PROJECT SUMMARY

Title: Groundwater-Lake Interaction: Response to Climate Change, Vilas County, Wisconsin

Project ID: R/UW-GSI-004

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Period of Contract: July 1, 2001 – June 30, 2002

Background/Need: There are numerous lakes and wetlands in Wisconsin and most have some connection with the groundwater system. Groundwater fluxes, while difficult to measure, may be important to the hydrology and chemistry of lakes. Stresses on the groundwater system and changes in groundwater fluxes affect surface water levels, which in turn affect groundwater levels in a dynamic feedback process. Problems in Wisconsin that critically depend on recognition and quantification of this feedback mechanism include predicting the effects of land use and proposed mining operations on groundwater and lake levels, urbanization on groundwater/surface water systems, agricultural drainage systems on wetlands, and potential global climate change on hydrologic systems.

Standard groundwater models assume that surface water levels are known inputs, and therefore do not recognize the true nature of the connection between surface water and groundwater. Recognition of the need for improvement in the way in which groundwater models handle surface water inputs led to development of specialized software packages for MODFLOW (the industry's standard code for groundwater flow modeling) that address the dynamic exchange of groundwater with rivers and reservoirs. Watersheds containing important lake and stream systems require models that include consideration of the dynamic exchange of waters among groundwater, lakes and streams.

The Trout Lake Basin study site is ideal for addressing issues related to groundwater-surface water interaction inasmuch as long-standing and on-going hydrological research with accompanying data collection and monitoring occurs at this site through the National Science Foundation's Long Term Ecological Research (LTER) program and the U.S. Geological Survey's Water, Energy, Biogeochemical Budgets (WEBB) program.

Objectives: (1) to determine effects on water levels of potential climate change in the Trout Lake Basin, Vilas County, Wisconsin and (2) to define the contributing groundwater basins and travel times to lakes within the Trout Lake Basin.

Methods: A regional groundwater-based watershed model of the Trout Lake Basin was calibrated under both steady-state and transient conditions and used to delineate lake capture areas and to assess the effects of potential climate change on surface water and groundwater levels. The industry standard groundwater flow code, MODFLOW, including the newly developed LAK3 package for simulating groundwater exchange with lakes and a beta version of the Streamflow Routing Package for simulating groundwater exchange with streams and routing of streamflow, was used to simulate groundwater flow in the watershed. The flow model was calibrated using a parameter estimation code, UCODE. Results from the flow simulation were input to a particle tracking code, MODPATH, and used to delineate steady-state capture areas for 30 lakes in the basin as well as three streams. MODPATH also calculated travel times within the capture areas for selected lakes.

Results and Discussion. The large lakes tend to have large capture zones; Trout Lake has the largest. Many lakes receive water that underflows or flows through another lake. Travel times range from 200 years within the Trout Lake capture area to less than 20 years within the Crystal Lake capture area.

Sensitivity of the model to changed climate conditions, simulated by “wet” and “dry” recharge scenarios, showed that in general, capture zones are smaller under the “wet” conditions, corresponding to lower groundwater inflow rates for most of the lakes. All lakes had increased rates of groundwater discharge during the “wet” scenario and decreased rates during the “dry” scenario. Crystal Lake, a small lake located near the regional groundwater divide, showed the most dramatic change in capture zone size between the two scenarios. Lake levels in the large drainage lakes were insensitive to changes in recharge since lake level is controlled by the outlet streams. Seepage lakes showed, on average, a half-meter stage change under both “dry” and “wet” conditions.

Conclusions/Implications/Recommendations: Calibration of the complex three-dimensional groundwatershed model demonstrated the importance of using multiple calibration targets including groundwater heads and fluxes as well as additional non-traditional targets. Delineation of lake capture areas verified the importance of three-dimensional flow in this watershed; capture areas clearly show the occurrence of underflow of water beneath lakes. In effect, the system of lakes acts as a conveyor of water moving water down gradient to Trout Lake. Simulations designed to test the sensitivity of the model to potential global climate change demonstrated that lake capture areas, lake stages and groundwater fluxes to/from lakes in the Trout Lake Basin are sensitive to changes in precipitation, evaporation and recharge rates.

The results of the climate change simulations will be of interest to water managers and to scientists interested in the hydrologic effects of changes in groundwater recharge at a watershed scale. The delineation of lake capture areas will be helpful in addressing questions related to potential impacts on lakes as a result of land use change. Travel times of water flow to the lakes are needed for on-going studies of the geochemical evolution of groundwater in the Trout Lake Basin and could be used in transport studies related to possible introduction of solutes from certain kinds of land use.

Key Words: Groundwater, modeling, climate change, lake capture area, travel time, groundwater age.