HYDROLOGIC REPORT

OF THE

EAST-CENTRAL OKLAHOMA MINOR BEDROCK GROUNDWATER BASIN

IN

SEMINOLE, HUGHES AND OKFUSKEE COUNTIES

Technical Report 97-2

by
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INTRODUCTION

The hydrogeologic report of the minor groundwater basin in Seminole, Hughes, and Okfuskee 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. 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.

The minor aquifer identified within the above mentioned counties constitutes a minor bedrock groundwater basin. This basin will be herein named the East-Central Oklahoma Minor Groundwater Basin (ECOMGB).

PHYSICAL SETTING

Location

This report is limited to Seminole, Hughes, and Okfuskee counties located in east-central Oklahoma. The three counties as a whole contain approximately 1,320,320 acres or 2,063 square miles. The counties were selected for this report on the basis of similar groundwater resources and geologic deposits. The minor groundwater basin for this study is comprised of Pennsylvanian aged rocks with some minor areas of Quaternary alluvium and terrace deposits.

The alluvium and terrace deposits associated with the Canadian River systems are designated as potential major basins and will not be considered in this report. Also excluded from this report is the Vamoosa-Ada Major Groundwater Basin which covers the majority of Seminole County and a portion of Okfuskee County. Figure 1 shows the limits of the study area.

Setting

The land encompassed within the study area is located in the Osage Plains section of the Central Lowland physiographic province. The land is a gently rolling to rolling plain interrupted at intervals of several miles by escarpments which generally follow a southwest-northeast course.

The topography in the study area is determined largely by the resistance of underlying parent material to weathering and geological erosion. The area is underlain by interbedded sandstone and shale and many relief irregularities result from the different rates of erosion. The shale is subject to more rapid erosion and therefore occupies the broad smooth valley between intervening ridges and escarpments that are protected by a cap rock of resistant sandstones and limestones.

Climate

Climate is warm-temperate and continental of the humid-subhumid type. The climate is characterized by pronounced daily and seasonal changes in temperature and variations in seasonal and annual rainfall. The changes between seasons 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. Winters are comparatively mild and short with only brief periods of low temperatures and snow cover. Summers are typically long and hot. Late spring and early summer are the most variable, bringing the heaviest precipitation and greatest number of severe storms (Mayhugh and Bartolina, 1979; Long, 1968; and Buckhannan, 1952).

