

Monitoring and Scaling of Water Quality in the Tomorrow-Waupaca Watershed

R/UW-SAM-002

by

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Contract: July 1, 2001 – June 30, 2003

Funding: University of Wisconsin System (UWS)

Focus Area: SAM

Key Words: Denitrification, Nitrate, Groundwater Age, CFCs, Spatial Scale, Temporal Scale, Baseflow Water Quality

Background/Need

Nitrate (NO_3^-) concentrations in groundwater fed streams are frequently lower than concentrations in groundwater beneath adjacent agricultural recharge areas. The cause of this discrepancy and similar discrepancies for other chemicals poses a key question for understanding how agricultural practices affect water quality in many river systems. Unfortunately, conventional stream monitoring approaches are insufficient to address this question.

Two factors that contribute to differences in groundwater NO_3^- concentrations between recharge areas and stream discharge points are: 1) the transformation of NO_3^- to gaseous forms (nitrous oxide, nitrogen gas) by denitrifying bacteria and 2) the amount of time it takes groundwater to move through the landscape from recharge areas to discharge points (lag time). To predict how these factors affect baseflow water quality a better understanding of the spatial and temporal scales of groundwater/surface water interactions is needed.

Objectives

The objectives of this study were to characterize the spatial and temporal scales of groundwater discharge to a 4th order stream within an agricultural basin and to quantify the influence of groundwater denitrification on baseflow NO_3^- concentrations.

Methods

This study was conducted in the Tomorrow/Waupaca River Watershed which is located in parts of Portage, Waupaca, and Waushara Counties in central Wisconsin. A network of miniature wells (minipiezometers) along 1st through 4th order stream corridors was established to map the primary discharge areas. The well screens were installed at a depth of approximately 70 cm below the streambed in order to sample groundwater immediately before it discharged to the stream. Groundwater samples were collected from the minipiezometers in late summer and fall 2002 to map the chemical characteristics of discharge to the stream network. Surface water samples were collected on October 19, 2002 to create a corresponding map of the baseflow water quality. Groundwater gas samples were collected from each minipiezometer in late summer and fall 2002 to determine the amount of denitrification occurring and to determine the lag time of the groundwater using chlorofluorocarbons (CFCs).

Results and Discussion

Baseflow was primarily derived from zones of discharge within 1st and 2nd order drainage corridors. Discharge occurred at a spatial scale of < 50,000 m cumulative stream length. Beyond 50,000 m cumulative stream length there was little communication between groundwater and surface water.

Contemporary baseflow was comprised, on average, of groundwater recharged nearly three decades ago, and reflected a temporal scale spanning nearly a half century. The mean lag time of groundwater discharge measured by apparent CFC age-dating was 28 (\pm 12) yrs.

Contemporary baseflow NO₃⁻ concentrations were strongly affected by denitrification in groundwater. The concentration of denitrified N was more or less constant across the 50-yr temporal scale. Denitrification reaction progress (percent of groundwater NO₃⁻ converted to harmless N₂ gas) was nearly complete (86%) in older groundwater (> 32 yr), which contributes about one-third of the discharge to the TWR, due to low O₂ and the availability of e⁻ donors. But reaction progress declined dramatically in younger groundwater (< 32 yr) in association with rising NO₃⁻ concentrations, higher O₂, and limited availability of e⁻ donors. Overall, more than half (59%) of the NO₃⁻ carried in groundwater was transformed to harmless N₂ gas by denitrifying bacteria before its release to baseflow.

Current concentrations of total NO₃⁻ (NO₃⁻ + denitrified N) in discharge to the TWR reflected land use practices between 1950 and the early 1990s, and strongly parallel the historical rise of N-fertilizer use. Using lag time distribution and denitrification data, stream baseflow NO₃⁻ concentrations were projected over a 110-yr period centered on the present (2002). Predicted baseflow NO₃⁻ concentrations were consistent with available historical baseflow data (1975, 1995, 2002). Projections for the future under a stable land use scenario suggest that rising baseflow NO₃⁻ concentrations will plateau between 2005 and 2020.

Conclusions/Implications/Recommendations

The lag time between groundwater recharge and groundwater discharge to baseflow dominated streams has confounded attempts to use conventional baseflow water quality monitoring approaches to assess relationships between land use practices and water quality in river systems.

In this study, we show that a basin-scale synoptic survey (combining water quality and recharge age-date measurements) at the groundwater/surface water interface is a highly effective tool for deciphering relationships between historic land use and contemporary and future baseflow water quality.

Similar lag time/denitrification studies should be performed in other basins where a longer baseflow water quality record will allow a more rigorous validation of baseflow projections against historical data.

Related Publications

None at this time.