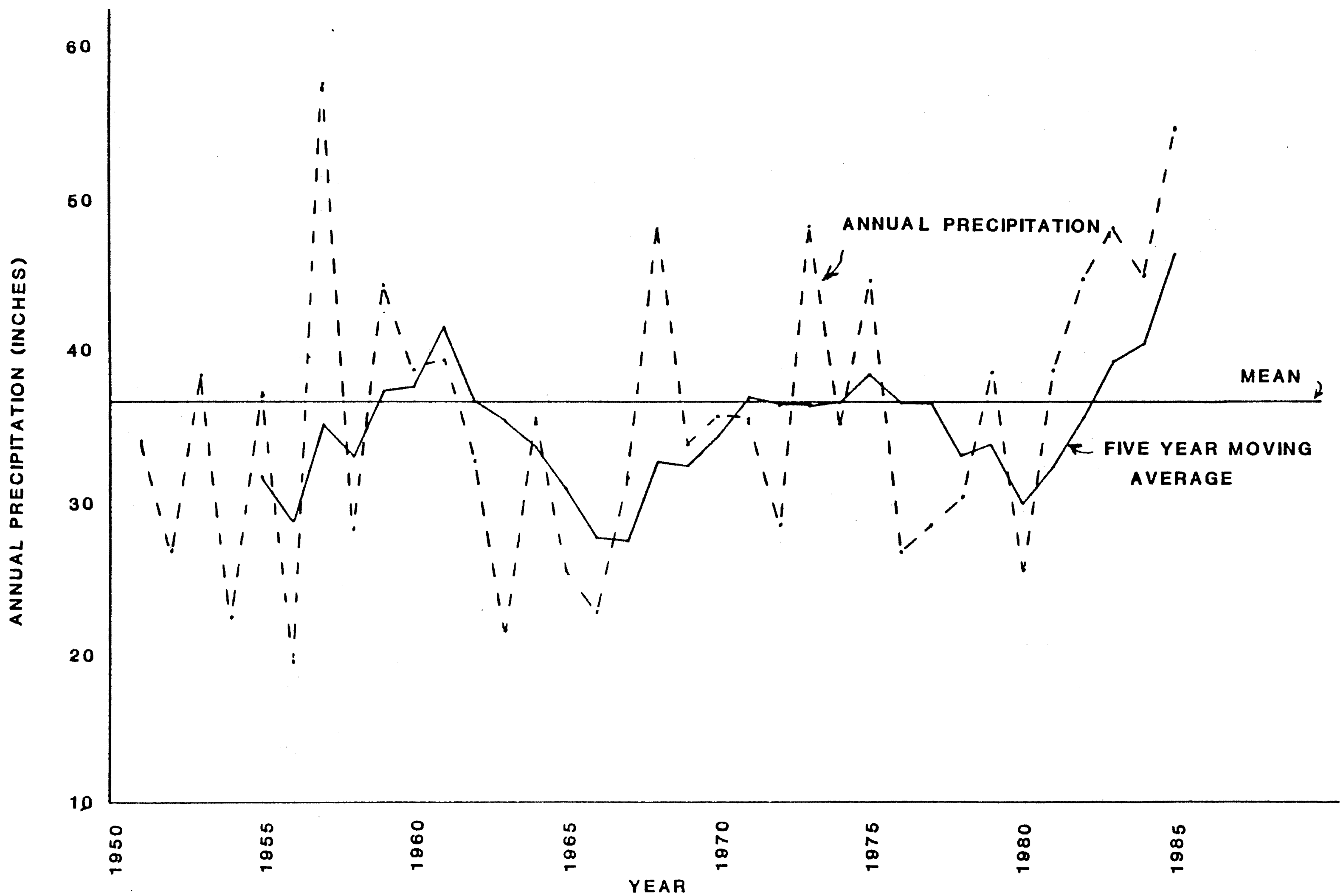
KONAWA, OKLAHOMA ANNUAL PRECIPITATION AND FIVE YEAR MOVING AVERAGE.



PAULS VALLEY, OKLAHOMA ANNUAL PRECIPITATION AND FIVE YEAR MOVING AVERAGE.

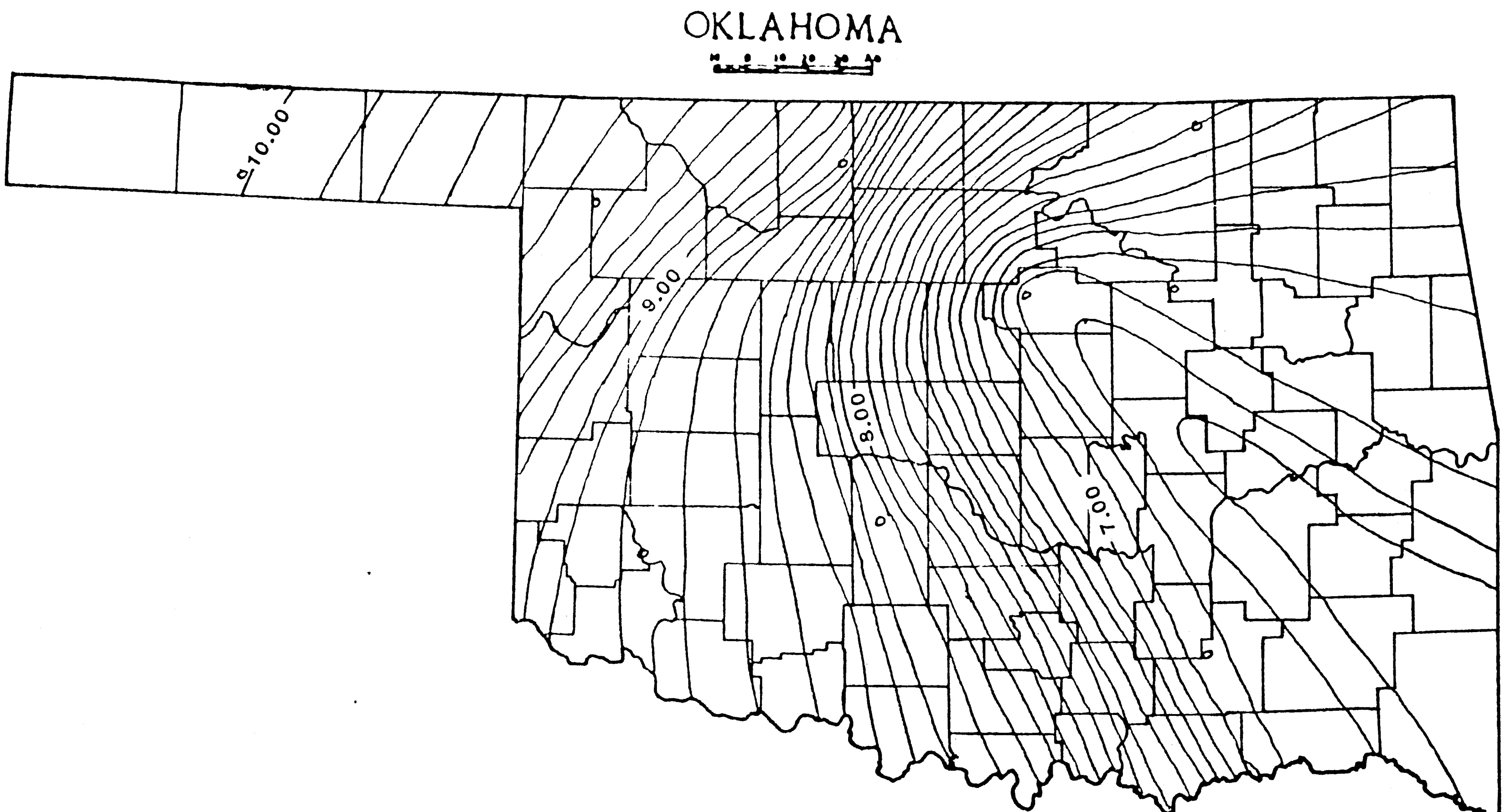


PURCELL, OKLAHOMA ANNUAL PRECIPITATION AND FIVE YEAR MOVING AVERAGE.

