EVALUATION OF AQUIFER PERFORMANCE AND WATER SUPPLY CAPABILITIES OF THE ISOLATED TERRACE (GERTY SAND) IN GARVIN, McCLAIN, AND PONTOTOC COUNTIES

By

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and

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Oklahoma State University

FINAL REPORT

Submitted
to

THE OKLAHOMA WATER RESOURCES BOARD

April, 1987

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EXECUTIVE SUMMARY

Project Title: Evaluation of Aquifer Performance and Water Supply Capabilities of the Isolated Terrace (Gerty Sand) in Garvin, McClain, and Pontotoc Counties.

Principal Investigator: Douglas C. Kent, Professor, Department of Geology, Oklahoma State University.

Institution Funded: Oklahoma State University.

Summary: The objective of this research is to determine the maximum annual yield of fresh water that can be produced by the Isolated Terrace (Gerty Sand) Aquifer of the Canadian River in Garvin, McClain, and Pontotoc Counties, Oklahoma. The determination of maximum annual yield is based on computer simulation, utilizing a mathematical model modified after similar studies such as the Enid Isolated Terrace Aquifer (Kent, et.al., 1982) in which the appropriative and subsequent allocated pumping was simulated for twenty years (June 1, 1973 to June 1, 1993). Title 82 Oklahoma Statutes Annotated Section 1020.4 and 1020.5 gives the Oklahoma Water Resources Board the powers and duties to make hydrologic investigations for fresh water basin or subbasins.

The maximum annual yield is 12,800 Acre feet per year proportional as 0.65 Af/A over the total area of the aquifer. The determination of the maximum annual yield is based on the following paramters: (1) the total area of the isolated terrace deposit modeled is 40,160 acres; (2) the initial amount of water in storage is 310,400 acre feet with an average saturated thickness of 28 feet; (3) the rates of natural recharge is 0.9 inches per year; (4) the assumed irrigation return flow rate for the area is 15 percent; (5) the coefficient of permeabilitiy and estimated specific yield

of the aquifer averages 427 gallons per day per foot^2, and 27.3 percent, respectively.

The potential for ground water pollution induced by ground water withdrawal is only slight due to lack of induced recharge from streams. Oil well drilling and pumping within the Gerty Sand Aquifer should not pose a threat to the ground water quality because of limited production and the majority of the oil wells are dry within the area modeled.

INTRODUCTION

This is the final report to the Oklahoma Water Resources Board in fulfillment of Contract No. OWRB N400040 through Oklahoma State University and the Department of Geology.

A hydrogeologic study of the Isolated Terrace (Gerty Sand) Aquifer of the Canadian River of Garvin, McClain and Pontotoc Counties, Oklahoma was performed using a mathematical model to determine an annual allocation rate and maximum annual yield. The determination of the maximum annual yield is accomplished under Title 82, Oklahoma Statutes Annotated, Waters and Water Rights, Section 1020.4 and 1020.5; which 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, (82 Okla. Stat. Ann. Tit. Sec. 1020.5):

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. transmissivity 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 aquifer by surface area to be depleted to a saturated thickness of five feet or less over a 20 year pumping period starting July 1, 1973.

LOCATION

The area of study is located in the south-central part of the state of Oklahoma, in northeastern Garvin, southeast McClain, and western Pontotoc counties (see Figure 1).

The Isolated Terrace Aquifer, the Gerty Sand, is an unconfined aquifer. The Isolated Terrace deposit covers approximately 40 square miles (25,600 acres), and is depicted as a dissected Plateau, geologically bounded by the Hunton Arch, Arbuckle Mountains, and the Pauls Valley Uplift. The terrace deposit is drained by three streams; to the northeast is Big creek, east is Spring Brook Creek, and to the southwest is Keel Sandy Creek. Other small creeks drain the terrace deposit to the west and northwest.

Previous Work

Taff (1898) described the Gerty Sand in Geology of MacAlester-Lehigh Coal Fields Indian Territory. Loomis (1922) described the limestone outcrop of Section 2, T.4N., R.3E. as Pennsylvanian limestone surrounded by Permian red beds. Morgan (1924) studied the geology of the Stratford, Oklahoma area and describes the limestone outcrop in Section 2, T.4N., R.3E. and names it as the Hart limestone. 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

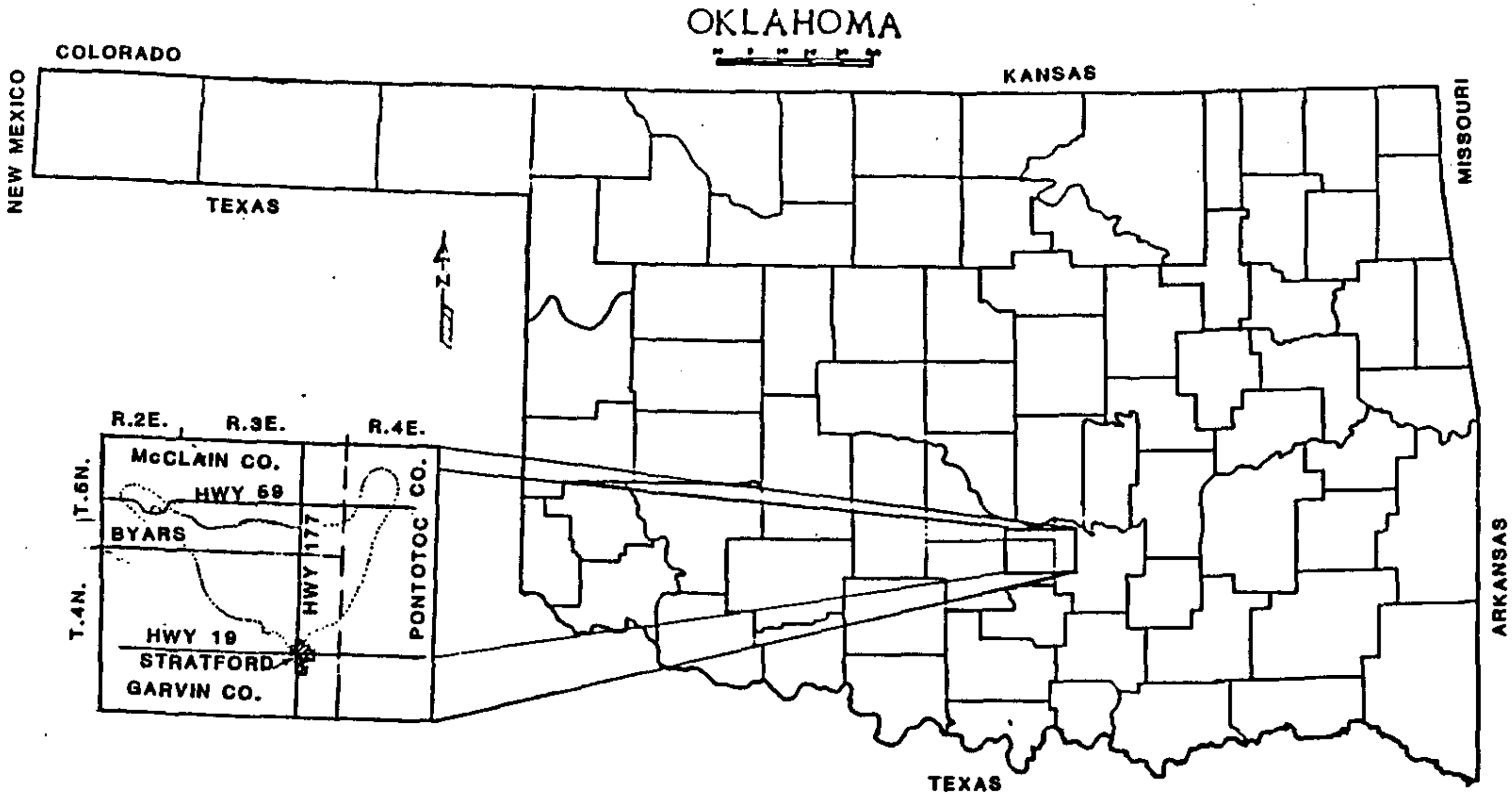


FIGURE 1. LOCATION OF STUDY AREA.

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 Cleveland and McClain Counties. Hendricks (1937) determined that 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 subsurface geology in "Subsurface Geology of T.4N., R.4 and 5E., Pontotoc county. Lowe (1968) described the stratigraphy of the Silurian to Pennsylvanian System and refered to 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) characteried the Konawa soils and determined the hydraulic conductivity of the soils in the vicinity of Stratford, 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 mathematical models for ground water management modeling of the following aquifers: Washita River Alluvium Aquifer in Grady, McClain, Garvin, Murray, Carter, and Johnston Counties in south-central Oklahoma (Kent, et. al., 1983); the Enid Isolated Terrace Aquifer in Garfield County, Oklahoma. (Kent, et. al., 1982); and the Elk City sandstone aquifer in west-central, Oklahoma. (Kent, et. al., 1981),

Geology

The geology of the Isolated Terrace aquifer is represented by the Quaternery deposits and formations in the Oscar Group, of Upper Pennsylvanian in age. The western boundary of the study area is bounded by younger sediments of Permian age called the Wellington Formation. Quaternary deposits are undifferentiated and cover a majority of the study area, as shown on the geologic map in Figure 2. The Gerty Sand is of Quarternary Age and is composed of rose colored chert quartzite cobbles. Well rounded quartzite cobbles can be found in isolated patches throughout the study area, and are believed to represent remnants of the Ogallala Formation of Pliocene age. Deposits of dune sand are also exposed within the study area.

The study area is located 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).

The geologic formations exposed in the study area are modified after Hart (1974). The formations exposed are the Wellington Formation, Oscar Group, Vanoss, and Quarternary deposits. The Wellington Formation is described as a shale, red-brown with several 20 foot to 30 foot bituminous sandstones at the base.

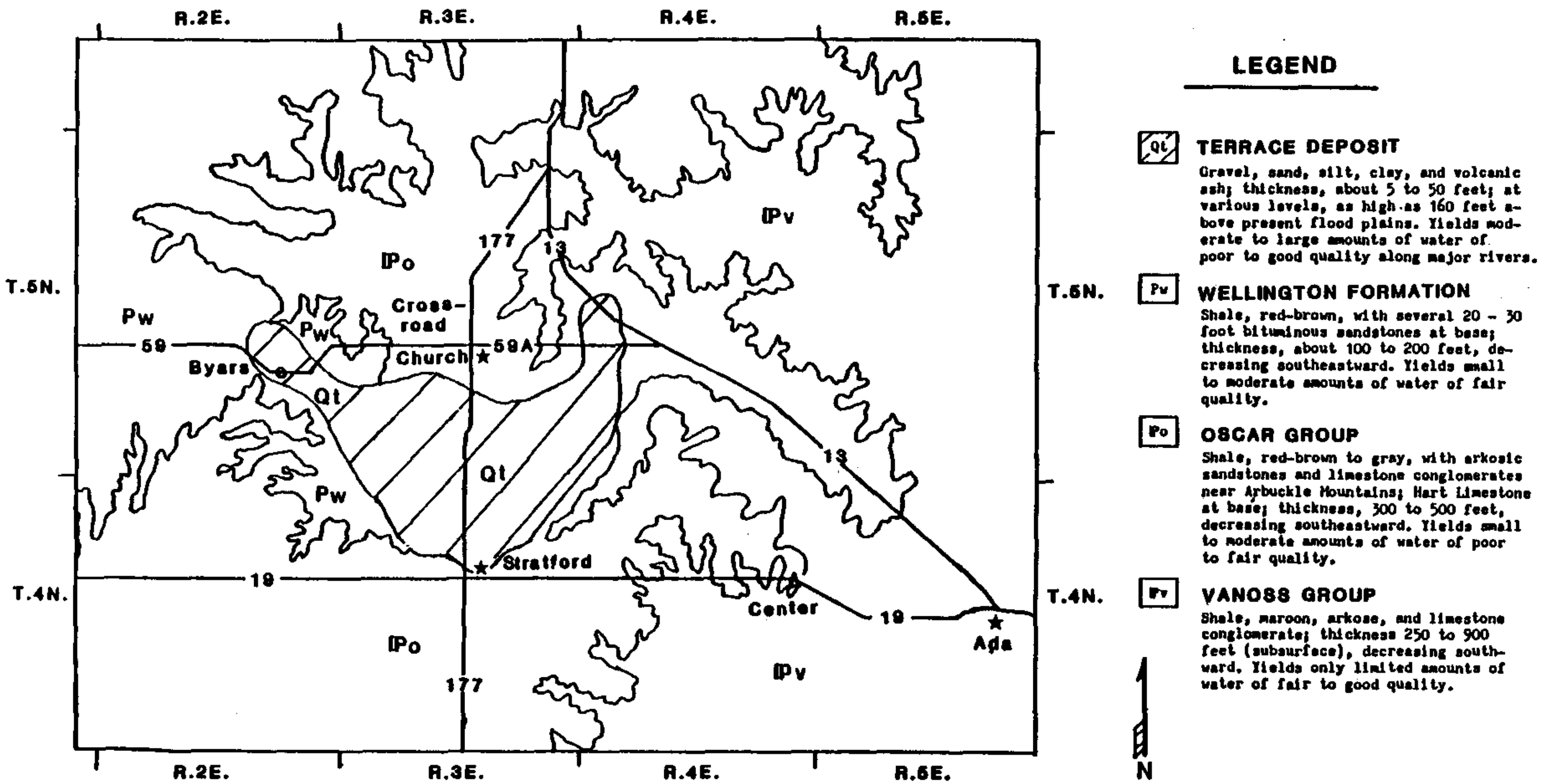


FIGURE 2. GEOLOGIC MAP OF ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. (MODIFIED AFTER HART, 1974)

SCALE 1:250,000.

The Oscar Group is described as a shale, red-brown to gray, with arkosic sandstones and limestone conglomerates which have been derived from the Arbuckle Mountains. The formation yields small to moderate amounts of water of poor to fair quality (Hart, 1974). Field investigation revealed a chemically precipitated buff to cream white limestone at the base and is correlated to the Hart limestone in Section 2, T.4N., R.3E.. The limestone is overlain by a shale interval which is overlain by a lime conglomerate.

The Terrace deposits consist of terrace alluvium which is composed of a yellow to tan, medium to coarse grain unconsolidated sand and are referred to as the Gerty Sand. The more recent deposits within the study area include the dune deposits and reworked sediments of the Gerty Sand . The finer Aeolian (dune) deposits can be found scattered throughout the study area. The dune deposits are light gray to tan color with a silty to gritty texture. Figure 3 represents conceptualized geologic cross sections of the Isolated Terrace Deposit.

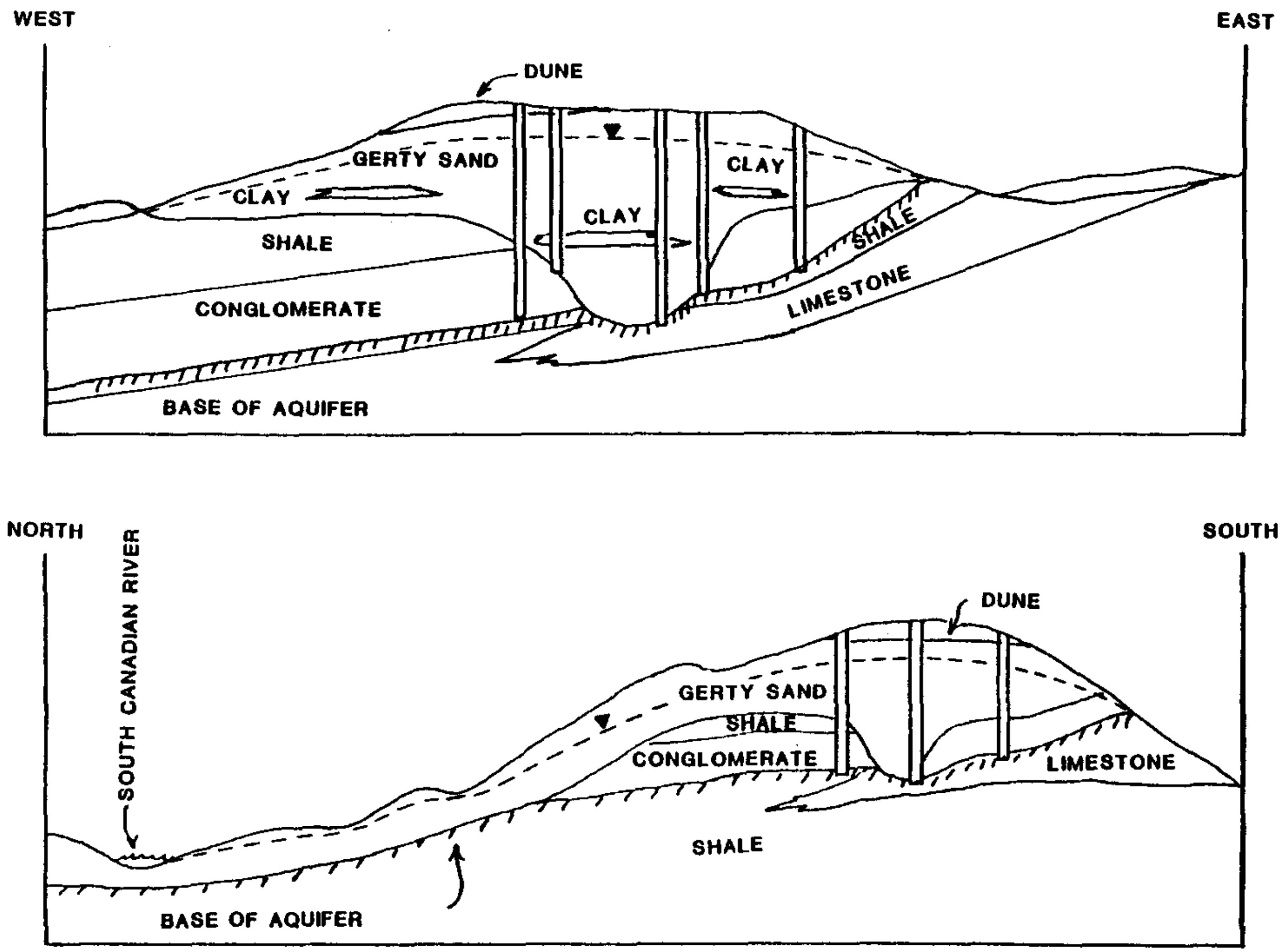


FIGURE 3. CONCEPTUALIZED GEOLOGIC CROSS-SECTION OF THE ISOLATED TERRACE DEPOSIT

Hydrogeology

General

The Isolated Terrace (Gerty Sand) aquifer is an unconfined system. The upper boundary of the aquifer is formed by the water table above and by the impermeable formations of the Oscar Group below. The water table gradient generally follows the topographic relief flowing north-northeast to the Canadian River and west-southwest to the Washita River. The water table gradient is very steep at its boundaries where seeps and springs are typically found.

The thickest portion of the dune deposits occurs near the Garvin-McClain County line. This area is believed to be the recharge zone of the aquifer. The sand exposure is typically five to forty feet thick, and is a tan, medium grained sand.

Climate

The Isolated Terrace deposit in Garvin, McClain, and Pontotoc counties is characterized as having a continental climate. Rainfall record for the period of 1950 to 1985 at Ada, Oklahoma were used to determine the average annual precipitation for the study area. The average annual precipitation for Ada, Oklahoma is shown in Figure 4. The mean average annual precipitation across the entire study area is approximately 36.60 inches per year. The monthly distribution of precipitation is highest for the month of May, and driest for the month of January (See Figure 5).

The yearly Evapotranspiration rate is estimated to be 22.74 percent of annual rainfall and is estimated using the most complete datum available from the National Oceanic Atmospheric Administration publication for the recording stations throughout Oklahoma. The recording stations are Altus,

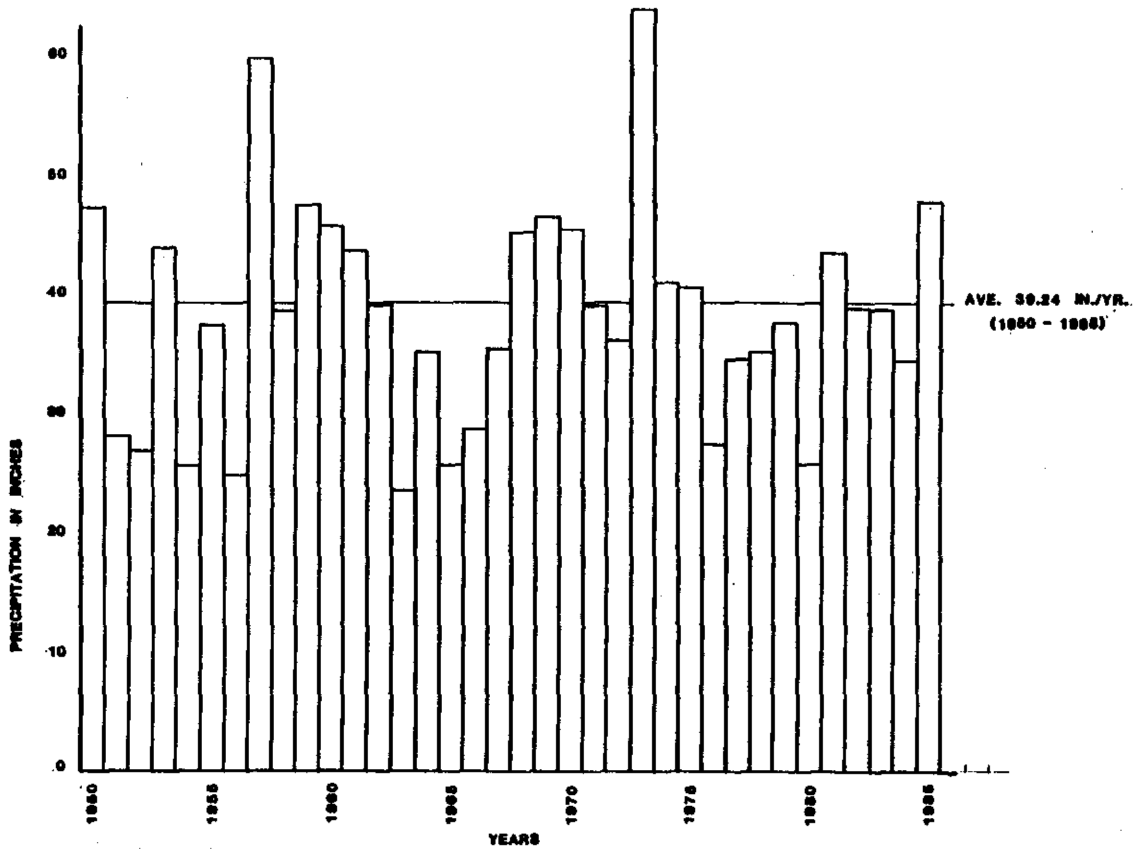


FIGURE 4. ANNUAL PRECIPITATION AT ADA, OKLAHOMA.