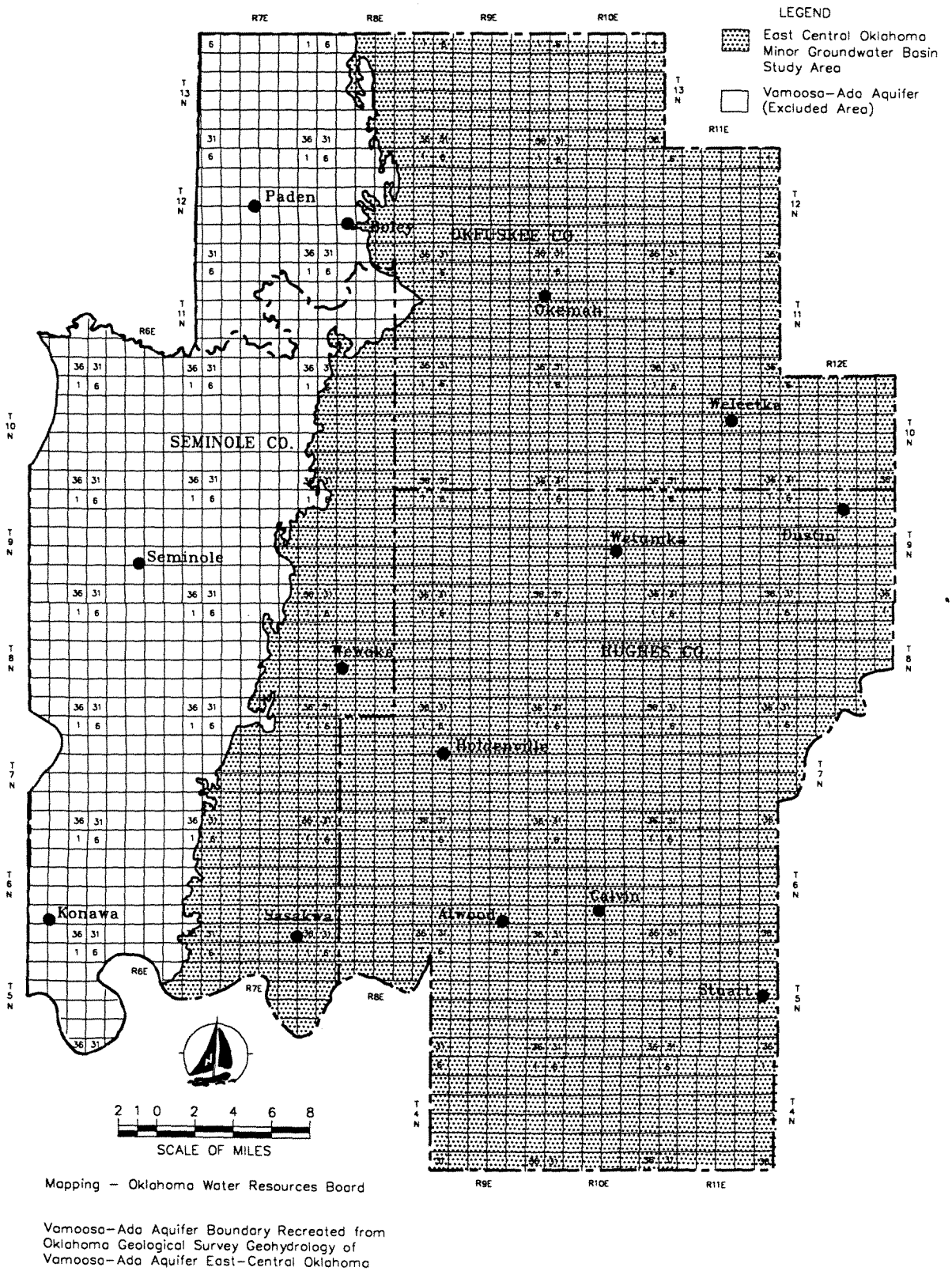

Figure 1. Boundary of East Central Oklahoma Minor Groundwater Basin

The mean annual precipitation ranges from 37 inches per year in northwestern Seminole County to 42 inches in southeastern Hughes County (OWRB, 1990). The mean annual precipitation for the study area was determined to be 40 inches. The minimum and maximum annual precipitation values range between 19 and 61 inches. Snowfall averages approximately 7 inches per year in the three county area. (Mayhugh and Bartolina, 1979; Long, 1968; and Buckhannan, 1952).

Average monthly temperature ranges from 38.4 degrees in January to 82.1 degrees in July, with an average annual temperature of 61 degrees. Winds generally prevail out of the south with the exception of January and February when northerly winds prevail (Mayhugh and Bartolina, 1979; Long, 1968; and Buckhannan, 1952).

Regional Geology

The study area for this report extends over two separate geologic provinces. The northwest quadrant of the study area is located in the Northern Shelf (Cherokee Platform) Province while the southeast quadrant is located in the Arkoma Basin (Johnston et al, 1989). Regional structure of the study area is a gently dipping homocline in which the strata dip westward in the western section and northwestward in the eastern section. The degree of dip averages approximately 0.5 to 1 degree (Ries, 1954).

Many northwest-striking en echelon faults are present in the study area forming a general northeast trend. Most of the faults are normal and parallel and few exceed three miles in length. The faults apparently formed during Late Pennsylvanian time as a result of uplift of the Nemaha Ridge. Vertical displacement across the faults is rarely more than 100 feet and is usually about 50 feet. Subsurface evidence shows that the amount of displacement diminishes with depth and that the faults probably do not extend below rocks of Pennsylvanian age (D'Lugosz et al, 1986).

Geologic formations in the study area include Pennsylvanian and Quaternary age deposits. The Pennsylvanian formations outcropping at the surface range from the Thurman Sandstone in Hughes County to the Hilltop Formation in Seminole County (See Table 1). The bedrock consists principally of alternating thick shales and fine to medium-grained sandstones, together with a few thin limestones and conglomerates (Bingham and Moore, 1975; Hart, 1974; and Marcher, 1969).

The Quaternary deposits in the study area include flood-plain sediment, terrace sands, residual high-level gravels, and eolian sands. Alluvium along the larger streams, such as the Canadian and North Canadian Rivers, ranges from 30 to 100 feet thick and is estimated to average 50 feet thick. The deposits consist of sand, silt, clay and lenticular beds of gravel. Terrace deposits range from a few feet to 100 feet and also consist of lenticular beds of sand, silt, clay and gravel. Alluvium along the smaller streams generally ranges from a few feet to 50 feet (Bingham and Moore, 1975).

Table 1. Pennsylvanian-aged Strata Outcropping at the Surface in the Study Area.