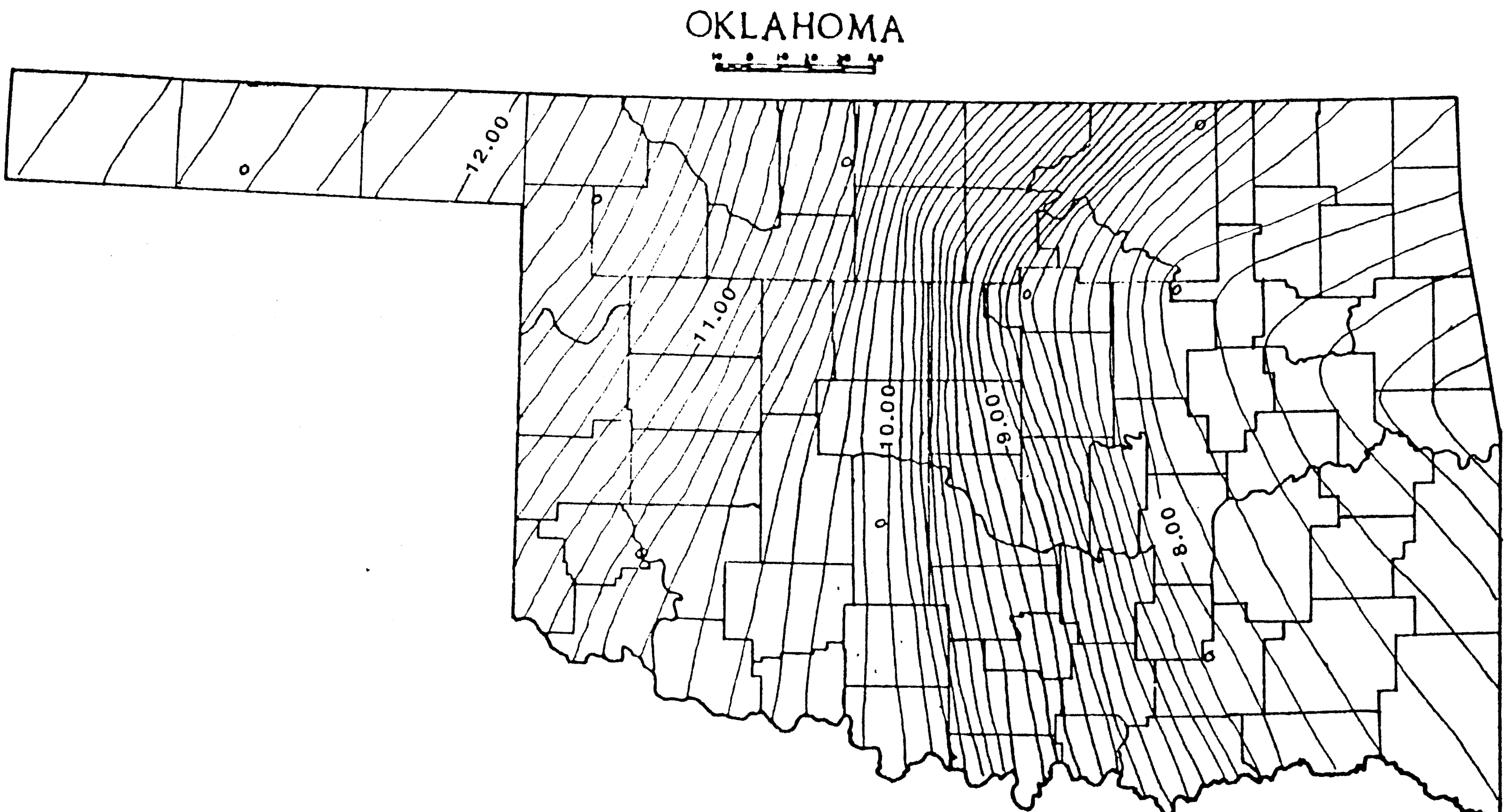


APPENDIX E

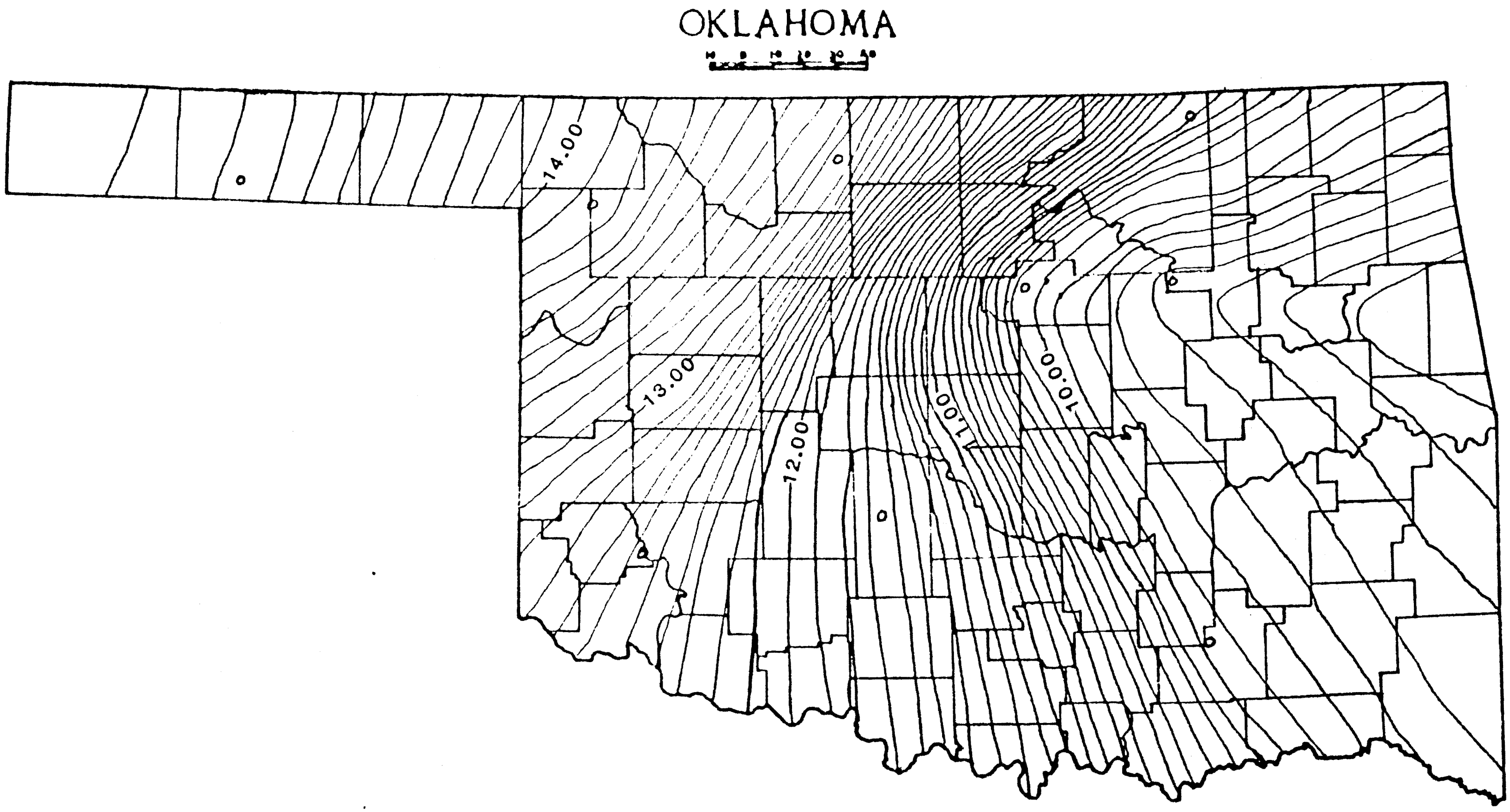
MAY TO OCTOBER MONTHLY EVAPORATION ISOHYET MAP



MAY MEAN EVAPORATION ISOHYET MAP
(1963-1983)

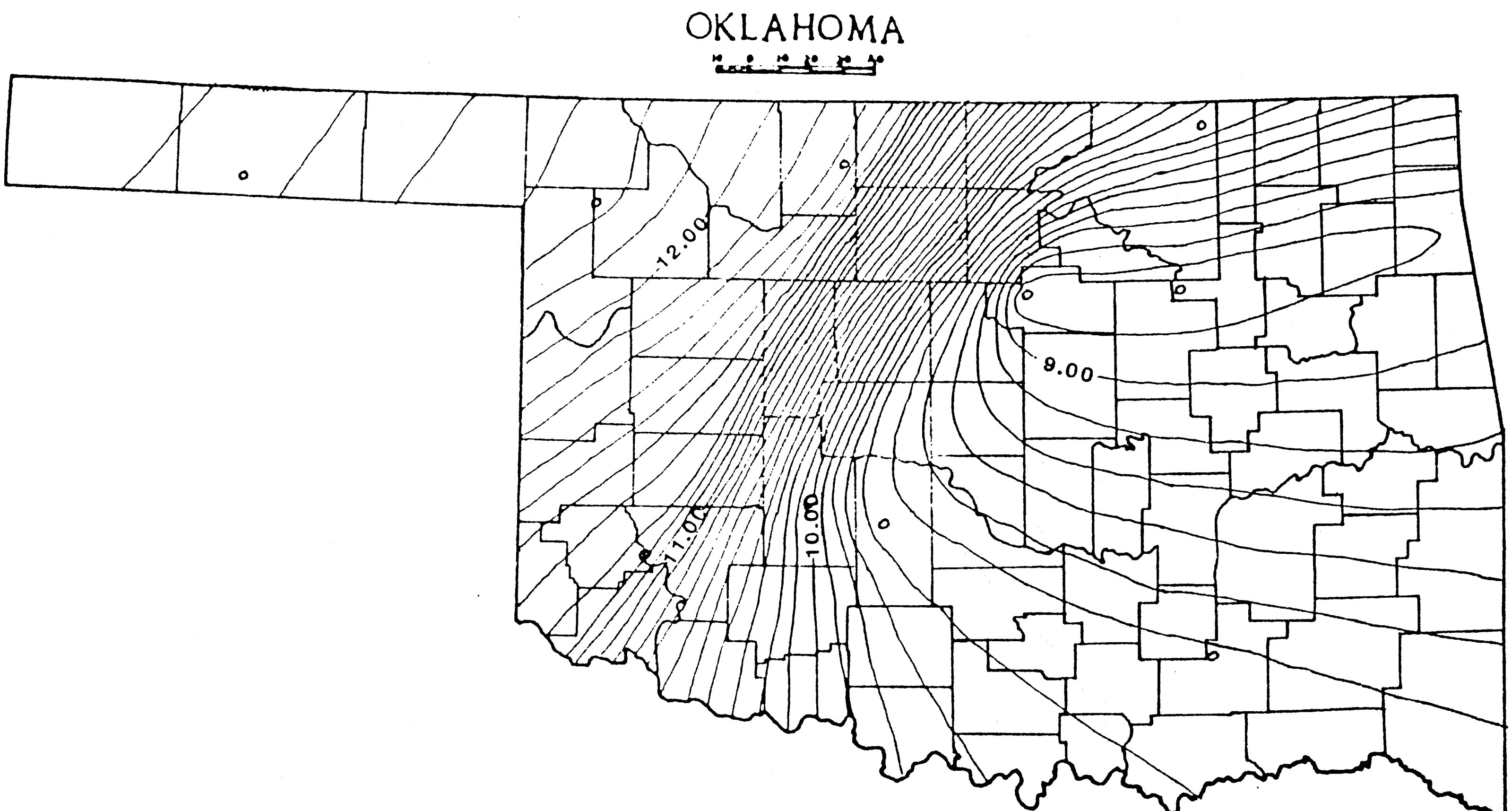


JUNE MEAN EVAPORATION ISOHYET MAP
(1963-1983)

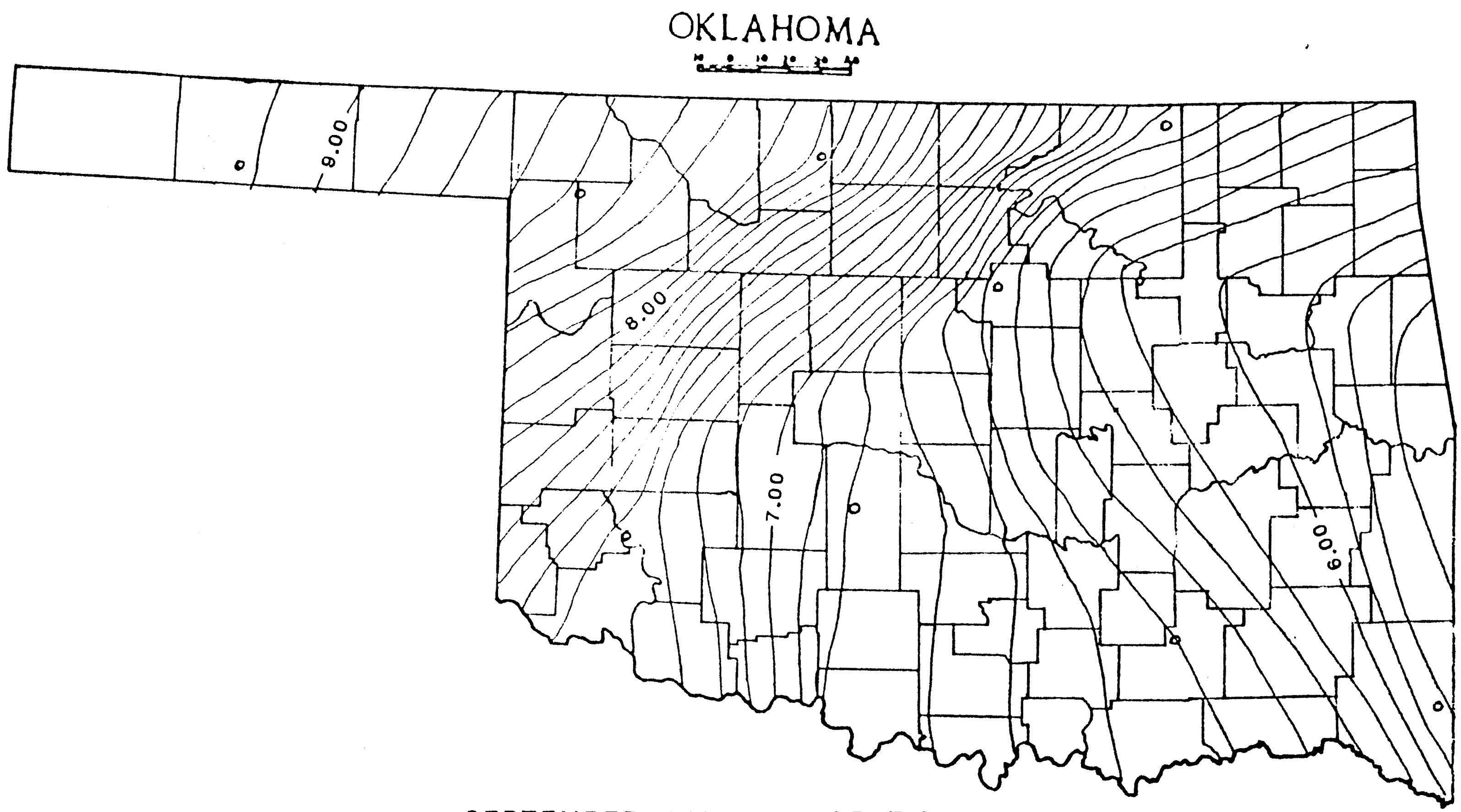


JULY MEAN EVAPORATION ISOHYET MAP

(1963-1983)