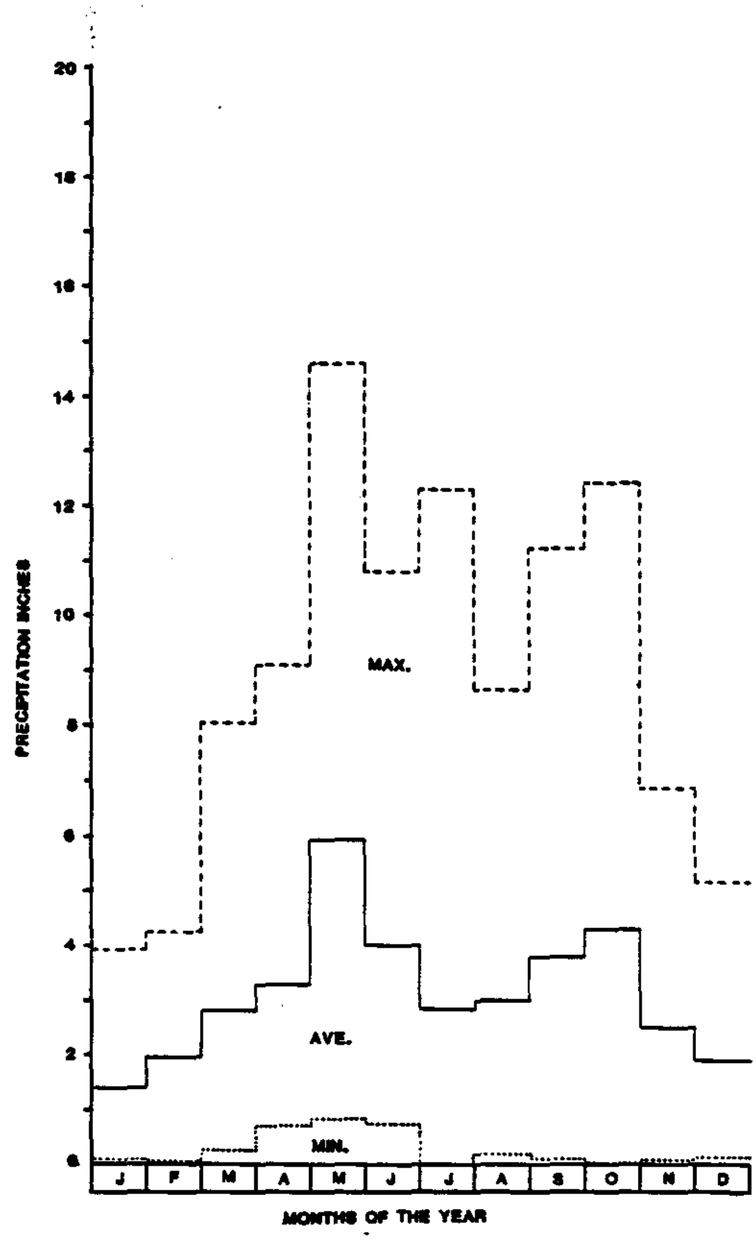


FIGURE 5 MONTHLY PRECIPITATION AT ADA, OKLAHOMA. (1960 - 1986)

Fort Gibson, Canton, Hulah, Great Salt Plains, Fort Supply, Keystone, Broken Bow, Grand River, Tenkiller Ferry, Oolagah, and Tipton Dams; and Chickasha Experiment Station. These stations all used a class A Evaporative recorder. The evaporation rate on a monthly basis revealed July to be the highest at 34.5 percent.

Ground Water

The Isolated Terrace deposit is an unconfined aquifer. The aquifer average thickness is 28 feet. The depth to water within the aquifer ranges from 10 to 110 feet. Depth to water was determined from field measurements of wells and reported data maintained by the Oklahoma Water Resources Board. The locations of, the May, August, November, 1985, and March, 1986 sample data (water level measurements, water quality, and aquifer test sites) are shown in Figure 6. The saturated thickness varies from five to 75 feet. Transmissivity, using pumping test data collected within the study area, ranges between 12,000 and 27,000 gallons per day per foot for the respective sites in the NW.1/4 of Section 9, T.4N., R.3E., and the NW.1/4 of the SW.1/4 of Section 11, T.4N., R.3E..

Hydrograph data and daily precipitation were collected for four sites within the study area. The best hydrograph record is the aeromotor site located in the W.1/2 of the NW.1/4 of Section 2, T.4N., R.3E. (see Figures 7, 7a, 8 and 8a, Aeromotor hydrograph and precipitation records from May 22, 1985 to December 31, 1985 and from January 1, 1986 to November 1, 1986.) Other hydrograph sites are the NW.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.. Each hydrograph appears to represent the same data.

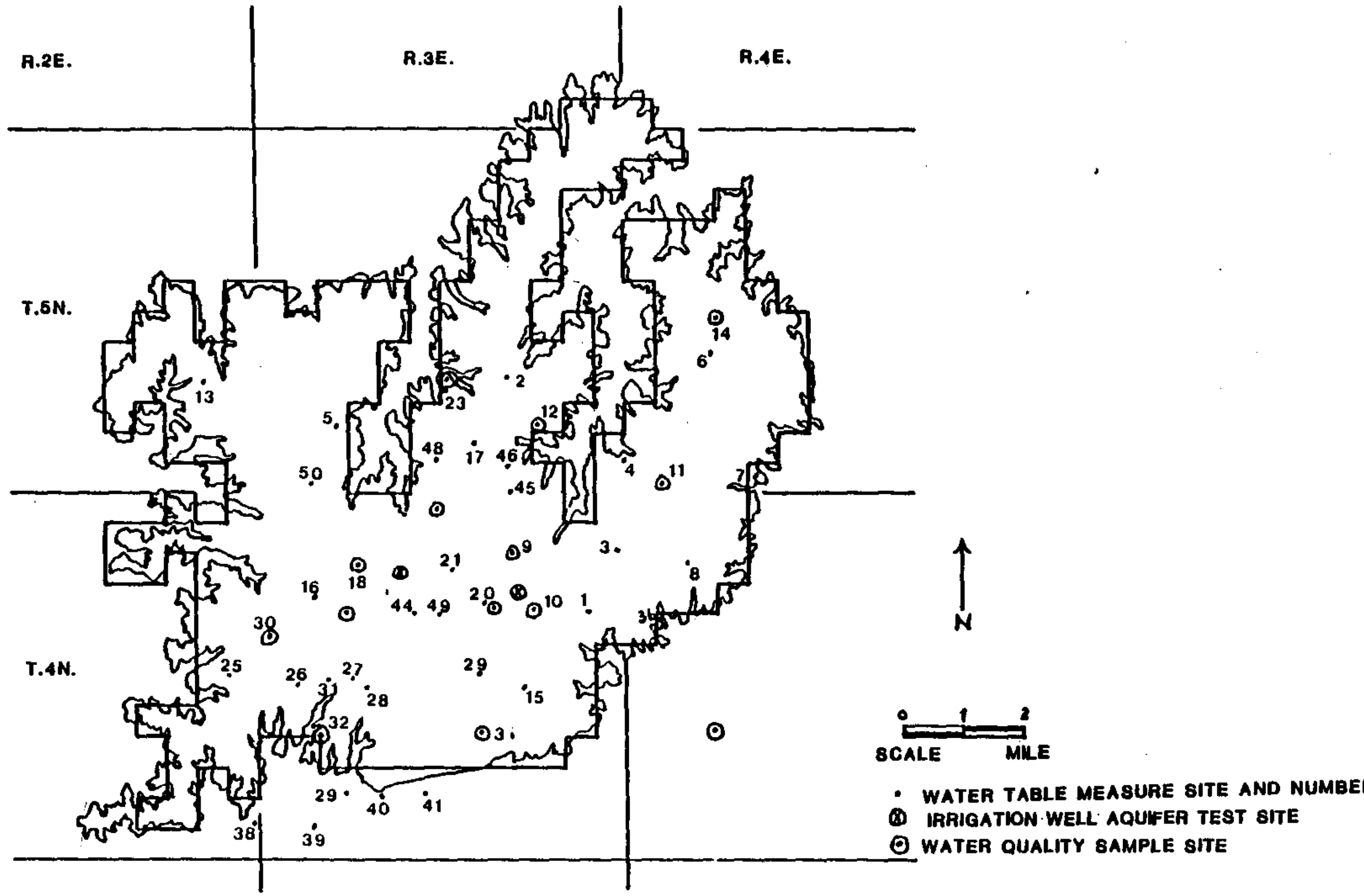


FIGURE 6 MAY, AUGUST, AND NOVEMBER, 1985: AND MARCH 1986 WATER LEVEL MEASURING, WATER QUALITY, AND IRRIGATION WELL AQUIFER TEST SITE LOCATION MAP.

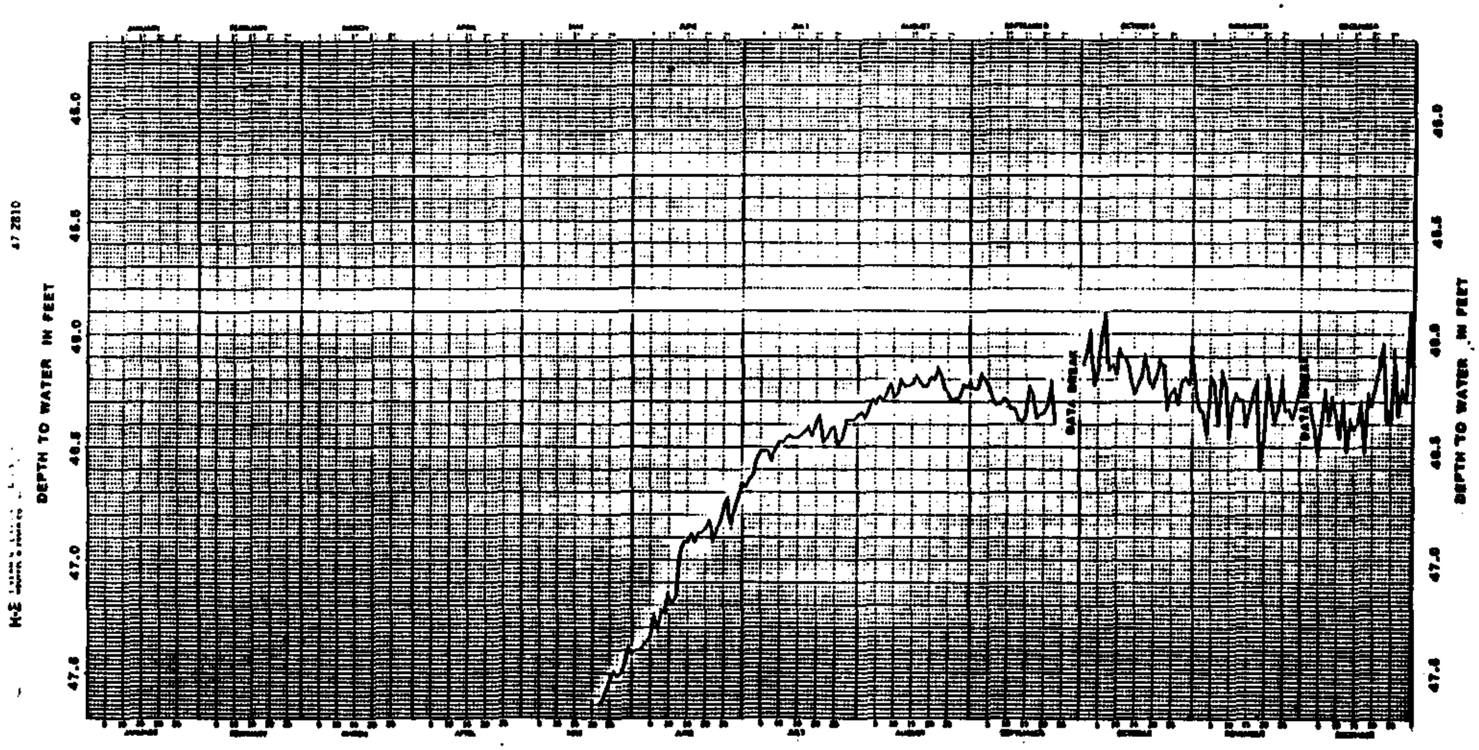


Figure 7. **AEROMOTOR HYDROGRAPH RECORD FROM MAY 22, 1985 TO DECEMBER 31, 1985.**

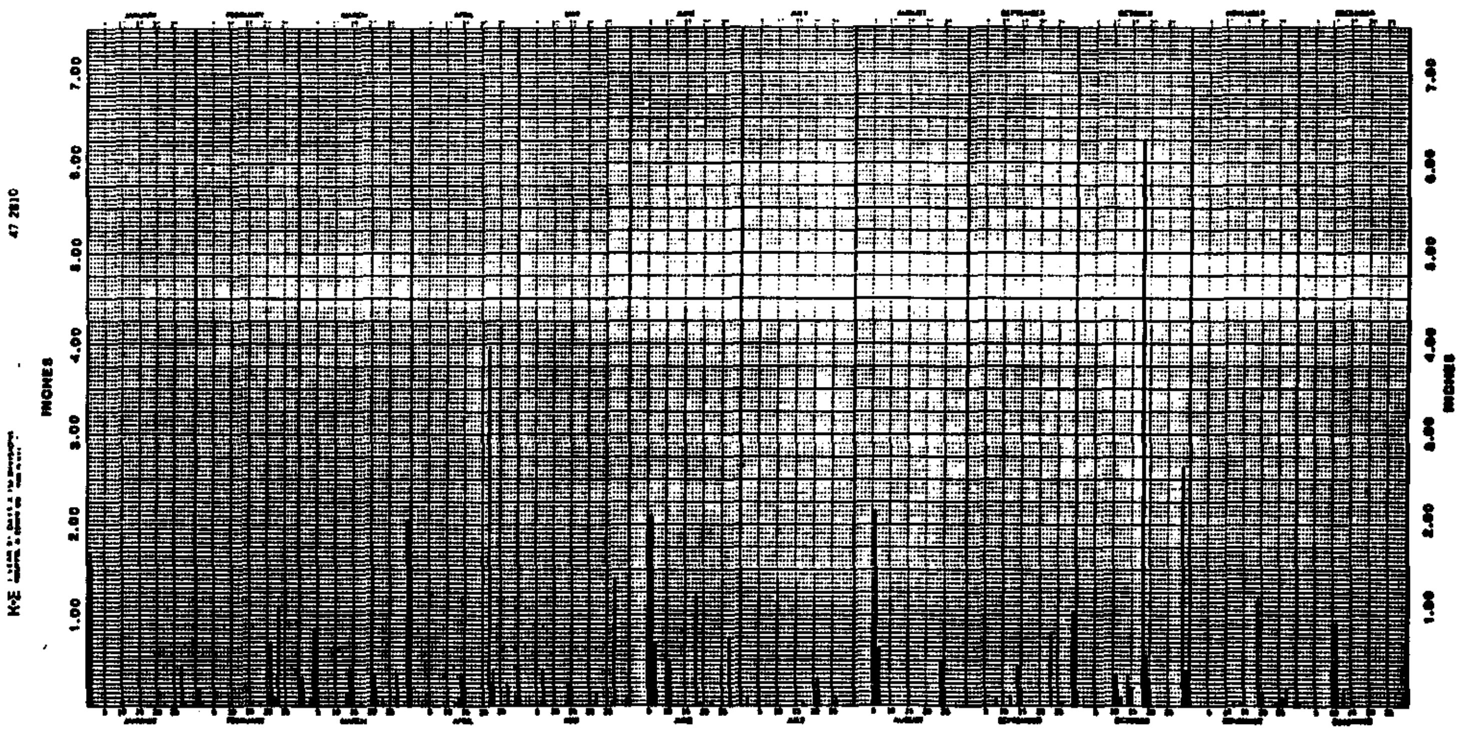


Figure 7a. **DAILEY PRECIPITATION FOR ADA, OKLAHOMA FOR YEAR 1985.**

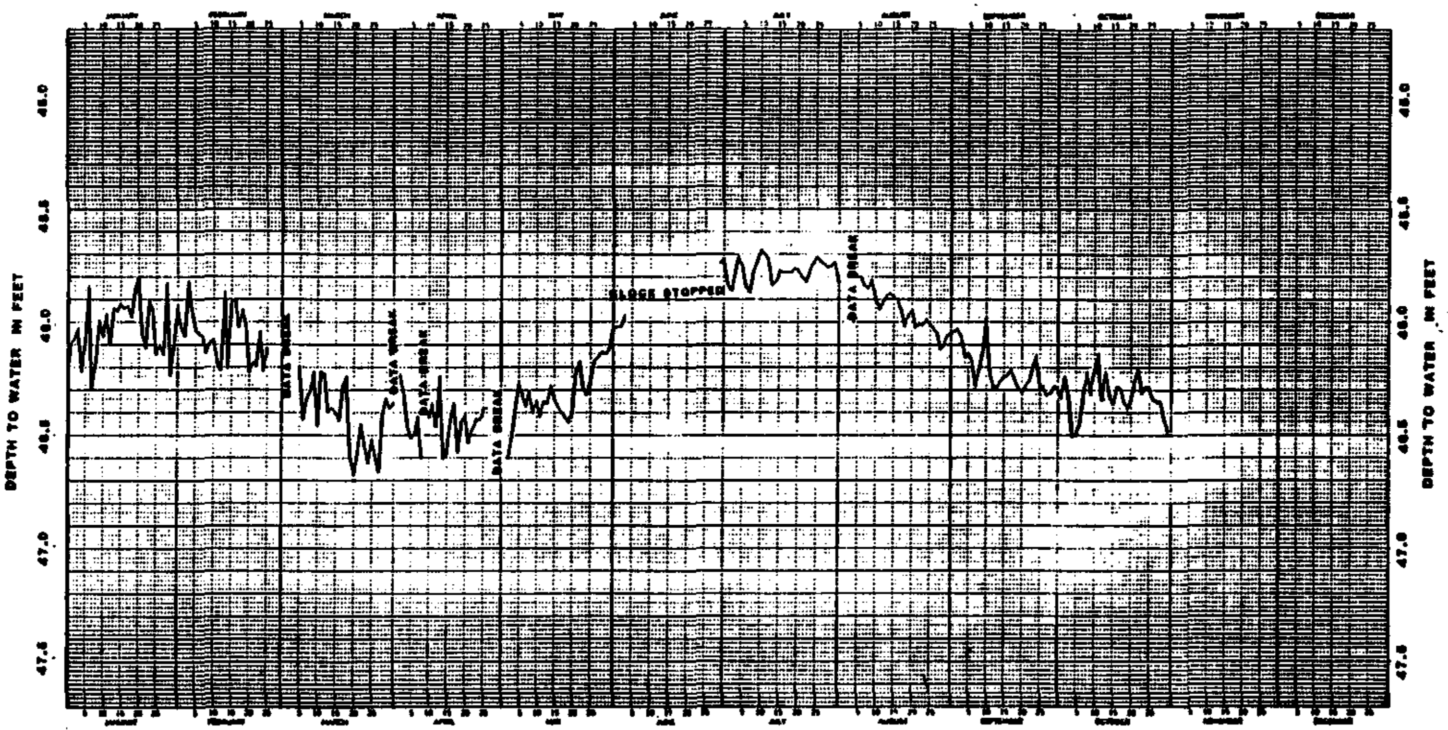


Figure 8. **AEROMOTOR HYDROGRAPH RECORD FROM JANUARY 1, 1986 TO NOVEMBER 1, 1986.**

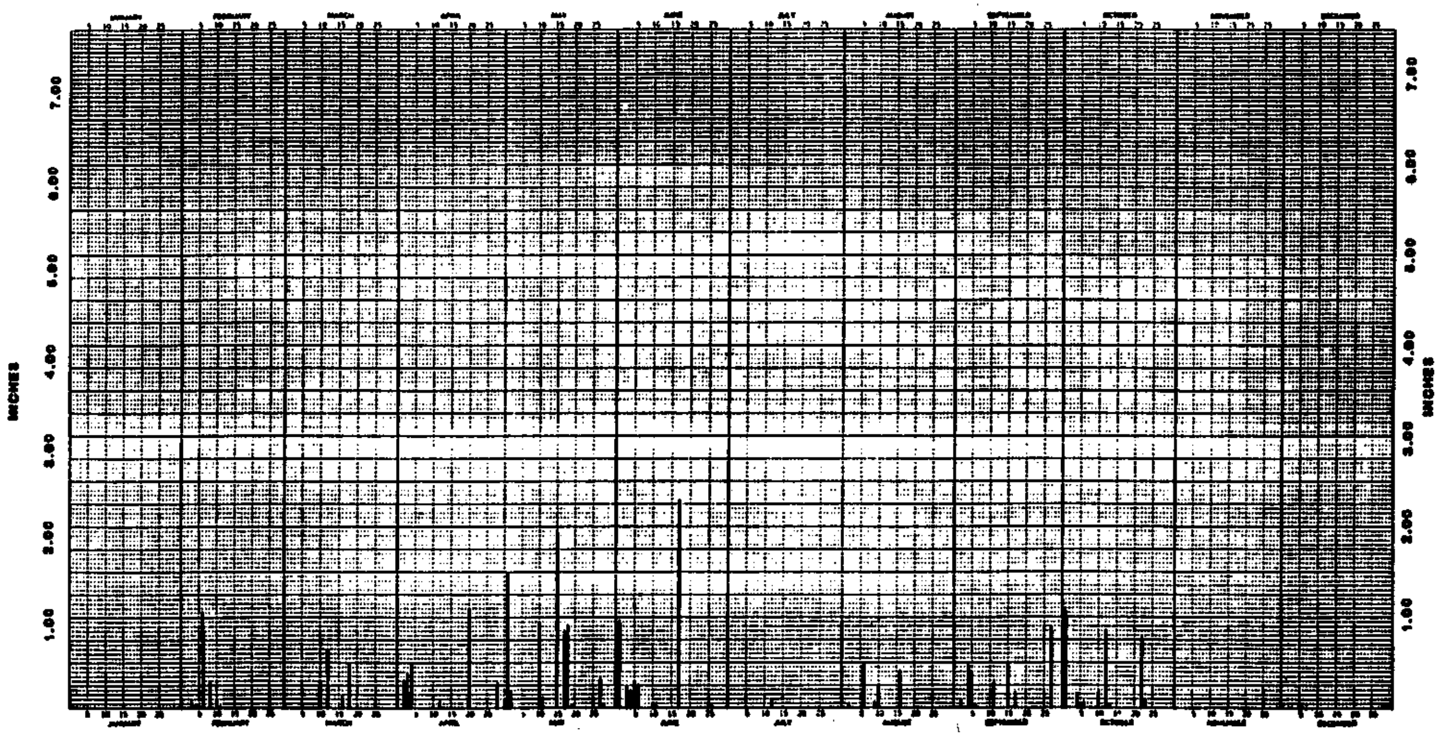


Figure 8a. **DAILEY PRECIPITATION FOR ADA, OKLAHOMA FROM JANUARY 1, 1986 TO NOVEMBER 1, 1986.**

Changes of the ground water levels are reflected by the hydrograph records shown in Figures 7a and 8a. There is a subtle relationship noted between the precipitation and the hydrograph data in Figures 7 and 8. The May, August, and November, 1985 and March, 1986 field measurements are also represented on the water table maps for the Gerty Sand Aquifer in Figures 9, 10, 11, and 12.

Irrigation Well Location, Distribution and Yield.

The distribution of irrigation wells was mapped by road survey and by prior rights well location descriptions (Figure 13). Some of the irrigation well logs contain good lithologic descriptions and some contain pertinent production test results, which were supplied by local water well drillers and by the Oklahoma Water Resources Board. The majority of the irrigation wells consists of a 30 inches diameter hole, a 12 inch slotted steel casing, and a nine inch annulus filled with gravel. The irrigation wells use a three bowl turbine type pump and use primarily electricity as a source of power to pump the water. Variations in pump yield may be due to changes in composition of the aquifer and to well completion. The Irrigation Well Data is shown in Table I.

Coefficient of Permeability.

The coefficient of permeability and transmissivity was calculated from geologic logs, specific capacity data from drillers log pump test data, and from two well production tests in the terrace alluvium.

