HYDROGEOLOGIC REPORT

OF THE

NORTHEASTERN OKLAHOMA MINOR GROUNDWATER BASIN

AND THE

NEOSHO RIVER MINOR GROUNDWATER BASINS

Technical Report 97-3

by
Kent Wilkins

OKLAHOMA WATER RESOURCES BOARD
Planning & Management Division

June 1997

ACKNOWLEDGMENTS

The author is grateful to Mark Belden, Noel Osborn and Robert Fabian in the Planning and Management Division for their technical support and review of the report.

Appreciation is also extended to James Leewright and Mike McGaugh of our Mapping and Drafting Section of the Administrative Services Division for the drafting of the figures in the report; Lou Klaver, Assistant Chief of the Planning and Management Division for her legal review of the document; and Mary Whitlow and Susan Birchfield for their review and editing of the report for final preparation for publication.

This publication is prepared, issued and printed by the Oklahoma Water Resources Board. 75 copies were prepared at a cost of $168.00. Copies have been deposited with the Publications Clearinghouse at the Oklahoma Department of Libraries.

INTRODUCTION

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

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

The purpose of this report is to review, assess, and evaluate hydrologic data pertaining to the groundwater resources in the study area. Data sources include records maintained by the Board, existing hydrogeologic reports and references which assess the study area and hydrologic reports or texts which evaluate hydrogeologic settings similar to the study area.

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

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

A minor bedrock groundwater basin and three minor alluvial and terrace groundwater basins were identified within the study area. The bedrock groundwater basin includes all Pennsylvanian aged units and post Keokuk Mississippian aged units that have not been previously identified as a major or potential major groundwater basin. The bedrock basin has been named the Northeastern Oklahoma Minor Groundwater Basin (NOMGB).

The alluvial and terrace deposits associated with the Neosho River and other smaller tributaries in the study area constitute three minor groundwater basins separated by Grand Lake of the Cherokees and Hudson Lake. The northern basin is comprised of alluvial and terrace deposits of the Neosho River and Spring River above Grand Lake. The middle basin is comprised of alluvial and terrace deposits below Grand Lake and above Hudson Lake along the Neosho River. The southern basin is comprised of alluvial and terrace deposits along the Neosho River below Hudson Lake to the Wagoner County line. Figures 1 and 2 show the boundaries of the respective groundwater basins superimposed upon the public land survey for the study area.

PHYSICAL SETTING

Location

This report will be limited to the minor groundwater basins in Adair, Cherokee, Craig, Delaware, Mayes, Ottawa, and Sequoyah Counties located in Northeastern Oklahoma. The seven county area contains approximately 3,067,000 acres. The counties were selected for this report on the basis of similar groundwater resources and geologic deposits and structure. The principal groundwater basin for this study in terms of surface area is comprised of Pennsylvanian and late Mississippian aged rocks with some minor alluvial and terrace deposits.

Included as separate basins for the study are the alluvial and terrace deposits associated with the Neosho River system. These basins are separated due to the presence of Grand Lake of the Cherokees and Hudson Lake. The Neosho River and the smaller tributary Spring River flow into Oklahoma from the State of Kansas and converge in Ottawa County. The Neosho River continues southward, flowing into Grand Lake of The Cherokees which is located primarily in Delaware County. Flow from the Neosho River then continues southwestward into Mayes County and Lake Hudson. Below Lake Hudson Dam, the Neosho River flows southward until it exits the study area into Wagoner County.

The alluvial and terrace deposits, associated with the Arkansas River system along the southern border of Sequoyah County are a potential major basin and will not be considered in this report. Also excluded from this report are the Keokuk and Reeds Spring Formation and St Joe Group (Boone Aquifer) which outcrop north and east of the study area and underlie the NOMGB. The deeper Mississippian, Devonian, and Ordovician aged formations which underlie both the NOMGB and the Boone Aquifer are considered major or potential major aquifers and have also been excluded.