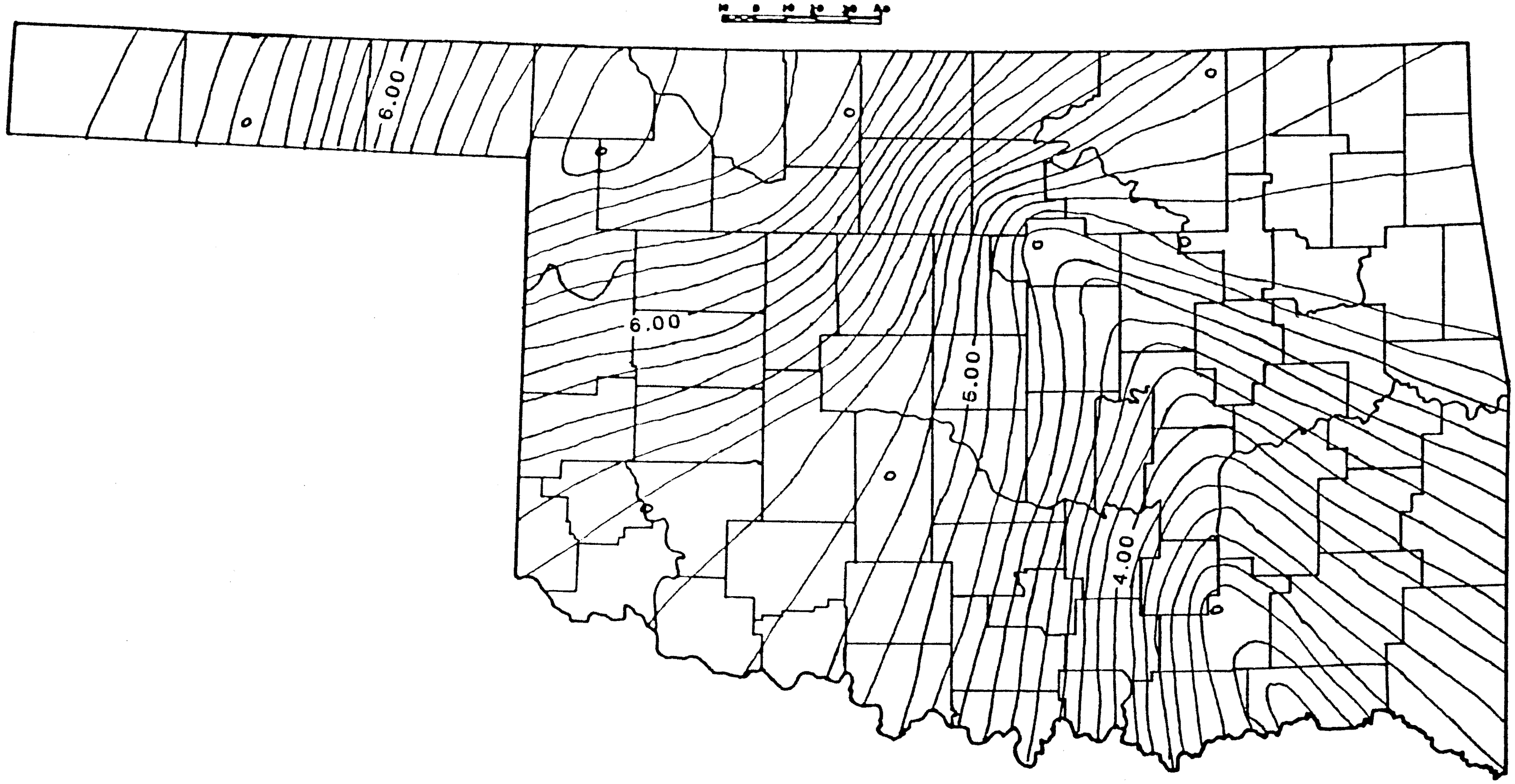


AUGUST MEAN EVAPORATION ISOHYET MAP
(1963-1983)



SEPTEMBER MEAN EVAPORATION ISOHYET MAP
(1963-1983)

OKLAHOMA



OCTOBER MEAN EVAPORATION ISOHYET MAP

(1963-1983)

APPENDIX F

PERMEABILITY FROM GEOLOGIC LOGS USING RANGE VALUES

PERMEABILITY FROM GEOLOGIC LOGS USING SATURATED THICKNESS INTERVAL ONLY. WATER TABLE ELEVATION FROM AVERAGE WATER TABLE MAP FOR COMPUTER SIMULATION. PERMEABILITY RANGE VALUES FROM ENID ISOLATED TERRACE REPORT (Kent, et. al., 1973).

OWNER/LOCATION	SURF. ELEV. (feet)	WT. ELEV. (feet)	DTW. (feet)	RANGE	1	2 (feet)	3	4	SAT. THICK (feet)
J. Jarrell	1140	1070	70	LITH.	11	4	7	4	26
NW, NE, SW, of				UPPER	55	240	2100	10200	484
Sec. 9, T4N, R3E.				MIDDLE	17	160	1470	6400	309
				LOWER	11	120	980	4000	197
K. Jarrell	1140	1070	70	LITH.	12	10	6	5	33
NE, SE, NW, of				UPPER	60	600	1800	12750	461
Sec. 9, T4N, R3E.				MIDDLE	18	400	1260	8000	293
				LOWER	12	300	840	5000	186
C. B. SMITH	1140	1077	63	LITH.	1	-	22	-	23
NE, NW, of				UPPER	5	-	6600	-	287
Sec. 17, T4N, R3E.				MIDDLE	2	-	4620	-	201
				LOWER	1	-	3080	-	134
C. B. SMITH	1130	1060	70	LITH.	-	7	7	-	14
NW, SW, of				UPPER	-	420	2100	-	180
Sec. 14, T4N, R3E.				MIDDLE	-	280	1470	-	125
				LOWER	-	210	980	-	85
AL. RUSS	1120	1082	38	LITH.	32	-	23	-	55
NW, SE, SE, of				UPPER	160	-	6900	-	128
Sec. 11, T4N, R3E.				MIDDLE	48	-	4830	-	89
				LOWER	32	-	3220	-	59
AL. RUSS	1120	1082	38	LITH.	27	5	18	-	50
SW, SW, SE, of				UPPER	135	300	5400	-	117
Sec. 11, T4N, R3E.				MIDDLE	41	200	3780	-	81
				LOWER	32	150	2520	-	54
AL. PHILLIP	1135	1075	60	LITH.	9	20	-	16	45
NW, NW, of				UPPER	45	1200	-	40800	934
Sec. 10, T4N, R3E.				MIDDLE	14	800	-	25600	587
				LOWER	9	600	-	16000	369
C. CASKEY	1130	1054	76	LITH.	-	10	-	14	24
SW, SW, of				UPPER	-	600	-	35700	1513
Sec. 14, T4N, R3E.				MIDDLE	-	400	-	22400	950
				LOWER	-	300	-	14000	596

Permeability from Geologic Logs (cont.)

OWNER/LOCATION	SURF. ELEV. (feet)	WT. ELEV. (feet)	DTW (feet)	RANGE	1	2	3	4	SAT. THICK (feet)
C. CASKEY	1125	1053	72	LITH.	-	-	-	9	9
NE, SE, of				UPPER	-	-	-	22950	-
Sec. 15, T4N, R3E.				MIDDLE	-	-	-	14400	-
				LOWER	-	-	-	9000	-
C. FREEMAN	1130	1068	62	LITH.	76	10	56	16	158
SW, NE, of				UPPER	380	600	16800	40800	371
Sec. 9, T4N, R3E.				MIDDLE	114	400	11760	25600	240
				LOWER	76	300	7840	16000	153
W. WATT	1140	1064	76	LITH.	-	8	-	5	13
NW, NW, of				UPPER	-	480	-	12750	1018
Sec. 21, T4N, R3E.				MIDDLE	-	320	-	8000	640
				LOWER	-	240	-	5000	403
E. L. GAMBLE	1120	1090	30	LITH.	20	-	-	10	30
SE, NW, of				UPPER	100	-	-	25500	853
Sec. 11, T4N, R3E.				MIDDLE	30	-	-	16000	534
				LOWER	20	-	-	10000	334

APPENDIX G

AQUIFER IRRIGATION PRODUCTION TEST DATA

FOR WATT AND JARRELL WELLS

WELL: Jarrell DATE: 5/21-22/85

LOCATION: Stratford, Oklahoma. STARTING TIME: 1530 hrs.

PUMP RATE: 182 GPM @ 1.00 MINUTES, 174 GPM @ 90.00 MINUTES
154 GPM @ 335.00 MINUTES, 140 GPM @ 1,075.00 MINUTES

DISCHARGE METER: Initial reading ---- gallon.

Final reading ---- gallon.

DISTANCE FROM PUMPING WELL: 200 feet.

	TIME (MIN)	DTW		TIME (MIN)	DTW
	INITIAL (SWL)	64.06			
				70.00	64.06
	0.50	-		80.00	64.06
	1.00	-		90.00	-
	1.50	-		100.00	64.07
	2.00	-		110.00	-
	2.50	-	2hr.	120.00	-
	3.00	-	3hr.	180.00	-
	4.00	-	4hr.	240.00	-
	5.00	-	5hr.	300.00	-
	10.00	64.06		335.00	64.07
	20.00	64.06		1,075.00	64.45
	30.00	64.06		1,163.00	64.51
	40.00	64.06		1,217.00	64.50
	50.00	-		1,358.00	64.58
1hr.	60.00	-		1,573.00	64.69

DEPTH TO WATER MEASURED FROM T.O.C. (Top of Casing)

CASING HEIGHT ABOVE PAD: -- INCHES.

HEIGHT OF PAD ABOVE GROUND: -- INCHES.

TOTAL DEPTH 69.6 feet. CASING DIA. 4 inches.
(from T.O.C.)

WELL BORE DIA. - inches.

TEST PERFORMED BY: D.C. kent, and P. Bayley.

PUMPED WELL RECOVERY

WELL: Jarrell

DATE: 5/21-22/85

LOCATION: Stratford, Oklahoma.

STARTING TIME: 1530 hrs.

STATIC WATER LEVEL: 84.07 feet (DTW)

DIAMETER OF WELL: 36 inches.

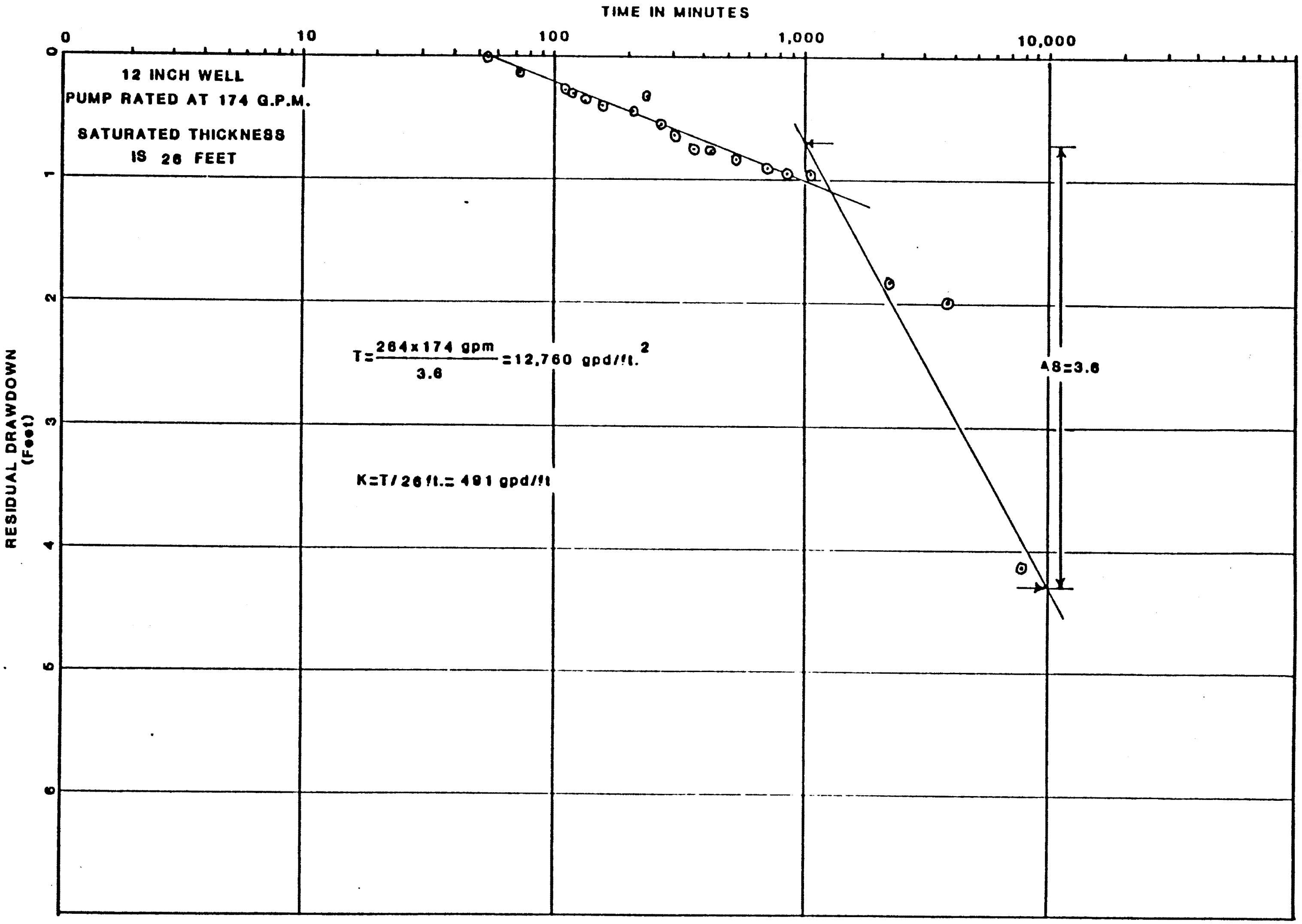
TD: 96 feet.

DISCHARGE: -- .

TIME (MIN)	DTW	TIME (MIN)	DTW
0.00	95.03	40.00	83.80
0.17	88.20	50.00	83.68
0.28	86.20	60.00	83.57
0.50	85.89	120.00	83.12
1.03	85.03	258.00	82.54
2.00	84.90	473.00	82.05
3.00	84.84		
4.00	84.71		
5.25	84.55		
10.00	84.36		
20.00	84.07		
30.00	83.95		

TEST PERFORMED BY: D. K., P. B., and L. D.

