APPENDIX 4: SAMPLE MODEL RESULTS

A. Evaluation of Groundwater Sustainability in the Ramsey Area

B. Evaluation of Groundwater Sustainability in the Woodbury Area

C. Evaluation of Future Drawdown Conditions in the Lakeville/Farmington Area

EXAMPLE OF MODEL USE: EVALUATION OF GROUNDWATER SUSTAINABILITY IN THE RAMSEY AREA

BACKGROUND

With major transportation corridors, the northwest portion of the Twin Cities metropolitan area is currently experiencing and expected to continue to experience significant population growth. With the increase in population comes increased water supply demand. Of primary concern is that the only available bedrock aquifer in the area is the Franconia-Ironton-Galesville (FIG) aquifer. The Mount Simon-Hinckley aquifer is also present in the area but its use is restricted under Minnesota Statues Section 103G.271. In many areas of the Twin Cities the FIG aquifer is less productive than the heavily used Prairie Du Chien-Jordan aquifer. The concern is that the FIG aquifer may not be able to support the large increase in water demand and cities in the northwest metropolitan area may need to seek out alternative water sources such as the Mississippi River. A local model was constructed to examine the sustainability of the FIG aquifer for the City of Ramsey.

MODELING METHODOLOGY

Projected water demands for the City of Ramsey and surrounding communities were used to assess how many additional wells each of the communities will need to meet demand in the year 2050. Well capacities for existing wells, along with aquifers currently used for supply, were considered in determining the number of additional wells needed and which aquifer they will withdraw from. This information was used to add additional wells to the Metropolitan Area Groundwater Model (Metro Model 2) to evaluate the impacts of additional withdrawals. The well were added near existing well fields using a well spacing of approximately one mile. This well spacing is greater than has often been used for existing wells in the area but represents and optimal spacing to limit the amount of well interference. In areas where more productive aquifers are available, such as in the Maple Grove and Osseo area, well spacing for additional wells was much less.

The regional model was then run to aid in selecting the size of the local model, with wells assigned the rate needed to meet the 2050 average day demand. The extent of the local model was chosen based on this simulation, extending to where little to no drawdown was observed. Telescopic mesh refinement (TMR) was used to construct the local model. TMR is the process of constructing a new flow model from a portion of a regional model by extracting both parameter values and a regional model solution. The new model covers a smaller area and can be re-discretized. The purpose of using a TMR approach is to be able to perform detailed simulations of a small area in a very computationally efficient manner without sacrificing the effects of the regional flow field. Constant head boundaries, extracted from the regional model, were used along the edge of the TMR model domain. No-flow boundaries in the northwest part of the regional model were also maintained in the TMR. The local model grid was then refined in the Ramsey area. Surface water features (rivers and lakes) were redefined to match the level of detail in the refined grid. Conductance values for surface water features (modeled using the River Package) were maintained based on the calibrated regional model conductance values.

Since the regional model was calibrated under steady state conditions, and transient simulations were to be run with the local model, a check was deemed necessary to see if the local model could accurately simulate transient conditions. For this check, the pumping test for Ramsey Well 7 (Unique No. 743832) was simulated in the local model. Drawdown from the simulated pumping test was much less than that observed in the field, suggesting that additional model calibration was necessary. A transient calibration of the local model was performed to include the pumping test data.

Steady state simulations using projected average day pumping rates for 2030 and 2050 were then run using the local model in order to obtain the permanent additional drawdown from current conditions expected from increased pumping. Transient simulations were then run for a two week peak pumping scenario for both 2030 and 2050. One stress period of 14 days with 20 time steps and a time step multiplier of 1.5 were used. A storage coefficient of 1.9×10^{-4} was used. This value was determined based on the transient calibration to the pumping test data. Modeled heads from the steady state 2030 and 2050 average day demand model runs were used as initial heads for the transient, two week peak pumping scenarios. For all simulations the boundary conditions and parameter values remained constant. Only the pumping rates and initial head values were changed between each simulation.

Model Predictions for Sustainability

Drawdown from each model simulation was then assessed. The following was observed in the Ramsey area.

