Title: **Hydrostratigraphic and Groundwater Flow Model: Troy Valley Glacial Aquifer, Southeastern Wisconsin**

Project I.D.: DNR Project #199

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Background/Need: Groundwater is an important resource in Wisconsin, especially in areas of southeastern Wisconsin outside the surface water divide of the Great Lakes that are prohibited from using water from Lake Michigan by the Great Lakes Compact. After decades of pumping, the potentiometric surface in the deep bedrock aquifer has dropped several hundred feet, causing some wells to draw water with high salinity and radium. Treating radium is expensive and many communities are looking for good quality shallow groundwater that would not require treatment. One possible source of shallow groundwater for these communities is the Troy Valley, a deep pre-glacial valley that was probably deepened by subglacial meltwater and is now filled mostly with glacial and related deposits.

Objectives: The objectives of this project were to define the character and spatial distribution of deposits in the Troy Valley and to estimate the effects of pumping from recently installed wells in the Troy Valley aquifer on groundwater and surface water levels.

Methods: The study location included the southern half of Waukesha County and northern portions of Walworth and Racine Counties. Subsurface data, including geophysical data and well logs, were used to construct a three-dimensional hydrostratigraphic model using the software program Rockworks™ v. 2006. The final model was selected from eleven possible models based on geologic reasoning and the fit to six hydrostratigraphic cross sections constructed from field information. The hydrostratigraphic model was imported into a regional groundwater flow model, which was calibrated to steady-state conditions, using MODFLOW with the River Package to represent surface water features.

Steady-state simulations showed the impacts on groundwater heads and flux to surface water features due to pumping from four recently installed wells in Waukesha and Walworth Counties. Sensitivity tests assessed the effect of the fixed flux boundary conditions. Stochastic MODFLOW was used to assess uncertainty in the hydraulic conductivity values of the glacial deposits and the pumping rate of a well near Lake Beulah (Walworth County). MODPATH was used to determine capture zones for the four recently installed pumping wells. Two local scale models in the vicinity of Lake Beulah and Vernon Marsh (Waukesha County) were extracted from the calibrated regional model. These models used the Lake, Stream Flow Routing, and River Packages in MODFLOW to assess the effects of pumping on surface water levels.

Results and Discussion: The results of both the regional and local scale models indicated that pumping in the Troy Valley near Vernon Marsh and Lake Beulah will reduce groundwater heads and groundwater flow to surface water features near the pumping wells. Groundwater inflow to Lake Beulah was predicted to decline by up to 40%. However, groundwater inflow to Lake Beulah calculated by the local scale models is only around 20% of total inflow. Under the fixed flux boundary conditions assumed in the model, the maximum change in head at depth in the vicinity of the well screens was predicted to be around 50 ft, while the maximum drawdown at the water table was approximately 7 ft around Lake Beulah and around 22 ft near Vernon Marsh.

Conclusions/Implications/Recommendations: Inverse distance weighting appears to produce geologically reasonable results when used to interpolate the spatial distribution of glacial deposits. Uncertainty analysis showed that the estimated value of hydraulic conductivity of the glacial deposits can significantly affect heads under pumping conditions. The regional model is considered to be a good first approximation model for use in groundwater management. However, the calibration of the local scale models is more uncertain; they would benefit from additional calibration efforts.

The hydrostratigraphic model, and thus also the groundwater flow models, could be improved by collection of additional data, especially near Vernon Marsh, which lacks detailed subsurface data. Ideally at least two wells should be drilled to bedrock using rotosonic drilling, which would improve the characterization of glacial deposits in the area. Field testing of these wells with pumping tests/slug tests would provide information on hydraulic conductivity. Additional geophysical work, using ground penetrating radar, for example, would also help to delineate the spatial distribution of glacial deposits.

Both the regional and local models could be improved by additional field work to determine site specific values of hydraulic conductivity. Additional monitoring wells would provide additional calibration targets that would result in a more accurate model. Furthermore, existing and new vertical head gradients could be used as targets. Transient calibration to pumping test data would also be helpful.

The local scale Lake Beulah and Vernon Marsh models would improve with improvements to the regional model since they were extracted from the regional model and use heads determined by the regional model to set boundary conditions. Additionally, monitoring lake levels and doing additional stream gaging in these areas would provide better calibration targets. Field work to determine site specific precipitation and evaporation rates for the lakes would also be helpful.

The use of indicator kriging or another type of geostatistical technique with the hydrostratigraphic model would allow for geologically more realistic assumptions about the deposits than the random distribution used in Stochastic MODFLOW. Additionally, uncertainty of the boundaries of each hydrofacies could be tested using more advanced geostatistical methods. An uncertainty analysis and stochastic analysis could be run on the Lake Beulah and Vernon Marsh models.

Related Publications: Dunkle, Kallina. (2008), Hydrostratigraphic and Groundwater Flow Model: Troy Valley Glacial Aquifer, Southeastern Wisconsin. MS thesis, Dept. of Geology & Geophysics, University of Wisconsin-Madison, 115 p.

Key Words: groundwater model, Troy Valley, glacial hydrostratigraphy, water supply

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