JARRELL RESIDUAL DRAWDOWN CURVE FOR PUMPING WELL



DISCHARGING WELL TEST

OWNER: Watts   DATE: August 17-18, 1985.

LOCATION: SE.1/4 of the NW.1/4 of the SW.1/4 of Section 17, T.4N., R.3E.

COUNTY: GARVIN

TD: 78 feet.   CASING HEIGHT: 0.90 inches.

DEPTH TO WATER (feet)*	METER READING (gallons)	ELAPSED TIME (min.)	DISCHARGE (gal./min.)
55.50	0	0	0
70.10	200	0.50	200
-	600	1.00	600
-	900	2.00	450
-	1,500	3.00	500
74.67	1,800	4.00	450
74.77	2,400	5.00	480
-	2,700	6.00	450
74.80	3,100	7.00	442
75.03	3,500	8.00	437.5
74.90	3,900	9.00	433
74.80	4,250	10.00	425
74.70	6,500	15.00	433
74.63	8,650	20.00	432
74.69	11,200	25.00	448
74.68	12,800	30.00	427
74.69	15,000	35.00	428
74.69	17,250	40.00	431
74.66	19,300	45.00	429
74.64	21,100	50.00	422
74.63	23,200	55.00	422
74.63	25,150	60.00	418
74.63	28,750	70.00	410
74.68	32,300	80.00	403
74.63	36,100	90.00	401
74.68	41,500	100.00	415
74.75	45,100	110.00	410
74.80	49,100	120.00	409
74.81	60,000	150.00	400
74.79	71,800	180.00	398
-	81,400	210.00	387
74.61	95,100	240.00	396
74.58	108,800	270.00	402
73.97	120,200	300.00	400
-	129,800	330.00	393
74.25	138,100	360.00	384
74.30	159,800	420.00	381
74.21	176,800	480.00	368
74.89	191,100	540.00	354

DEPTH TO WATER (cont.)	METER READING (cont.)	ELASPED TIME (cont.)	DISCHARGE (cont.)
-	-	600.00	-
74.50	225,100	660.00	341
74.58	243,300	720.00	337
74.70	270,500	780.00	-
74.66	294,500	840.00	-
-	-	900.00	-
-	-	960.00	-
-	-	1,020.00	-
-	-	1,080.00	-
-	-	1,140.00	-
-	424,680	1,200.00	-
-	461,100	1,260.00	-
-	484,300	1,320.00	367
73.68	503,600	1,380.00	-
-	521,500	1,440.00	-
-	-	1,500.00	-
-	567,000	1,560.00	-
-	589,000	1,620.00	-
-	610,600	1,680.00	360
-	631,600	1,740.00	-
-	652,000	1,800.00	-
-	653,100	1,860.00	-

PUMP SHUT DOWN

* values adjusted from casing height.

RECOVERY OF WELL

OWNER: Watt DATE: August 18, 1987

LOCATION: SE.1/4 of the NW.1/4 of the SW.1/4 of Section 17, T.4N., R.3E.

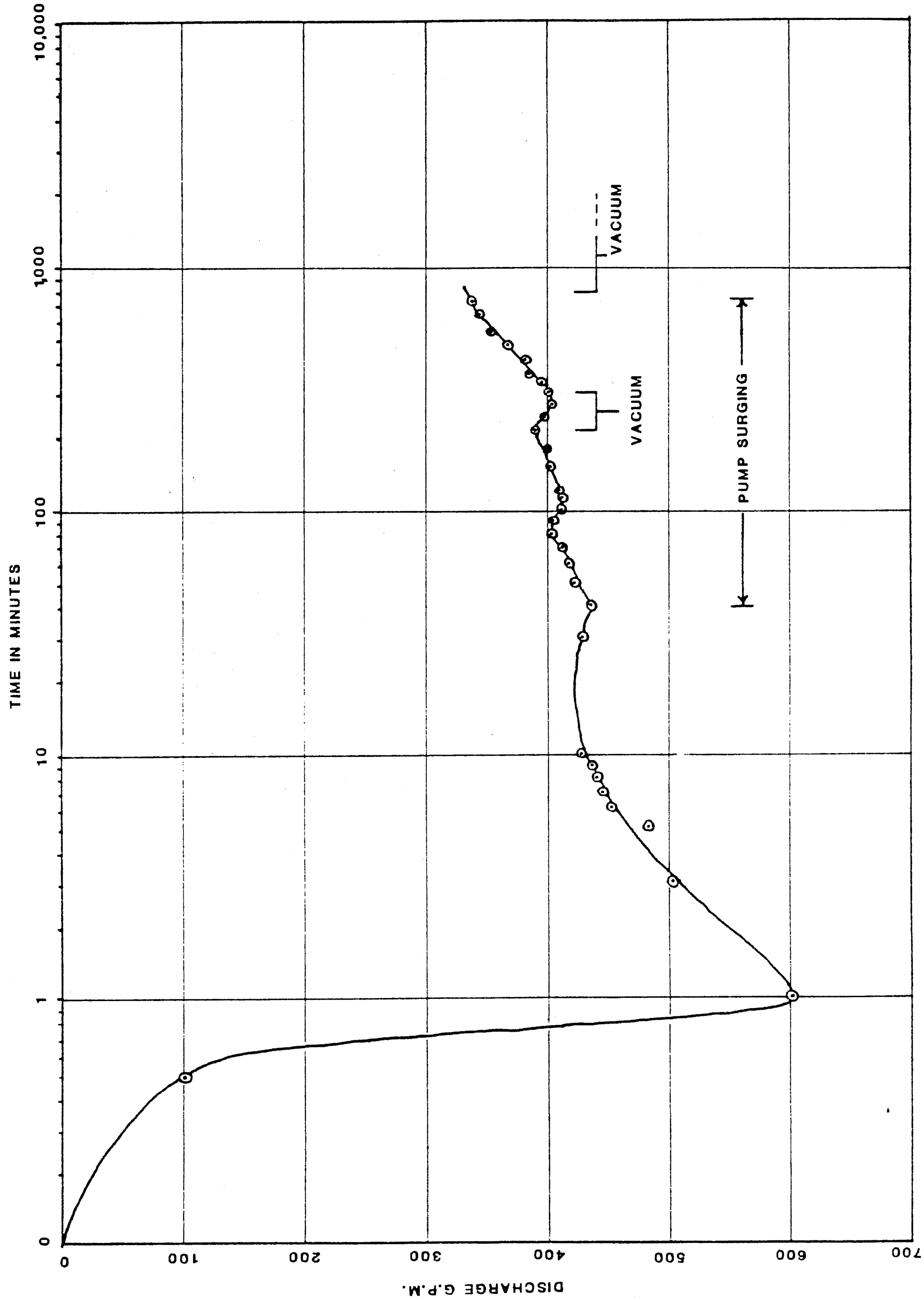
COUNTY: Garvin

TD 78 feet. CASING HEIGHT: 0.90 feet.

DATE	TIME	T (min)	T' (min)	DEPTH TO WATER (feet)*	REMARKS
8/18/85	2:25p	1440	0	75.63	Release vac.
		1440.5	1/2	57.50	
		1441	1	63.56	
		1442	2	63.74	
		1443	3	63.78	
		1444	4	63.74	
		1445	5	63.73	
		1446	6	-	
		1447	7	63.67	
		1448	8	63.65	
		1449	9	63.63	
	2:30p	1450	10	63.59	
		1455	15	63.51	
	2:45p	1460	20	63.40	
	2:55p	1470	30	63.18	
	3:05p	1480	40	63.01	
	3:15p	1490	50	62.89	
	3:25p	1500	60	62.77	
	3:35p	1510	70	62.66	
	3:45p	1520	80	62.54	
	3:55p	1530	90	62.46	
	4:05p	1540	100	62.37	
	4:15p	1550	110	62.28	
	4:25p	1560	120	62.21	
	4:55p	1590	150	62.00	
	5:25p	1620	180	61.83	
	5:55p	1650	210	61.66	
	6:25p	1680	240	61.51	
	6:55p	1710	270	61.40	
	7:25p	1740	300	-	
	7:55p	1770	330	61.13	
	8:25p	1800	360	61.08	
	8:55p	1830	390	60.99	

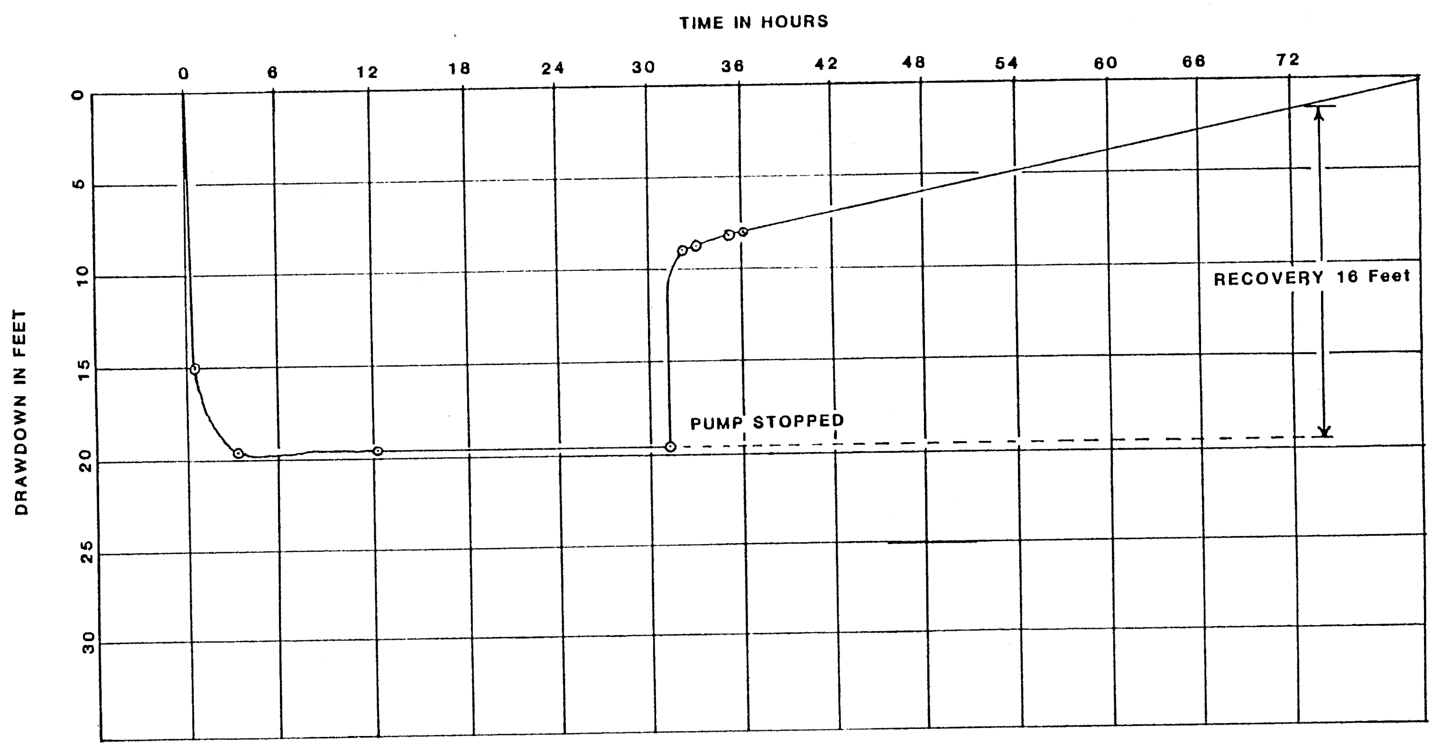
* values adjusted from casing height.

TEST PERFORMED BY: L. D., AND B. T.