- Maximum drawdown in the FIG aquifer for 2030 and 2050 average day demand was found to be 18 and 29 feet respectively.
- Maximum drawdown for layer one of the model (the water table) for 2030 and 2050 average day demand was found to be 4 and 7 feet respectively
- Maximum drawdown in the FIG aquifer for 2030 and 2050 two-week peak demand was found to be 74 and 88 feet respectively
- Maximum drawdown in layer one of the model (the water table) for 2030 and 2050 two-week peak demand was found to be 5 and 8 feet respectively.
- The hydraulic head above the top of the Franconia Formation after the simulated 2050 two week peak pumping scenario was found to be a minimum of 39 feet with many areas greater than 75 feet above the top of the aquifer.

Overall, the results of the model simulation show that the FIG aquifer in the Ramsey area should be able to meet projected demands. However, potential drawdown in the water table may have detrimental effects on surface water bodies in the area, in particular, wetlands. As additional wells are added, close monitoring of both the surficial aquifer and the FIG aquifer is recommended.

EXAMPLE OF MODEL USE: EVALUATION OF GROUNDWATER SUSTAINABILITY IN THE WOODBURY AREA

BACKGROUND

The City of Woodbury was planning the development of municipal water supply wells for the eastern portion of Woodbury. A primary concern regarding this development from the standpoint of sustainability is the effects of pumping that new wells might have on base flows (i.e. groundwater contributions) to Valley Creek (a state-designated trout stream), whose headwaters are located about 2 miles east of the proposed East Woodbury well field. Another concern was the drawdown effects pumping might cause on nearby wells.

In planning for future demands, as many as 15 new wells have been contemplated in the area along Cottage Grove Drive in eastern Woodbury. In consultation with the DNR, it was agreed that only the first three wells (Wells 15, 16, and 17) would be evaluated using the groundwater model. Based on the evaluations of these three wells, the effects of additional wells additional monitoring data would be collected and additional modeling would be performed.

MODELING METHODOLOGY

This modeling evaluation required a model area that included all of southern Washington County. The model was extensively refined in the vicinity of the proposed East Woodbury well field. Well 15 was installed by the city and two month-long pumping tests were performed on this well, with extensive monitoring of water levels in nearby wells. Tests such as these are crucial to the predictive capabilities of the model for problems such as these because they provide real-world data on how pumping affects groundwater flow and groundwater elevations. These data were used to recalibrated the groundwater flow model in the east Woodbury area.

The model calibration process involved performing “transient” model simulations of the pumping tests. The program PEST was used to change model parameters within expected ranges until a reasonable match was obtained between the model’s results and the observations that were made during the pumping tests.

At this stage, the City of Woodbury installed Well 16. The model was used to design a three-month long pumping test for Wells 15 and 16 combined by predicting where and by how much groundwater levels would change during the course of the test. This allowed for a very focused monitoring program for the Wells 15 and 16 pumping test.

After the Wells 15 and 16 test was completed, the model's predictions were compared to the monitored data. At that point, it was decided that an additional model calibration was needed – this time, the Well 15 pumping tests were simulated along with the new Wells 15 and 16 test in the calibration process.

Model Predictions for Sustainability

After calibrating to the tests, the model was used to predict how future wells in the area would affect the base flows into the headwaters of Valley Creek. The City of Woodbury identified possible locations for Well 17 and wanted to see if pumping at these locations would affect the base flows.

The model was used to simulate pumping for 4-year period from 2008 through 2011. Two conditions were modeled: one with the new Well 17 and one without the well. Seasonal changes in pumping of existing wells and considerations for increased pumping due to increased demand during the 4-year period were incorporated into the model's simulation. The model results focused primarily on how Well 17 may affect base flows into Valley Creek.

The preliminary results of this modeling indicate that pumping of Well 17, along with additional water demands during the next four years, may cause small reductions in base flows to Valley Creek (about 0.13 cubic feet per second, or 3% of the base flow of the headwaters portion of Valley Creek). This amount of reduction is may not be measurable, because of seasonal fluctuations in stream flow conditions. However, results do indicate that there is possibility of impacts on the trout stream from groundwater withdrawals.

EXAMPLE OF MODEL USE: EVALUATION OF FUTURE DRAWDOWN CONDITIONS IN THE LAKEVILLE/FARMINGTON AREA

BACKGROUND

Lakeville and Farmington in Dakota County obtain water from wells completed in the Prairie du Chien-Jordan aquifer. During dry periods in the summer, high pumping demand has resulted in a temporary lowering of groundwater levels in the area, including areas of unincorporated Scott County where private individual wells are relied upon. Some of these individual wells (which may be drilled to shallower depths than municipal wells) have experienced problems believed to be the result of "well interference" effects with municipal wells in the area.

