Project #238 – Water Security in Armenia, WI: Modeling for informed decision-making in a nitrate-impacted watershed

Project Summary

In the Central Sands region of Wisconsin, concerns have grown regarding the export of nitrogen in the form of ionic nitrate (NO_3^-) from agricultural areas to private wells, where nitrate can be a contaminant of concern particularly to infants and pregnant mothers. Reducing the risk of private well nitrate contamination requires an understanding of the source regions that contribute to water extracted by the well (i.e., the "capture zone"). The capture zone of private wells can be influenced by a variety of factors including local hydrostratigraphy (i.e., the arrangement of geologic units), aquifer parameters associated with hydrostratigraphic units (i.e., hydraulic conductivity and porosity), total depth of the well, and the portion of the well that is screened (i.e., open to the surrounding geologic formation).

This study represents an application of numerical groundwater modeling to an area of interest in Juneau and Wood counties surrounding the township of Armenia (henceforth, "the Armenia region") – part of the Central Sands region of the State. Numerical groundwater models with particle tracing provide a method for estimating the capture zones – and associated travel time for water – contributing to the water quality observed at a given location, such as a private well. We collected data relevant to the hydrology of the Armenia region to develop this numerical model, including: 1) Estimated aquifer pumping rates based on data from the DNR high capacity well database; 2) Land cover, slope, and climate data supporting estimates of annual groundwater recharge; 3) Aquifer water levels (heads) recorded at a newly-installed set of water table and multi-level wells; 4) Aquifer hydraulic property estimates obtained from a series of slug tests and a tracer test performed in the region; 5) Stream stage and flow measurements at nearby surface water bodies including Petenwell Lake and the Yellow River; and 6) depth to bedrock estimates obtained via passive seismic monitoring.

The results of this study indicate that groundwater flow directions are generally to the south and east in the vicinity of residential wells near Petenwell Lake, where the majority of wells determined to

have high nitrate by EPA sampling were located. Locations “up-gradient” (i.e., to the north and west) are likely contributors to nitrate measurements at these locations. Beyond horizontal flow directions, however, our model also simulates the vertical travel of water in the region. Model results demonstrate how wells with increased depth may capture water that originates at larger distances from the receptor with associated longer travel-times.

By post-processing of particle tracking results from MODFLOW, we assessed – for each model cell and a specified depth range – the amount of water passing through the cell that originated on agricultural land versus water that originated on non-agricultural land. These post-processed results were converted into a GIS layer that provides the percentage of water originating from locations where agricultural land uses are present. For a given land parcel and well construction – e.g., a well screened from 50-60 foot depth below land surface – this product provides a decision support tool to local water users that can inform their assessment of water contamination risks.

Note: The majority of work under this project took place during the period of time when the COVID-19 pandemic affected operations at the University of Wisconsin-Madison (Spring 2020 through Spring 2022).