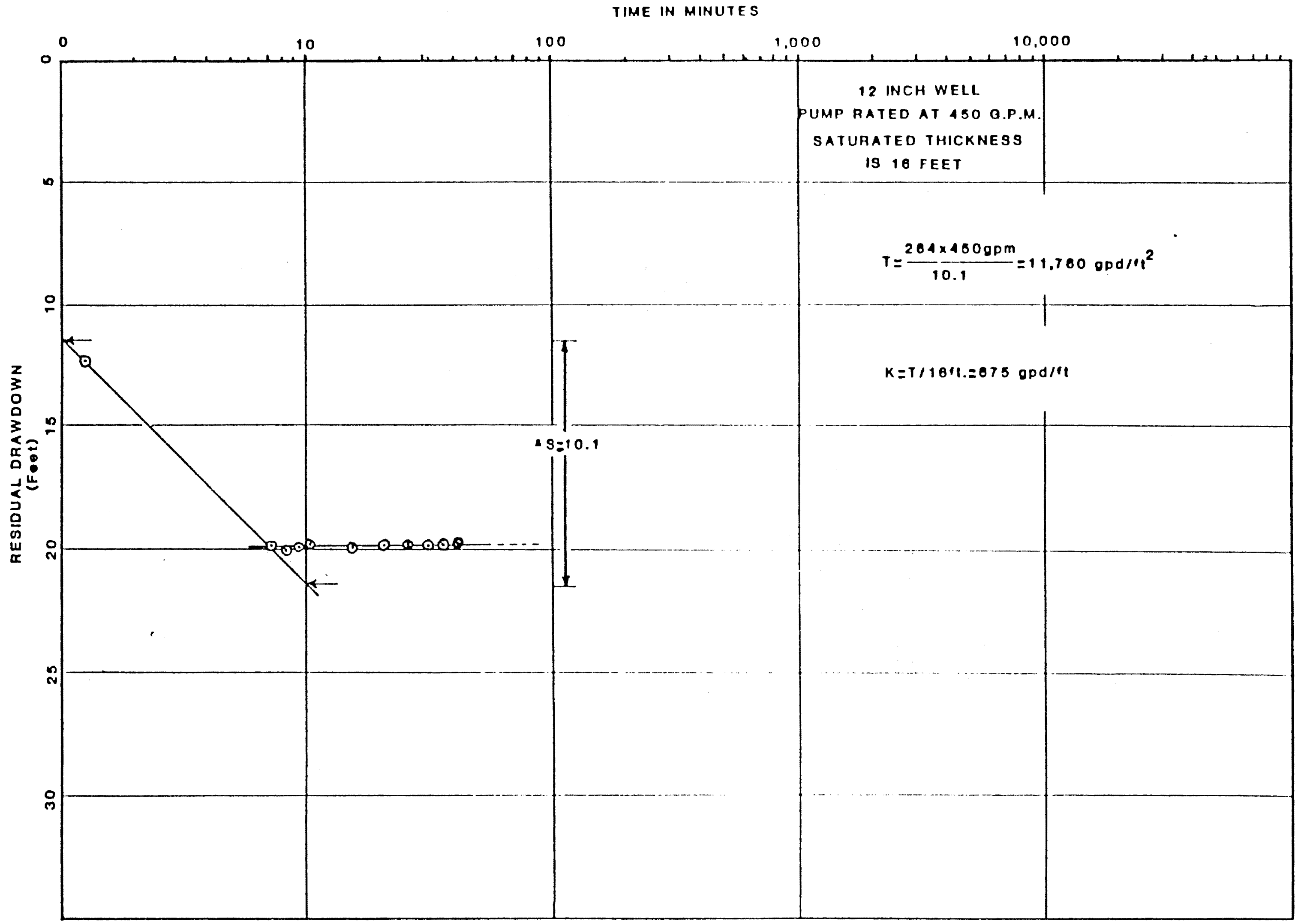


WATT PUMPING WELL DISCHARGE CHART

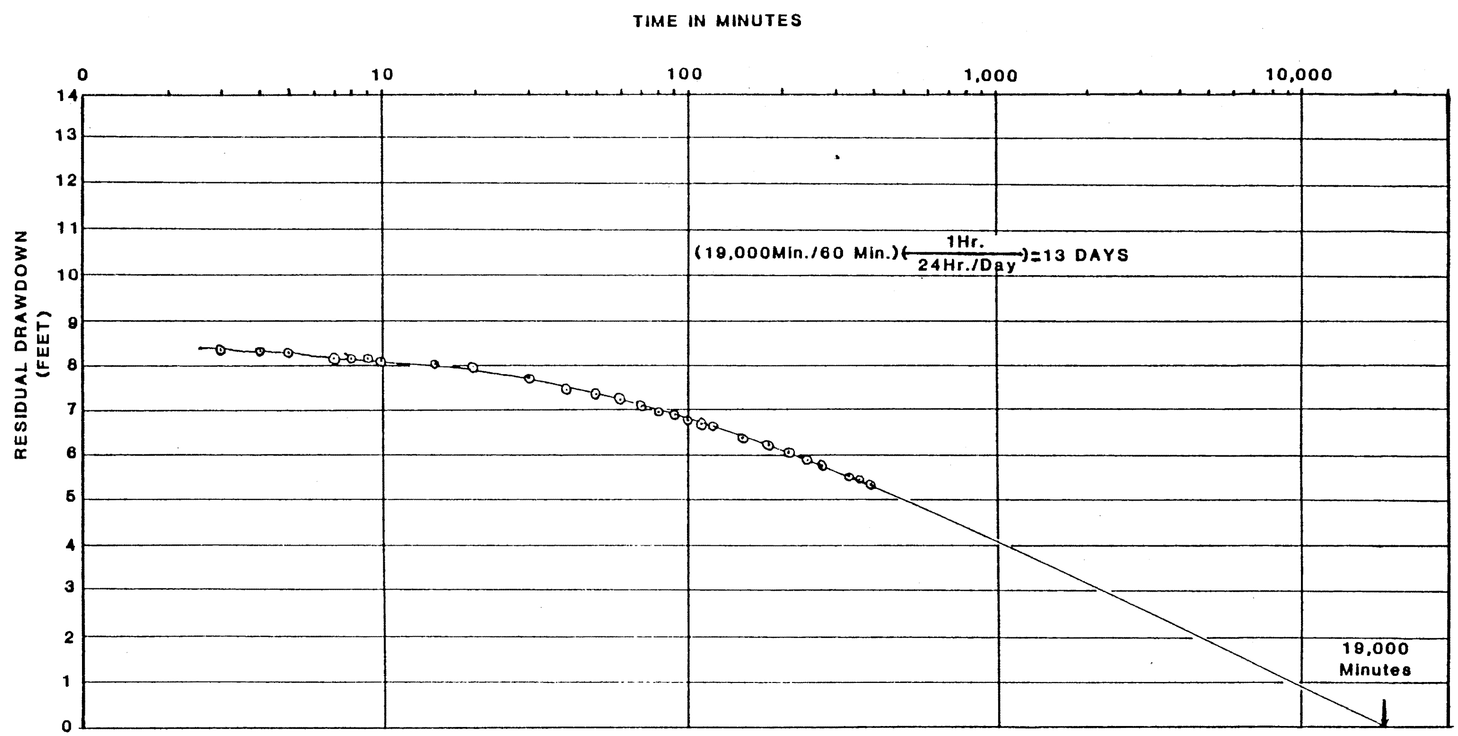
WATT WELL PUMPING AND RECOVERY TIME



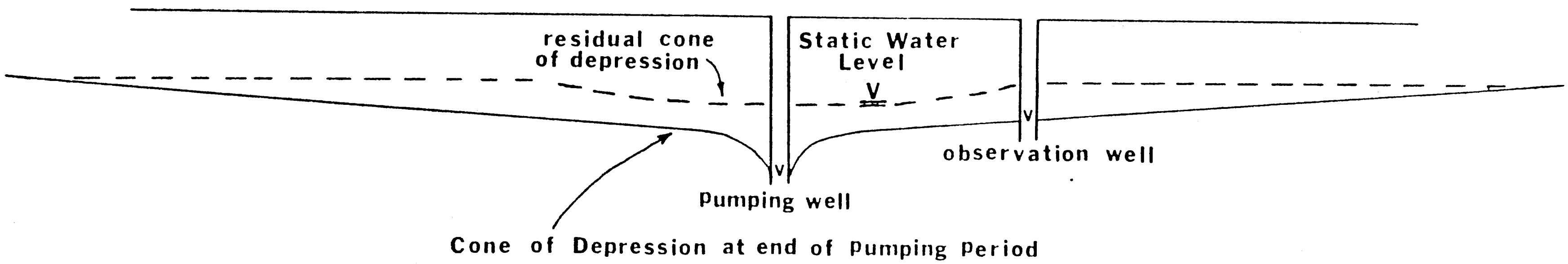
WATT RESIDUAL DRAWDOWN CURVE FOR PUMPING WELL

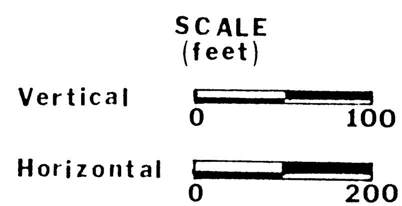


WATT PUMPED WELL RECOVERY



WATT IRRIGATION WELL AND INFLUENCE OF CONE OF DEPRESSION





APPENDIX H

WATER QUALITY ANALYSIS

Station Identification Number	OWRB Number	Legal Description
1-1	03005	SE SE SW Sec. 11, T.4N., R.3E.
1-2	03004	SW SW SW Sec. 2, T.4N., R.3E.
1-3	03006	SE SE SE Sec. 30, T.5N., R.4E.
1-4	03007	NW NW NE Sec. 20, T.5N., R.4E.
1-5	03008	SE SW SE Sec. 20, T.5N., R.3E.
2-1	03009	NE NE NE Sec. 27, T.5N., R.3E.
2-2	03010	NE NE NE Sec. 4, T.4N., R.3E.
2-3	03011	SW SE Sec. 10, T.4N., R.3E.
2-4	03012	NW NE Sec. 8, T.4N., R.3E.
3-1	03013	SE SW Sec. 8, T.4N., R.3E.
3-2	03014	NW SW NW Sec. 18, T.4N., R.3E.
3-3	03015	SE SE SE Sec. 19, T.4N., R.3E.
3-4	03016	SE SW SE Sec. 22, T.4N., R.3E.
3-5	03017	SE SE SW Sec. 20, T.4N., R.4E.

		Station Identification Number				
		1-1	1-2	1-3	1-4	1-5
Parameter	units	remarks	remarks	remarks	remarks	remarks
Chloride	MG/L	113.00	12.00	16.00	66.00	29.00
Nitrite-Nitrate as N	MG/L	3.60	1.20	1.70	1.90	0.50
Specific Conductance	UMHOS/OM	390.00	420.00	230.00	525.00	660.00
Solids, Total diss.	MG/L	251.00	272.00	186.00	301.00	346.00
Hardness,	MG/L	134.00	154.00	57.00	130.00	< 10.00
Barium	UG/L	230.00	< 200.00	< 200.00	260.00	< 200.00
Calcium	MG/L	35.00	44.00	14.00	31.00	1.00
Copper	UG/L	150.00	14.00	20.00	63.00	5.00
Lead	UG/L	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00
Manganese	UG/L	< 20.00	< 20.00	< 20.00	< 20.00	< 20.00
Sodium	MG/L	39.00	50.00	35.00	56.00	154.00
Fluoride	MG/L	0.22	0.21	0.28	0.28	0.51
pH	STD	6.80	6.80	6.50	6.00	9.20
Sulfate	MG/L	< 20.00	< 20.00	< 20.00	21.00	< 20.00
Alkalinity	MG/L	220.00	274.00	159.00	186.00	378.00
Arsenic	UG/L	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00
Cadnium	UG/L	< 2.00	< 2.00	< 2.00	< 2.00	< 2.00
Chromium	UG/L	< 10.00	< 10.00	< 10.00	< 10.00	< 10.00
Iron	UG/L	< 100.00	250.00	< 100.00	< 100.00	< 100.00
Magnesium	MG/L	10.00	8.00	4.00	10.00	< 1.00
Selenium	UG/L	< 5.00	< 5.00	< 5.00	< 5.00	< 5.00
Zinc	UG/L	21.00	52.00	10.00	920.00	< 4.00
Water Temp.	C	18.00	18.00	18.00	20.00	18.00

< less than detection limit

Parameter	Units	Station Identification Number 2-1 remarks		2-2 remarks		2-3 remarks		2-4 remarks
Chloride	MG/L		113.00		24.00		53.00		26.00
Nitrite-Nitrate as N	MG/L	<	0.50		3.80		6.10		2.80
Specific conductance	UMHOS/OM		1,000.00		3,100.00		-		580.00
Solids, Total diss.	MG/L		750.00		230.00		417.00		416.00
Hardness	MG/L	<	10.00		84.00		295.00		275.00
Barium	UG/L		330.00		400.00		540.00		530.00
Calcium	MG/L		1.00		20.00		92.00		74.00
Copper	UG/L		8.00		94.00		8.00		17.00
Lead	UG/L	<	20.00	<	20.00	<	20.00	<	20.00
Manganese	UG/L	<	20.00	<	20.00	<	20.00	<	20.00
Sodium	MG/L		340.00		32.00		39.00		57.00
Fluoride	MG/L		0.83		0.25		0.27		0.32
pH	STD		9.00		6.50		-		6.90
Sulfate	MG/L		29.00	<	20.00	<	20.00		25.00
Alkalinity	MG/L		704.00		137.00		297.00		348.00
Arsenic	UG/L	<	10.00	<	10.00	<	10.00	<	10.00
Cadmium	UG/L	<	2.00	<	2.00	<	2.00	<	2.00
Chromium	UG/L	<	10.00	<	10.00	<	10.00	<	10.00
Iron	UG/L	<	100.00	<	100.00	<	100.00	<	100.00
Magnesium	MG/L	<	1.00		8.00		12.00		16.00
Selenium	UG/L	<	5.00	<	5.00	<	5.00	<	5.00
Zinc	UG/L	<	4.00		10.00		38.00		38.00
Water Temp.	C		20.00		-		18.00		17.50

