ESTIMATING THE SPATIAL DISTRIBUTION OF GROUNDWATER RECHARGE RATES USING HYDROLOGIC, HYDROGEOLOGIC, AND GEOCHEMICAL METHODS

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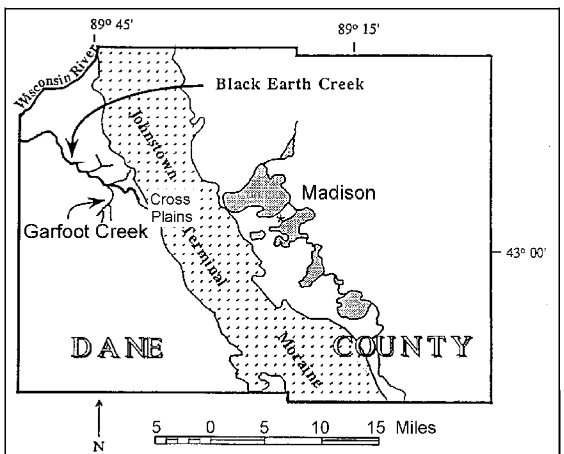
Kenneth W. Potter (P.I.), Department of Civil & Environmental Engineering, University of Wisconsin-Madison, Madison, Wisconsin 53706, Telephone: [608] 262-0040, and Carl J. Bowser, Department of Geology & Geophysics, University of Wisconsin-Madison, Madison, Wisconsin 53706, Telephone: [608] 262-8955

ABSTRACT

Groundwater quality and quantity are often negatively impacted by land use activities such as application of agricultural chemicals, disposal of solid wastes in landfills, operation of septic systems, groundwater pumping, and land development. Sound management of these activities can usually afford a major degree of groundwater protection but information needed to implement sound management practices is often lacking. One of the principal segments of information usually lacking is the rate at which water from precipitation, streamflow, or snow melt is added to the zone of saturation of an aquifer to affect its recharge. Operational tools for estimating spatial and temporal distribution of groundwater recharge exist; however, they are not reliable because there is usually no way of confirming the data derived as a result of applying these tools. To address this issue, measurements and models of surface and groundwater flows, levels, and chemistry were undertaken around Black Earth Creek (BEC) to estimate the spatial distribution of groundwater recharge in a southwestern Dane County, Wisconsin watershed. The area was selected for study because groundwater discharge is responsible for much of the base flow of BEC, increased demands from urban expansion threaten groundwater in the region, and abundant hydrologic information on the area already exists. Initial field investigations concentrated on locating and measuring groundwater discharge sites. The discovery of many springs in the Garfoot Creek (GC) portion of the watershed focused our attention on this sub-watershed because the basin is relatively small and amenable to an efficient and consummate evaluation of the parameters needed to evaluate groundwater recharge. The GC watershed is entirely within Wisconsin's Driftless Area and has a U. S. Geological Survey (USGS) gauge at its mouth. The area is representative of other small watersheds so that conclusions derived there could be applied on a larger scale over the entire BEC watershed and other watersheds in Wisconsin's Driftless Area.

TECHNICAL SUMMARY



INTRODUCTION: Black Earth Creek occupies an outwash valley cut and filled during the Wisconsin Ice Age which ended about 10,000 years ago. The northeast portion of the watershed is covered with glacial till whereas the South and Western portions, including all of Garfoot Creek, lie in Wisconsin's Driftless Area. GC is a man made channel created around the turn of the century to drain the wetland which occupied the valley bottom. It joins the main channel of BEC about 1.6 km west of the village of Cross Plains (Figure 1), draining an area of about 13.8^2 km that consists of rolling uplands, steep hillslopes, and heavily cultivated valleys. The average annual precipitation in the area from 1948 to 1991 was 79 cm with about 60% falling as rain and the remainder snow. During the summer soil moisture is usually deficient because evapotranspiration exceeds precipitation. Late autumn and spring rains and snow melt constitute the principal events likely responsible for recharging the aquifer. The following strategy was used to estimate the spatial and temporal distribution of groundwater recharge:

! A hydrogeological and hydrogeochemical investigation was conducted to develop an understanding of the hydrogeology of the watershed;
! The dominant spring in the watershed was gauged to quantify the amount of recharge and to provide information about the temporal distribution of recharge;
! A conceptual model of recharge was developed for the watershed based on the results of the hydrogeological and hydrogeochemical investigations; and
! Additional monitoring capability was developed to test and quantify the conceptual model.

