Title: Characterizing the sources of elevated groundwater nitrate in Dane County, Wisconsin

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Background/Need: Private domestic wells are the source of drinking water for approximately 25% of Wisconsin residents, and statewide it is estimated that 12% of these exceed health standards for nitrate concentrations. In Dane County, the exceedance rate is higher, and has been estimated at 25%. Despite the severity of the problem, little is known about the geographic distribution of nitrate in the shallow aquifer and trends in concentrations over time.

Objectives: The objectives of this study were to

- Develop a comprehensive, updatable database of nitrate concentration data from shallow wells,
- Identify county-wide spatial patterns and changes in these patterns and concentrations over time using geospatial and statistical analysis, and
- Utilize the recently completed WGNHS Dane County Groundwater Model to characterize the age and origin of well water, and combine this information with nitrate and land use/hydrogeologic data to explore sources and changes in nitrate loading to groundwater over time.

Methods: Nitrate data for locatable shallow wells in Dane County were compiled from a number of sources. In all, over 60,000 unique records were identified spanning from the 1970's to 2014. Data were binned into 5-year intervals and spatially interpolated. Public well (noncommunity) data provided several hundred continuous timeseries from 1994-2013, these data were subjected to additional analysis to characterize concentration trends. The Dane County Groundwater Model was utilized in forward particle tracking mode to approximate the average age of groundwater in the 4,800 wells in the database for which depth information was also available from well construction reports, and modeled ages were then combined with 23,000 nitrate observations from these wells for final analysis.

Results and Discussion: The current (2010-2014) spatially-weighted mean nitrate concentration is 6.3 mg/L, and 14% of the county currently exceeds 10/mg/L. Clear and consistent spatial patterns were revealed in well water nitrate concentrations that to some extent

reflect density of agricultural activity, but the hydrogeology of the county appears to be the primary driver of average nitrate concentrations in wells. In general, lower nitrate concentrations are observed nearer to major surface water features such as lakes, rivers and streams and hence farthest from the major groundwater divides, whereas higher concentrations are observed further from surface water features and hence near major groundwater divides. These spatial patterns also correlate with patterns in modeled groundwater age, with younger water exhibiting higher average nitrate concentrations. Areas of intensive residential development do not appear to have significantly influenced local nitrate concentrations. The total area of the county exceeding 10 mg/L (average) is declining. Public well timeseries data suggest that while the majority of these wells were previously increasing in concentration, more than half are now decreasing. Spring and stream baseflow data, which appear to be good integrators of groundwater concentrations in their watersheds/capture areas, indicate that groundwater nitrate concentrations increased from the 1940's through the 1980's, with concentrations leveling off since the 1990's and possibly decreasing slightly in more recent years. Hindcasting nitrate concentrations using modeled average well water age revealed an identical pattern, which also corresponds remarkably well to records of historical agricultural nitrogen application.

Conclusions/ Implications/ Recommendations: This study has revealed strong spatial patterns in shallow well nitrate concentrations throughout Dane County that have remained fairly stable over time, and identified those regions most at-risk for unsafe levels of nitrate in drinking water where testing efforts should be focused. These patterns are driven by a combination of agricultural land use and hydrologic setting, with higher concentrations occurring high in the landscape near groundwater divides (younger water) and lower concentrations occurring low in the landscape near surface water features (older water). Agricultural nitrogen application appears to be responsible for nitrate contamination at the county-wide scale. In some aspects, groundwater quality in Dane County is slightly improving, likely due in large part to improvements in agricultural nutrient management. Most notably the area of the county where average nitrate concentrations exceed the Maximum Concentration Limit (MCL) of 10 mg/L is declining, and the incidence of very high nitrate concentrations in well water appears to be decreasing. A continued/broadened emphasis on reducing agricultural nitrogen inputs and minimizing leaching is recommended to continue/accelerate this trend.

Related Publications: The results of this study will also be published as a WGNHS technical report. In addition, a related manuscript is currently in preparation for publication in the peer-reviewed literature.

Key Words: Nitrate, drinking water, Dane County, MODFLOW

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Final Report: A final report containing more detailed information on this project is available for loan from Wisconsin's Water Library, University of Wisconsin - Madison, 1975 Willow Drive, Madison, Wisconsin 53706 (608) 262-3069.