< less than detection limits

Parameter	Units	Station Identification Number 3-1 remarks		3-2 remarks		3-3 remarks		3-4 remarks		3-5 remarks
Chloride	MG/L		283.00		51.00		20.00		35.00	134.00
Nitraite-Nitrate as N	MG/L	<	0.50		4.10		1.10	<	0.50	-
Specific Conductance	UMHOS/OM		1,600.00		510.00		695.00		860.00	1,620.00
Solids, Total Diss.	MG/L		1,108.00		299.00		434.00		499.00	871.00
Hardness, Total	MG/L	<	10.00		132.00		238.00		315.00	639.00
Barium	UG/L	<	200.00	<	200.00		370.00	<	200.00	290.00
Calcium	MG/L		2.00		28.00		63.00		82.00	125.00
Copper	UG/L		5.00		7.00		14.00		11.00	11.00
Lead	UG/L	<	20.00	<	20.00		31.00	<	20.00	< 20.00
Manganese	UG/L	<	20.00	<	20.00	<	20.00	<	20.00	< 20.00
sodium	MG/L		540.00		68.00		75.00		82.00	35.00
Fluoride	MG/L		2.40		0.36		0.84		0.34	0.30
pH	STD		9.10		7.00		7.10		6.90	6.80
sulfate	MG/L		46.00		32.00	<	20.00	<	20.00	31.00
Alkalinity	MG/L		618.00		223.00		379.00		499.00	261.00
Arsenic	UG/L	<	10.00	<	10.00	<	10.00	<	10.00	< 10.00
Cadnium	UG/L	<	2.00	<	2.00	<	2.00	<	2.00	< 2.00
Chromium	UG/L	<	10.00	<	10.00	<	10.00	<	10.00	< 10.00
Iron	UG/L	<	100.00	<	100.00	<	100.00	<	100.00	500.00
Magnesium	MG/L	<	1.00		10.00		16.00		22.00	56.00
Selenium	UG/L	<	5.00	<	5.00	<	5.00	<	5.00	< 5.00
Zinc	UG/L	<	4.00	<	4.00		94.00		16.00	130.00
Water Temp.	C		18.00		18.00		16.50		17.50	17.00

< less than detection limit

APPENDIX I

PRIOR RIGHTS ALLOCATION FOR GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA

OKLAHOMA WATER RESOURCES BOARD

FINAL ORDER ESTABLISHING PRIOR GROUND WATER RIGHTS IN GARVIN COUNTY, OKLAHOMA COVERING ALL OR PARTS OF TOWNSHIPS 1N, 2N, 3N, AND 4N, AND RANGES 1WIM, 2WIM, 3WIM, 4WIM, 1EIM, 2EIM, AND 3EIM.

The Oklahoma Water Resources Board establishes this order under the authority of 82 O. S. 1981, Sections 1085.2, 1020.14 and pursuant to Oklahoma Water Resources Board Rules and Regulations, Chapter VIII, Section 875.1 - 875.17, reviewed all active ground water files and all known claims by person not having previously filed an application in Garvin County. The Oklahoma Water Resources Board finds that the following persons have established a prior right to the use of ground water in the amounts shown:

BAKER, L. B. Application #66-352 - filed 8/19/66
PRIORITY DATE(S) AND AMOUNTS: 8/19/66 - 70 a. f. TOTAL: 70 a. f.
PURPOSE: To irrigate 102 acres located in N.1/2 of the NW.1/4 and SW.1/4 of the NW.1/4, Section 13, Township 4N, Range 3EIM, from wells located in the same legal description.

BRYANT, LYDIA R. Application #63-363 - filed 11/1/63
PRIORITY DATE(S) AND AMOUNTS: 11/1/63 - 150 a. f. Total: 153 a. f.
PURPOSE: To irrigate 80 acres located in E.1/2 of the NE.1/4, Section 15, Township 4N, Range 3EIM, from wells located in the same legal description.

BRUNDIDGE, BEN %FLOYD BRUNDIDGE Application #73-58 - filed 4/10/73
PRIORITY DATE(S) AND AMOUNTS: 4/10/73 - 150 a. f. Total: 150 a. f.
PURPOSE: To irrigate 130 acres located in the S.1/2 of SW.1/4 and W.1/2 of NE.1/4 and S.1/2 of NW.1/4 of SW.1/4, Section 10, Township 4N, Range 3EIM, from wells located in the same legal description.

CHRIST, PAUL Application #64-144 - filed 2/26/64
PRIORITY DATE(S) AND AMOUNTS: 2/26/64 - 138 a. f. Total: 138 a. f.
PURPOSE: To irrigate 157 acres located in SE.1/4, Section 9, Township 4N, Range 3EIM, from wells located in the SW.1/4 of the NE.1/4 of the SE.1/4, Section 9, Township 4N, Range 3EIM.

CROSBY, S. R. Application #64-197 - filed 3/23/64
PRIORITY DATE(S) AND AMOUNTS: 3/23/64 - 192 a. f. Total: 192 a. f.
PURPOSE: To irrigate 131 acres located in the SE.1/4, Section 10, Township 4N, Range 3EIM, from wells located in the NW.1/4 of the SW.1/4 of the SE.1/4, Section 10, Township 4N, Range 3EIM.

EASTER, M. T. Application #63-324 - filed 10/7/63
PRIORITY DATE(S) AND AMOUNTS: 10/7/63 - 60 a. f. Total: 60 a. f.
PURPOSE: To irrigate 30 acres located in the NW.1/4 of the NW.1/4, Section 23, Township 4N, Range 3EIM, from wells located in the same legal description.

ELDRED, MR. AND MRS. JIMMY D. Application #66-440 - filed 7/21/66
PRIORITY DATE(S) AND AMOUNTS: 7/21/66 - 52 a. f. Total: 52 a. f.
PURPOSE: To irrigate 63 acres located in E.1/2 of the NE.1/4, Section 14, Township 4N, Range 3EIM, from wells located in the same legal description.

FREEMAN, W. L. Application #64-229 - filed 3/27/64
PRIORITY DATE(S) AND AMOUNTS: 3/27/64 - 172 a. f. Total: 172 a. f.
PURPOSE: To irrigate 110 acres located in NE.1/4, Section 9, Township 4N, Range 3EIM, from wells located in the same legal description.

GALLUP, J. G. Application #64-312 - filed 4/13/64
PRIORITY DATE(S) AND AMOUNTS: 4/13/64 - 243 a. f. Total: 243 a. f.
PURPOSE: To irrigate 200 acres located in S.1/2, Section 21, Township 4N, Range 3EIM, from well located in the W.1/2 of the SE.1/4, Section 21, Township 4N, Range 3EIM.

GRAY, BAXTER Application #66-68 - filed 2/8/66
PRIORITY DATE(S) AND AMOUNTS: 2/8/66 - 37 a. f. Total: 37 a. f.
PURPOSE: To irrigate 30 acres located in the SW.1/4, Section 14, Township 4N, Range 3EIM, from wells located in the NW.1/4 of the SW.1/4 of the SW.1/4, Section 14, Township 4N, Range 3EIM.

GRAY, GUS Application #67-601A - filed 7/7/67
PRIORITY DATE(S) AND AMOUNTS: 7/7/67 - 12.5 a. f. Total: 12.5 a. f.
PURPOSE: To irrigate 21.4 acres located in S.1/2 of the SW.1/4, Section 9, Township 4N, Range 3EIM, from well located in the S.1/2 of the SW.1/4, Section 9, Township 4N, Range 3EIM.

JARRELL, JIMMIE L. Application #56-550 - filed 7/27/56
PRIORITY DATE(S) AND AMOUNTS: 7/27/67 -130 a. f. Total: 130 a. f.
PURPOSE: To irrigate 150 acres located in the E.1/2 of the SE.1/4, Section 15, and 67.5 acres S.1/2 of the SW.1/4, Section 14, Township 4N, Range 3EIM, from wells located in the S.1/2 of the SW.1/4, Section 14, Township 4N, Range 3EIM.

JARRELL, JIMMIE L. Application #67-601B - filed 7/7/67
PRIORITY DATE(S) AND AMOUNTS: 7/7/67 - 42.4 a. f. Total: 42.4 a. f.
PURPOSE: To irrigate 80 acres located in the N.1/2 of the SW.1/4, Section 9, Township 4N, Range 3EIM, from wells located in the same legal description.

JARRELL, KENNETH Application #63-162 - filed 6/14/63
PRIORITY DATE(S) AND AMOUNTS: 6/14/63 - 103 a. f. Total: 103 a. f.
PURPOSE: To irrigate 80 acres located in the W.1/2 of the NE.1/4, Section 9, Township 4N, Range 3EIM, from well located in same legal description.

JARRELL, KENNETH Application #67-103 - filed 2/9/67
PRIORITY DATE(S) AND AMOUNTS: 2/9/67 - 59 a. f. Total: 59 a. f.
PURPOSE: To irrigate 80 acres located in E.1/2 of the NW.1/4, Section 9, Township 4N, Range 3EIM, from wells located in the NE.1/4 of the SE.1/4 of the NW.1/4, Section 9, Township 4N, Range 3EIM.

MERCER, CONNIE T. Application #56-938 - filed 12/28/56
PRIORITY DATE(S) AND AMOUNTS: 12/28/56 - 63 a. f. Total: 63 a. f.
PURPOSE: To irrigate 40 acres located in the SE.1/4 of the SE.1/4, Section 21, Township 4N, Range 3EIM, from wells located in the same legal description.

RUSS, ALBERT J. Application #73-68 - filed 4/10/73
PRIORITY DATE(S) AND AMOUNTS: 4/10/73 - 97 a. f. Total: 97 a. f.
PURPOSE: To irrigate 170 acres located in the E.1/2 of the NW.1/4 of the SE.1/4 and SW.1/4 of the SE.1/4 and E.1/2 of the SE.1/4 and SW.1/4 of the SE.1/4 and S.1/2 of the NW.1/4 of the SE.1/4, Section 11, Township 4N, Range 3EIM, from wells located in the SE.1/4 of the SE.1/4 and SW.1/4 of the SE.1/4, Section 11, Township 4N, Range 3EIM.

SLAUGHTER, W. P. Application #66-205 - filed 4/25/66
PRIORITY DATE(S) AND AMOUNTS: 4/25/66 - 40 a. f. Total: 40 a. f.
PURPOSE: To irrigate 210 acres located in the NE.1/4 and NE.1/4 of the SE.1/4 and E.1/2 of the NE.1/4 of the NW.1/4, all Section 2, Township 4N, Range 3EIM, from wells located in the NW.1/4 of the SE.1/4 of NE.1/4, Section 2, Township 4N, Range 3EIM.

SMITH, CHARLES E. Application #64-180 - filed 3/16/64
PRIORITY DATE(S) AND AMOUNTS: 3/16/64 - 160 a. f. Total: 160 a. f.
PURPOSE: To irrigate 80 acres located in the S.1/2 of the NW.1/4 and 20 acres in the N.1/2 of SW.1/4, Section 14, Township 4N, Range 3EIM, from well located in the NW.1/4 of the NW.1/4 of the SW.1/4, Section 14, Township 4N, Range 3EIM.

SMITH, ROYCE Application #63-126 - filed 5/22/63
PRIORITY DATE(S) AND AMOUNTS: 5/22/63 - 234 a. f. Total: 234 a. f.
PURPOSE: To irrigate 130 acres located in SE.1/4 of NE.1/4, Section 22, Township 4N, Range 3EIM, from wells located in the NE.1/4 of the NE.1/4, Section 22, Township 4N, Range 3EIM.

SMITH, ROYCE Application #63-437 - filed 12/16/63
PRIORITY DATE(S) AND AMOUNTS: 12/16/63 - 120 a. f. Total: 120 a. f.
PURPOSE: To irrigate 100 acres located in the NE.1/4 of the NW.1/4, Section 17, Township 4N, Range 3EIM, from wells located in the same legal description.