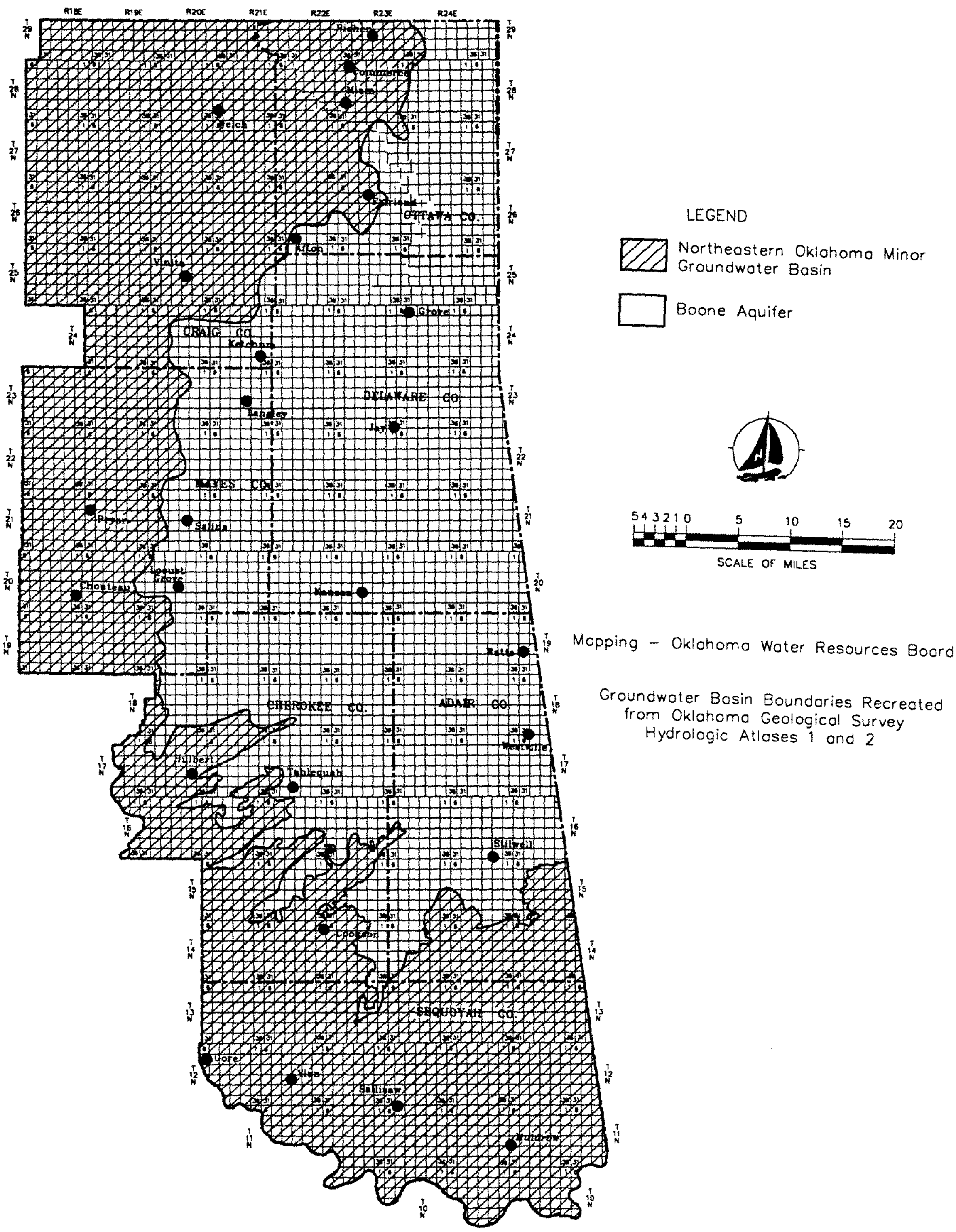


Figure 1. Boundary Map for Northeastern Oklahoma Minor Groundwater Basin

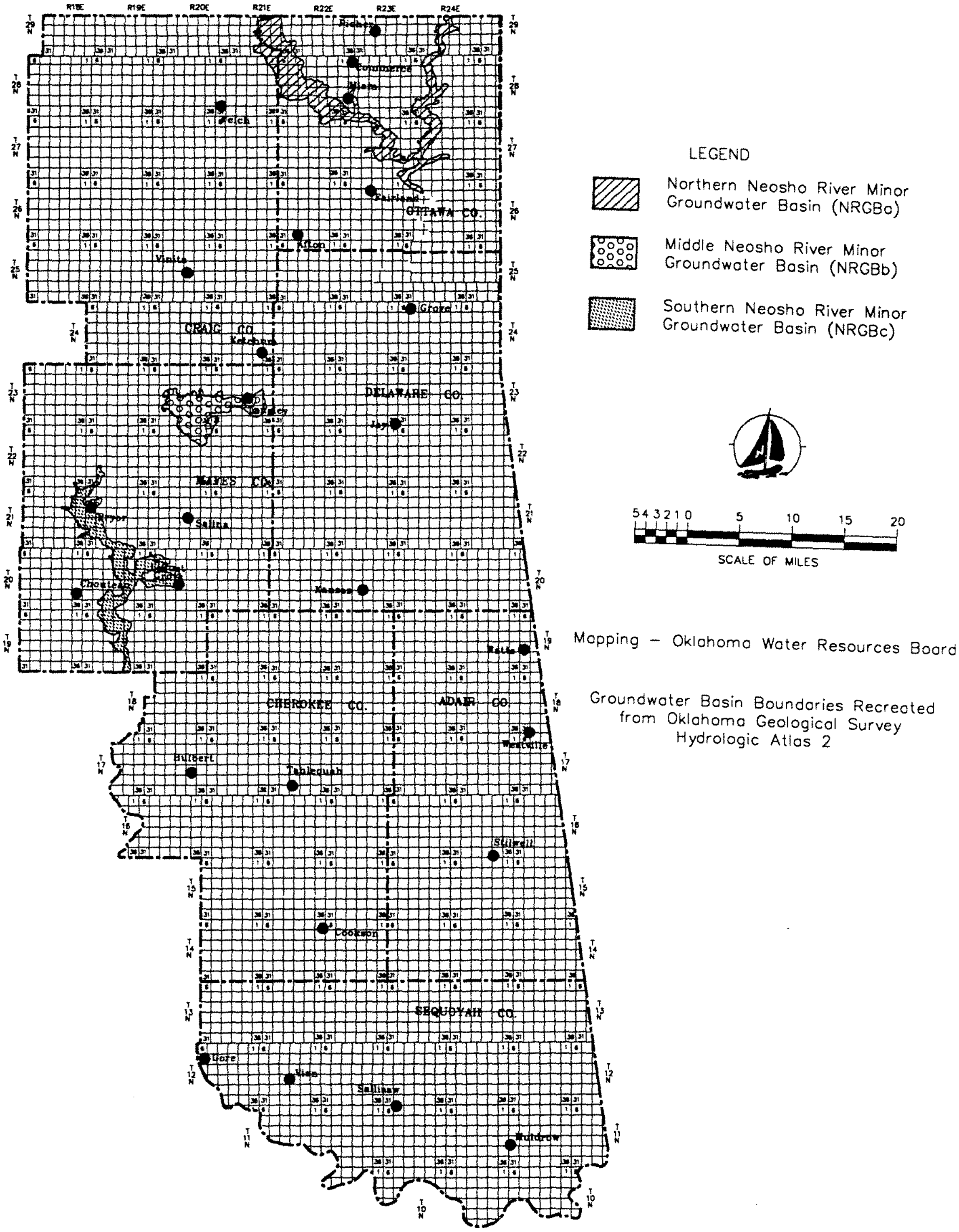


Figure 2. Boundary Map for Neosho River Minor Groundwater Basins

Setting

The land encompassed within the study area varies from farm and rangeland areas to forest areas. Topographic differences range from less than 500 feet above sea level along the Arkansas River in southern Sequoyah County to over 1200 feet above sea level in Delaware County.

The study area covers three separate Physiographic Provinces. The eastern section of the study area is located in the Ozark Plateau Province. This area has developed on cherty limestones of Mississippian age that have relatively uniform resistance to erosion. The land surface is gently rolling along the broad interstream, but becomes hilly to rugged toward the stream valleys. The western section of the study area is in the Osage Plains. This area is underlain by weakly resistant formations from the Krebs and Cherokee Groups which form a broad, nearly featureless plain. The southern section of the study area is located in the Ouachita Province and consists of broad, gently rolling plains and valleys with local hills and ridges capped with resistant sandstones of Pennsylvanian age. (Marcher et al, 1987).

Climate

Climate in the study area ranges from a temporate, continental climate in the north to a warm-temporate, continental climate in the south. The climate is characterized by pronounced daily and seasonal changes in temperature and variations in seasonal and annual rainfall. Seasonal changes are gradual, but the characteristics of each season are distinct. Rapid change is common and results in significant fluctuations of temperature, humidity, wind and precipitation (Cole et al, 1970, Cherokee and Delaware Counties; Abernathy, 1970, Sequoyah County; and Newland, 1973, Craig County).