Using the geologic logs, the coefficient of permeability and transmissivity was generated in the manner developed by Kent, et. al., (1973). Coefficient of permeaibility is related to median grain size and divided into four ranges. A weighted permeability was calculated by

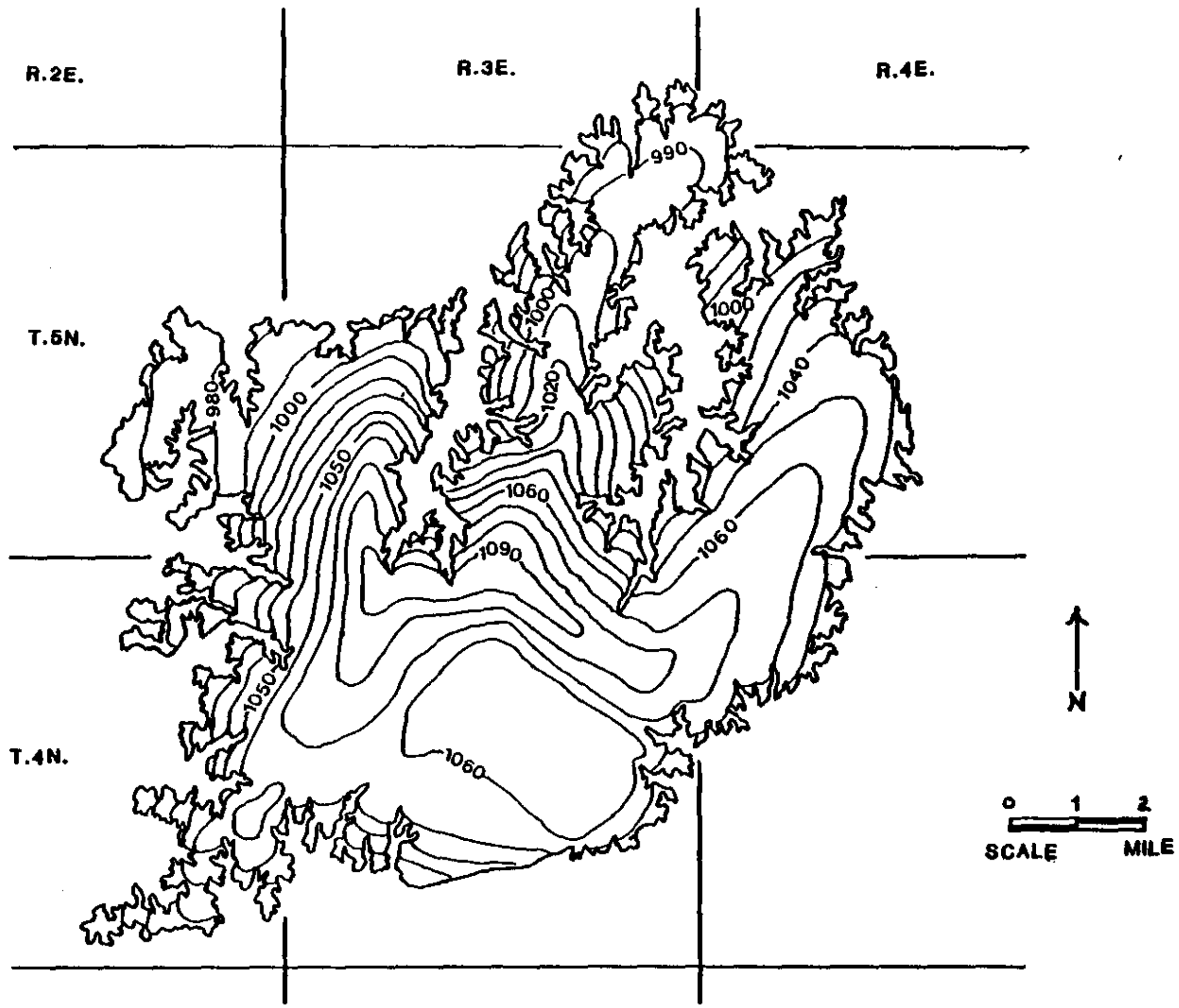


Figure 9. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.
MAY 21 - 22, 1985 WATER TABLE MAP.

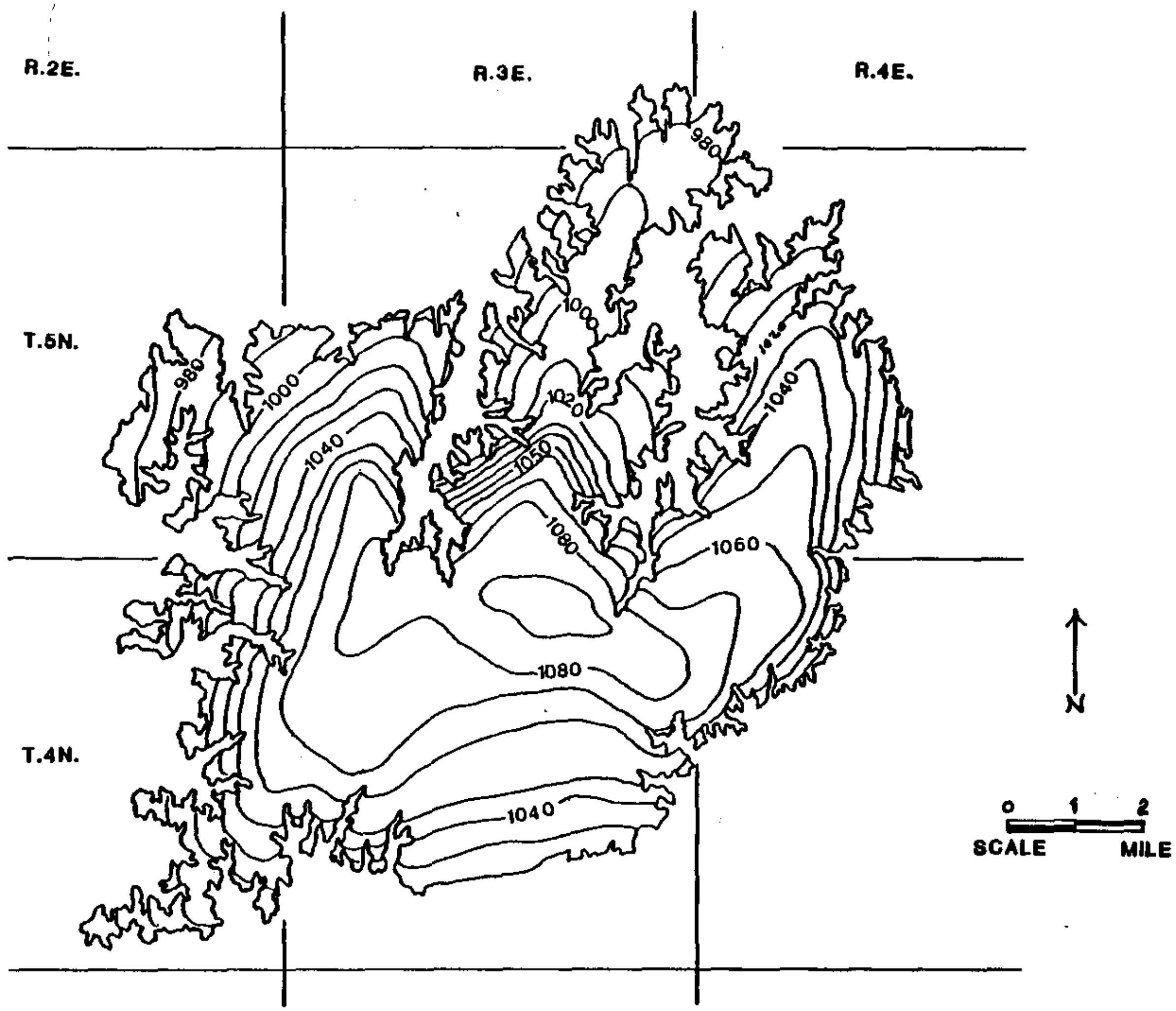


Figure 10. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.
AUGUST 12, 13, AND 17, 1985 WATER TABLE MAP.

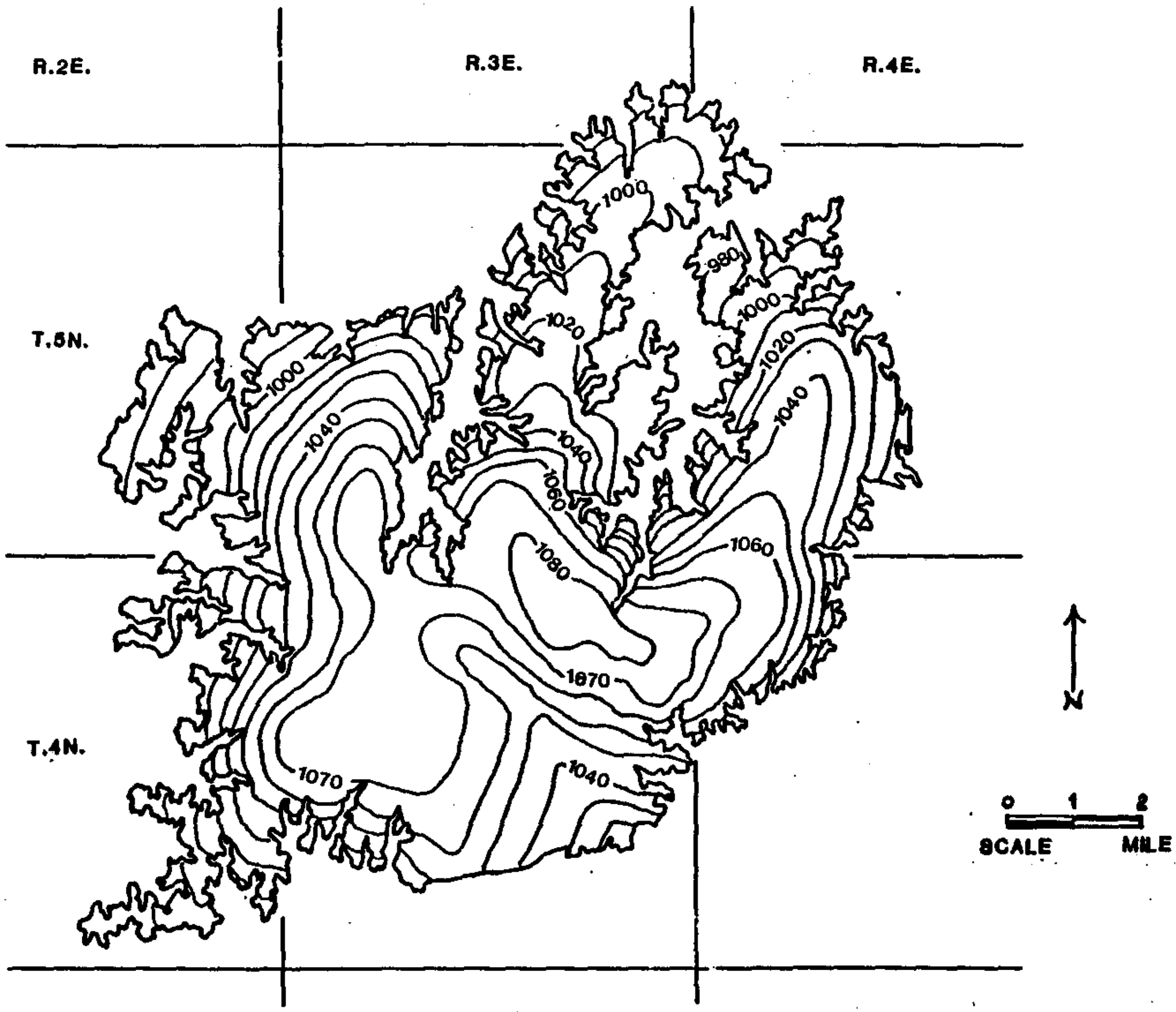


Figure_11. ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. NOVEMBER 11, AND 19, 1985 WATER TABLE MAP.

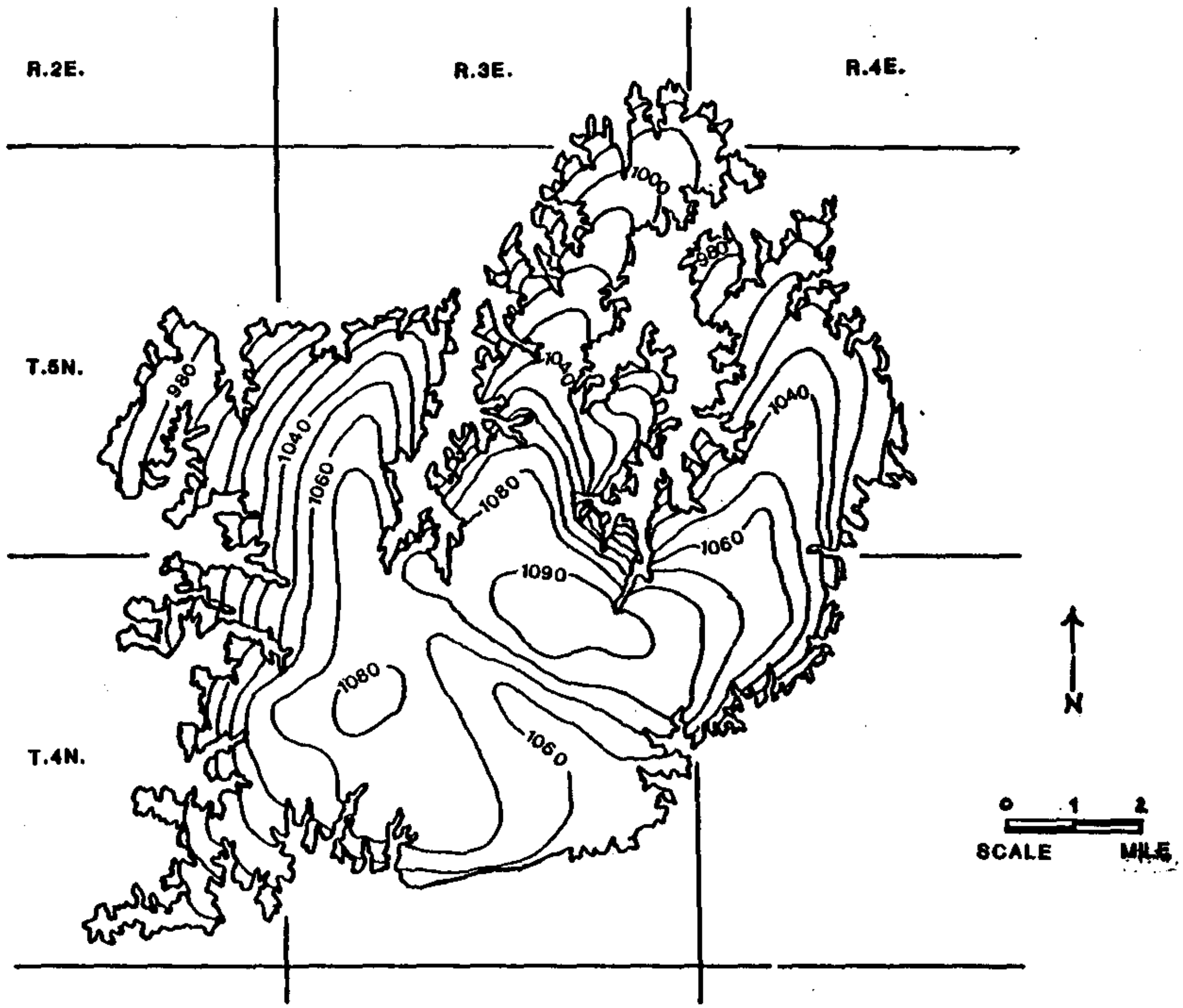


Figure 12, ISOLATED TERRACE DEPOSIT OF THE CANADIAN RIVER OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA. MARCH 5, AND 6, 1986 WATER TABLE MAP.

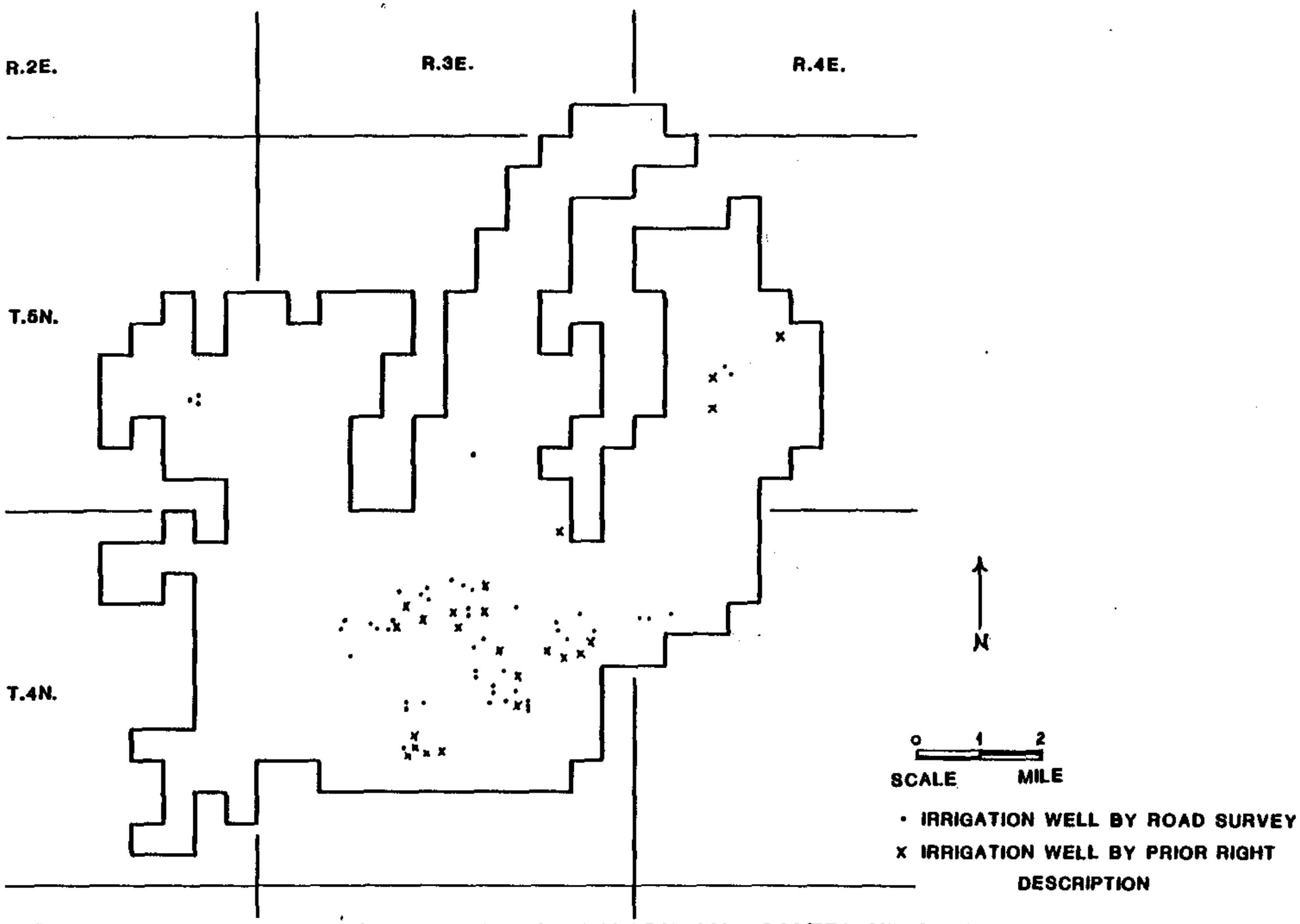


Figure 13. IRRIGATION WELL LOCATION AND DISTRIBUTION MAP.

TABLE I

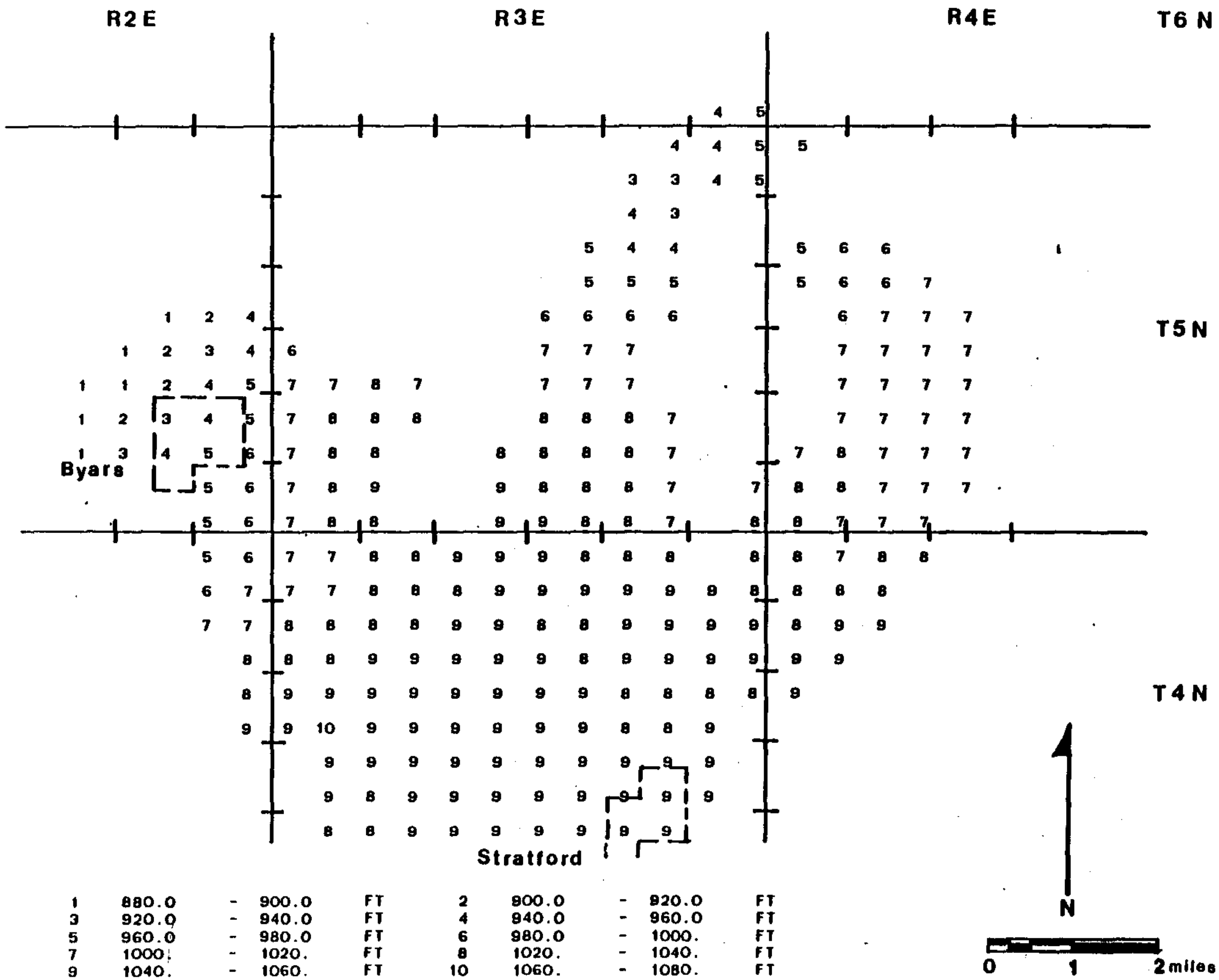
WELL DATA FOR IRRIGATION WELLS.

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	-	-

multiplying a selected coefficient of permeability for each of the four size ranges by the percentage of saturated thickness of each range and summing up the total for all the ranges. The coefficient of permeability for each range was obtained from the coefficient of permeability/grain size envelope developed by Kent, et. al., (1973). The saturated thickness was based on the difference between water table and base of aquifer elevations. The base of aquifer is represented as a contour map showing the distribution of the elevation at the base of the aquifer (see Figure 14). An analysis of specific capacity was also conducted on the most complete well log records. The specific capacity data represent a range of 0.10 to 0.30.

The permeability and transmissivity values were also calculated from pumping tests. The first pumping test (Jarrell) was performed on May 21-22, 1985 in the NE.1/4 of the SW.1/4 of the NW.1/4 of Section 9, T.4N., R.3E.. This well has an inital discharge rate of 182 gpm, at 90 minutes a discharge of 174 gpm, at 335 minutes a discharge of 154 gpm, and at 1075 minutes a discharge of 140 gpm. Using the Jacob method for calculation of T by residual drawdown vs. time ratio an average permeability value of 460 gallons per day per square foot was calculated. Data are shown in Appendix D.

The second aquifer test site (Watt)is located in the NW.1/4 of the SW.1/4 of Section 11, T.4N., R.3E.. This well had an initial discharge rate of 600 gpm, at two minutes a discharge rate of 450 gpm, at 100 minutes a discharge rate of 415 gpm, and at 720 minutes a discharge rate of 338 gpm. Using the Jacob method by residual draw-down vs. time ratio, average permeability of 455 gallons per day per square foot was calculated. Data are shown in Appendix D.



1	880.0	- 900.0	FT		2	900.0	- 920.0	FT
3	920.0	- 940.0	FT		4	940.0	- 960.0	FT
5	960.0	- 980.0	FT		6	980.0	- 1000.	FT
7	1000.	- 1020.	FT		8	1020.	- 1040.	FT
9	1040.	- 1060.	FT		10	1060.	- 1080.	FT
11	1080.	- 1100.	FT					

FIGURE 14 Elevation of aquifer bottom

A summary of analytical test data is shown in Table II, the data includes the specific capacity values, transmissivity from specific capacity, permeability from specific capacity values from the geologic logs, and permeability from aquifer test site data.

Land Use

The majority of the crops grown in the study area are alfalfa, wheat, corn, soybean, peanut, milo, cotton, and orchard (peaches). The irrigation of these crops is hydrologically connected to the aquifer system. The edge of the terrace deposit is typically pasture and range lands. Outside of the terrace boundary range land occurs with densely wooded areas. The woodlands typically consisit of post oak vegetation.