Future growth will require additional groundwater withdrawals in the area that may exacerbate well interference problems. A TMR of the Metro Model 2 was used to predict how groundwater levels might change due to both average pumping and peak summer pumping in the years 2030 and 2050.

MODELING METHODOLOGY

For the cities in Dakota and Scott Counties average annual and peak summer water demand projections for 2030 and 2050 were evaluated. For these four demand conditions, pumping rates of existing wells were increased according to the percentage of the current use in order to meet the municipality's future demand. While it is anticipated that future demand will be met, primarily, through the installation of new wells in the Prairie du Chien-Jordan aquifer, the location of future wells within each municipality is not precisely known. Therefore, it was assumed that future additional pumping would be supplied though existing wells. It is recognized that physical limitations of existing wells make this assumption somewhat unlikely; however, it is a useful method for assigning future pumping and at the scale of this evaluation, assuming that existing wells can pump at future demands should provide reasonable predictions.

Unlike the evaluation of the Ramsey area, this study did not use further model mesh refinement in the form of constructing a more local/sub-regional model. Rather, the existing model's discretization (grid cell size of 200 x 200 m) was employed to demonstrate how the model, in its current refinement, can be used as a predictor of future pumping effects. Regional model parameter values were not changed for this evaluation.

For the average demand conditions of 2030 and 2050, steady-state simulations were used and drawdown was referenced to the model's predictions of groundwater elevations for current average pumping conditions. For peak demand in 2030 and 2050, a two-week transient simulation was performed that used as starting conditions, the model's predictions for average groundwater levels for the respective year. The drawdown for peak pumping conditions (with reference to current average pumping conditions) was determined to be the drawdown at the end of the two-week transient simulation.

Since the model was calibrated under steady state conditions and transient simulations were to be run, storage parameters needed to be included in the model. Values of confined storage (storativity) were assigned on the basis of pumping tests for Lakeville and Apple Valley (2.3×10^{-4}). Unconfined storage was assumed to be 0.15. The transient simulation's stress period was 14 days, with 50 time steps and a time-step multiplier of 1.4.

Pumping rates were adjusted for the following communities in the model to reflect future average and peak pumping conditions: Lakeville, Farmington, Burnsville, Apple Valley, Elko-New Market, Savage, and Prior Lake. For all future conditions, dewatering of the Burnsville Quarry was assumed to have ceased.

Model Predictions for Future Drawdown

Drawdown from each model simulation was assessed. The following was observed.

- Groundwater levels at the Burnsville Quarry will recovery by as much as 50 to 75 feet at the quarry. This prediction assumes that dewatering of the quarry will have ceased before 2030.
- Drawdowns in Lakeville under average pumping conditions in

2030 will increase by about 20 feet in the Prairie du Chien-Jordan aquifer. Drawdowns in the Prior Lake will increase by about this same amount. Drawdowns in the water table aquifer will increase by about 10 feet. These drawdowns may reduce base flows to portions of the Vermillion River or other surface water features in the area.

- Drawdowns in Lakeville under two-week maximum pumping conditions in 2030 will increase by about 35 feet in the Prairie du Chien-Jordan aquifer. Groundwater levels in the water table aquifer will increase by about 15 feet. However, the model predicts only small amounts of drawdown west of Lakeville, in currently undeveloped areas.
- Drawdowns in Lakeville under average pumping conditions in 2050 will increase by about 25 feet in the Prairie du Chien-Jordan aquifer, compared to current conditions. Drawdowns in the Prior Lake will increase by about this same amount. Groundwater levels in the water table aquifer will increase by about 20 feet. These drawdowns may reduce base flows to portions of the Vermillion River or other surface water features in the area.
- Drawdowns in Lakeville under two-week maximum pumping conditions in 2050 will increase by about 50 feet in the Prairie du Chien-Jordan aquifer, compared to current average conditions. Groundwater levels in the water table aquifer will increase by as much as feet. The model predicts drawdown west of Lakeville, in currently undeveloped areas, to be about 15 to 20 feet during maximum pumping conditions in the Prairie du Chien-Jordan aquifer.

In some areas of the County there is very limited head above the Prairie du Chien Group. As this part of the region continues to be developed, careful monitoring of water level trends and impacts to surface water features will be necessary to ensure supplies are developed sustainably.