Winters are comparatively mild and short with only brief periods of low temperatures and snow cover. Summers are typically long and hot. Spring is a season of variable weather as noted by the greatest amounts and intensities of precipitation and the most frequent occurrences of severe local storms and tornadoes (Cole et al, 1970, Cherokee and Delaware Counties; Abernathy, 1970, Sequoyah County; and Newland, 1973, Craig County).

The mean annual precipitation ranges from 41 inches per year in western Craig County to 44 inches in southern Sequoyah County (OWRB, 1990). The mean annual precipitation for the study area was determined to be 42 inches. The minimum and maximum annual precipitation values have been 18.84 and 75.36 inches respectively in the study area. Snowfall ranges from about 4.5 inches per year in Sequoyah County to 8.7 inches in Craig County (Cole et al, 1970, Cherokee and Delaware Counties; Abernathy, 1970, Sequoyah County; and Newland, 1973, Craig County). .

Average monthly temperature ranges from 38.0 degrees in January to 82.0 degrees in July with an average annual temperature of 60 degrees. Winds generally prevail out of the south or southeast with the exception of winter when northerly winds prevail (Cole et al, 1970, Cherokee and Delaware Counties and Newland, 1973, Craig County).

Regional Geology

The area of study is dominated structurally by the Ozark Uplift, a broad dome centered in southern Missouri and extending into northeastern Oklahoma. Because the study area is on the western flank of this structural high, progressively younger formations outcrop from the east to west. The regional dip of the formations in the northern portions of the study area is towards the west-northwest at approximately 30 feet per mile. The dip is interrupted by local folds of small magnitude and minor faults with displacement of a few tens of feet (Marcher et al, 1984, Branson, 1965, Huffman, 1966, and Starke, 1961).

The southern portion of the study area is located in the Arkoma Basin. Formations in the basin have been folded to form northeast to east treading synclines and anticlines. Dips on the limbs of the structures generally range from 10 to 40 degrees. The crests on some anticlines have been broken by thrust faults with displacement of several hundred feet (Marcher et al, 1987).