Recharge

The amount of recharge distributed across the study area included two classes: Loam and Sand (dunes). A typical sand exposure and a loam soil distribution across the study area is shown in Figure 15. The surface dune sand exposures range in thickness from less than five feet to as much as 80 feet. The annual amount of precipitation distributed over the study area is 35.60 inches per year. The average rainfall available for ground water recharge was estimated to be 2.4 inches.

Ground Water Quality

Water quality sampling of the aquifer was conducted on May 21-22, 1985 by personnel from Oklahoma State University and Oklahoma Water Resources Board. The pH and field conductance was measured in the field at most locations of water quality sampling sites. Water quality samples were then tested by the Oklahoma Department of Health. Table III shows the mean water quality analysis for the Isolated Terrace Deposit.

TABLE II.

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

	Basic Data							Calculated Data									
														Average Permeability Using S. C. 0.20		Aquifer Data Using Jacob Method	
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. 0.10	Transmissivity from S. C. 0.20	Permeability from S. C. 0.10	Permeability from S. C. 0.20	Geologic log perm. Lower	Geologic log perm. Upper	Lower	Upper	Lower	Upper
SW NE 9 4N 3E	220	154	800	48	54	156	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	26,802	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.

TABLE III

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

Parameter	Remarks	Mean Value	Max. Values	min. Values	Units	No. of samples above MDL
Chloride		55.25	283.00	12.00	MG/L	14
Nitrite-Nitrate as N		2.92	6.10	0.50	MG/L	9
Specific Conductance		937.69	3,100.00	230.00	Umhos/om	14
Solids, Total Diss.		418.36	1,108.00	186.00	MG/L	14
Hardness, Total		136.27	639.00	< 10.00	MG/L	11
Barium		368.75	540.00	<200.00	UG/L	8
Calcium		43.71	125.00	1.00	MG/L	14
Copper		30.50	150.00	5.00	UG/L	14
Lead		20.78	31.00	<20.00	UG/L	14
Manganese	<	20.00	<20.00	<20.00	UG/L	14
Sodium		114.43	540.00	32.00	MG/L	14
Floride		0.53	2.40	0.21	MG/L	14
pH		6.76	9.20	6.00	STD	13
Sulfate		30.67	46.00	<20.00	MG/L	6
Alkalinity		330.93	704.00	137.00	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	UG/L	2
Magnesium		12.75	56.00	<1.00	MG/L	11
Selenium	<	5.00	-	-	UG/L	14
Zinc		132.90	920.00	<4.00	UG/L	10
Water Temperature		15.31	-	-	oC	13

< Less Than Detection Limit
MDL Minimum Dectection Limit

The total hardness in the terrace alluvium is moderately hard. Water with a total hardness of less than 150 MG/L is moderately hard; 150 - 300 MG/L is hard; and greater than 300 MG/L is very 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. The sulfate concentration has a mean value of

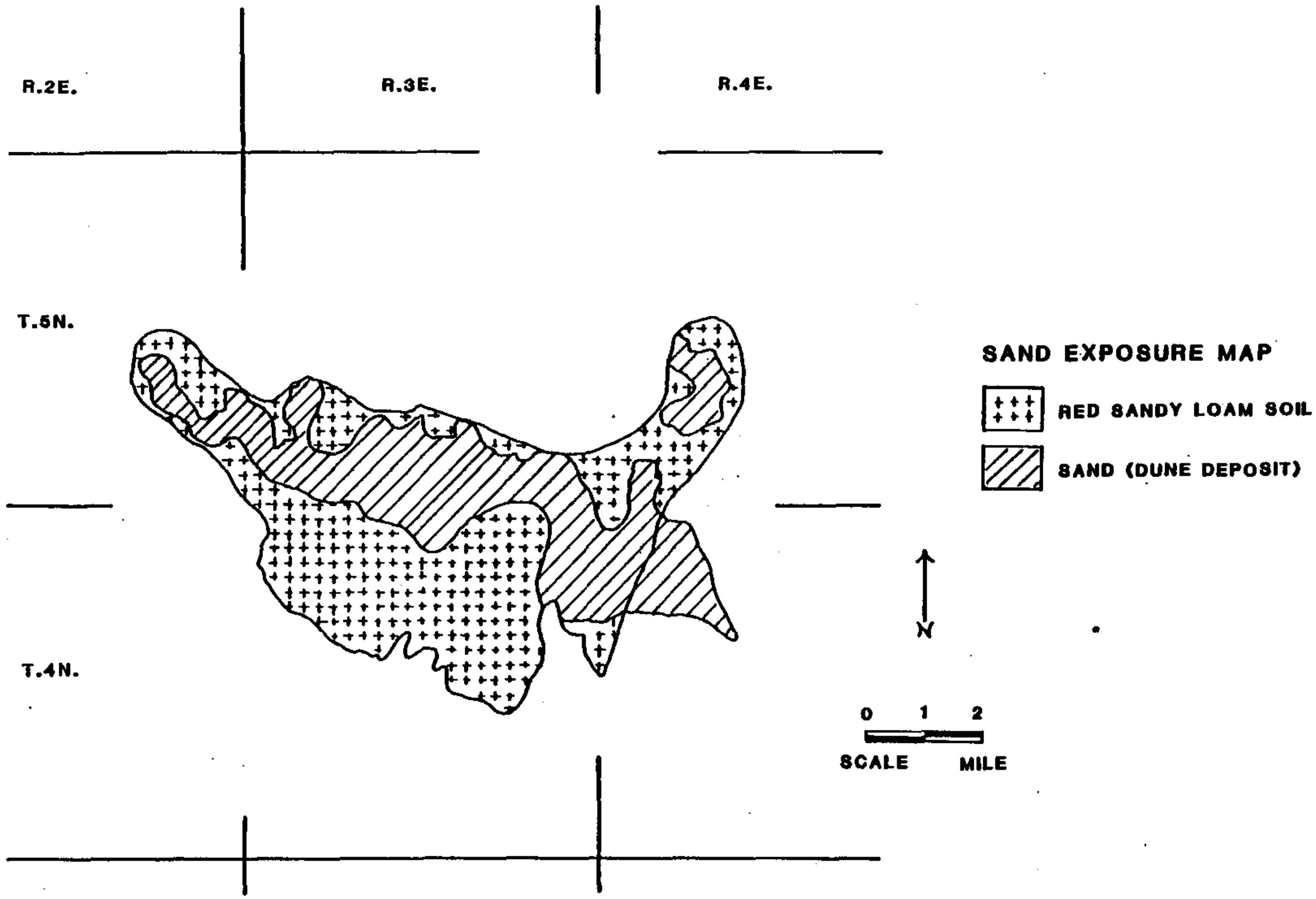


Figure 15. SAND EXPOSURE MAP DISTRIBUTION FOR THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA USED AS RECHARGE.

30.7 MG/L, which is thought to occur due to the presence of organic material from the terrace alluvium. The chloride concentration has a mean value of 55.3 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, cadmium chromium, and selenium are below the detection limit and pose no threat to the general public within the terrace alluvium. Overall, the water quality of the terrace alluvium is good. Field measurements of water quality, pH and field specific conductance reveals that the terrace alluvium acts as a buffer. The pH at the edge and beneath the terrace alluvium is about 9.0 (STD). The pH within the terrace alluvium is near neutral. The specific conductance within the terrace alluvium is ten times lower than the edge of the terrace alluvium.

Municipal and Rural Water District

The municipal demand for the City of Stratford and Byars, Oklahoma is reflected in the projected increase in municipal wells. The population of Stratford, Oklahoma is 1,459 and the population of Byars, Oklahoma is 353 from the 1980 Census. The estimated per capita water use 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 currently utilizes four wells. Three of the wells are rated at 75 gpm and the fourth is rated at 600 gpm. The 600 gpm well represents short yield and is mainly used. The peak demand in the city of Stratford, Oklahoma is 14,400,000 gallons per month or 44.2 acre-feet per month for the 40 acres of allocation. Table IV shows the monthly water usage for the city of Stratford, Oklahoma.

TABLE IV

MONTHLY WATER USAGE FOR THE CITY OF

STRATFORD, OKLAHOMA

	Date/ Month	Water Pumped 1,000 gallons per day
	January	2,218,700
	February	7,286,300
	March	8,142,600
1	April	10,060,500
9	May	11,380,500
8	June	14,488,400
5	July	12,781,800
	August	12,896,800
	September	12,254,100
	October	11,451,300
	November	10,992,300
	December	8,563,800
	January	11,177,000
	February	9,882,700
	March	10,981,200
1	April	10,721,700
9	May	11,001,000
8	June	11,027,100
6	July	13,470,600
	August	12,983,700
	September	10,540,800
	October	-
	November	10,744,500
	December	10,499,400

The rural water district well that is located within the study area is in the N.1/2 of Section 17, T.4N., R.3E. and is shown on the rural water pipe line map in Figure 16. This well is used by the Wynnewood, Oklahoma Rural Water District. 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

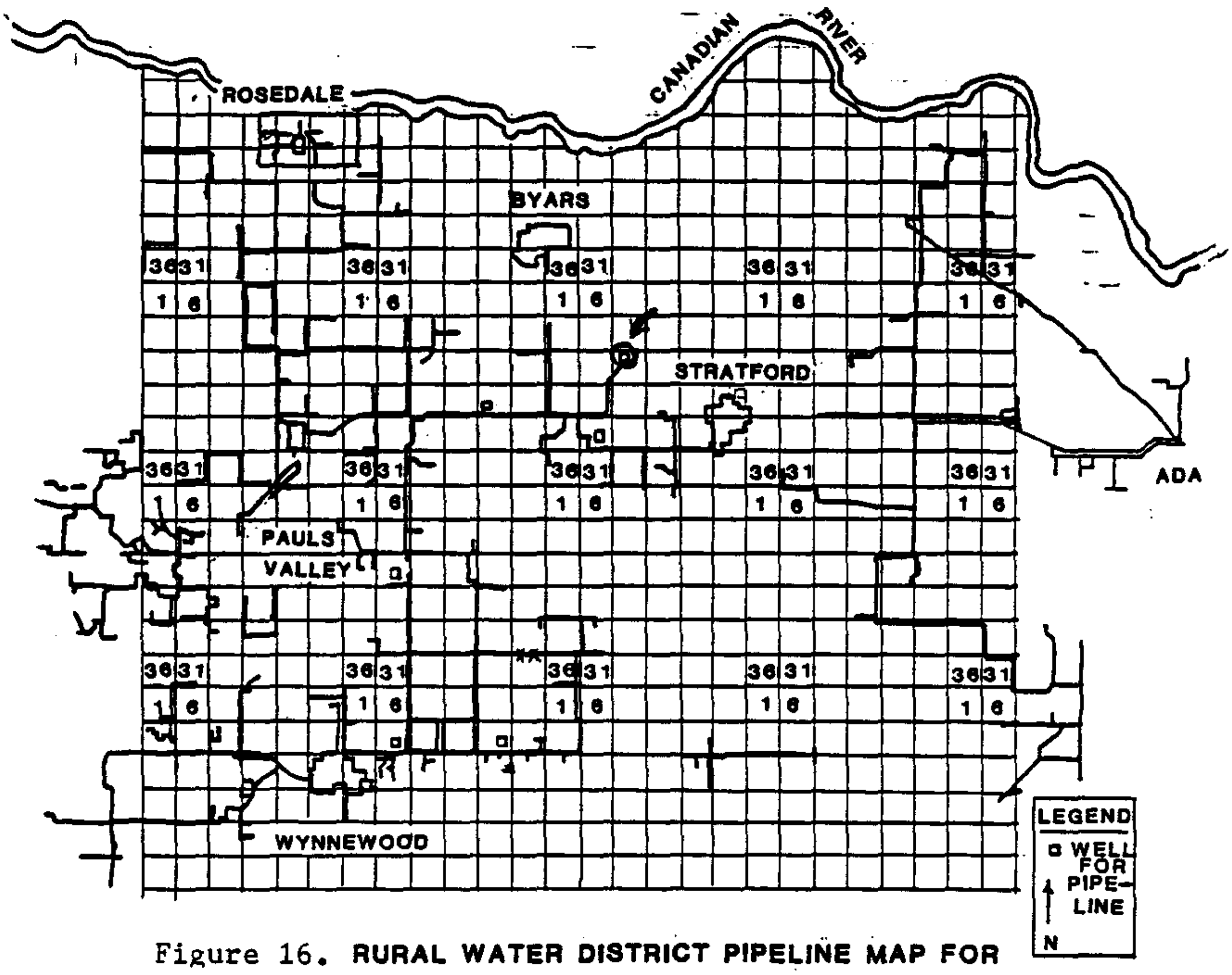


Figure 16. **RURAL WATER DISTRICT PIPELINE MAP FOR ISOLATED TERRACE DEPOSIT.**

(MODIFIED AFTER RURAL WATER SYSTEMS IN OKLAHOMA, 1980)

installing a flow meter onto the 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 V shows the meter readings and gallons used for the well located in Section 17. Generally, the meter readings were taken at the middle of the month.

TABLE V

WYNNEWOOD OKLAHOMA RURAL 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	1,918,000
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	2,063,000
11/14/86	57,045,000	2,205,000
"	"	"

The amount of water used for the rural water district is 0.638 acre-feet per month per 100 acres of the allocation.

Prior Rights Allocation

The prior rights and priority of rights of landowners within the study area were mapped and categorized based on data of priority and legal description for Garvin, McClain, and Pontotoc counties, Oklahoma. The allocation in acre-feet divided by the number of acres to be irrigated provides a weighted average in acre-feet per acre for each of the owners of prior rights. An interim allocation of two acre-feet was assigned by the Oklahoma Water Resources Board. The summary of Prior Right allocations for each county is provided in Table VI. The legal description of prior rights allocation will show the specific property under irrigation (see Figure 17).

TABLE VI

PRIOR RIGHT ALLOCATIONS FOR THE ISOLATED TERRACE DEPOSIT OF GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

Garvin County: Date	Priority By Date	Type	Name	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	Jarrel, Jim L.	130	150	0.86
5/22/63	4	Irrigation	Smith, Royce	234	130	1.80
6/14/63	5	Irrigation	Jarrel, 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	Jarrel, Kenneth	59	80	0.74
7/ 7/67	22	Irrigation	Gray, Gus	12.5	21.4	0.58
7/ 7/67	23	Irrigation	Jarrel, 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/ 5/68	26	Irrigation	Russ, Albert J.	97	170	0.57
4/10/73	27	Irrigation	Brundridge, Ben	150	130	1.15
Pontotoc County:						
12/ 9/64	1	Irrigation	Younger, Les	45	80	0.56
7/28/66	2	Irrigation	Wood, Wallace	160	45	3.56
8/ 8/66	3	Irrigation	Wood, J. B.	40	40	1.00
9/20/66	4	Irrigation	Opitz, June	167	120	1.39
8/17/67	5	Irrigation	Herndon, James F.	80	160	0.50
8/17/67	6	Irrigation	Herndon, James F.	3	40	0.08
8/25/67	7	Irrigation	Atton, Jim	56	35	1.24
McClain County:						
4/25/66	1	Irrigation	Slaughter, W. O. or Billie	40	20	2.00

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

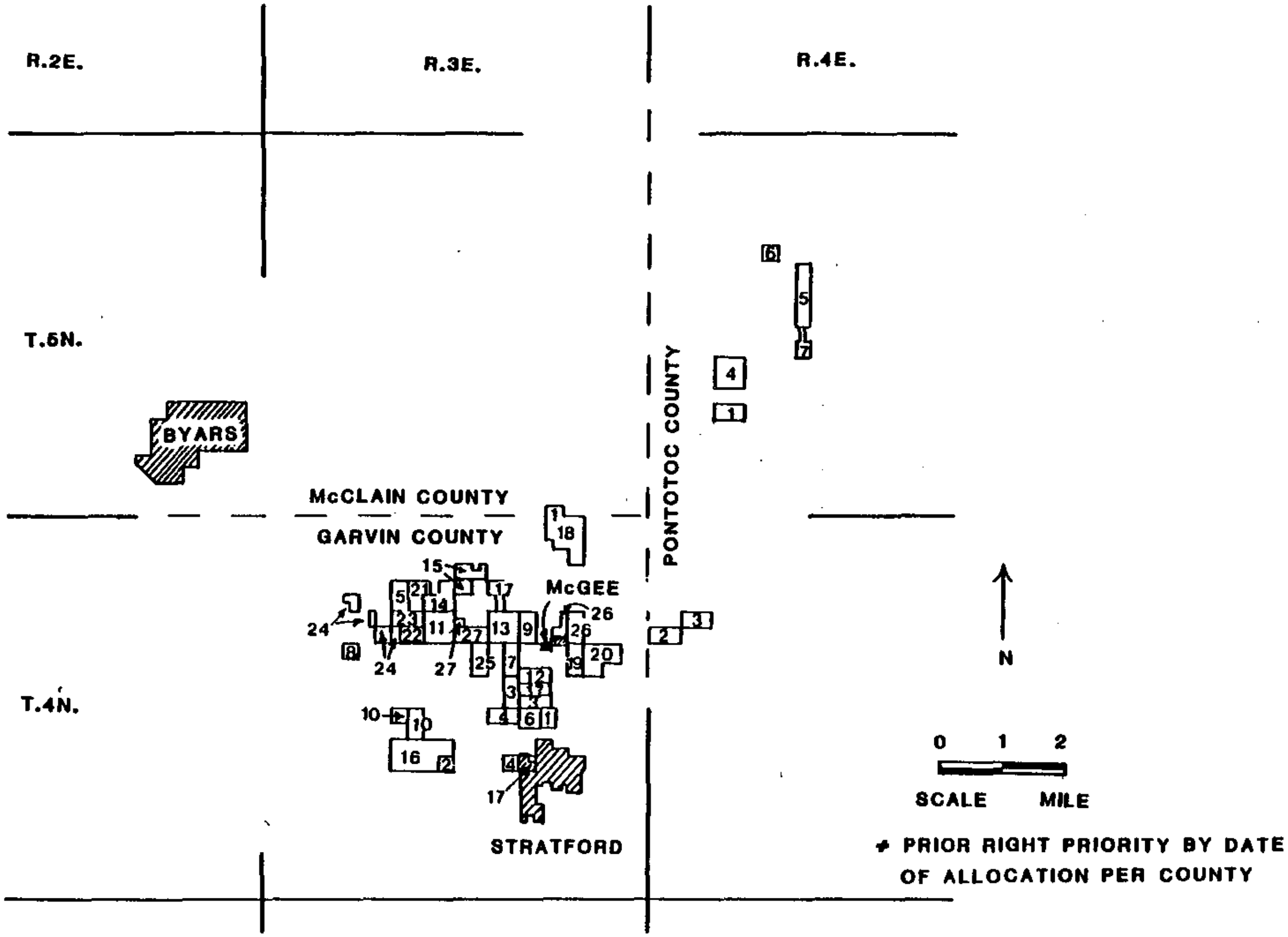


Figure 17. PRIOR RIGHTS PRIORITY DISTRIBUTION MAP PER COUNTY FOR GARVIN, McCLAIN, AND PONTOTOC COUNTIES, OKLAHOMA.

GROUND-WATER

MODELING

Simulation Procedure

The primary variables of the aquifer in the model are initial ground water levels, pumping rate, and transmissivity. The quantitative values must be assigned to the hydrogeologic parameters of the aquifer in order to model the aquifer within the accuracy of the data used. The quantitative values are either assigned directly by the hydrogeologist or generated by the computer model. A value for each hydrogeologic parameter is assigned to every quarter mile section (node) in the aquifer. The model output consist of a mass balance and estimated volume of ground water in storage, as well as maps of predicted ground water table elevations and saturated thickness at five year intervals throughout the 20-year minimum basin life of the Isolated Terrace deposit.

The modeling program used in this investigation was originally written by Konikow and Brederhoeft and revised by Kent, et.al. (1986) to include features used in the model by Trescott, Pinder, and Larson (1976). The finite difference model simulates ground water flow in two dimensions for an artesian aquifer, a water table aquifer or a combination of the two. Further modifications by Kent and LeMaster allowed the model to be applied to the Isolated Terrace Deposit of Garvin, McClain, and Pontotoc Counties, Oklahoma.

The matrix was designed using a 160 acre portions of a one square mile section to represent a node. The Terrace deposit or Gerty Sand aquifer boundary was established through the use of the Hydrologic Atlas of the Ardmore-Sherman Quadrangle, 7.5 minute U.S.G.S. topographic maps of the area, and field investigations. The node grid map initially used has been modified inorder to reflect calibration of the model.

The boundary condition of the Isolated Terrace deposit was determined by geologic parameters derived from driller sample logs, surface geophysical data, and outcrop exposures of shales, limestone, and conglomerate materials found adjacent to and beneath the terrace deposit. The bedrock which was assumed to be impermeable included the shale and limestone, which underlies the conglomerate. Seepage rates were calculated along the modeled boundaries inorder to determine water inflow and outflow from the boundaries.

The simulation period was determined to be one full year (365 days), which was divided into two pumping periods per year and finally into time steps. A time-step is the period in which the computer readjusts the water table elevations in response to recharge and discharge from the aquifer system. Each time-step usually required two iterations to complete each time-step for a pumping period.

Computer runs of the Isolated Terrace deposit were calibrated by entering in data in the form of digitized maps. The data and matrices were checked for errors in a one year calibration run. Additional adjustments were made by calibration, and the model was calibrated using prior appropriative pumping. Simulation runs using a 20 year allocation/prior appropriative pumping rate were made to determine the allocation in acre-feet per acre per year that would allow 50 (%) percent of the aquifer to "go dry". The term "dry" refers to saturated thickness of less than 5.5 feet.

RESULTS

Allocation

The final 20-year computer simulation was conducted for the 1973 to 1993 period for the ground-water basin using pumping rates of prior appropriative right owners. This simulation was repeated with allocation pumping in conjunction with prior appropriative pumping.

Maximum annual yield was determined by adjusting the amount of allocated pumpage that would cause 50 percent of the nodes to go dry by the end of the simulation period (20 years). The maximum annual yield and allocated pumpage was optimized by repeating 20-year simulation in order to obtain the required 50 percent dry area. The maximum annual yield is 12,800 Acre feet per year proportioned as 0.65 Af/Ac over the total surface area of the aquifer assuming a net return flow of 15 percent and a net recharge of approximately one inch per year.

A saturated thickness of five feet was considered dry due to the size limitations of screen length and the size of a submersible pump which would be set at the bottom of a fully penetrating well. An annual allocation of 0.65 acre-feet per acre was determined to cause 52.6 percent of the nodes to go dry after 20 years.

Each node (160 acres) was pumped continuously for a 4-month period during the summer of each year at three times the annual allocation rate. This schedule was continued throughout the 20-year period unless the node became dry prior to that time. It is assumed in the model that all acreage is pumped at the average maximum legal limit (0.65 acre-feet per acre). Under these conditions, various parts of the area go dry at different times. This is due to the nonhomogeneous nature of the alluvium (variable transmissivity and corresponding specific yield). The 50 percent dry criteria was used to accommodate this variability. The wells are turned off in the model when the 5.5-foot saturated thickness is reached and will turn on periodically to remove accumulation due to recharge. The maximum annual yield is the resulting amount of water recovered over the 20-year period during which wells are being turned off and on as the aquifer is depleted and recharged. Because of these factors, the maximum annual yield does not simply equal the product of allocation rate times the area.

The computer simulation results are summarized in the ground-water budget summaries shown in Figures 18 and 19. Basic assumptions are also included in the budget summary. In addition, initial and 20-year ground water distribution summaries for prior rights and allocation pumping are shown in Table VII. Simulated changes in saturated thickness and of areas that became dry (less than five feet) are shown in five-year increments (1973 to 1993) in Figures 20 through 24. Other computer simulation results for five-year increments in the 20-year period include transmissivity, head elevations, and water depths (Appendixes A, B, and C).

