

## **The Sturgeon Bay wellhead-protection project: Delineation of contributing areas for municipal wells in fractured dolomite.**

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A wellhead-protection study for the city of Sturgeon Bay, Wisconsin, demonstrates the necessity of combining detailed stratigraphic analysis with groundwater modeling to delineate zones of contribution for municipal wells in a fractured dolomite aquifer. The city of Sturgeon Bay lies in Wisconsin's Door Peninsula between Lake Michigan and Green Bay. Dolomite of Silurian age forms an important aquifer and contains numerous vertical and horizontal fractures. Soils over the dolomite are thin and sometimes absent, making the area extremely vulnerable to groundwater contamination. The flow system in the dolomite is highly transient, with short, high-intensity recharge events and rapid fluctuations in groundwater levels.

We combined a numerical model (MODFLOW) with a particle-tracking code (MODPATH) to simulate the regional groundwater system in the dolomite and to delineate capture zones for five municipal wells. The hydrostratigraphic model included vertical and horizontal fractures and high-permeability zones. Correlating stratigraphic interpretations with field data such as geophysical and flowmeter logs, packer tests, and fracture mapping resulted in the construction of a transient, three-dimensional numerical model with five high-permeability zones related to bedding planes or facies changes. These zones serve as major conduits for horizontal groundwater flow. Dipping fracture zones were simulated as thin high-permeability layers. The locations of exposed bedrock and surficial karst features were used to identify areas of enhanced recharge.

Model results show the high vulnerability of the municipal wells to contamination. Contributing areas for the wells extend several kilometers north and south from the city. Travel times from recharge to all wells were generally less than one year. These travel times are consistent with measured seasonal and event-correlated variations in groundwater temperature, electrical conductivity, and oxygen isotope ratios.

Local officials are currently using the results of this work to develop wellhead-protection policies for the Sturgeon Bay area.