Formations outcropping at the surface range from the Moorefield Formation of late Mississippian age to the Oologah Formation of Pennsylvanian age (see Table 1). The formations for this study range in thickness from a few feet along the western edge of the Keokuk-Reeds Spring outcrop to approximately 700 feet in the northwestern and southeastern portions of the study area.

The Pennsylvanian deposits in the study area consist of 70 percent shale, 20 percent sandstone, and 10 percent limestone and other types. The percentage of shale decreases from south to north whereas the percentage of limestone increases. Shale units typically are 50-100 feet thick and limestone and sandstone units are 5-20 feet thick (Marcher et al, 1984). Mississippian aged formations, which underly the Pennsylvanian deposits and outcrop in the northeastern portion of the study area, consist mainly of cherty limestones with a few thin shale units (Marcher et al, 1984).

Alluvium along the Neosho River may be as much as 30 feet thick, but generally is less than 20 feet (Marcher et al, 1984). Because of the predominantly shale bedrock in most of the area, alluvium consists mainly of sandy silt and clay silt with thin layers of sand or gravel at the base. Terrace deposits also consist almost entirely of clay to sandy silt, but can consist of sand in localized areas.

TABLE 1. PENNSYLVANIAN AND LATE MISSISSIPPIAN-AGED STRATA IN THE STUDY AREA.

SYSTEM	SERIES	GROUP	FORMATION
Pennsylvanian	Des Moines	Marmaton	Oologah
			Labette
			Fort Scott
		Cabaniss	Senora
		Krebs	Boggy
			Savanna
			McAlester
			Hartshorne
	Atoka	Atoka	Atoka
Mississippian	Chester		Pitkin
			Fayetteville
			Batesville
			Hindville
	Meramec		Moorefield

Taken from Marcher, 1969 and Marcher and Bingham, 1971

GROUNDWATER RESOURCES

Northeastern Oklahoma Minor Groundwater Basin

The NOMGB for the seven county area comprises 1,621,338 acres of Pennsylvanian, and late Mississippian deposits that occur as shale, siltstone, coal, thin limestones, and widely separated sandstone units. The boundary for the NOMGB is shown on Figure 1.

Because of the geologic structure, the Pennsylvanian and late Mississippian formations are slightly tilted at the surface exposing bedding plane openings between the layers of sandstone and partings between laminae of shale. Bedding plane openings are the principal avenues for water entry and movement. Water also moves through fractures and joints formed during folding of the brittle rocks. Recharge entering the basin is derived mainly from precipitation falling on the outcrop. Most discharge is by evaporation, although some water is discharged to streams during periods of high water levels. A small quantity of water is discharged by pumping domestic water wells.

Groundwater in the upper portions of the aquifer is generally unconfined, whereas water in the deeper portions of the aquifer is confined and may flow to the surface in times of high water levels. In shallow unconfined portions of the aquifer, the slope of the potentiometric surface coincides with the slope of the land surface so the local direction of water movement is toward the streams and valleys (Marcher et al, 1984).

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be represented in terms of storage coefficient and transmissivity. For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. For this study, specific yield was estimated to be 0.01. This number represents an approximate mean of the range of values given by Driscoll (1986) for the type of formations which comprise the NOMGB. Typical deposits in the basin consist of a sequence of interbedded shale, sandstone, and limestone. The formations have very little primary porosity and their ability to store and transmit water is limited (Marcher et al, 1984).

Figure 3 is a thickness map for the Pennsylvanian and late Mississippian formations in the study area. Data for Figure 3 were derived from OWRB Multi-Purpose Completion Reports, measured sections reported by Huffman et al (1966), and oil and gas well data and measured sections reported by Branson et al (1965). Average formation thickness was estimated to be 250 feet. Review of the Multi-Purpose Completion Reports indicates that groundwater in the basin is generally encountered within 50 feet of land surface. Therefore, the average saturated thickness was estimated at approximately 200 feet.