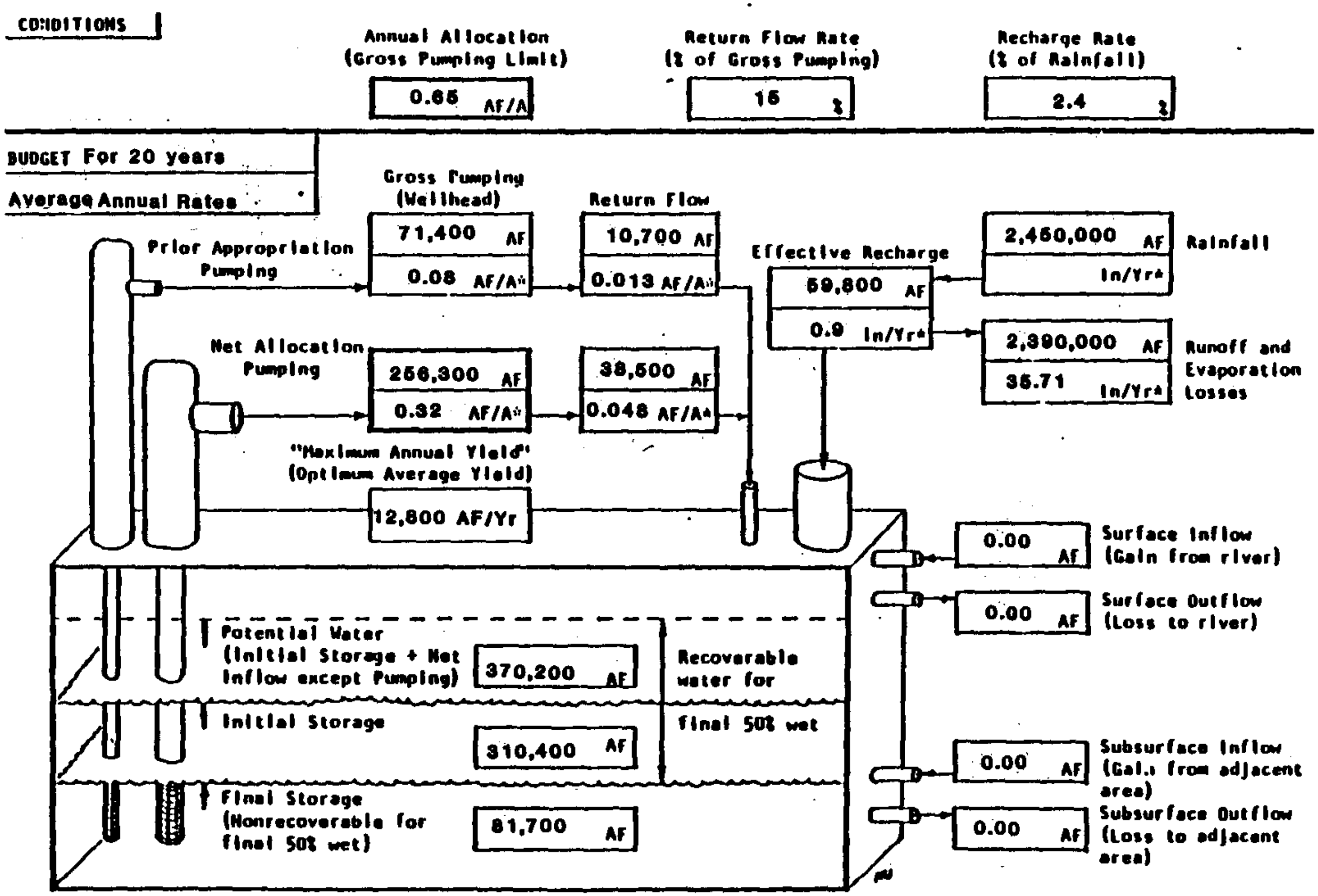


Figure 18. Twenty-year Ground-Water Budget (after Kent, 1980)

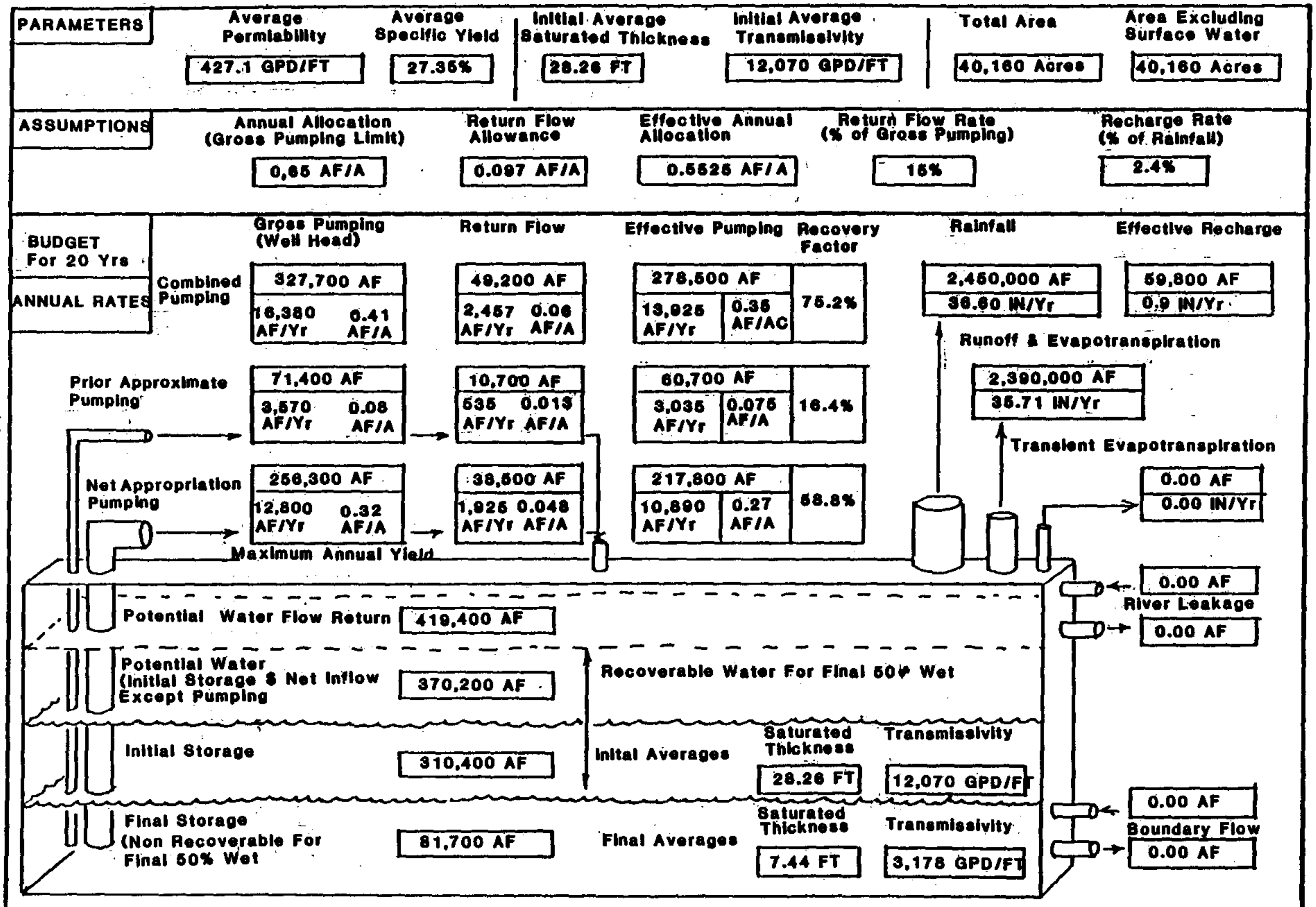


Figure 19. Flow Diagram For Ground-Water Budget

TABLE VII

WATER DISTRIBUTION SUMMARY
STRATFORD; ALLOCATION 0.65 AF/AC/YR; MAY - APRIL; BEGIN PUMP
FINAL 1973 - 1993

SATURATED THICKNESS RANGE (FEET)	AREA (% OF TOTAL)	AREA (ACRES)	AVERAGE SATURATED THICKNESS (FEET)	AVERAGE SPECIFIC YIELD (%)	STORED WATER (ACRE FT.)
0.0- 5.5	52.6	21120.0	4.0	27.3	22905.1
5.5- 10.0	35.9	14400.0	6.2	27.4	24623.3
10.0- 20.0	5.6	2240.0	13.9	27.3	8515.9
20.0- 30.0	2.4	960.0	22.8	27.3	5980.6
30.0- 40.0	0.8	320.0	35.4	27.3	3092.8
40.0- 50.0	0.8	320.0	46.9	27.3	4098.9
50.0- 60.0	1.6	640.0	55.4	27.3	9682.9
60.0- 70.0	0.4	160.0	64.3	27.3	2811.6
ALL RANGES	100.0	40160.0	7.4	27.3	81711.2

WATER DISTRIBUTION SUMMARY
STRATFORD; ALLOCATION 0.65 AF/AC/YR; MAY - APRIL; BEGIN PUMP
INITIAL 1973

SATURATED THICKNESS RANGE (FEET)	AREA (% OF TOTAL)	AREA (ACRES)	AVERAGE SATURATED THICKNESS (FEET)	AVERAGE SPECIFIC YIELD (%)	STORED WATER (ACRE FT.)
0.0- 5.5	0.0	0.0	0.0	0.0	0.0
5.5- 10.0	8.4	3360.0	8.5	27.3	7827.3
10.0- 20.0	29.1	11680.0	15.5	27.3	49492.6
20.0- 30.0	22.3	8960.0	24.6	27.4	60181.8
30.0- 40.0	17.5	7040.0	34.8	27.3	67076.8
40.0- 50.0	15.1	6080.0	45.5	27.3	75613.6
50.0- 60.0	4.4	1760.0	53.7	27.3	25843.2
60.0- 70.0	2.0	800.0	67.2	27.3	14692.6
70.0- 80.0	1.2	480.0	73.7	27.3	9663.9
ALL RANGES	100.0	40160.0	28.3	27.3	310391.9

TABLE VII (cont.)

WATER DISTRIBUTION SUMMARY
STRATFORD; PRIOR RIGHTS; BEGIN PUMP; 15% RETURN FLOW
FINAL PRIOR 1973-1993

SATURATED THICKNESS RANGE (FEET)	AREA (% OF TOTAL)	AREA (ACRES)	AVERAGE SATURATED THICKNESS (FEET)	AVERAGE SPECIFIC YIELD (%)	STORED WATER (ACRE FT.)
0.0- 5.5	2.4	960.0	3.3	27.3	859.3
5.5- 10.0	7.2	2880.0	7.8	27.3	6101.4
10.0- 20.0	30.3	12160.0	14.4	27.4	47830.9
20.0- 30.0	25.5	10240.0	24.6	27.3	68873.9
30.0- 40.0	15.1	6080.0	34.2	27.3	56886.2
40.0- 50.0	9.2	3680.0	43.9	27.3	44121.8
50.0- 60.0	3.6	1440.0	55.8	27.3	21963.4
60.0- 70.0	2.4	960.0	63.7	27.3	16725.3
70.0- 80.0	0.8	320.0	76.3	27.3	6675.8
80.0- 90.0	0.8	320.0	84.7	27.3	7407.9
90.0-100.0	0.8	320.0	96.5	27.3	8439.7
100.0-110.0	1.6	640.0	104.7	27.3	18309.4
110.0-120.0	0.4	160.0	113.9	27.3	4982.5
ALL RANGES	100.0	40160.0	28.2	27.3	309177.4

