Causes of Historical Changes in Groundwater Recharge Rates in Southeastern Wisconsin

Project Number R/UW-HDG-005

Douglas S. Cherkauer, Professor, Department of Geosciences, University of Wisconsin-Milwaukee and Craig J. LaCosse, Research Assistant, Department of Geosciences, University of Wisconsin-Milwaukee

Contract: July 1, 1999 to June 30, 2001
Funding: University of Wisconsin System (UWS)
Focus Area: HDG
Key Words: Recharge, groundwater resources.

BACKGROUND/NEED

Recharge is the process by which rain, snowmelt and surface waters infiltrate to and replenish groundwater. As such, it is the ultimate source of all of our groundwater resources. Yet it is also very difficult to measure, because of its diffuseness. Information on the rates of recharge is usually sparse. To date there has been very little examination of how recharge rates vary through time in response to climatic or land-use changes, making long-term planning difficult for groundwater-dependent communities.

The spatial distribution of recharge in SE Wisconsin was examined during a previous Groundwater Research Program project, showing that it can be quantitatively linked to a number of topographic, hydrogeologic and land-use properties. That work has successfully provided recharge influxes for regional groundwater flow models of southeastern Wisconsin and Fond du Lac County. It has assumed, however, that the recharge rates are static, which they clearly are not. As areas undergo droughts or extended wet periods, recharge undoubtedly varies. As regional or global climate changes, so too will recharge. The question is, how much?

OBJECTIVES

The purpose of this work was to define how recharge rates change through time in response to precipitation changes, to ascertain what factors control that response, and then to develop a mechanism for predicting future recharge changes.

METHODS

Stream baseflow was used as a surrogate measure for recharge. Baseflow is groundwater discharge, so it is equivalent to surface infiltration less evapotranspiration, or net recharge. The use of baseflow opens up the entire USGS streamflow monitoring database as a source of recharge information. There are hundreds of gaging sites in Wisconsin alone, and many have an extensive historical record. Net recharge was obtained for 14 study watersheds in SE Wisconsin using stream baseflow separation (with the USGS HYSEP program).

For each of the watersheds, precipitation and temperature were obtained using Thiessen polygon weighting of daily values from nearby NOAA weather sites. A 34-year time period (1963 through 1997) was selected for analysis. In addition, measures of topography (surface slope, watershed area and shape, among others), hydrogeology (depths to water table and rock, water table gradient, composite subsurface transmissivities and porosities), and land cover (natural, developed, and agricultural) were obtained using GIS databases.

The procedure used was to determine what factors control the baseflow/recharge response to precipitation change in southeastern Wisconsin, which has relatively uniform geologic conditions. Then these relations were tested on another 14 watersheds distributed throughout Wisconsin to ascertain whether they are universal. These test watersheds were selected to include very different bedrock and surficial geology from that in southeast Wisconsin.

RESULTS/DISCUSSION

Time series data (precipitation, temperature, baseflow) were plotted as cumulative departures from average conditions. During the study period, most of Wisconsin experienced drier than normal conditions from 1963 to 1971. The period 1971 to 1993 was wetter than average, and from 1993 to 1997, precipitation dropped below normal again. Baseflow in some watersheds in southeastern Wisconsin follows the precipitation trend almost identically; precipitation 20% below normal produces baseflow/recharge 20% below normal. In other watersheds, the baseflow response is smaller than the precipitation change, and in a few urbanized watersheds, baseflow and precipitation appear almost unrelated.

The rate of baseflow/recharge change with respect to precipitation change (dQ/dP) was compared to all the independent controlling factors for the study watersheds. It was found that dQ/dP is directly related to the product of land surface slope and length of overland flow (S*L), which explains 74% of the observed variation. No other factor or combination thereof (including temperature) showed any significant relation to dQ/dP. When the observed relationship was used to calculate dQ/dP for the 14 test watersheds, it explained 75% of the variance in all areas except the unglaciated southwest.

CONCLUSIONS/IMPLICATIONS/RECOMMENDATIONS

The temporal variation of recharge in Wisconsin is controlled directly by the temporal variation of precipitation. In areas of steep slopes, or where water must travel a long distance before it enters a main channel (often regions with less-developed drainage networks or very permeable soils), the response is essentially 1:1. In areas where slopes are gentle and/or main channels are more closely spaced, recharge changes at only a fraction of the rate of change of precipitation.

The relation uncovered is valid for all of Wisconsin except the Driftless Area. We do not have an explanation for its failure there. However, in glaciated areas, the relation can be coupled with climate change projections to give communities a handle on how much their groundwater supply is likely to change in the foreseeable future.