KANSAS GEOLOGICAL SURVEY
OPEN-FILE REPORT 89-25

GROUNDWATER RESOURCES OF GMD5:
HOW RENEWABLE ARE THEY?

by

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Quantification of the current rate of natural groundwater recharge is a basic prerequisite for efficient groundwater resource management. It is particularly vital in semiarid regions with large demands for groundwater supplies, such as the Great Bend Prairie, where such resources are the key to economic development. If uncontrolled overdevelopment of an aquifer occurs because of false assumptions about groundwater recharge (especially when evaluating water rights applications), there are often serious consequences. These vary widely with hydrogeologic conditions, but can include (1) increased pumping costs, yield reductions, and even complete failure of production/irrigation wells, (2) encroachment of saline water into freshwater aquifers, and (3) land subsidence resulting from settlement of underconsolidated aquifers. Knowledge of recharge rates is also crucial in assessing "minimum risk" waste disposal locations, for developing efficient pollution prevention plans, and in assessing artificial recharge potential.

However, the rate of aquifer recharge is one of the most difficult factors to measure in the evaluation of groundwater resources. Estimates, by whatever method, are normally subject to large uncertainties and errors. In addition, determination of recharge variability in space and time creates a number of unresolved problems, clearly indicating a focus for further investigations. To reduce such uncertainties, we must monitor aquifer behavior on a continuous or periodic basis to ensure that adequate data are collected. This approach may be the only practical way to improve the reliability of groundwater recharge estimates and is often the most cost-effective way in the long run. The application of several independent groundwater recharge estimation methods is likely to improve our knowledge of aquifer recharge provided that an adequate hydrogeologic database exists and that aquifers are monitored on a long-term basis.

We know from experience that water placed on the soil as natural precipitation or irrigation does one of four things: runs off (thus increasing streamflow), drains from the root zone or the soil profile (thus recharging the aquifer), evaporates from soil and plant surfaces—a process called evapotranspiration—(thus replenishing the humidity of the atmosphere), or is stored in the soil (thus building up soil moisture). To develop methods to conserve our limited water supplies and to estimate total aquifer input (i.e., recharge), we need a basic understanding of this water cycling, known as the hydrologic cycle. The water balance equation commonly used to quantify this water cycle is

$$P + I = RO + D + ET + S \qquad (1)$$

where

P = precipitation,
I = irrigation,
RO = surface runoff,
D = deep drainage and recharge,
ET = evapotranspiration, and
S = water stored in the soil.

From this equation one can appreciate that deep drainage (and hence aquifer recharge) is dependent on meteorologic conditions, soil, vegetation, physiographic characteristics, and properties of the geologic material through which water flows. Therefore, to understand the recharge process more fully, we need a fundamental knowledge of all these factors.

Under nonirrigated conditions [i.e., $I = 0$ in equation (1)], the left-hand side of equation (1) is fixed (i.e., we cannot do much about it). Hence a decrease in any of the right-hand-side terms forces an equal increase in the other terms to maintain the equality (i.e., the water balance). For example, a decrease in surface runoff, RO (e.g., as a result of increased infiltration through better tillage practices) may increase the amount stored in the soil profile, S; an increase in S would tend to increase deep drainage and recharge D and evapotranspiration ET.

The GMD5, in close cooperation with the Kansas Geological Survey and other agencies, has conducted and/or supported a number of projects to evaluate the groundwater resources of the Great Bend Prairie aquifer, for example, studies on the Pawnee Valley and on the Rattlesnake Creek watershed and an ongoing study of groundwater recharge assessment in the district.

According to the **Rattlesnake Creek watershed** study, average groundwater recharge in the watershed is estimated to be 3.88 inches per year based on (1) an average precipitation of

23.1 inches, (2) an average of 16.5 inches of irrigation (for both winter and summer crops in a crop rotation) and (3) an irrigated land coverage of 21% of the total watershed acreage (the same proportion of irrigated to total land acreage is true for the whole district). This recharge estimate is based on a soil-moisture budget computer simulation of the central portion of the Rattlesnake Creek basin (representing 392,000 acres centered around Trousdale, Edwards County). This numerical soil-moisture budget simulator estimates, among other hydrologic components, deep drainage below the root zone; this water drainage is assumed to be equal to groundwater recharge. Also, average surface runoff for the basin is 0.81 inches per year, actual evapotranspiration is 25.42 inches per year, and the resulting soil-moisture deficit of the root zone is 3.57 inches per year. It should be noted that, according to the district records, 824,732 acre-feet of groundwater per year had been appropriated for irrigation by 1986. This amounts to 3.94 inches per year over the 2,511,104 acres of GMD5 area. If we translate the Rattlesnake Creek study numbers to the whole GMD5, we find that out of the 5,553,000 acre-feet of precipitation and irrigation water applied each year, 812,000 acre-feet of water are added to the aquifer, 5,319,000 acre-feet of water are lost by evapotranspiration, 169,000 acre-feet of water are lost by runoff from the land, and 747,000 acre-feet of water are needed to fill up the soil root zone to field capacity annually.