SYSTEM	SERIES	GROUP	FORMATION
Pennsylvanian	Missourian		Hilltop
			Belle City
			Tallant
			Barnsdall
			Wann and Inola
			Chanute
			Dewey Limestone
			Nellie Bly and Hogshooter
			Coffeyville and Checkerboard
			Seminole
	Desmoinesian	Marmaton	Holdenville Shale
			Wewoka
			Wetumka
		Cabaniss	Calvin
			Senora
			Stuart
			Thurman

Taken from Bingham and Moore, 1975

GROUNDWATER RESOURCES

Basin Characteristics

The ECOMGB comprises approximately 984,320 acres (1,538 square miles) of Pennsylvanian deposits that occur as shales and fine to medium-grained sandstones, together with a few thin limestones and conglomerates. Minor Quaternary alluvium and

terrace deposits along the smaller streams are considered to be linked hydrologically with the underlying sediments of the ECOMGB and will not be distinguished as a separate minor basin.

The occurrence, storage, and movement of water in the Pennsylvanian and other minor deposits are largely controlled by the geologic structure, the lateral and vertical distribution of rock units, and their physical characteristics, particularly permeability. The en echelon faults mentioned earlier in this report may be significant in that they either retard groundwater movement or provide open conduits for rapid recharge to the aquifer. This depends on the amount of fracturing of near-surface rocks and the amount of brecciation and shearing along the faults (D'Lugosz et al, 1986).

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. Groundwater encountered in the ECOMGB in shallow strata is typically under unconfined conditions whereas groundwater encountered in deeper strata is under confined conditions.

Review of OWRB Multi-Purpose Completion Reports indicates that fresh water has been encountered in wells within the ECOMGB at depths ranging from 300 to 400 feet. Oklahoma Corporation Commission (1982) Base of Treatable Water Maps indicate a decline in water quality throughout the basin at depths ranging from 300 to 500 feet. Based on the available data, the average base of fresh water is determined to be 350 feet. Using an average depth to water of 50 feet and a value of 350 feet for the base of the fresh water zone, the average total saturated thickness is 300 feet.

Typical deposits from the ECOMGB range from fine to medium-grained sandstone to siltstone and shale (Bingham and Moore, 1975). Sandstone and conglomerate units in the study area comprise from 10 to 40 percent of the total formation thickness (Tanner, 1956 and Baumeister, 1942). Using an approximate value of 30 percent and a total formation thickness of 300 feet, the combined sandstone and conglomerate units are estimated to comprise 90 feet of the total formation thickness. The shale and siltstone units constitute the remaining 70 percent of the total thickness or 210 feet.

Hydraulic conductivity for the sandstone units is estimated to range from 0.001 to 2.5 ft/day with an average of 1.25 ft/day. Hydraulic conductivity for the shale and siltstone units is estimated to be 0.0001 ft/day (Heath, 1983). Transmissivity, a product of the saturated thickness and hydraulic conductivity, is estimated to be 0.021 ft^2/day for the shale units and 112.5 ft^2/day for the sandstone units. The weighted average transmissivity, based on the percentage of shale to sandstone, is estimated to be 33.7 ft^2/day. Specific yields of 0.125 and 0.005 for the sandstone and shale units, respectively, were selected from Driscoll (1986).

Bingham and Moore (1975) reported the amount of annual recharge to the basin to range from 4 to 10 percent of average annual precipitation. For the purpose of this report, an average recharge rate of 7 percent of the average annual precipitation or 2.8 inches per year was selected.

Aquifer Storage and Yield Capabilities

Initial storage for the ECOMGB is estimated to be approximately 12,107,100 acre-feet of groundwater. This value is obtained by multiplying the specific yield of the sandstones and the specific yield of the shales, by the area of the basin (984,320 acres), and the estimated saturated thicknesses as shown in Table 2.

Table 2. Aquifer Storage Parameters for the ECOMGB.

Aquifer Material	Specific Yield or Storage Coefficient	Saturated Thickness (Feet)	Area of Basin (Acres)	Storage (Acre-Feet)
Sandstone	0.125	90	984,320	11,073,600
Shale	0.005	210	984,320	1,033,500
Total		300	984,320	12,107,100

The yields of most wells in the ECOMGB as reported by drillers on well records, generally are less than 15 gallons per minute, and many yield only a few gallons per minute. Locally, a few wells penetrating thicker units of sandstone have been reported to yield as much as 30 gallons per minute (OWRB, 1995).

Water Use

In many parts of the study area, adequate supplies of suitable groundwater are not available. Water districts have been established to meet the domestic, commercial, and agricultural water needs of rural areas. Thousands of farm ponds have also been constructed to provide water for livestock.

The total amount of groundwater currently permitted in the ECOMGB is 975.0 acre-feet per year. Reported water use for 1995 from permit holders was 39.9 million gallons, or 122.7 acre-feet. Commercial use accounted for two-thirds of the total amount while public water supply accounted for the remaining one-third. Table 3 summarizes the permit and water use data for the basin.