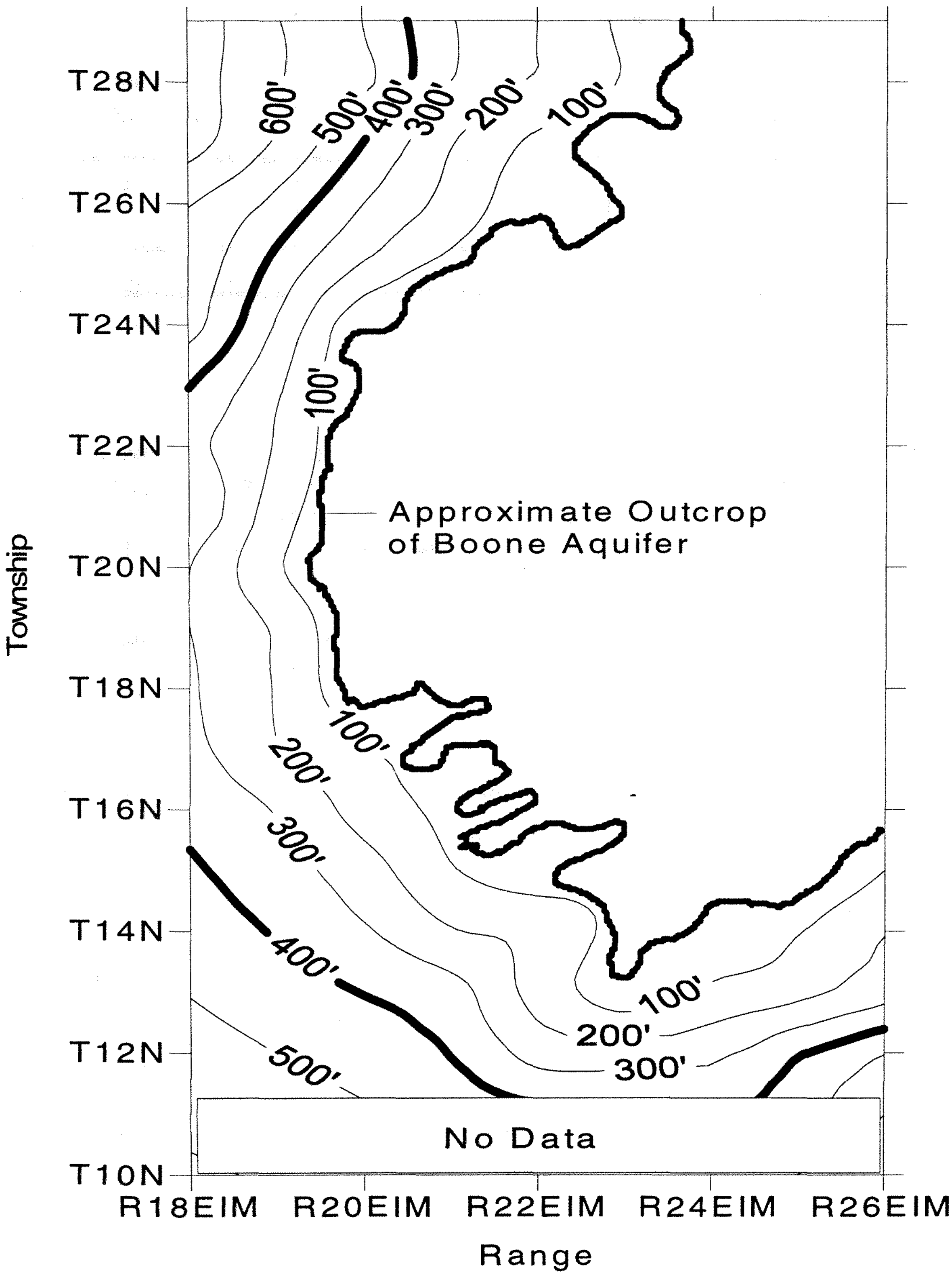
Hydraulic conductivity (K) is estimated for the NOMGB based on the mean K taken from hydrogeologic texts which provide ranges of possible K values for different consolidated aquifers (Freeze and Cherry, 1979). Formations which consist primarily of slightly fractured shale, siltstone, cherty limestone, and sandstone are reported to have K values ranging from 2.8×10^{-2} ft/day to 2.8×10^{-5} ft/day. For this study, K was estimated at 0.003 ft/day. Transmissivity, a product of the saturated thickness and hydraulic conductivity, is estimated to be 0.6 ft^2/day.

Recharge is generally very limited, but can be significant in areas where bedding planes or joints or fractures are exposed at the surface. The amount of annual recharge to the basin is estimated to be 2.1 inches per year, which is 5 percent of the average annual precipitation (Marcher, 1969).

Aquifer Storage and Yield Capabilities

Initial storage for the NOMGB is estimated at approximately 3,243,000 acre-feet of groundwater. This value is obtained by multiplying the area of the basin by the specific yield and the estimated saturated thickness of the basin.

FIGURE 3. Thickness Map of Pennsylvanian & Mississippian Formations in the NOMGB



Groundwater availability is limited in the study area. Most wells yield only a fraction of a gallon per minute to a few gallons per minute (Marcher and Bingham, 1971). The mean well yield as determined from OWRB well records is approximately 4 gallons per minute. Locally, yields of 20 gallons per minute have been obtained from wells penetrating thicker sandstone units in the area (Marcher and Bingham, 1971). Table 2 shows a summary of the aquifer parameters and aquifer storage for the NOMGB.

Table 2. Summary of Aquifer Parameters and Storage for the NOMGB.

Area (acres)	Specific yield	Saturated Thickness (ft)	K (ft/day)	T (ft^2/day)	Recharge (in/yr)	Mean Well Yield (gpm)	Storage (acre-ft)
1,621,338	0.01	200	0.003	0.6	2.1	4	3,243,000

K - Hydraulic Conductivity
T - Transmissivity

Water Use

Groundwater use in the study area appears to be limited primarily to household and stock water use. In many parts of the study area, adequate supplies of suitable groundwater are not available and water districts have been established to meet the domestic, commercial, and industrial needs of rural areas. Farm ponds have also been constructed to provide water for livestock.