SMITH, WILLIAM E. Application #68-51 - filed 2/14/68
PRIORITY DATE(S) AND AMOUNTS: 2/14/68 - 136 a. f. Total: 136 a. f.
PURPOSE: To irrigate 80 acres located in the E.1/2 of the NW.1/4, Section 15, Township 4N, Range 3EIM, from wells located in the same legal description.

STRATFORD, CITY OF Application #54-340 - filed 6/30/54
PRIORITY DATE(S) AND AMOUNTS: 6/30/54 - 392 a. f. Total: 392 a. f.
PURPOSE: For municipal use on acres located in NE.1/4 of the NW.1/4, Section 23, Township 4N, Range 3EIM, from wells located in same legal description.

TOWNSEND, KENNETH Application #67-736 - filed 9/28/67
PRIORITY DATE(S) AND AMOUNTS: 9/28/67 - 85 a. f. Total: 85 a. f.
PURPOSE: To irrigate 100 acres, 20 acres located in the W.1/2 of the SW.1/4 of the SW.1/4, Section 9 and 33 acres in the SE.1/4 of the SE.1/4 and 20 acres in E.1/2 of the NW.1/4 of the SE.1/4, and 27 acres in the SE.1/4 of the NW.1/4, Section 8, all in Township 4N, Range 3EIM, from wells located in the SW.1/4 of the SE.1/4 of the SE.1/4 of Section 8, Township 4N, Range 3EIM.

WATTS, DONALD Application #64-282 - filed 4/2/64
PRIORITY DATE(S) AND AMOUNTS: 4/2/64 - 80 a. f. Total: 80 a. f.
PURPOSE: To irrigate 60 acres, 20 acres located in the SW.1/4 of the SW.1/4 and S.1/2 of the SE.1/4 of the SW.1/4 and W.1/2 of the NW.1/4 of the SE.1/4 of the SW.1/4, Section 3, and 40 acres in the NW.1/4 of the NW.1/4, Section 10, all in township 4N, Range 3EIM, from well located in the NW.1/4 of the NW.1/4, Section 10, Township 4N, Range 3EIM.

WATT, WILLIE Application #59-2 - filed 1/5/59
PRIORITY DATE(S) AND AMOUNTS: 1/5/59 - 150 a. f. Total: 150 a. f.
PURPOSE: To irrigate 85 acres located in the W.1/2 of the SW.1/4, Section 11, Township 4N, Range 3EIM, from wells located in the SE.1/4 of the NW.1/4 of the SW.1/4, Section 11, Township 4N, Range 3EIM.

WATT, WILLIE Application #64-167 - filed 3/11/64
PRIORITY DATE(S) AND AMOUNTS: 3/11/64 - 72 a. f. Total: 72 a. f.
PURPOSE: To irrigate 120 acres located in the NW.1/4 of the NW.1/4, Section 21, Township 4N, Range 3EIM, from wells located in the NE.1/4 of the NW.1/4, Section 21, Township 4N, Range 3EIM.

FINAL ORDER ESTABLISHING PRIOR GROUND WATER RIGHTS IN PONTOTOC COUNTY, OKLAHOMA, COVERING ALL OR PARTS OF TOWNSHIPS 1N, 2N, 3N, 4N, AND 5N, AND RANGES 4EIM 5EIM, 6EIM, 7EIM, AND 8EIM.

ALTOM, JIM — Application #67-678 - filed 8/25/67
PRIORITY DATE(S) AND AMOUNT: 8/25/67 - 56 a. f. Total: 56 a. f.
PURPOSE: To irrigate 35 acres located in the SE.1/4 of the NW.1/4, and 10 acres in the W.1/2 of the E.1/2 of the NE.1/4 of the NW.1/4, all in Section 21, Township 5N, Range 4EIM, from wells located in the Center of the SE.1/4 of the NW.1/4 of Section 21, Township 5N, Range 4EIM.

HERNDON, JAMES F. — Application #67-652 - filed 8/17/67
PRIORITY DATE(S) AND AMOUNT: 8/17/67 - 3 a. f. Total: 3 a. f.
PURPOSE: To irrigate 40 acres located in the SE.1/4 of the SE.1/4, Section 8, Township 5N, Range 4EIM, from wells located in the same legal description.

HERNDON, JAMES F. — Application #67-651 - filed 8/17/67
PRIORITY DATE(S) AND AMOUNT: 8/17/67 - 80 a. f. Total: 80 a. f.
PURPOSE: To irrigate 160 acres located in the E.1/2 of the W.1/2, Section 16, Township 5N, Range 4EIM, from wells located in the SE.1/4 of the NE.1/4 of the SW.1/4 and the NE.1/4 of the SE.1/4 of the SW.1/4 and NW.1/4 of the SW.1/4 of the NW.1/4 and SE.1/4 of the NE.1/4 of the NW.1/4, Section 16, Township 5N, Range 4EIM.

WOOD, J. B. — Application #66-498 - filed 8/8/66
PRIORITY DATE(S) AND AMOUNT: 8/8/66 - 40 a. f. Total: 40 a. f.
PURPOSE: To irrigate 40 acres located in N.1/2 of the SE.1/4, Section 7, Township 4N, Range 4EIM, from wells located in the same legal description.

WOOD, WALLACE — Application #66-469 - filed 7/28/66
PRIORITY DATE(S) AND AMOUNT: 7/28/66 - 160 a. f. Total: 160 a. f.
PURPOSE: To irrigate 45 acres located in the S.1/2 of the SW.1/4, Section 7, Township 4N, Range 4EIM, from wells located in the same legal description.

OPITZ, JUNE — Application #66-603 - filed 9/20/66
PRIORITY DATE(S) AND AMOUNT: 9/20/66 - 167 a. f. Total: 167 a. f.
PURPOSE: To irrigate 120 acres located in the SW.1/4, Section 20, Township 5N, Range 4EIM, from wells located in the same legal description.

FINAL ORDER ESTABLISHING PRIOR GROUND WATER RIGHTS IN McCLAIN COUNTY, OKLAHOMA COVERING ALL OR PARTS OF TOWNSHIPS 5N, 6N, 7N, 8N, AND 9N, AND RANGES 1WIM, 2WIM, 3WIM, 4WIM, 1EIM, 2EIM, 3EIM, AND 4EIM.

SLAUGHTER, W. P. OR BILLIE Application #66-204 - filed 4/25/66
PRIORITY DATE(S) AND AMOUNT: 4/25/66 - 40 a. f. Total: 40 a. f.
PURPOSE: To irrigate 20 acres located in SE.1/4 of the SE.1/4 of the SW.1/4 and SW.1/4 of the SW.1/4 of the SE.1/4, Section 35, Township 5N, Range 3EIM, from wells located in the same legal description.

YOUNGER, LES Application #64-995 -filed 12/9/64
PRIORITY DATE(S) AND AMOUNT: 12/9/64 - 45 a. f. Total: 45 a. f.
PURPOSE: To irrigate 80 acres located in the S.1/2 of the NW.1/4, Section 29, Township 5N, Range 4EIM, from well located in the same legal description.

APPENDIX J

POLITICAL SURVEY QUESTIONS AND HISTOGRAM

(PERCENTAGE) RESULTS

1985 GROUND WATER USE SURVEY
DEPT. OF GEOLOGY
OKLAHOMA STATE UNIVERSITY

GENERAL

1. How long have you lived at your present address? (mark one)
- 6% a) less than one year
- 0% b) one to three years
- 33% c) three to ten years
- 61% d) greater than ten years

2. From which of the following do you and your spouse derive income? (check all that apply)
- 32% a) agriculture, crop production
- 29% b) livestock production
- 3% c) retail sales
- 3% d) clerical
- 9% e) retirement
- 24% f) other (please specify) ______________________.

3. Do you live in a incorporated town?
- 6% yes
- 94% no

4. How many people reside in your household?
1) 0% 2) 33% 3) 22% 4) 28% 5) 11% 6) 6%

5. Indicate which of the following conveniences you now utilize in your home? (check all that apply)
- 26% a) automatic dishwasher
- 34% b) washing machine
- 6% c) automatic garbage disposal
- 18% d) central air conditioning
- 10% e) window unit air conditioning
- 6% f) lawn and/or garden sprinkling system
- 0% g) swimming pool

WATER USE

6. What is your direct source of water? (check your source of water)
- 0% a) municipal
- 0% b) rural water district
- 100% c) private (domestic) well
- 0% d) private reservoir (lake or pond)

7. How many gallons of water does your household use per month? (make an estimate of your use)
- 0% a) 0 - 2,000 gallons
- 17% b) 2,000 - 5,000 gallons
- 56% c) 5,000 - 10,000 gallons
- 6% d) 10,000 - 15,000 gallons
- 6% e) 15,000 - 20,000 gallons
- 0% f) 20,000 - (+) gallons

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Note answer questions 8 a. b. c. only if you have that appliance in your home.

8. How often do you use the following:

a) dishwasher

14% 1) once a day
0% 2) two times a day
4% 3) once a week
2% 4) twice a week
6% 5) other ______________
(state how often)

b) washing machine

18% 1) daily
12% 2) every two or three days
2% 3) once a week
0% 4) once every other week
2% 5) other ______________
(state how often)

c) garbage disposal

6% 1) once a day
0% 2) two times a day
0% 3) three times a day
0% 4) once a week
0% 5) other ______________
(state how often)

9. While living in your present community, have you ever experienced a water shortage or low pressure?

6% yes
94% no

If yes, what was the reason (if known) and for which months of the year?
____

10. If water supplies became scarce would you be in favor of increased water rates in an effort to ration water?

39% yes
39% no

11. If you are involved in Agriculture, what is the total Acreage of your farm operation at present owned or leased?

______ acres.

500, 320, 20, 800, 590, 230, 160, 10, 127, 1420, 155, 80, 160, 195, 240, 1500, 80.

12. Indicate those Agricultural crops grown commercially or for livestock production, and the number of acres of crops grown (estimate).

		crops	# of Acres
13%	a)	alfalfa	140, 100, 20.
15%	b)	wheat	145, 150.
10%	c)	corn	70, 110.
3%	d)	soybeans	40, 170.
15%	e)	peanuts	75, 38, 85.
3%	f)	milo	40
5%	g)	cotton	0
3%	h)	sorghum	0
8%	i)	orchard crops	-
20%	j)	other (please specify)	Garden 10.

13. Do you use crop rotation?
56% yes
6% no

14. Do you use fertilizer?
67% yes
6% no

15. Do you use herbicides?
44% yes
17% no

16. Do you use insecticides?
50% yes
17% no

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17. What is the type and amount of fertilizer applied to the various agricultural crops grown commercially for your operation?

	Type: Granule	Type: Liquid	Amount: lbs/Acre	Amount: Pints/Gallon
alfalfa	*		200, 75, 300	
wheat	*		200, 300, 18/46/0	
corn	* 10/20/10		400, 6/24/24	
soybeans	*		200	
peanuts	* 15/15/15		300, 2--6/24/24	
milo	*		400	
cotton				
sorghum				
orchard crops				

18. What is the type and amount of herbicides applied to the various Agricultural crops grown commercially for your operation?

	Type: Granule	Type: Liquid	Amount: lbs/Acre	Amount: pints/gallon
alfalfa		*		3\2· 1/5
wheat				
corn		*		2/5, 2/5
soybeans		*		2/5
peanuts		* (+)		3/5, 6/-, 2/-,
milo				
cotton				
sorghum				
orchard crops				

(+) Herbicide applied is 1 pint/5gallons, 1 pint/5 gallons, 6 pint/--.

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19. What is the type and amount of insecticide applied to the various Agricultural crops grown commercially for your operation?

	Type		Amount	
	Granule	Liquid	Lbs/Acre	Pints/Gallon
alfalfa		*		1/5, 1 1/2/5, 2/5
wheat				
corn				
soybeans				
peanuts	*	*	1/2Ac.	1/-
milo				
cotton				
sorghum				
orchard crops				

20. Do you irrigate farm land?
44% yes
22% no

21. How many irrigation wells do you currently operate?
1,7,1,1,5,2,4,6,1,1.

22. How many Acres are under irrigation.
20,800,40,140,240,24,200,400,75.

23. How long have you irrigated.
6,26,21,17,21,15. years.
20,22.

24. Have you added irrigation wells to your operation.
33% yes
28% no
If yes, when ____________(which years).
If yes, what was the reason for adding irrigation wells
More Land Under Irrigation, Need More Water In 1975.

25. What type of irrigation system do you use?
39% a) furrow
11% b) sprinkler
0% c) center pivot
0% d) trickle or drip
6% e) other (please specify) ____________.

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26. What is the main type of irrigation well pump you use?
6% a) centrifuge
44% b) turbine
0% c) other (please specify) ______________.