METHODS: Because groundwater discharge is equal to groundwater recharge in a steady-state system, field work focused on locating and measuring discharge for use with a water budget method to calculate recharge. Preliminary hydrogeologic studies included direct measurements of 3 major spring flows using a calibrated weir or bucket and estimations of 3 minor springs using channel morphology and flow rate of the stream measured by a float. Four sets of mini-piezometers were installed in GC to determine direction and magnitude of vertical gradients beneath the creek bottom. Two sets of nested piezometers were used to determine vertical hydraulic gradients in the alluvium. A set of monitoring wells in bedrock were also installed. Determination of valley stratigraphy and characterization of alluvial sediments was accomplished from drilling cores. Horizontal gradients were determined from a 7.5 min quadrangle water table map prepared by WGNHS. An automatic sampler was installed adjacent to the major spring to facilitate high frequency sampling (1 to 12 hour intervals) and other sites were sampled monthly plus on both ends of major storm events. Field and laboratory measurements included water temperature, pH, conductivity, dissolved oxygen, alkalinity, and major ion chemistry including calcium, magnesium, sodium, potassium, chloride, sulfate, silica and nitrate. Five samples were collected in the area for analysis of tritium and samples for radon analysis were taken from 5 springs and six wells.

RESULTS: The conceptual model of the Garfoot Creek watershed incorporates 2 years of observation during which and extensive field assessments, geochemical analyses, and hydrogeologic measurements were made. The data Conclusions:and discussion covers 31 pages of the final technical report and includes 5 contour maps, 6 tables, and 5 graphs and plots which support the following conclusions:

! Groundwaters in the GC watershed consist of calcium-magnesium-bicarbonate water, reflecting the area's dolomite bedrock. The chemistry of the waters suggest that there are 2 distinct flow systems operating in the watershed. The springs seem to be a mixture of the 2 systems.
! GC flow is supported primarily by spring discharge. Groundwater seepage into the creek is negligible compared to the large flow from springs. Based on catchment areas delineated from contour maps, the observed spring discharge rate exceeded the generally accepted recharge rate (7 to 10 inches/year) for this area, but the 2 winters spanning the study were atypical.
! Recharge occurs in the uplands and forested slopes. Absence of runoff from the St. Peter Sandstone led to the conclusion that waters infiltrate through thin soils covering sandstone bedrock throughout the year. Forested hillslopes are also important recharge areas because they have large macropores and maintain a permeability even when frozen. Recharge does not occur through frozen tilled fields in winter or in the lowlands where there are strong upward vertical gradients.
! Land use in the recharge area influenced the groundwater chemistry observed in private wells beneath upland fields. High levels of nitrate, chloride, and sulfate affected local wells. The lower concentration of these constituents downgradient indicated that they were diluted along the way or failed to reach the discharge area during the course of the study. Groundwater beneath cropped fields in the lowland discharge area was not affected by the agricultural nutrients applied to the overlying lands because of the upward vertical hydraulic gradient in the area.
! The groundwater system active in the GC watershed appears to be influenced by a regional groundwater flow system. Regional groundwater discharge means that the recharge area is larger than the local topographic basin. Therefore, land management decisions on the protection of critical recharge areas need to be extended to include areas outside the immediate watershed.

PROJECT INFORMATION: This summary is based on the Hydrogeology Project 92-HDG-1 which was conducted between July **1,** 1991 and June 30, 1993. The project was supported in part by General Purpose Revenue Funds of the State of Wisconsin through the University of Wisconsin System. Administrative management of the project was provided by the UW-Madison Water Resources Center (WRC). The final technical report for this project has been published and is available on loan from the WRC Library as document number WRC-GRR-95.07 (WRC Library call number 051119). To request a document call (608) 262-3069, email the library at askwater@mace.wisc.edu, or visit us on campus at 1975 Willow Drive,

Madison, WI 53706.