Table 3. Permit and Water Use Information in the ECOMGB by County during 1995.

County	Purpose	No. of Permits	Permitted Amount	Reported Use
Seminole	Municipal	4	452.0 ac-ft	22.4 ac-ft
	Irrigation	1	40.0 ac-ft	00.0 ac-ft
	Commercial	4	113.0 ac-ft	25.9 ac-ft
Hughes	Municipal	1	25.0 ac-ft	19.9 ac-ft
	Irrigation	1	200.0 ac-ft	00.0 ac-ft
	Commercial	6	140.0 ac-ft	51.6 ac-ft
Okfuskee	Commercial	1	5.0 ac-ft	2.9 ac-ft
	Total	18	975.0 ac-ft	122.7 ac-ft

1995 OWRB Water Use Data

Prior Groundwater Rights

Groundwater rights established within this basin prior to July 1, 1973 and recognized by Board Order total 74 acre-feet per year. This amount represents 49 acre-feet from Seminole County and 25 acre-feet from Hughes County. No prior rights within the ECOMGB are recognized in Okfuskee County.

GROUNDWATER QUALITY

The chemical quality of groundwater in the Pennsylvanian rocks in the study area is variable. The groundwater can have unique chemical properties dependent upon the particular geologic formations that are present. The quality can range from excellent to poor, and the presence of an undesirable constituent or excessive hardness can make the water unsuitable for some purposes.

The most common source of natural pollution to this basin is brine water lying below the zone of fresh water. Marcher (1986) reported that brines were a major source of pollution in the Vamoosa-Ada Aquifer which is adjacent to and characteristically similar to the study area. Excessive local pumping may lower the hydraulic head in the aquifer sufficiently to induce upward migration of the underlying brine. Also, brines discharged to the aquifer or on the land surface can also degrade the groundwater in the basin.

The United States Geologic Survey (USGS) has collected general water quality data for the study area. Water sampling and analysis were conducted on 23 wells within the ECOMGB. Additional information on groundwater quality was also determined by the USGS through calculations and from various published reports. Based on this information, it appears that groundwater in the basin generally has a hardness of more than 120 milligrams per liter. Locally groundwater can contain sulfate and chloride in excess of the maximum recommended for drinking water. Concentrations of dissolved solids typically range from 100 to 900 milligrams per liter. Table 4 is a summary of selected chemical properties of groundwater sampled from wells within Pennsylvanian age formations primarily in the ECOMGB. The table shows the minimum, mean, median and maximum concentrations for the selected parameters.

Table 4. Summary of Chemical Analyses from Wells Completed in Pennsylvanian Aged Formations.

Parameter	Maximum	Mean	Median	Minimum	No. of Samples
Hardness as $CaCO_3$ (mg/l)*	2,760	N/A	164	9.0	73
Sulfate (mg/l)[1]	408	49	24	12	23
Chloride (mg/l)[1]	105	32	26	8.8	23
Nitrate (NO_3) (mg/l)*	160	N/A	2.0	0.0	61
Dissolved solids (ROE in mg/l)[1]	952	311	241	77	23

mg/l - milligrams per liter
ROE - residue on evaporation at 180° Celsius
* - includes entire Oklahoma City Quadrangle
1 - includes only water wells from the ECOMGB
N/A - Not Available
(Taken from Bingham and Moore, 1975)

In summary, the water quality of the study area is extremely variable. The water is, however, probably suitable for all beneficial uses except in localized areas. Potential problems from natural contamination could include chloride, high iron, manganese, and dissolved solids. However, with proper well completion techniques (sealing out lower quality water zones and lowering pumping velocity), water treatment techniques, and water quality sampling and analysis, negative health affects can be mitigated.

SUMMARY

The following data on the East-Central Oklahoma Minor Groundwater Basin were derived in order to calculate and determine the MAY and EPS of the basin:

1) The total land area overlying the basin is 984,320 acres;
2) The amount of water in storage in the basin was determined to be 12,107,100 acre-feet;
3) The estimated rate of recharge is 7 percent of the average annual precipitation (40 inches) and totals 4,550,000 acre-feet of recharge over the life of the basin (20 yrs). The total amount of groundwater established under prior rights is 74 acre feet per year with a total discharge determined to be 1,480 acre-feet over the life of the basin (20 yrs);
4) The transmissivity of the basin is estimated at 33.7 ft^2/day;
5) The possibility of pollution of the basin from natural sources such as chloride, high iron, manganese, and dissolved solids can be minimized by proper well construction, treatment, and water quality testing and analysis.

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GLOSSARY

Alluvium

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

Aquifer

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

Equal Proportionate Share

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

A 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.

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.

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.