The total amount of groundwater permitted within the NOMGB is 96.0 acre-feet per year. No permits have been issued in Adair, Delaware, Mayes and Ottawa Counties within the basin. OWRB records indicate that no water use was reported by permit holders within the NOMGB for 1996. Table 3 summarizes the permit and water use data for the basin.

Table 3. Permit and Water Use Information in the NOMGB by County for 1996.

County	Purpose	No. of Permits	Permitted Amount	Reported Use
Cherokee	Commercial	1	2.0 ac-ft	0.0 ac-ft
Craig	Industrial	1	56.0 ac-ft	0.0 ac-ft
Sequoyah	Commercial	1	5.0 ac-ft	0.0 ac-ft
	Irrigation	2	33.0 ac-ft	0.0 ac-ft
	Total	5	96.0 ac-ft	0.0 ac-ft

Compiled from OWRB data

Prior Groundwater Rights

Groundwater rights established within this basin prior to July 1, 1973, and recognized by Board Order, total 33 acre-feet per year. This total amount is allocated in Sequoyah County. There are no prior rights recognized in any other county within the NOMGB.

Neosho River Minor Groundwater Basins

The NRGB comprises approximately 81,000 acres of Quaternary alluvial and terrace deposits that occur as channel and floodplain deposits and overlie the Pennsylvanian and Mississippian formations in the area. The alluvium along the Neosho River typically consists of variable proportions of sand, clay, and silt in the upper portions of the deposit (Marcher et al, 1984). Marcher and Bingham (1971) reported that the alluvium can be as much as 30 feet thick with 5 to 15 feet of sand and gravel at the base. The average total thickness of the deposits is estimated at 20 feet.

The NRGB is separated into three basins, northern (NRGBa), middle (NRBGb), and southern (NRGBc) Neosho River, due to the presence of Grand Lake of the Cherokees and Hudson Lake. NRGBa which contains 38,000 acres begins at the Kansas State line where the Neosho River and Spring River enter the State of Oklahoma and extends south to Grand Lake of the Cherokees in Ottawa County. The NRGBb contains 16,000 acres and begins in Mayes County just below Grand Lake of the Cherokees and extends south along the Neosho River to Lake Hudson. The NRGBc contains 27,000 acres and begins below Lake Hudson dam on the Neosho River and extends south to Fort Gibson Reservoir. The NRGBc includes deposits from the Neosho River and also from Pryor Creek in Mayes County. Figure 2 shows the basin boundaries of the NRGBa, NRGBb, and NRGBc.

Aquifer Parameters

The hydraulic characteristics of an aquifer describe its ability to store and transmit water and can be described in terms of storage coefficient and transmissivity (T). For unconfined aquifers, storage coefficient and specific yield are nearly equivalent. Specific yield for the NRGBs is estimated at 0.15 which is comparable for other alluvial and terrace basins in Oklahoma. The average saturated thickness as reported by Marcher et al, 1984 is 10 feet.

The deposits consist of variable proportions of sand, silt, clay and gravel and can have as much as 5 to 15 feet of sand and gravel present at the base of the deposit. The sand and gravel are estimated to comprise approximately 25% of the saturated section of the NRGBs. From Freeze and Cherry (1979), mean K values for the sand and gravel interval and the sand, clay, and silt interval are approximated at 700 ft/day and 7 ft/day, respectively. To account for the greater portion of the saturated interval being fine-grained, a weighted K value of 80 ft/day was estimated. Transmissivity, a product of the mean saturated thickness and K is estimated to be 800 ft^2/day for the NRGB(s).

The amount of annual recharge to the basin is estimated to be 10 percent of the average annual precipitation or approximately 4.2 inches per year. This percentage of recharge was selected by comparison of previous alluvial and terrace deposit studies.

Aquifer Storage and Yield Capabilities

Determination of the initial storage of a groundwater basin is calculated by multiplying the area of the basin by the specific yield and the saturated thickness. Initial storage of the NRGB by each individual basin is as follows: NRGBa - 57,000 acre-feet, NRGBb - 24,000 acre-feet, NRGBc - 40,500 acre-feet.

Average well yield in the NRGB is less than 10 gallons per minute (Marcher et al, 1984). Wells can yield as much as 100 gallons per minute in localized areas with thicker deposits (Marcher and Bingham, 1971). Table 4 summarizes the aquifer parameters and storage parameters for the northern, middle and southern NRGBs.

Table 4. Summary of Aquifer Parameters and Storage for the NRGBs.

Basin	Area (acres)	Specific Yield	Saturated Thickness (ft)	K (ft/day)	T (ft^2/day)	Mean Well Yield (gpm)	Storage (ac-ft)
NRGBa	38,000	0.15	10	80	800	10	57,000
NRGBb	16,000	0.15	10	80	800	10	24,000
NRGBc	27,000	0.15	10	80	800	10	40,500

K - Hydraulic Conductivity T - Transmissivity

Water Use

Groundwater use in the study area of the NRGB(s) appears to be limited to household and stock water use. No groundwater permits have been issued by the Board in these basins.

