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Natural Ground Water Recharge Assessment for the Big Bend Ground Water Management District No. 5

by

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A report to the GMD5 Board of Directors

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Importance of ground water recharge. Reliable estimation of rates of aquifer replenishment (ground water recharge) is basic to the assessment of ground water resource potential so that efficient long-term management schemes can be developed to avoid any adverse environmental consequences. It is particularly vital in arid and semiarid regions where such resources are often the key to economic development. Furthermore, knowledge of recharge rates is crucial in assessing aquifer contamination potential and for developing efficient prevention plans. However, the rate of aquifer replenishment is one of the most difficult of all factors in the evaluation of ground water resources to measure.

Recharge estimation methods. The main techniques that can be employed specifically to estimate ground water recharge rates in arid and semiarid regions may be divided into physical methods and chemical methods. The physical methods consist of 1) Hydrometeorological and soil-crop data processing (hydrologic balance); 2) Hydrological data interpretation, including i) water table fluctuations, and ii) differential stream or canal flow; and 3) Soil Physics measurements, including i) estimation of water fluxes beneath the root zone using unsaturated hydraulic conductivity functions and the gradients in water potential, and ii) the zero flux plane method. The chemical methods --which provide an indirect measure of recharge, with the results affected by the mechanisms of infiltration-- consist of chemical and isotopic analyses from the saturated and unsaturated zones.

The applicability and potential accuracy of any given method depends largely on two semi-independent facets of the ambient conditions: a) the surficial geological environment, which determines the spatial variability of the recharge process and the extent of development of surface runoff; and b) the vegetation system and whether native or agricultural, with or without irrigation. It is likely that, the greater the aridity of a region, the smaller and more variable the recharge flux will become, necessitating long periods of measurement.

Problems related to recharge assessment. Current research and developments relating to ground water recharge indicate a number of problems. Estimates, by whatever method, are normally, and almost inevitably, subject to large uncertainty and, thus, error. This will be evident from a) the numerous limitations of each of the techniques previously mentioned; b) the wide spatial variability characteristic of rainfall and runoff events; c) widespread lack of lateral uniformity in soil profiles and hydrogeological conditions; d) frequent inadequacies in the hydrogeologic database. Hence, no single comprehensive estimation technique can yet be identified from the spectrum of methods available; all are reported to give suspect results.

Suggested action. When confronted by such uncertainty, it is strongly advisable for management strategy to be sufficiently flexible as not to require radical change in the event of initial predictions proving subject to considerable error, due to wrong assumptions about recharge rates or other hydrogeologic factors. Where the hydrogeologic database and project constraints permit, the application of more than one independent method, in combination with long term monitoring, is likely to be the best way to improve knowledge of aquifer recharge mechanisms and rates.

Methodology and recharge estimates for the GMD5. For ground water recharge assessment of the Great Bend Prairie region of Kansas we are following all three main physical methods outlined previously. The hydrologic balance can be represented, in the absence of significant surface runoff, by:

$$R = P - Ea - DS$$

where: R = recharge
P = precipitation
Ea = actual evapotranspiration
DS = the change in soil water storage in the upper vadose zone

A range of techniques for estimation of Ea based on Penman-type equations and other methods can be used. The data requirements of these methods are large, and a number of scientists suggest that large errors can occur unless the accounting period is less than 10 days. For our study, we are following weekly measurements of soil water storage, and continuous measurements of climatic and water - level variables at 10 sites distributed throughout the District. The errors inherent in the soil water balance approach can be significantly reduced in situations where the prediction of recharge can be corroborated and calibrated by unequivocal fluctuations of a relatively shallow ground water table, as we did in our study.

Another commonly applied method is the interpretation of natural water table fluctuations in terms of an aquifer recharge input. In Ground Water Hydrology, the concept of specific yield or storativity is used to transform a change in ground water level to an equivalent change in water storage and, hence, recharge. The method is attractive since ground water level observations often are available; the method could also give information on temporal and areal recharge variations. However, the method, when applied in isolation, is not reliable unless accurate values of aquifer storativity are available from a reliable independent method, which is rarely the case. It can be misleading if the water level fluctuations are confused with those due to pumping, barometric or other causes. However, by associating water table rises to specific precipitation events, and by combining the recharge estimates from the soil water balance analysis with the consequent water table rises, we obtained reliable average specific yield values for each recharge study site. These average storativity values are valid for estimating ground water recharge from water table rises during wet periods (hybrid water fluctuation method).