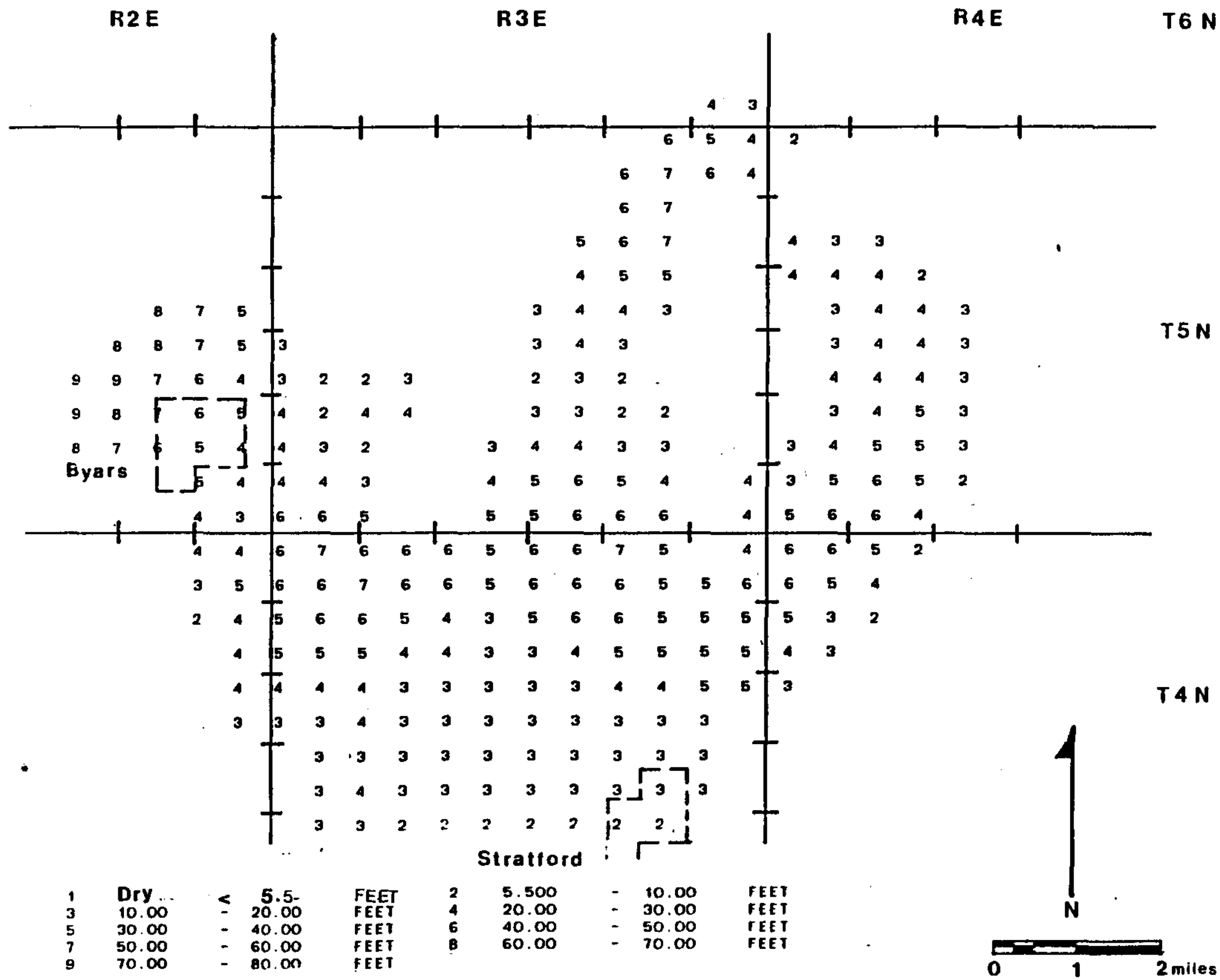


Figure 20. SATURATED THICKNESS --------- 0.000 YEARS

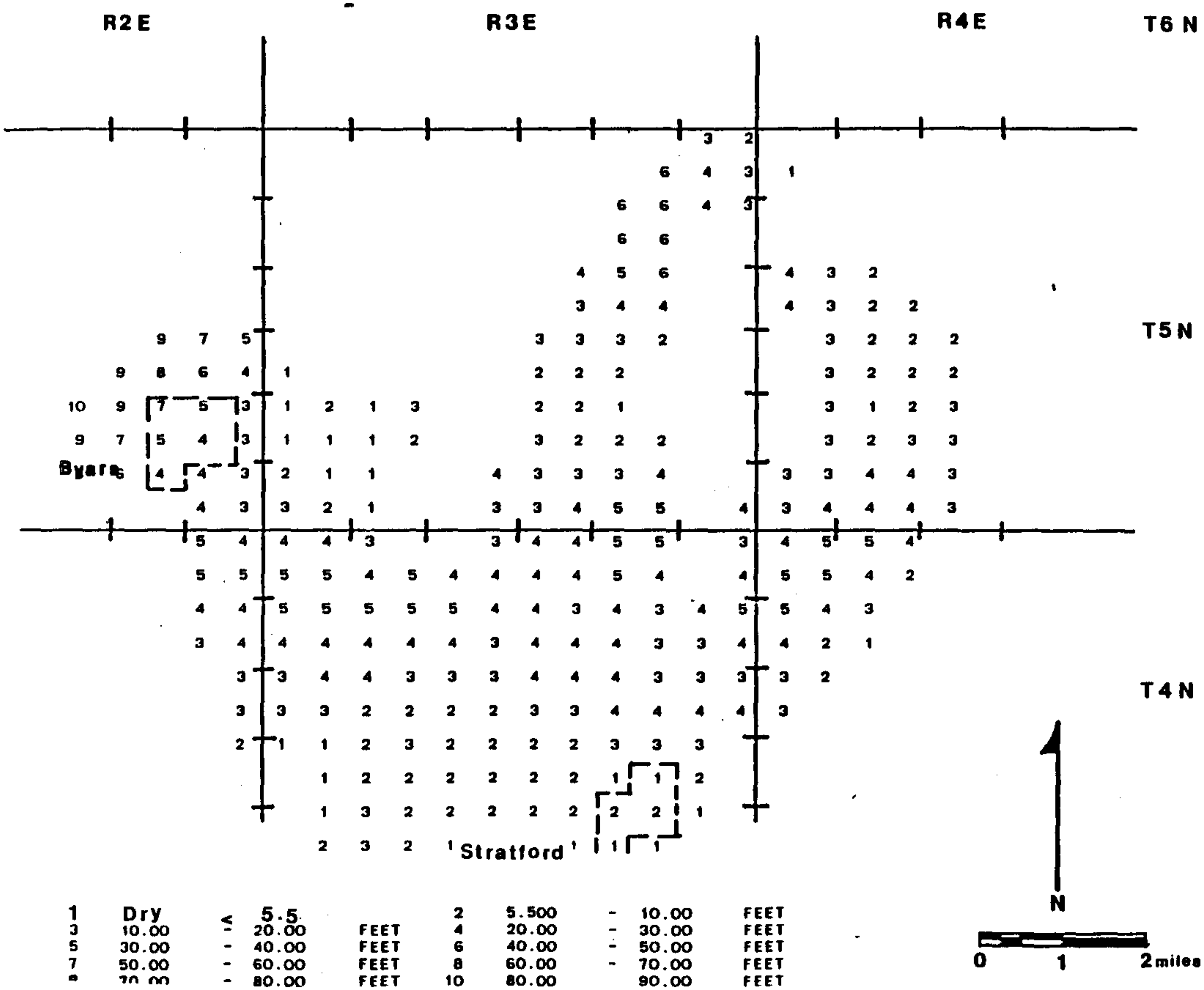


Figure 21. SATURATED THICKNESS -------- 5.000 YEARS

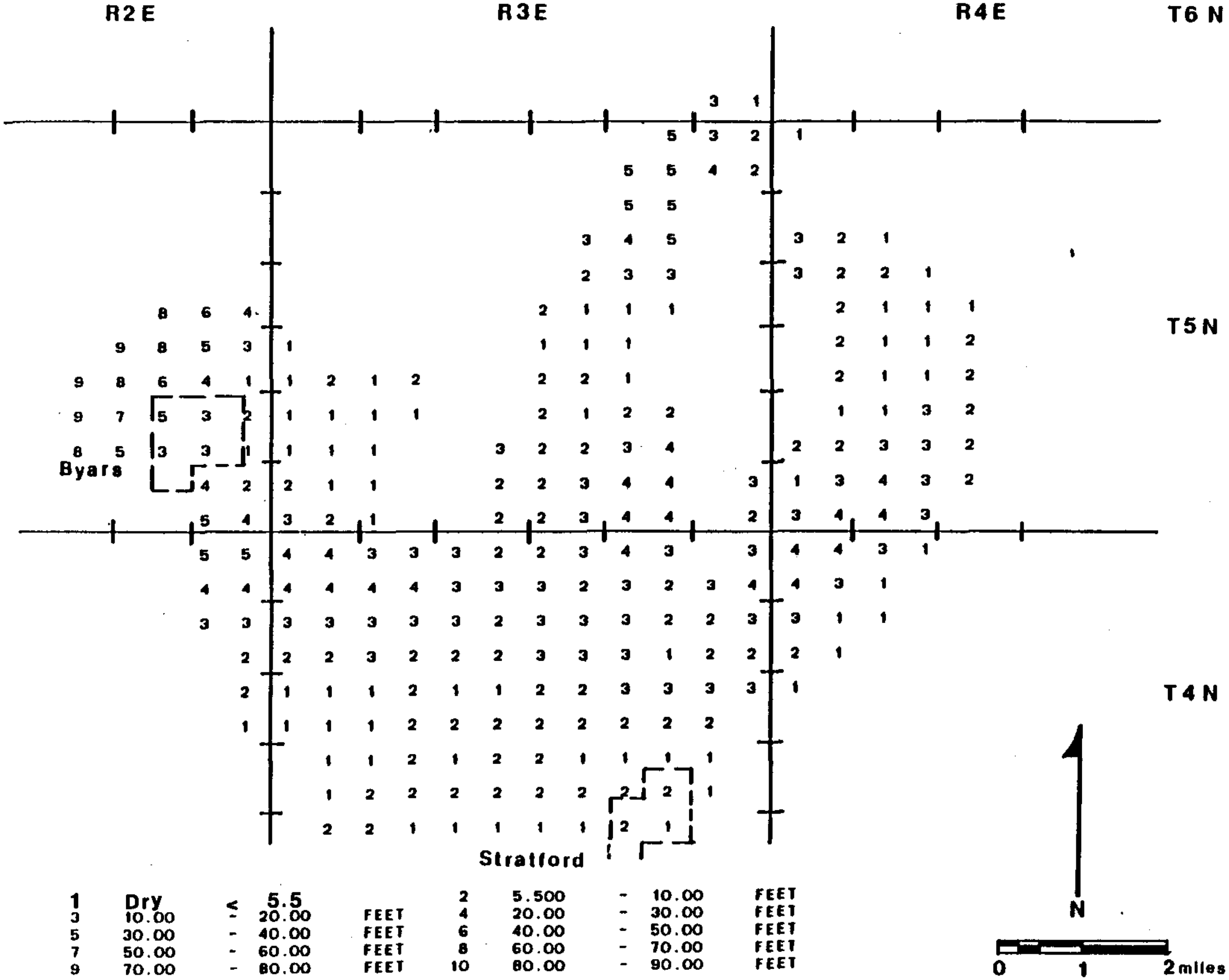


Figure 22. SATURATED THICKNESS ------- 10.00 YEARS

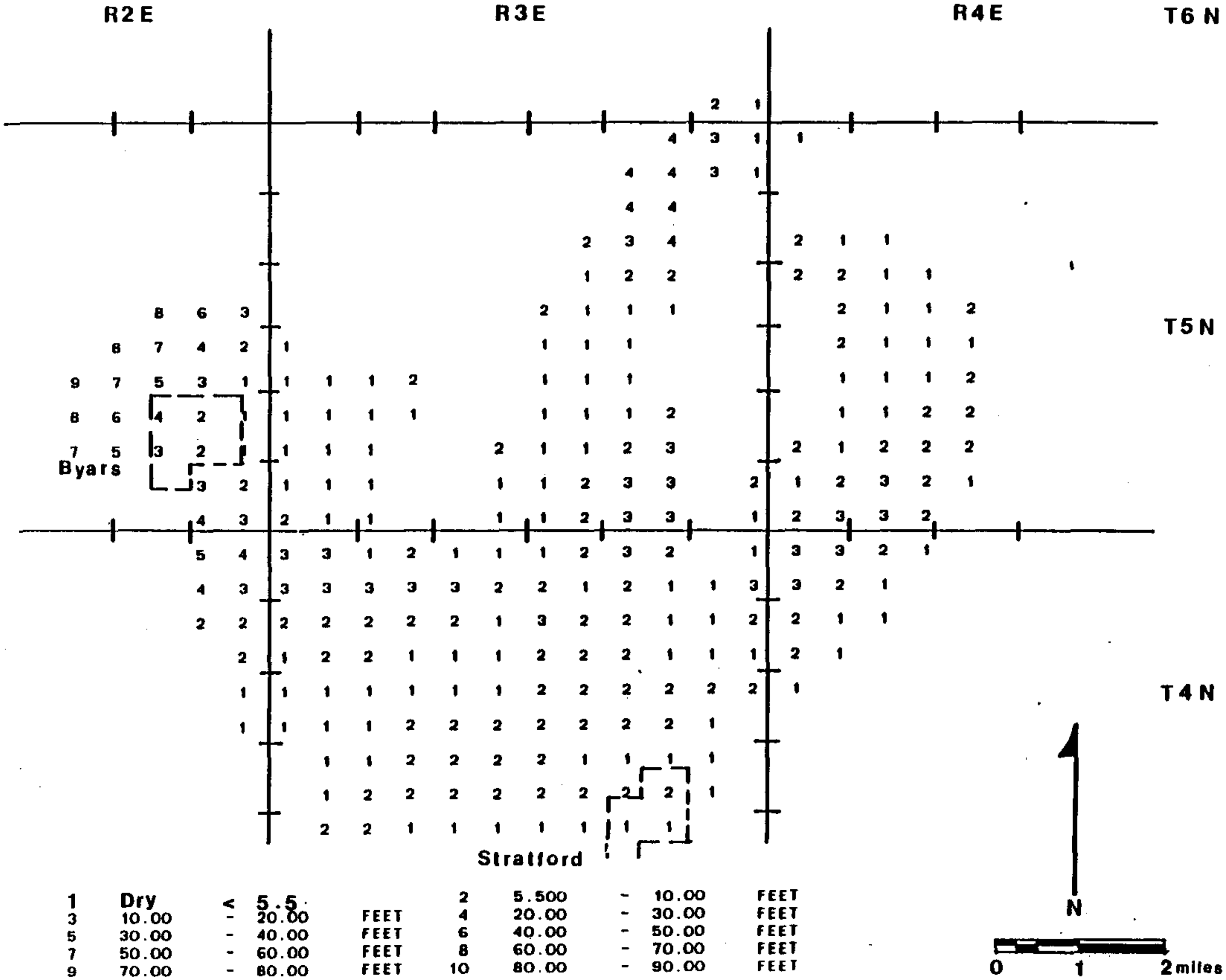


Figure 23. SATURATED THICKNESS -------- 15.000 YEARS

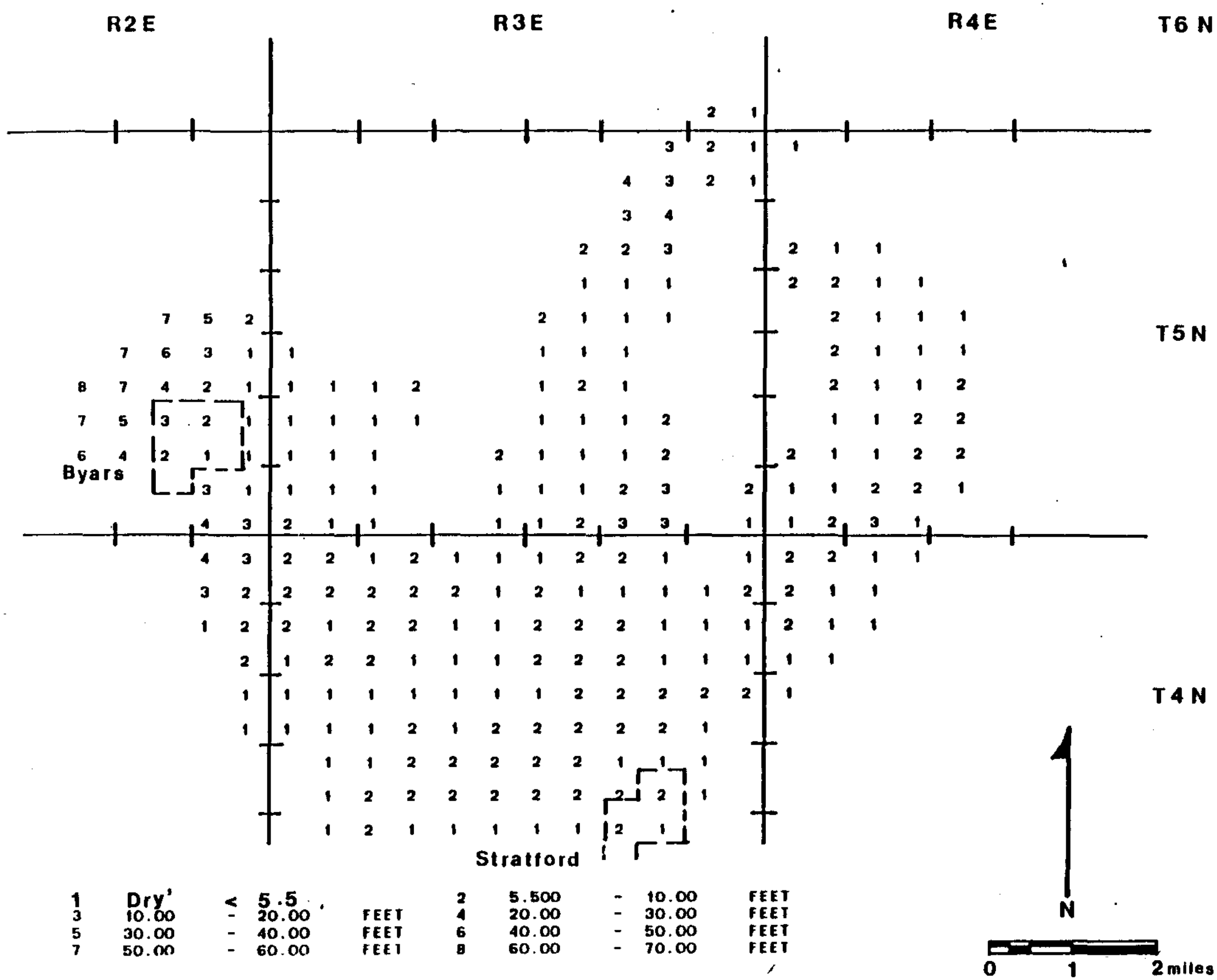


Figure 24. SATURATED THICKNESS -------- 20.000 YEARS

Ground Water Quality

Ground water quality is dependent on initial rain-water quality and chemical reactions which may occur during net recharge (downward percolation) into the aquifer. The ground water was analyzed and tested at several sites in the Isolated Terrace deposit for total hardness, total dissolved solids, sulfate, and chloride. Concentration of these dissolved mineral are a result of the period of contact between the ground water and geologic formations and as a result of natural and man-made pollution. No significant degradation of ground water quality is expected because of the lack of recharge from streams as a result of aquifer depletion.

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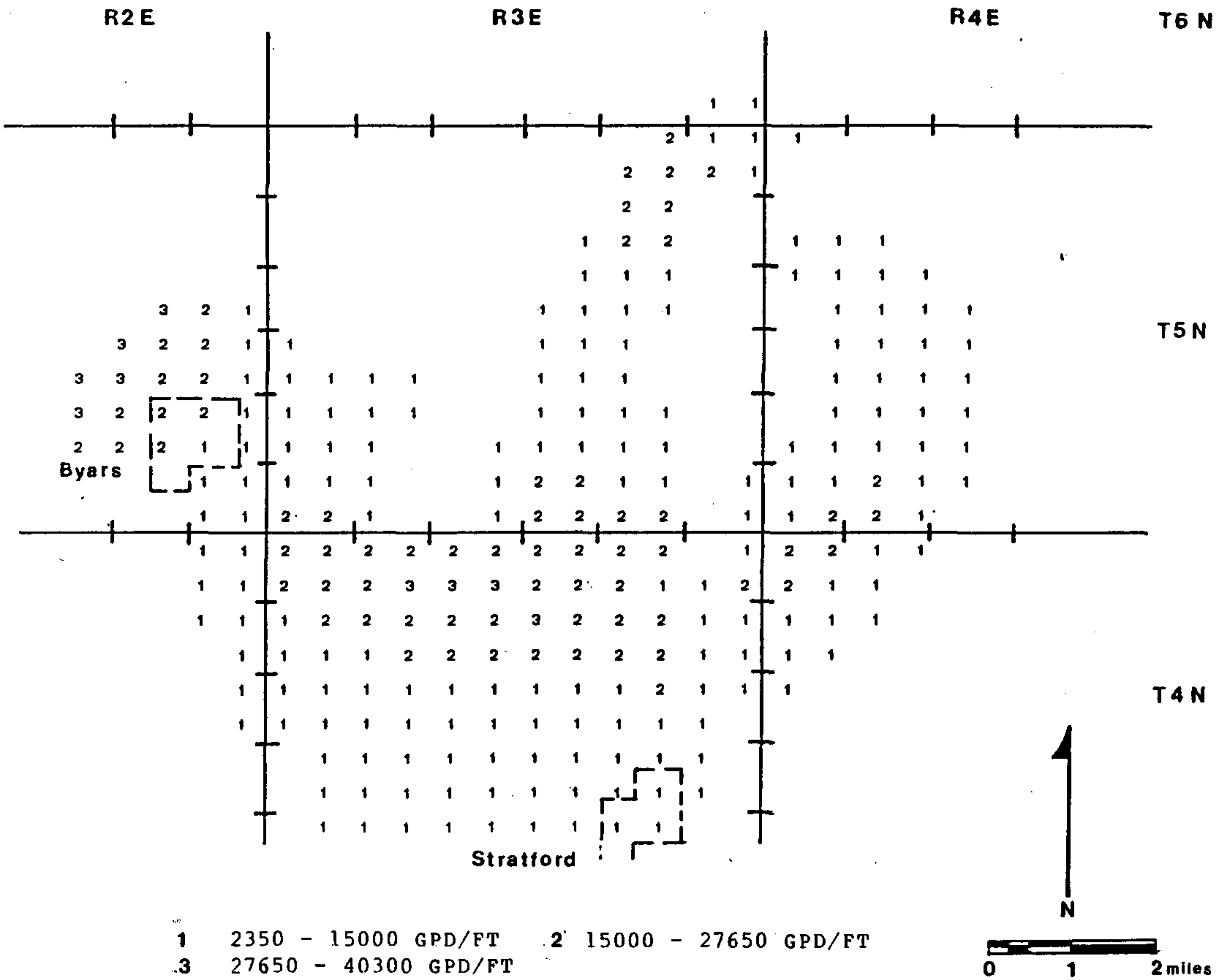
APPENDICES