Prior Groundwater Rights

No prior groundwater rights have been established within these basins.

GROUNDWATER QUALITY

Northeastern Oklahoma Minor Groundwater Basin

The area is underlain mainly by Pennsylvanian shale, siltstone, and sandstone and by Mississippian limestone and shale above the Mississippian Keokuk Formation. The chemical quality of water from these formations is extremely variable and depends on lithology, location in the local and regional flow system, and depth (Marcher et al, 1987). Typically, the groundwater is a sodium bicarbonate or calcium bicarbonate type although many variations in water type occur. Concentrations of total dissolved solids range from

71 to 3,700 milligrams per liter (mg/l) and pH ranges from 6 to 8. Hardness generally ranges from hard to very hard. Water from sandstone is least highly mineralized, whereas that from shale, particularly shale that contains coal beds, is most highly mineralized (Marcher et al, 1987).

Table 5 is a summary of selected physical and chemical properties of groundwater sampled from wells within the Pennsylvanian and Mississippian age formations. The table shows the minimum, median and maximum concentrations for the selected parameters.

Table 5. Selected Chemical Constituents in Water from Wells Completed in Pennsylvanian and Mississippian Age Formations.

Parameter (mg/l)	Maximum	Median	Minimum	No. of Samples
Hardness*	3020	206	4	141
Sulfate	2640	120	0.0	36
Chloride	700	30	0.0	35
Nitrate*	228	1.5	0.0	140
Total Dissolved Solids	3700	700	71	35

* Results from entire Tulsa and Fort Smith Quadrangles (Marcher, 1969 and Marcher and Bingham, 1971)

In summary, the water quality of the NOMGB is probably suitable for most beneficial uses except in localized areas. The major natural sources of pollution in the area that might impact some portions of the basin include hardness and total dissolved solids. However, with proper well completion techniques (sealing out lower quality water zones), water treatment techniques, and water quality sampling and analysis, negative health affects can be mitigated.

Neosho River Groundwater Basins

Groundwater quality information regarding the NRGB(s) is somewhat limited. Marcher and Bingham, 1971, reported sample analyses from three wells completed in the alluvial and terrace deposits along the Neosho River. Table 6 shows the selected chemical characteristics of groundwater from the three wells. Results indicate that the water is a calcium and magnesium bicarbonate type and is generally considered to be hard. Total dissolved solids are low to moderate with all samples results well below EPA's maximum contaminant level of 500 mg/l. Sulfate and chloride levels are also low to moderate.

Table 6. Selected Chemical Characteristics of Water from Alluvial and Terrace Deposits in NRGB(s)*.

Parameter (mg/l)	Maximum	Median	Minimum	Number of Samples
Sodium + Potassium	34.5	23	11.5	3
Bicarbonate	244	198	152.5	3
Sulfate	60	36	0	3
Chloride	35	17.5	0	3
Calcium + Magnesium	262.5	200	150	3
Nitrate*	30	0.8	0	18
Total Dissolved Solids	241	235	228	3

* results from entire Tulsa Quadrangle - Taken from Marcher and Bingham, 1971

In summary, the water quality of the NRGB is probably suitable for most beneficial uses except in localized areas. The major natural sources of pollution in the area that might impact some portions of the basin include hardness and total dissolved solids. However, with proper well completion techniques (sealing out lower quality water zones), water treatment techniques, and water quality sampling and analysis, negative health affects can be mitigated.

SUMMARY

The following data on the Northeastern Oklahoma Minor Groundwater Basin and the Neosho River Minor Groundwater Basin(s) were derived in order to calculate and determine the Maximum Annual Yield and Equal Proportionate Share of the basins:

Northeastern Oklahoma Minor Groundwater Basin

1. The total land area overlying the basin is 1,621,338 acres;
2. The amount of water in storage in the basin on July 1, 1997 was determined to be 3,243,000 acre-feet;
3. The average rate of recharge is estimated to be 2.1 inches or 5 percent of the average annual precipitation (42 inches) and totals approximately 5,674,683 acre-feet, and the total discharge of the basin is 660 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 0.5 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment, and water quality testing and analysis.