Table 1 presents the results of our recharge estimates for each of the original five recharge sites during the years 1985 to 1987 based on the hybrid water level fluctuation analysis, and on the soil water balance based on individual precipitation events. The crucial importance of timing and amount of precipitation in aquifer recharge is evident from that Table, as well as the large variability of recharge from year to year and from one area to another. Please note that these first five recharge sites were chosen in sandy soils and pasture land, mostly next to irrigated fields, in order to obtain an idea of the upper limits of ground water recharge occurring in the District.

The detailed methodology of soil physics measurements is also being pursued for ground water recharge estimation in the GMD5. This method involves the regular monitoring over several years of the variations in soil water suction and moisture content in a nest of tensiometers and neutron access tubes to as great a depth as feasible. Such data are capable of analysis to yield soil water fluxes, as well as recharge fluxes, although technical problems of determining the required input functions for recharge estimation limit widespread use of this method. Detailed flooding tests to derive the necessary input functions required in this method were conducted for seven recharge sites during 1987 and 1988. A Master of Science thesis at Kansas University primarily based on this methodology, for the GMD5 is currently near completion (G. Coble, 1989).

Table 1. 1985-87 Groundwater Recharge Estimates for GMD5 Based on Daily Soil Water Balance and Water Fluctuation Methods.

	Year	Total Precipitation (inches)	Minimum and Maximum depth to water table/(feet)	Maximum change in water level/(feet)	Estimated total recharge[1] (inches)	Estimated total recharge[2] (inches)	Comments
Site 1							
Edwards Co.-	1985	23.30	18.2 - 20.2	(2.04)	0.8<R<2.0	1.3	Rains in spring and fall
Grizzell	1986	26.54	18.5 - 20.5	(2.03)	1.5	1.1	Rains in late spring & summer
T25S, R16W, S13	1987	34.05	9.8 - 18.5	(8.7)	3.3	5.2	Rains in spring; no fall and winter rains
S_y = .048							
Site 2							
Stafford Co. -	1985	26.47	24.2 - 26.7	(2.56)	1.1<R<4.9	2.8	Rains in spring and fall
Bliss	1986	27.86	24.0 - 26.5	(2.45)	1.9	1.7	Rains in summer
T23S, R13W, S36	1987	26.10	19.2 - 24.1	(4.85)	0.2<R<3.5	3.9	Rains in spring, no summer, fall, or winter rains
S_y = .061							
Site 3							
Stafford-Barton Co.-	1985	29.83	16.4 - 23.0	(6.55)	0.9<R<8.2	2.8	Rains spring, summer and fall
Schlocktermeier	1986	22.17	15.9 - 19.4	(3.57)	0.6	0.7	Rains spring and summer
T21S, R13W, S7	1987	28.11	14.6 - 18.3	(3.61)	0.3<R<5.2	1.3	Rains spring and summer; no fall and winter rains
S_y = .036							
Site 4							
Reno Co.-	1985	31.19	2.4 - 4.9	(2.45)	6.7<R<12.6	6.7+	
Bradshaw and Sherow	1986	32.96	2.6 - 4.7	(2.13)	4.5<R<6.3	8.3	
T26S, R10W, S1	1987	37.09	0.5 - 3.3	(2.76)	11.1<R<14.4	11.9	
S_y = .1026							
Site 5							
Stafford-Pratt Co.-	1985	30.15	10.1 - 14.6	(4.43)	5.8<R<7.6	5.9	Spring & fall rains (fall main event)
Harrison	1986	32.51	10.4 - 13.7	(3.28)	6.3	4.1	Summer and fall rains
T25S, R13W, S36	1987	30.69	6.2 - 10.5	(4.29)	3.1	3.8	Spring and summer rains; no fall rains
S_y = .058							

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1. Soil water balance method based on storm events.

2. "Hybrid" water table fluctuation method.