COMPUTER SIMULATION RESULTS

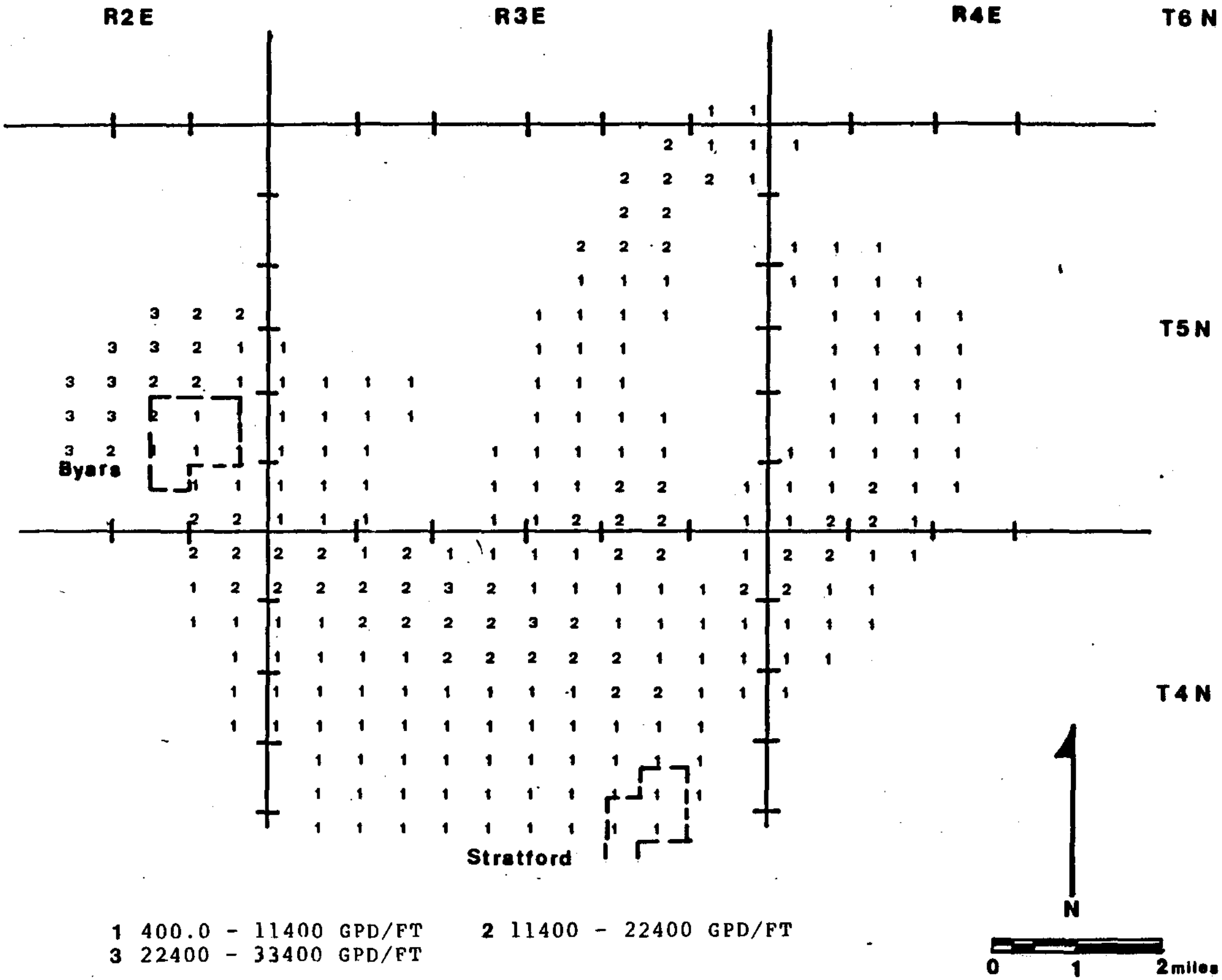
AQUIFER TEST DATA

APPENDIX A

Transmissivity

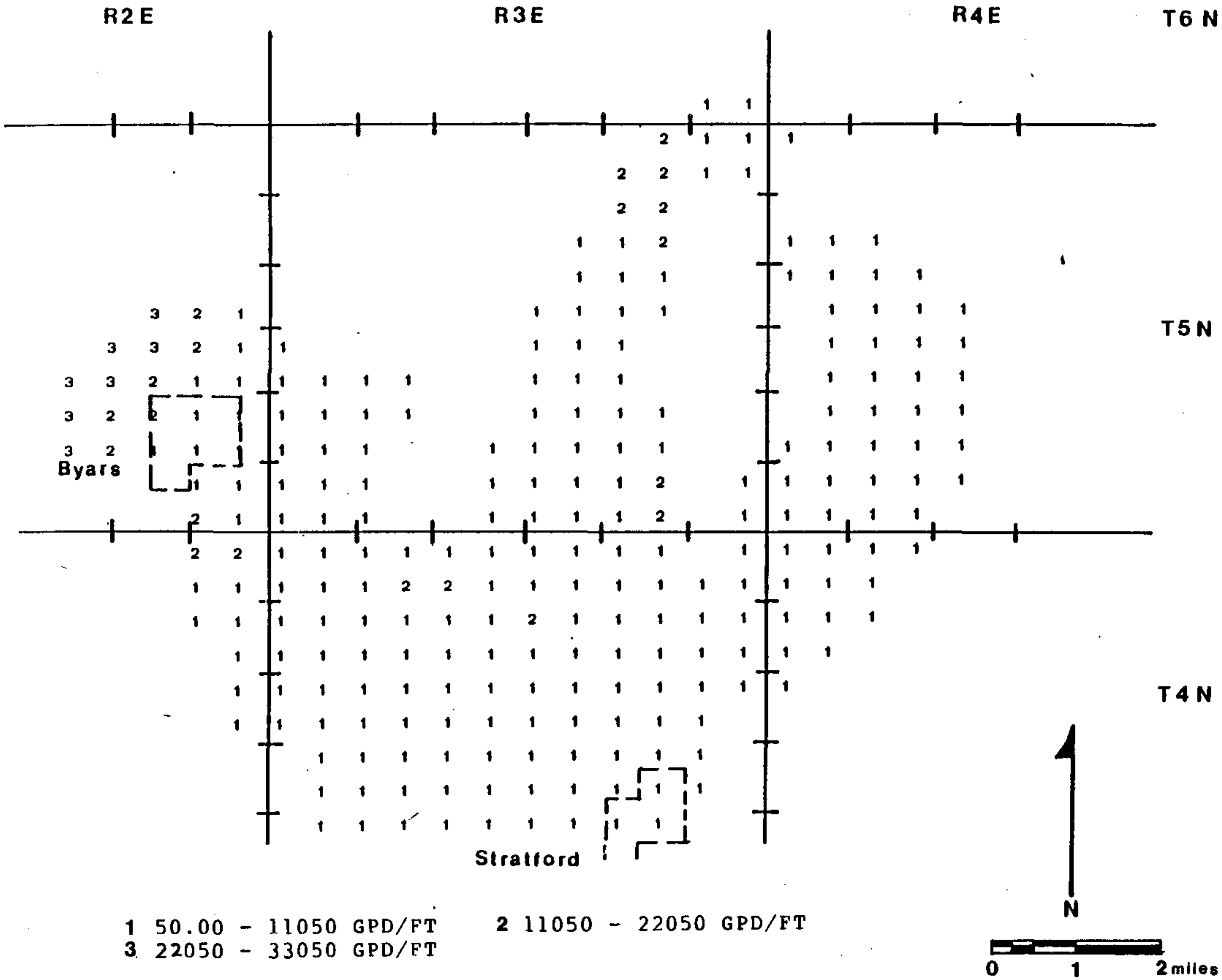


TRANSMISSIVITY --------- 0.000 YEARS

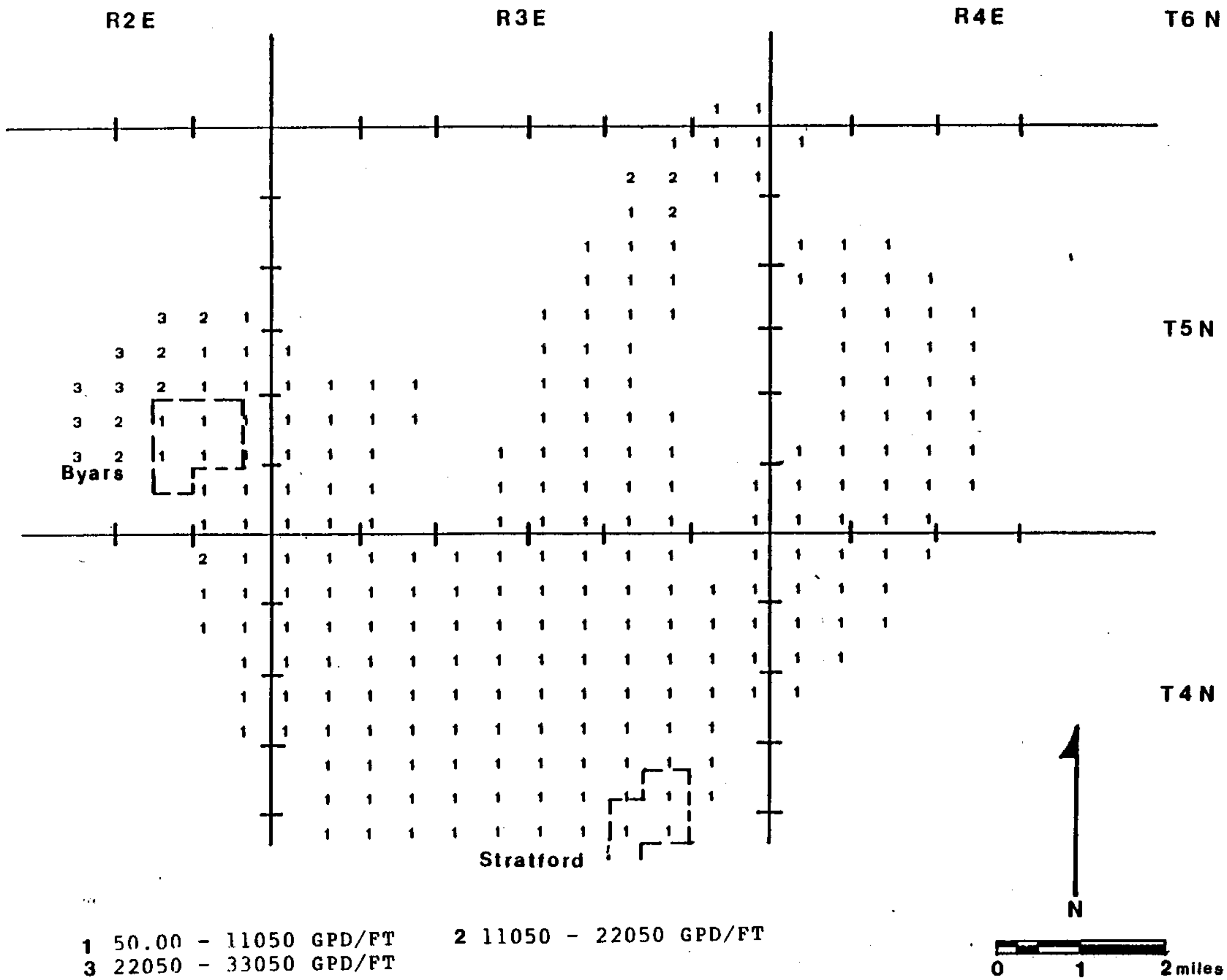


1 400.0 - 11400 GPD/FT
2 11400 - 22400 GPD/FT
3 22400 - 33400 GPD/FT

TRANSMISSIVITY --------- 5.000 YEARS

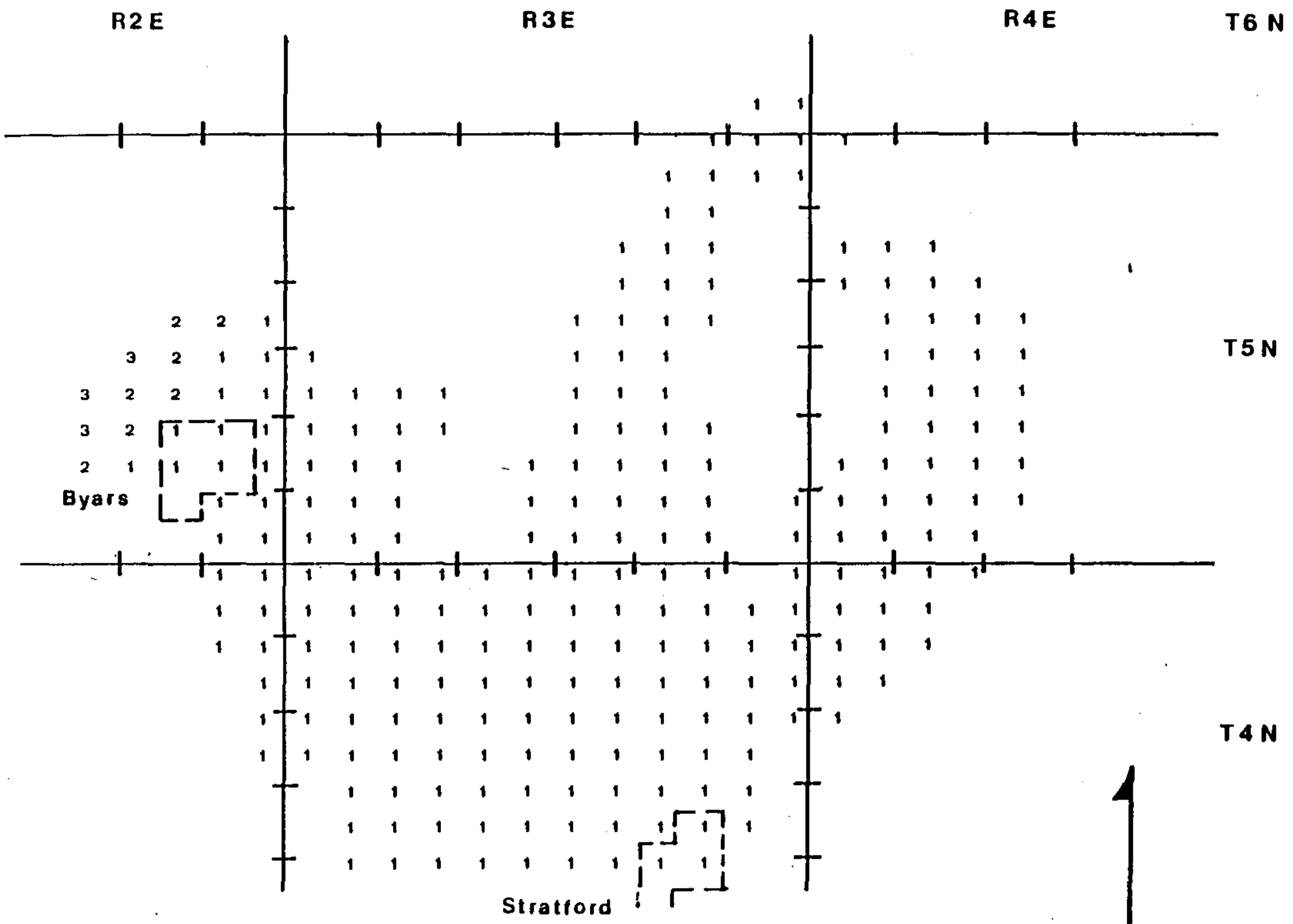


TRANSMISSIVITY --------- 10.000 YEARS



1 50.00 - 11050 GPD/FT 2 11050 - 22050 GPD/FT
3 22050 - 33050 GPD/FT

TRANSMISSIVITY -------- 15.000 YEARS

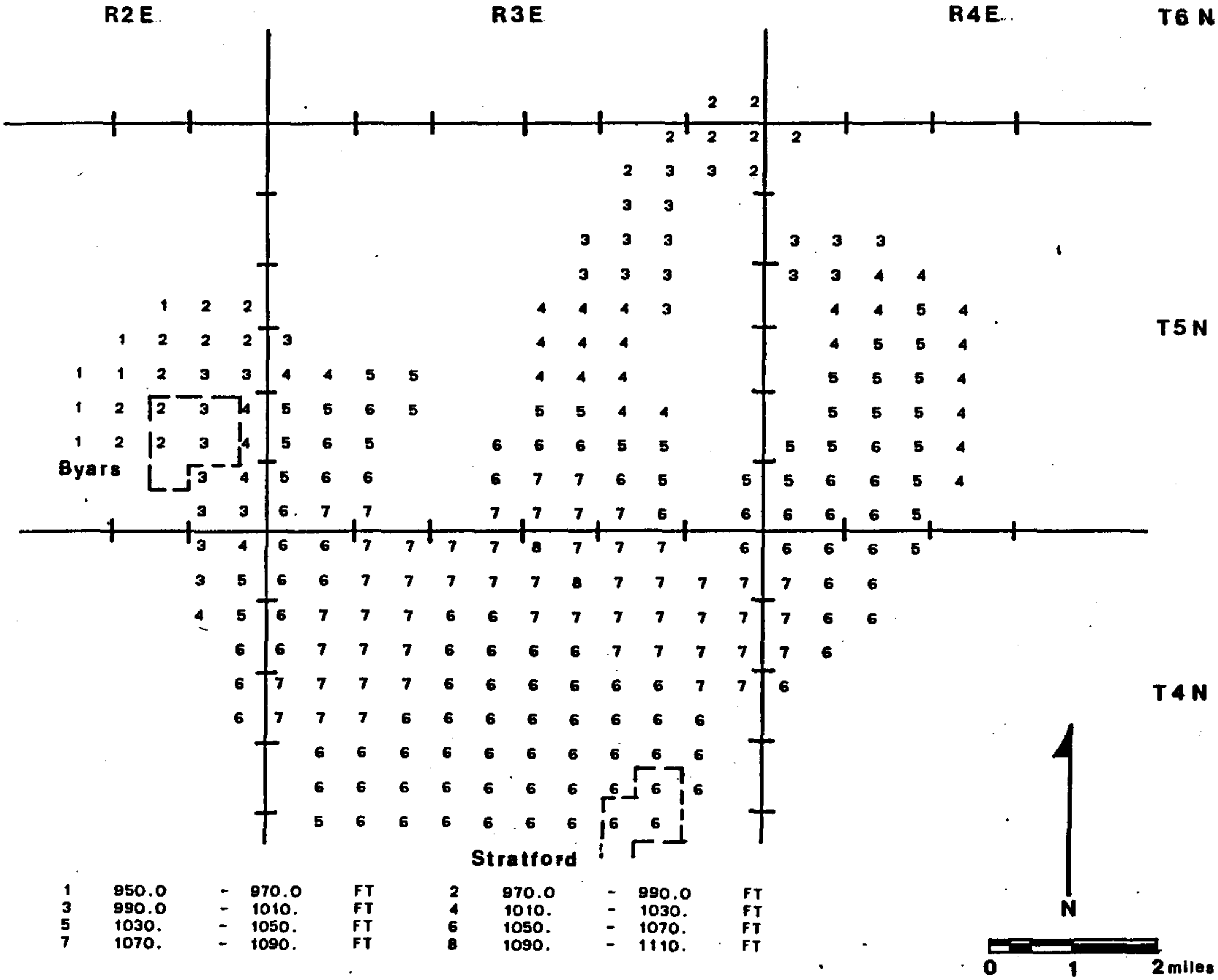


1 60.00 - 11060 GPD/FT   2 11060 - 22060 GPD/FT
3 22060 - 33060 GPD/FT

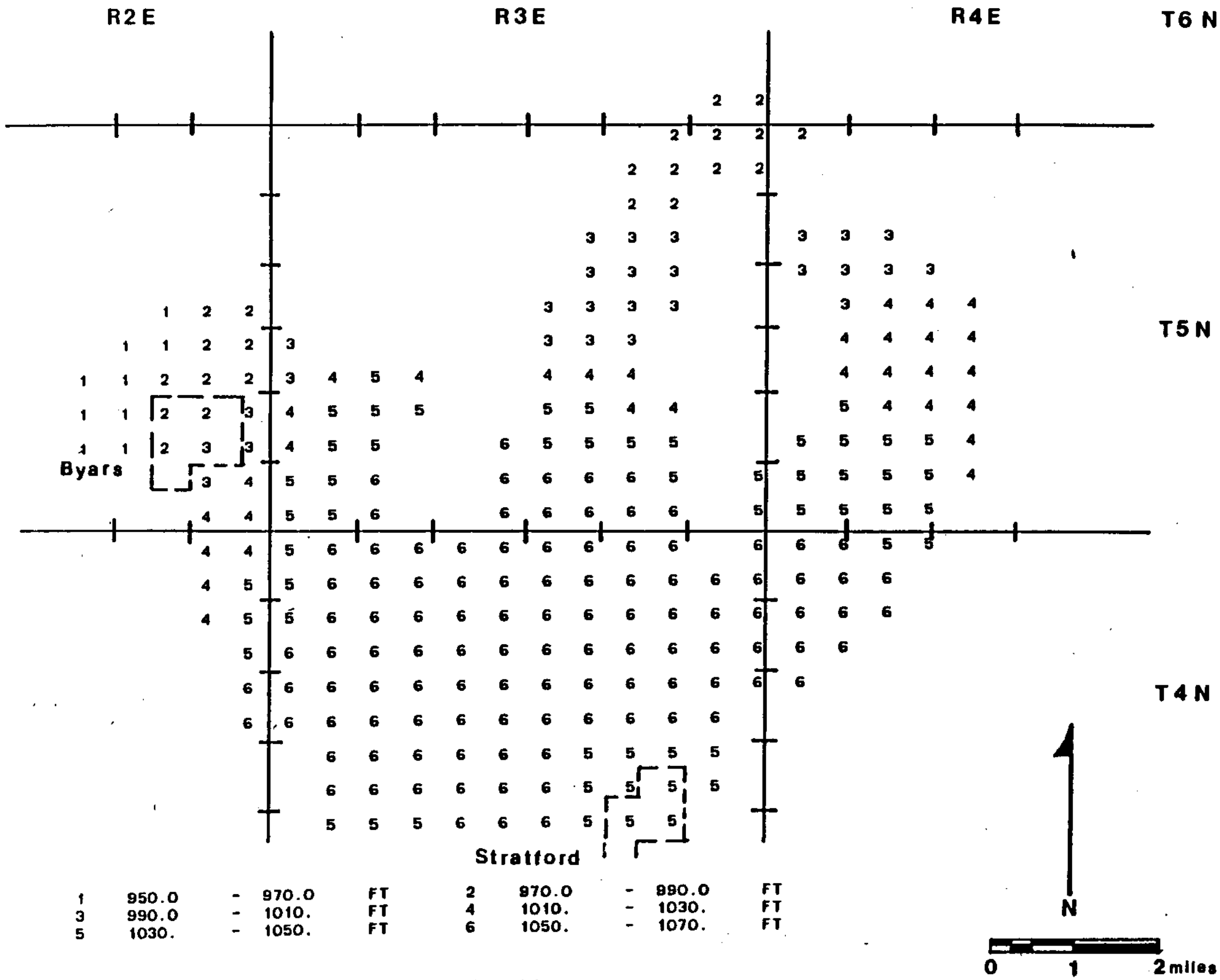
TRANSMISSIVITY --------- 20.000 YEARS

APPENDIX B

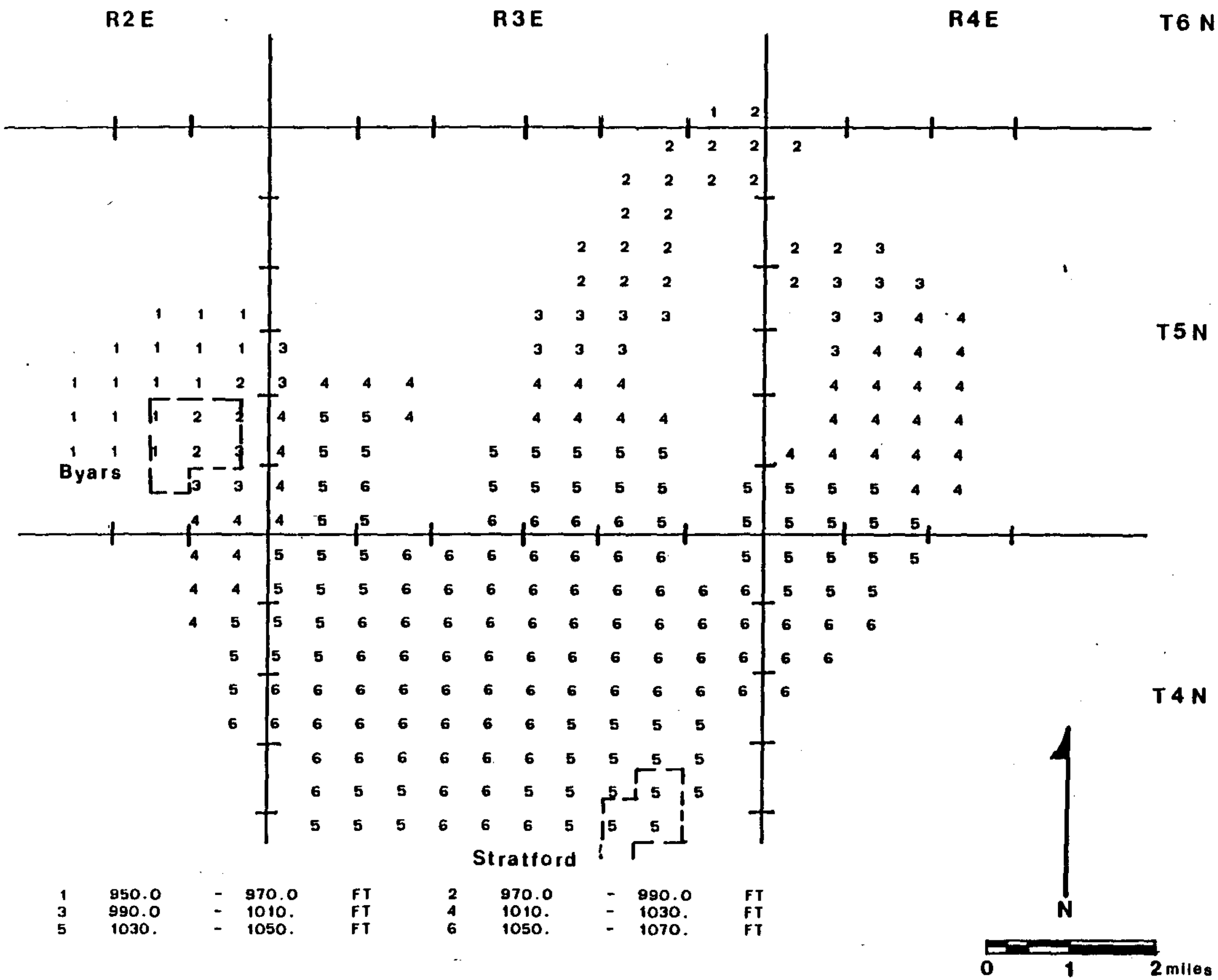
Head Elevation



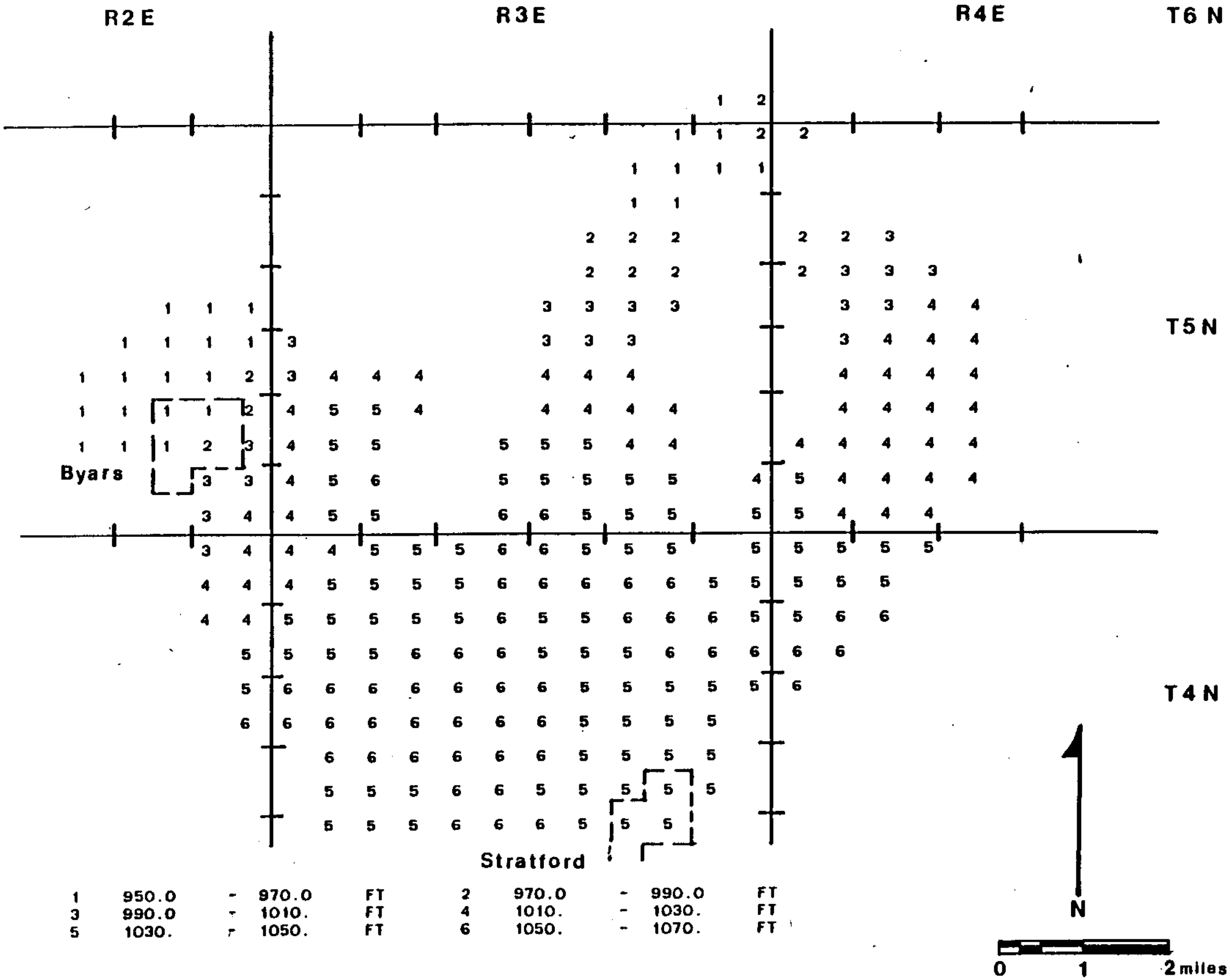
HEAD ELEVATION ---------- 0.000 YERAS



HEAD ELEVATION ----------- 5.000 YEARS

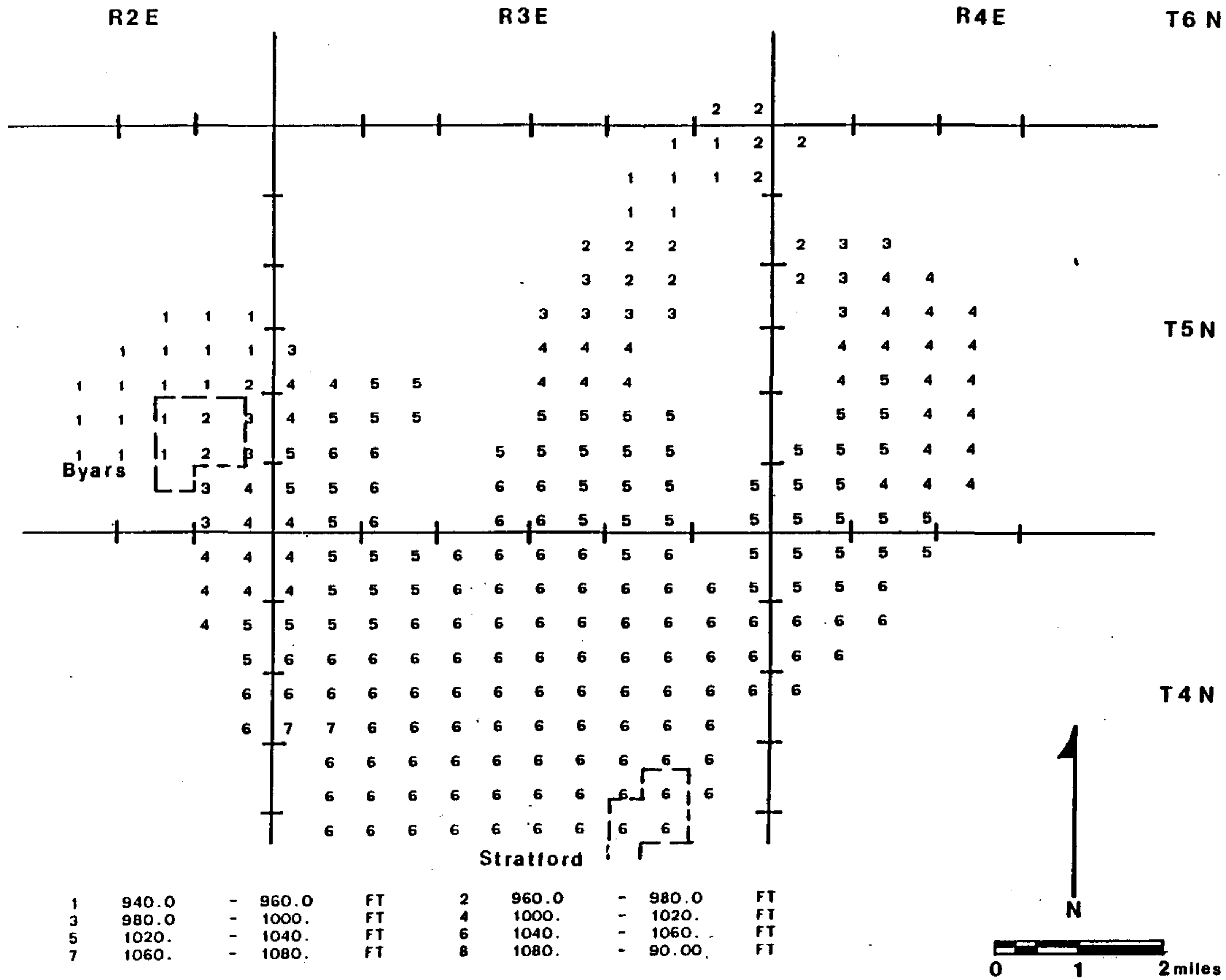


HEAD ELEVATION ----------- 10.000 YEARS



1	950.0	-	970.0	FT
2	970.0	-	990.0	FT
3	990.0	-	1010.	FT
4	1010.	-	1030.	FT
5	1030.	-	1050.	FT
6	1050.	-	1070.	FT

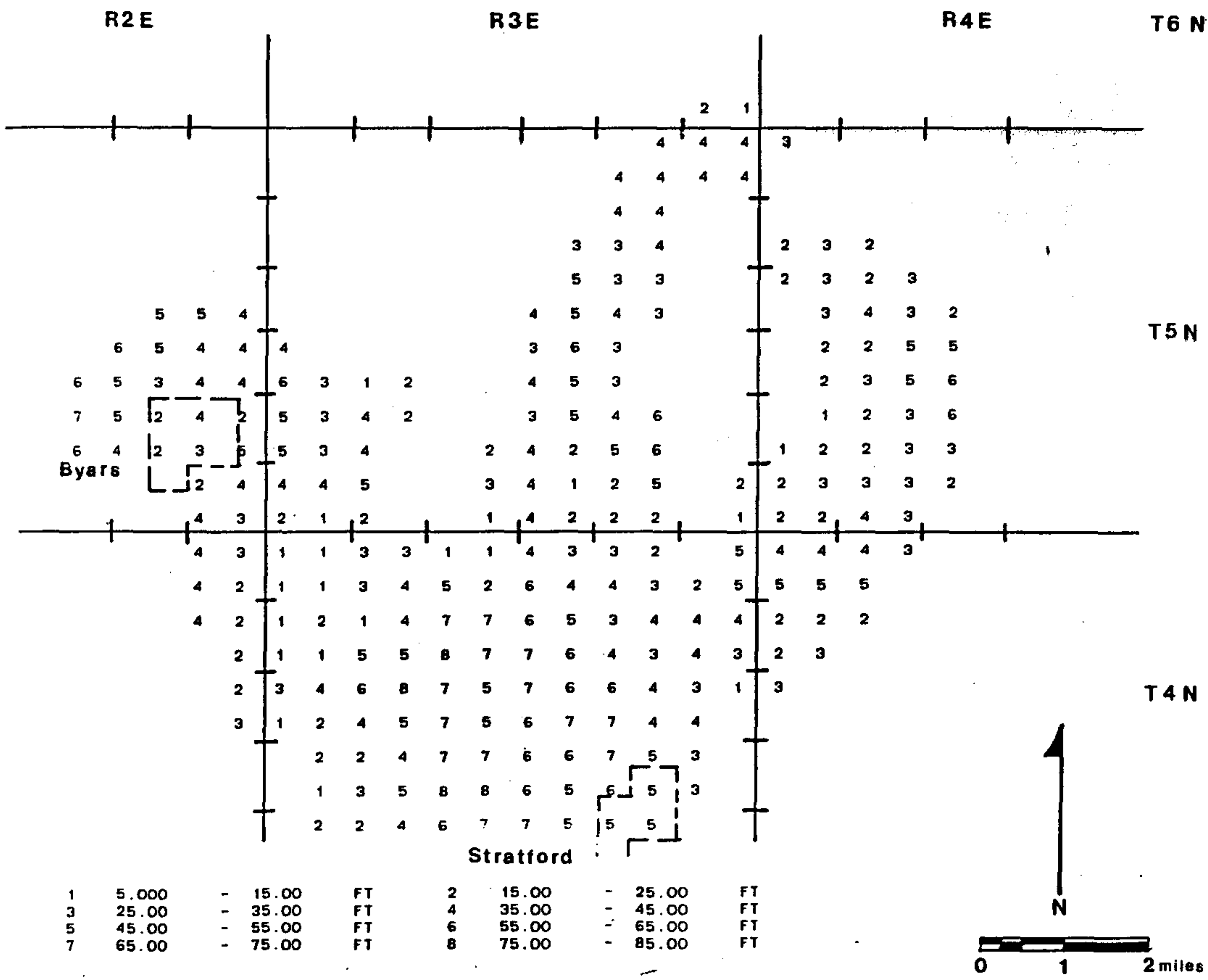