Northern Neosho River Minor Groundwater Basin (NRGBa)

1. The total land area overlying the basin is 38,000 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 57,000 acre-feet;
3. The estimated rate of recharge is 4.2 inches per year or 10 percent of the average annual precipitation (42 inches) and totals approximately 266,000 acre-feet, and the total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 800 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment, and water quality testing and analysis;

Middle Neosho River Minor Groundwater Basin (NRGBb)

1. The total land area overlying the basin is 16,000 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 24,000 acre-feet;
3. The estimated rate of recharge is 4.2 inches per year or 10 percent of the average annual precipitation (42 inches) and totals approximately 112,000 acre-feet, and the total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 800 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment, and water quality testing and analysis;

Southern Neosho River Minor Groundwater Basin (NRGBc)

1. The total land area overlying the basin is 27,000 acres;
2. The amount of water in storage in the basin on July 1, 1997 was approximately 40,500 acre-feet;
3. The estimated rate of recharge is 4.2 inches per year or 10 percent of the average annual precipitation (42 inches) and totals approximately 189,000 acre-feet, and the total discharge of the basin is 0.0 acre-feet over the life of the basin (20 years);
4. The transmissivity of the basin is estimated to be 800 ft^2/day;
5. The possibility of pollution of the basin from natural sources such as hardness and total dissolved solids can be minimized by proper well construction, water treatment, and water quality testing and analysis;

REFERENCES

Abernathy, Edward J., 1970, Soil Survey of Sequoyah County, Oklahoma: U.S.Department of Agricultural, Soil Conservation Service, pp 1, 48-49.

Branson, Carl C. et al, 1965, Geology and Oil and Gas Resources of Craig County, Oklahoma, Oklahoma Geological Survey, Bulletin 99, p. 47, 50, 67.

Cole, Everett L., 1970, Soil Survey of Cherokee and Delaware Counties, Oklahoma: U.S. Department of Agricultural, Soil Conservation Service, pp 1, 70-71.

Driscoll, Fletcher, 1986, Groundwater and Wells, Second Edition, p 737-738.

Freeze, R.A. and Cherry, J.A., 1979, Groundwater, Prentice-Hall, Inc., Englewood Cliffs, NJ, p. 604.

Huffman, George G., et al, 1966, Geology of Northern Adair County, Oklahoma, Oklahoma Geology Survey, Circular 68, p. 35.

Marcher, Melvin V., 1969, Reconnaissance of the Water Resources of the Fort Smith Quadrangle, East-Central Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 1, 1:250,000, 4 Sheets.

Marcher, Melvin V, and Bingham, Roy H., 1971, Reconnaissance of the Water Resources of the Tulsa Quadrangle, Northeastern Oklahoma: Oklahoma Geological Survey Hydrologic Atlas 2, 1:250000, 4 sheets.

Marcher, Melvin V., Kenny, J.F., et al, 1987, Hydrology of Area 40, Western Region, Interior Coal Province, Kansas, Oklahoma and Missouri: U.S. Geological Survey, Water-Resources Investigations, Open-File Report 83-266.

Marcher, Melvin V. et al, 1987, Hydrology of Area 41, Western Region, Interior Coal Province, Oklahoma and Arkansas: U.S. Geological Survey, Water-Resources Investigations, Open-File Report 84-129.

Newland, Claude T., 1973, Soil Survey of Craig County, Oklahoma: U.S. Department of Agricultural, Soil Conservation Service, pp 1, 62.

Oklahoma Water Resources Board, 1990. Oklahoma Water Atlas. University of Norman Printing Services, Norman, OK. p 16.

Oklahoma Water Resources Board, 1995, Unpublished Multi-Purpose Completion Report Records: Craig, Adair, Ottawa, Delaware Mayes, Cherokee, and Sequoyah Counties.

Oklahoma Water Resources Board, 1996, Unpublished Water Use Data for Craig, Adair, Ottawa, Delaware, Mayes, Cherokee, and Sequoyah Counties.

Starke, John, M. Jr., 1961, Geology of Northeastern Cherokee County, Oklahoma, Oklahoma Geology Survey, Circular 57, p. 39, 43.

GLOSSARY

Alluvium

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

Aquifer

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

Equal Proportionate Share

That portion of the maximum annual yield of water from a groundwater basin which shall be allocated to each acre of land overlying such basin. The percentage of the maximum annual yield is equal to the percentage of the land overlying the fresh groundwater basin which is owned or leased by an applicant for a regular permit.

Fresh Water

Water which has less than five thousand (5,000) parts per million total dissolved solids. All other water is salt water.

Groundwater

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

Groundwater Basin

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

Hydraulic Conductivity

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

Life of a Groundwater Basin

That period of time during which pumping of the maximum annual yield for a minimum twenty year life of such basin will result in a final basin storage which approaches zero. Fifteen feet of saturated thickness is maintained in bedrock aquifers to provide for domestic use.

Major Groundwater Basin

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

Maximum Annual Yield

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

Minor Groundwater Basin

A distinct underground body of water overlain by contiguous land and having substantially the same geological and hydrological characteristics and from which groundwater wells yield less than fifty gallons per minute on the average basinwide if from a bedrock aquifer and less than one hundred fifty gallons per minute on the average basinwide if from an alluvium and terrace aquifer, or as otherwise designated by the Oklahoma Water Resources Board (Board).

Natural Recharge

All flow of water into a groundwater basin by natural processes including percolation from irrigation.

Permeability

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

Porosity

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

Prior Groundwater Right

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

Specific Yield

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

Storage Coefficient

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

Terrace Deposits

Deposits of older alluvium which occupy positions topographically higher than recent alluvium and mark the former position of a stream.

Total Discharge from the Basin

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

Transmissivity

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