According to the **Pawnee Valley** study, over the 20 year period from 1959 to 1978, the average annual value for groundwater recharge is 0.5 inches, the surface runoff is 0.3 inches, and the actual evapotranspiration is 22.5 inches. The average annual precipitation over the same 20-year period (1959–1978) was 22.7 inches. That study indicates that by 1978–79 the Pawnee Valley aquifer had been depleted by 37% compared to 1945–47. It also shows that the groundwater appropriations in the Pawnee Valley aquifer by 1978–79 amount to 11 times the amount of estimated groundwater recharge.

According to the **ongoing GMD5 recharge assessment** project, in which recharge-related variables are field-monitored on a year-round basis at a number of instrumented sites, groundwater recharge is highly variable both from year to year and from one area to another. Table 1 gives the estimated recharge values for the last four complete years for which field data have been collected from the five original recharge sites (sites 1 through 5) and the measured yearly precipitation and depth to water ranges at these sites. The disproportionately high recharge values calculated for site 4 are due to the site being located on a stream bank where the depth to water is only a couple of feet. The year 1988 was very dry (see precipitation values in table 1). If we exclude that dry year and site 4 from the district-wide recharge calculation (because they are generally unrepresentative of the district's conditions), the average recharge estimate for the district is 2.9 inches per year. Including site 4 it raises the recharge estimate to 4.1 inches per year. If we include the 1988 drought year, the average recharge estimate drops to 2.3 inches per year (including site 4 results in 3.4 inches per year). Compare these numbers with the previously mentioned 3.9 inches of groundwater rights already appropriated over the district. Since late 1987, five additional recharge sites (sites 6 through 10) have been added to the district. Up to now we only have the 1988 complete year for recharge estimation to go by; thus these new sites have not yet been included in the average district-wide recharge estimates. It should be evident that to get a good handle on groundwater recharge, we need a multiyear database from which representative averages can be taken.

Table 1. 1985-1988 Groundwater Recharge Estimates for GMD5

Site No.	County/Legal	Land Owner	Year	Total Precipitation (inches)	Minimum and Maximum depth to Water Table (feet)	Estimated Groundwater Recharge (inches)
1	Edwards Co	Grizzell	1985	23.30	18.2–20.2	1.3
	Sec. 13, T. 25 S.,		1986	26.54	18.5–20.5	1.1
	R. 16 W.		1987	34.05	9.8–18.5	5.2
			1988	14.91	14.2–19.6	0.7
2	Stafford Co.	Bliss	1985	26.47	24.2–26.7	2.8
	Sec. 36, T. 23 S.,		1986	27.86	24.0–26.5	1.7
	R. 13 W.		1987	26.10	19.2–24.1	3.9
			1988	14.52	22.3–26.8	0.2
3	Stafford-Barton Co.	Schlockterneier	1985	29.83	16.4–23.0	2.8
	Sec. 7, T. 21 S.,		1986	22.17	15.9–19.4	0.7
	R. 13 W.		1987	28.11	14.6–18.3	1.3
			1988	15.66	15.5–21.9	0.0
4	Reno Co.	Bradshaw and	1985	31.19	2.4–4.9	6.7
	Sec. 1, T. 25 S.,	Sherow	1986	32.96	2.6–4.7	8.3
	R. 9 W.		1987	37.09	0.5–3.3	11.9
			1988	18.00	1.6–5.7	3.7
5	Stafford-Pratt Co.	Harrison	1985	30.15	10.1–14.6	5.9
	Sec. 36, T. 25 S.,		1986	32.51	10.4–13.7	4.1
	R. 13 W.		1987	30.69	6.2–10.5	3.8
			1988	14.95	8.6–14.4	0.9
6	Stafford Co. Sec. 36, T. 23 S., R. 12 W.	Wendelburg	1988	16.27	10.0–22.8	0.6
7	Pratt Co. Sec. 11, T. 26 S., R. 14 W.	Moore	1988	14.95+	15.1–26.5	0.5
8	Pawnee Co. Sec. 14, T. 23 S., R. 15 W.	Tranbarger	1988	14.36	23.6–26.3	0.0
9	Edwards Co. Sec. 5, T. 24 S., R. 16 W.	Schartz	1988	14.73	29.3–31.9	0.0
10	Edwards Co. Sec. 1, T. 25 S., R. 19 W.	Olsen	1988	15.02	46.7–48.7	0.0

+ Precipitation taken from site 5 (the nearest site).