HEAD ELEVATION ----------- 15.000 YEARS



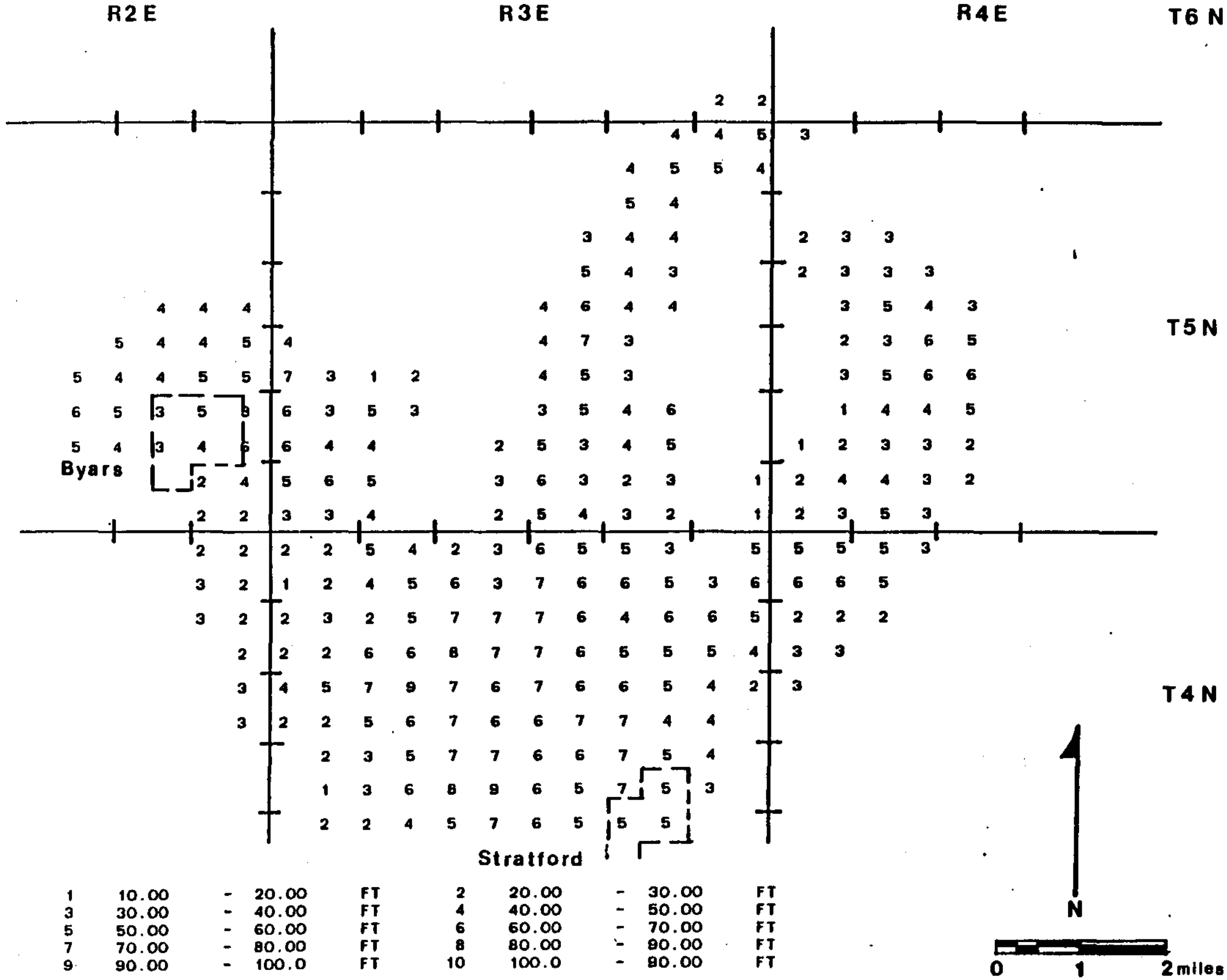
HEAD ELEVATION ----------- 20.000 YEARS

APPENDIX C

Depth To Water

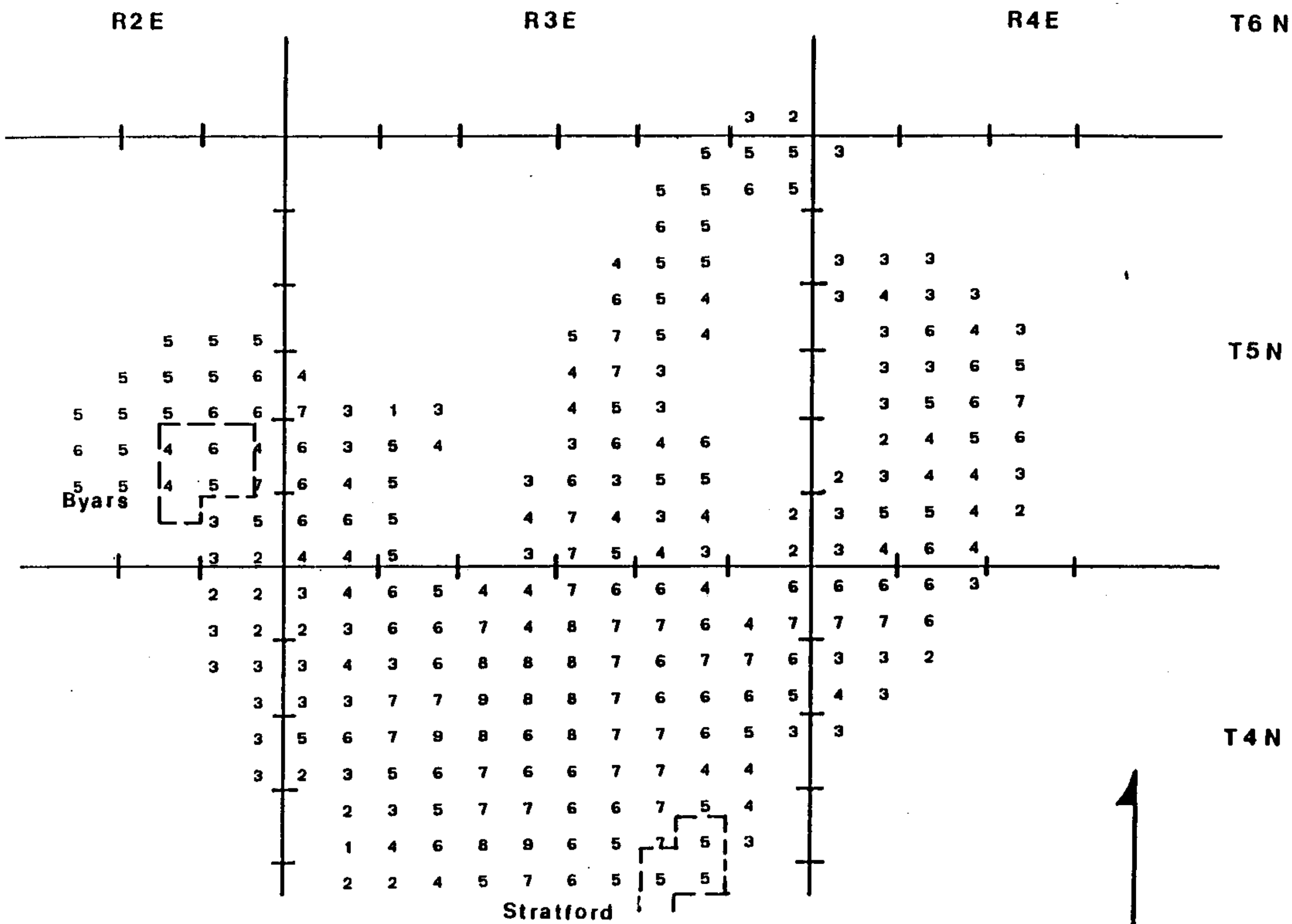


DEPTH TO WATER ---------- 0.000 YEARS



1	10.00	-	20.00	FT	2	20.00	-	30.00	FT
3	30.00	-	40.00	FT	4	40.00	-	50.00	FT
5	50.00	-	60.00	FT	6	60.00	-	70.00	FT
7	70.00	-	80.00	FT	8	80.00	-	90.00	FT
9	90.00	-	100.0	FT	10	100.0	-	80.00	FT

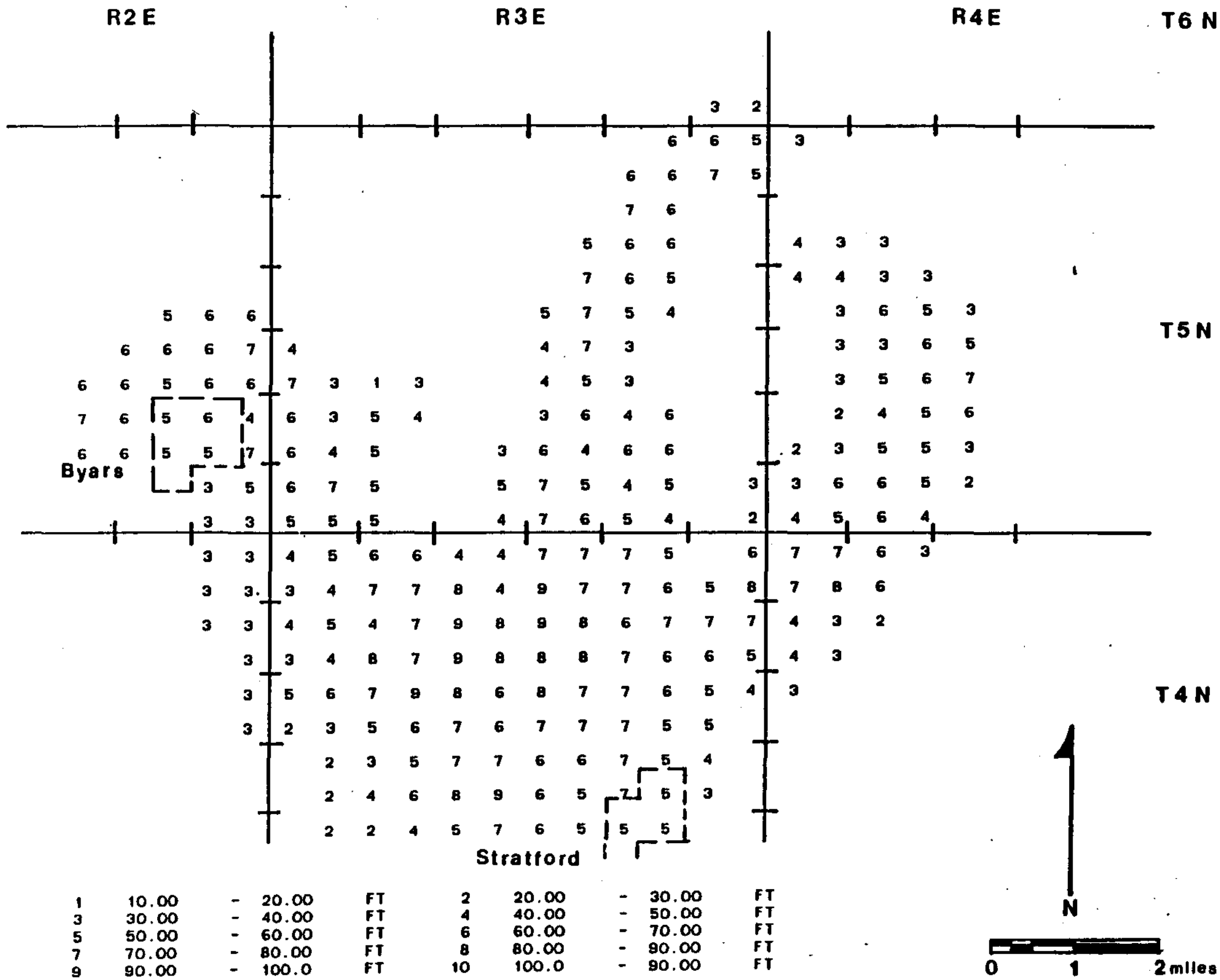
DEPTH TO WATER ---------- 5.000 YEARS



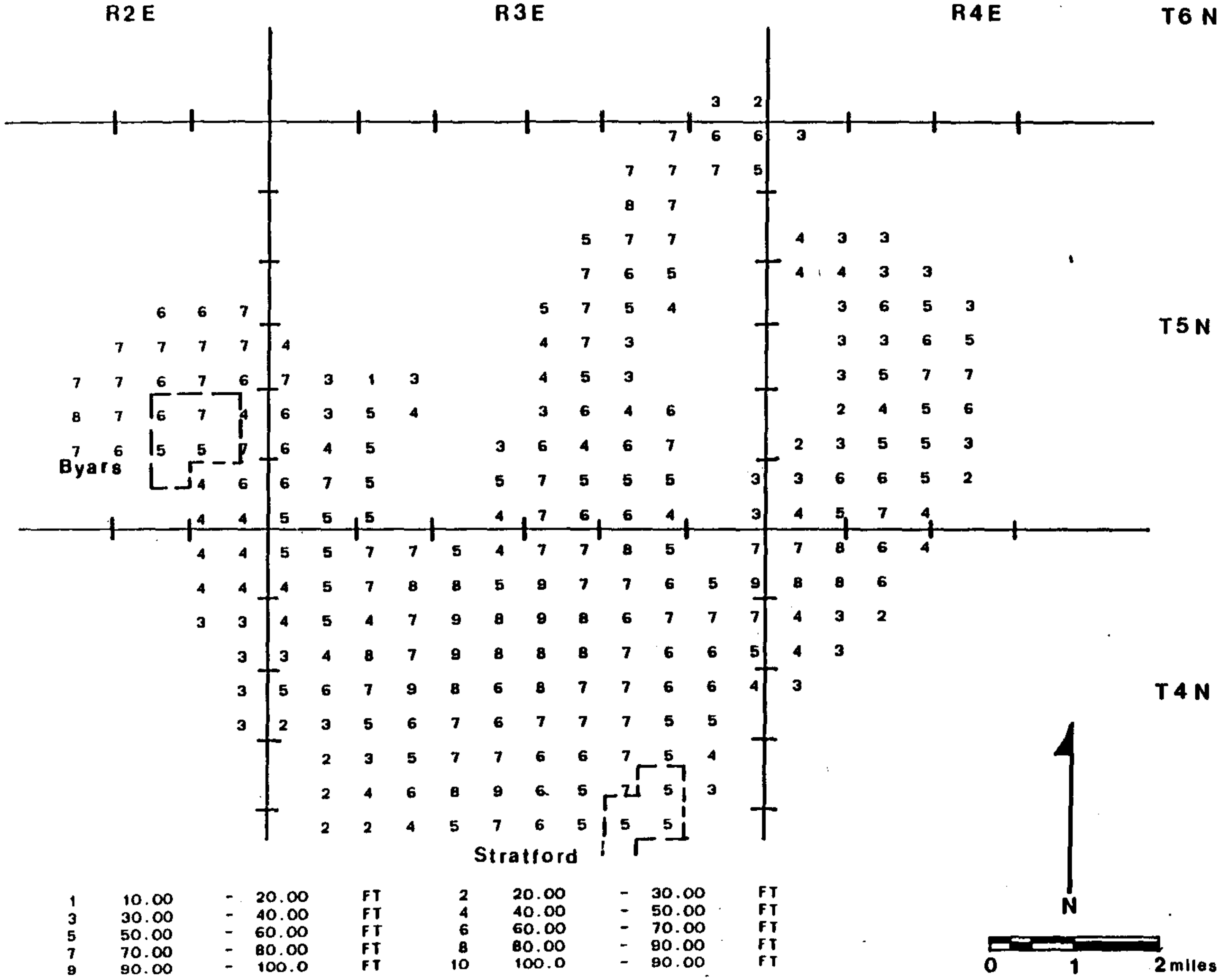
1	10.00	- 20.00	FT		2	20.00	- 30.00	FT
3	30.00	- 40.00	FT		4	40.00	- 50.00	FT
5	50.00	- 60.00	FT		6	60.00	- 70.00	FT
7	70.00	- 80.00	FT		8	80.00	- 90.00	FT
9	90.00	- 100.0	FT		10	100.0	- 90.00	FT

0 1 2 miles

DEPTH TO WATER ---------- 10.000 YEARS



DEPTH TO WATER---------- 15.000 YEARS

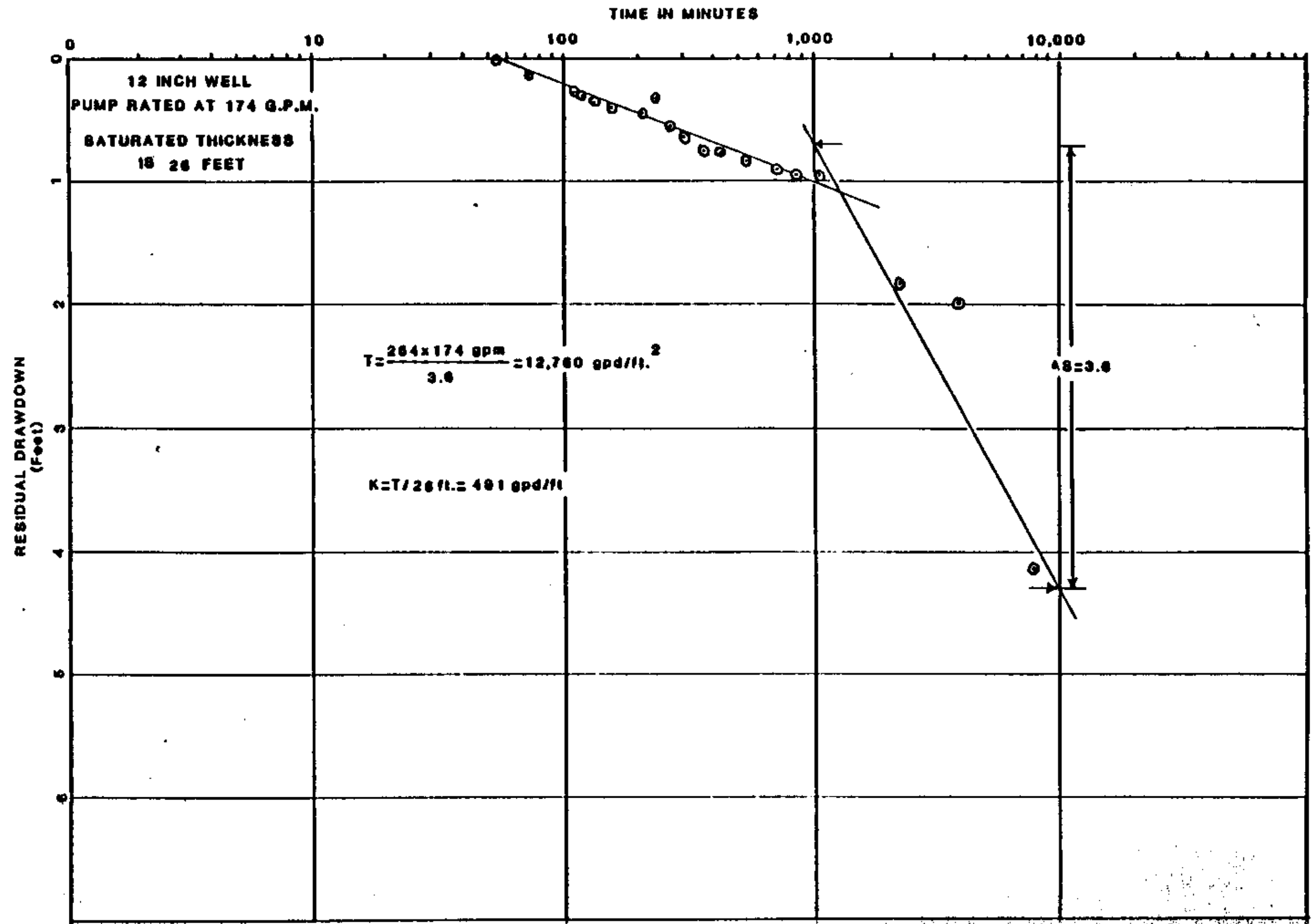


DEPTH TO WATER ---------- 20.000 YEARS

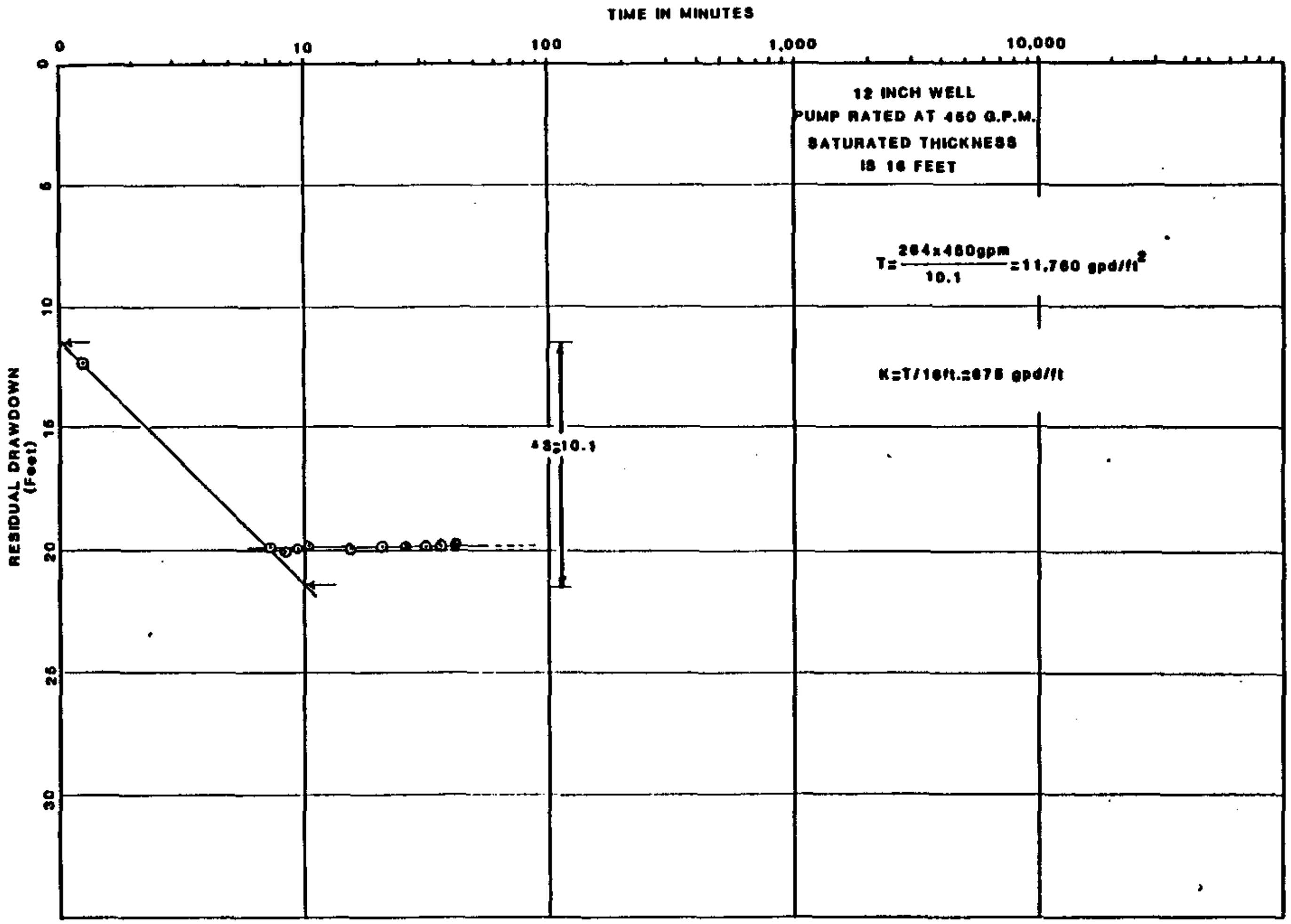
APPENDIX D

AQUIFER TEST DATA

JARRELL RESIDUAL DRAWDOWN CURVE FOR PUMPING WELL



WATT RESIDUAL DRAWDOWN CURVE FOR PUMPING WELL



WATT IRRIGATION WELL AND INFLUENCE OF CONE OF DEPRESSION