27. What type energy (fuel) do you use to pump the water for irrigation. (check all that you use and number of wells using that fuel source). Number of Wells
0% a) diesel ______
0% b) gasoline ______
22% c) LP 2,3.
0% d) natural gas ______
39% e) electricity 6,5,1,1,7.

28. Would you be willing to have a meter installed in your irrigation system to determine your well yield?
22% yes
17% no

29. If water supplies for irrigation became scarce, what would you do to offset or prevent the problem? Change Crop Operation. Dry-Land: Dig More Well: Use More Surface Water: And Never Go Back To Irrigation.

30. Has changes in energy costs had an effect on the crops you grow?
44% yes
22% no

POLITICAL

31. How would you describe the current water supply in your area?
17% a) abundant
61% b) adequate
17% c) less than adequate
0% d) scarce
6% e) comments Water Available Is Weaker Than Use To Be.

32. If certain measures were necessary for ground water management, how would you feel about the following methods?

	strongly favor	would accept	strongly disagree
a) well spacing	33%	50%	6%
b) meters	17%	28%	39%
c) allocation & rotation	17%	6%	61%
d) taxes on Agriculture Users	6%	0%	78%
e) crop changing	17%	44%	17%

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33. Do you feel you pay too much in land taxes?
50% yes
33% no

34. If a radio control device became available and were used by electric utility company to shut irrigation system down during the day of summer months peak demand.
Would you be in favor or disagree. (check one)
22% a) strongly favor
11% b) would accept
56% c) strongly disagree

35. For the next series of questions rank as strongly agree, agree, neutral, disagree, or strongly disagree.

	Strongly Agree	Agree	Nuetral	Disagree	Strongly Disagree
a) Present ground water law in Oklahoma is more than adequate in meeting any future crisis in water supply.	11%	28%	22%	33%	0%
b) Managing groundwater would be performed by a single state agency within the state.	6%	39%	6%	28%	17%
c) Water conservation is the best alternative for meeting the needs of water users in this region of the state.	22%	61%	6%	6%	0%
d) Farmers in this region will eventually have to return to dry-land farming techniques.	6%	50%	6%	28%	6%
e) The state should establish ground water management districts for protection of these supplies.	6%	61%	11%	11%	6%
f) Ground water districts should have power to enforce rules and impose controls on ground water use.	28%	39%	11%	11%	6%
g) Local county and townships should establish ground water management system.	22%	44%	6%	17%	6%

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36. People have different ideas about how water resources should be managed and consumed. Please indicate the extent to which you agree or disagree with each of the following statements.

	Strongly Agree	Agree	Nuetral	Disagree	Strongly Disagree
a) Ground water should be considered public property rather than private property.	0%	11%	0%	39%	44%
b) Water for irrigation should be a higher priority than industrial use.	50%	17%	11%	11%	6%
c) ground water is a renewable resource.	11%	50%	17%	17%	0%
d) The state should be divided into ground water districts.	11%	61%	0%	22%	6%
e) By the year 2000 ground water in this country will be depleted.	0%	17%	11%	56%	11%
f) Ground water law in Oklahoma is adequate to solve the problems of shortages in the future.	0%	22%	6%	44%	17%
g) In order to insure more efficient uses of water, some have suggested the use of a graduated tax per unit of irrigation water pumped. The state should consider this as a management option in the event of depletion.	6%	22%	0%	33%	33%

37. Concerning the environmental and natural resource issues facing the state, how serious is each of the following!

	Very Serious	Serious	Not sure very Serious	No Problem
air pollution	0%	17%	33%	44%
water pollution	17%	33%	22%	22%
commodity farm prices	33%	39%	0%	11%
drought	11%	39%	17%	22%
population growth	0%	22%	22%	44%
strip coal mining	0%	22%	17%	44%
water shortages	0%	39%	17%	39%
soil erosion	28%	44%	6%	11%
flooding	6%	28%	22%	33%
energy costs	50%	28%	6%	11%
soil depletion	17%	50%	6%	17%
ground water depletion	11%	39%	17%	28%
waste disposal	44%	22%	0%	28%

38. Your general comments on any of the above issues or questions:

Develop A Comprehensive Water Program And Laws That Are Enforceable; State Water Laws Do Not Protect Individual Landowners: And Cost And Production Of Farmers Are Of Concern in Meeting Supply And Demands.

THANK YOU FOR YOUR TIME AND COOPERATION IN FILLING OUT THIS SURVEY.

APPENDIX K

IRRIGATION SYSTEM EVALUATION FORMS

FORM 1. SPRINKLER-LATERAL IRRIGATION EVALUATION

1. Location ________________________, Observer _______, Date _________
2. Crop _______________, Root zone depth ___ft, MAD _____%, MAD ____in
3. Soil: texture ________, available moisture ____in/ft, SMD ______in
4. Sprinkler: make ___________, model _____, nozzles ______ by ____in
5. Sprinkler spacing _____ by _____ft, Irrigation duration ______hrs
6. Rated sprinkler discharge ______gpm at _____psi giving _____in/hr
7. Lateral: diameter ____in, slope _______%, Riser height ________in
8. Actual sprinkler pressure and discharge rates:

	Sprinkler location number on test lateral					end
Initial pressure (psi)	____	____	____	____	____	____
Final pressure (psi)	____	____	____	____	____	____
Catch volume (gal)	____	____	____	____	____	____
Catch time (min or sec)	____	____	____	____	____	____
Discharge (gpm)	____	____	____	____	____	____

9. Wind: direction relative to
   Part 10: initial _____, during _____, final _____
   Speed (mph): initial _____, during _____, final _____
10. Container grid test data in units of ______, Volume/depth ______ml/in
    Container grid spacing _____ by ______ft
    Test: start _______, stop _______, duration ___hr ____min = ______hr

____	____	____	____	____	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____	____	____	____	____
____	____	____	____	____	____	____	____	____	____	____	____	____

11. Evaporation container: initial _______ final ______ loss ________in
12. Sprinkler pressures: max ____psi; min ____psi, ave ____psi
13. Comments ____
    ____

FORM 2. FURROW INFILTRATION EVALUATION

1. Location ____________________, Observer ______, Date ________
2. Furrow: Identity ________, shape ____________, condition ___________
   age ________, soil ___________, moisture ______, slope ___%

a	b	c	d	e		f	g		h
Time			Station A _ Flow Rate			Station B _ Flow Rate			Intake
Watch	Diff. min.	Cum. min.		___	gpm		___	gpm	gpm/100ft
Accuracy range									

2. Furrow: Identity ________, shape ____________, condition ___________
   age ________, soil ___________, moisture ______, slope ___%

Time			Station A _ Flow Rate			Station B _ Flow Rate			Intake
Watch	Diff. min.	Cum. min.		___	gpm		___	gpm	gpm/100ft
Accuracy range									

3. Comments: ____

FORM 3. FURROW IRRIGATION WATER ADVANCE EVALUATION

1. Location ______________, Observer ____________, Date ______________________________

2. Crop ___________, Age ________, Root depth _____ft, Row: spacing _____in, length _____ft

3. Soil: texture _______________, available moisture _____in/ft, SMD _______________in

4. Irrigation: duration _____hrs, frequency ____________days, MAD _______%, MAD _______in

5. A: ______________ B: ______________ C: ______________ D: ______________

Stream: _______gpm _____________gpm _____________gpm _____________gpm

Time _ min.			Station		Time _ min.			Station		Time _ min.			Station		Time _ min.			Station
Watch	Diff.	Cumu.	feet		Watch	Diff.	Cumu.	feet		Watch	Diff.	Cumu.	feet		Watch	Diff.	Cumu.	feet

6. Comments: ____

FORM 4. TRICKLE IRRIGATION EVALUATION

1. Location ______________, Observer _______, Date ______________
2. Crop: type ___________, age _____years, spacing ___-by ___-feet
   root depth ______ft, percent area covered or shaded ____%
3. Soil: texture _______________, available moisture ________in/ft
4. Irrig: duration ___hrs, frequency ____days, MAD ___%, _______in
5. Filter pressure: inlet ___psi, outlet ___psi, loss _______psi
6. Emitter: make _____________, type _______, point spacing ____ft
7. Rated discharge per emission point ________gph at __________psi
   Emission points per plant ____, giving ___gallon per plant per day
8. Hose: diameter ____in, material ____, length ____ft, spacing___ft
9. System layout, general topography, and test locations:

10. System discharge _____gpm, No. of manifolds _____ and blocks _____
11. Average test manifold emission point discharges at ________psi

    Manifold = (sum of all averages ______gph) / (number of averages ___________) = __________gph

    Low 1/4 = (sum of low 1/4 averages ______gph) / (number of low 1/4 averages ______) = __________gph

12. Adjusted average emission point discharges at ____________psi

    System = (DCF _____) X (manifold average _____gph) = _______gph

    Low 1/4 = (DCF ____) X (manifold low 1/4 _____gph) = _______gph

13. Comments: ____

____

____

FORM 5. TRICKLE IRRIGATION EVALUATION (Cont.)

14. Discharge test volume collected in ____ min (1.0 gph = 63 ml/min)

Outlet Location on Lateral		Lateral Location on the Manifold: inlet end		1/3 down		2/3 down		far end	
		ml	gph	ml	gph	ml	gph	ml	gph
inlet end	A								
	B								
	Ave								
1/3 down	A								
	B								
	Ave								
2/3 down	A								
	B								
	Ave								
far end	A								
	B								
	Ave								

15. Lateral inlet ____ psi ____ psi ____ psi ____ psi
closed end ____ psi ____ psi ____ psi ____ psi

16. Wetted area ____ ft^2 ____ ft^2 ____ ft^2 ____ ft^2
per plant ____ % ____ % ____ % ____ %

17. Estimated average SMD in wetted soil volume ________ in

18. Minimum lateral inlet pressures, MLIP, on all operating manifolds:

Manifold: Test A B C D E F G Ave.

Pressure-psi: ____ ____ ____ ____ ____ ____ ____ ____ ____

19. Discharge correction factor, DCF, for the system is:

$$DCF = \frac{2.5 \times (\text{average MLIP} \_\_\_\_ \text{psi})}{(\text{average MLIP} \_\_\_\_ \text{psi}) + 1.5 \times (\text{test MLIP} \_\_\_\_ \text{psi})} = \_\_\_\_$$

or if the emitter discharge exponent x = ________ is known

$$DCF = \left[\frac{(\text{average MLIP} \_\_\_\_ \text{psi})}{(\text{test MLIP} \_\_\_\_ \text{psi})} \right]^{x} = \_\_\_\_ = \_\_\_\_\_\_\_\_$$

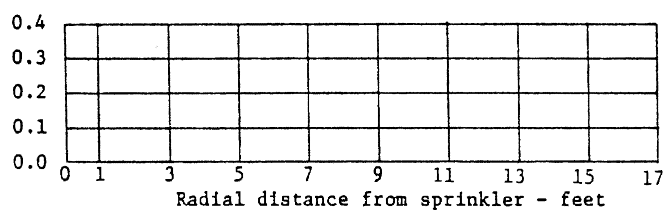
FORM 6. ORCHARD SPRINKLER IRRIGATION EVALUATION

1. Location ________________, Observer _______, Date ________________
2. Crop __________, Root zone depth ____ ft, MAD ___ %, MAD ______ in
3. Soil: texture __________, available moisture ____ in/ft, SMD ___ in
4. Tree: pattern ____________, spacing ____ by ____ ft
5. Sprinkler: make _________, model ________, nozzles _____ by ___ in
   spacing ____ by ____ ft, location to trees __________
6. Irrigation: duration ___ hrs, frequency ___ days
7. Rated sprinkler discharge ____ gpm at ____ psi and diameter ____ ft
8. Sprinkler jet: height ____ ft, interference ______________
9. Actual sprinkler pressure and discharge (see back for location):

Sprinkler locations:	_____	_____	_____	_____
Pressure (psi)	_____	_____	_____	_____
Catch volume (gal)	_____	_____	_____	_____
Catch time (sec)	_____	_____	_____	_____
Discharge (gpm)	_____	_____	_____	_____
Wetted diameter (ft)	_____	_____	_____	_____

Comments: ____

10. Container row test data in units of ______ , Volume/depth ____ ml/in
    Test: start ________, stop ________, duration ___ hr ___ min= ______ hr
    Catch ( ): ____ ____ ____ ____ ____ ____ ____ ____ ____
    Rate (iph): . . . .



11. Discharge pressures: max ____ psi, min ____ psi, ave ________ psi
12. Comments: ____
____
____

VITA

Lester Dean Duckwitz

Candidate for the Degree of

Master of Science

Thesis: GROUND WATER MANAGEMENT OF THE ISOLATED TERRACE DEPOSIT (GERTY SAND) OF THE CANADIAN RIVER IN GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

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