
APPENDIX C

GROUNDWATER MODELING

Several scenarios were simulated using the four layer Dane County groundwater flow model (Krohelski, et al., 2000) constructed using the U.S. Geological Survey groundwater flow model code, MODFLOW, and a new model constructed from the Dane County model using the Telescopic Mesh Refinement technique (TMR) to more accurately simulate conditions in the region around UW 29. The Dane County groundwater flow model has a grid with 200 rows and 240 columns and a grid spacing of 1312.4 feet on a side. The TMR creates a new grid within the boundaries of the original model, assigning appropriate boundary conditions based on the original model. The new model covers an area of approximately 32 square miles in the vicinity of UW 29 and has 100 columns and 100 rows with a grid spacing of approximately 301 feet on a side. Since the new model has not been calibrated (additional data would be necessary for model calibration), the model is considered useful as a screening tool. The model was run for steady state conditions in which input parameters do not change over time. The U.S. Geological Survey particle tracking post-processing package, MODPATH, was used with the MODFLOW results to compute particle paths and travel times. The particles move in response to the average linear groundwater velocity as computed by the model.

The model was used for two general objectives, to confirm the source of water to UW 29 as depicted in previous simulations (Bradbury, 2003) and to evaluate the potential for well impacts from Sycamore Landfill. Sycamore Landfill is a closed facility located approximately 1500 feet west and downgradient of UW 29 (Figure 1). The groundwater beneath the landfill is impacted with volatile organic compounds and is monitored by the city of Madison. Based on the above objectives, the following scenarios were simulated:

1. Long term pumping of UW 29 to confirm the zone of contribution (Figure 1).
2. Particle tracking from impacted groundwater beneath Sycamore Landfill to determine whether the particles are captured at Well 29 and over what time period (Figure 3).
3. Particle tracking from Sycamore Landfill in which the confining layer (Eau Claire shale) is absent to determine direction of flow when no pumping is occurring (Figure 4).
4. Particle tracking from Sycamore Landfill in which the confining layer (Eau Claire shale) is absent and UW 29 is pumping at 2,000 gpm for 20 years and 30 years (Figures 5 and 6)
5. Particle tracking from Sycamore Landfill in which the confining layer (Eau Claire shale) is absent and UW 29 is open to both upper and lower aquifers (i.e. short circuiting or open hole at UW 29) and is pumping 2,000 gpm (Figure 7).
6. Particle tracking from Sycamore Landfill in which the confining layer is intact but particles are already in the lower sandstone aquifer and UW 29 is pumping 2,000 gpm (Figure 8).

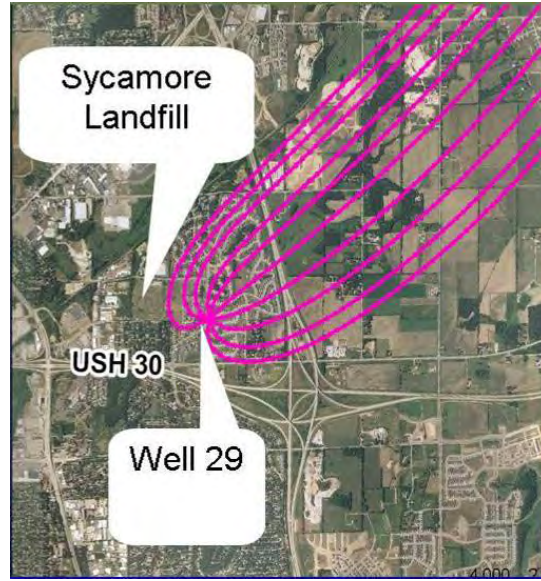


Figure 1. The zone of contribution (source of water) for Well 29

The source of water for Well 29 is to the northeast which compares favorably to previous simulations (Bradbury, 2003). The predicted pumping rate for year 2025 is 1.383 MGD or approximately 960 gpm. The pumping rate used to delineate the zone of contribution was the maximum sustained pumping rate (one-half the design capacity of the well) of 1.584 MGD or 1,100 gpm.

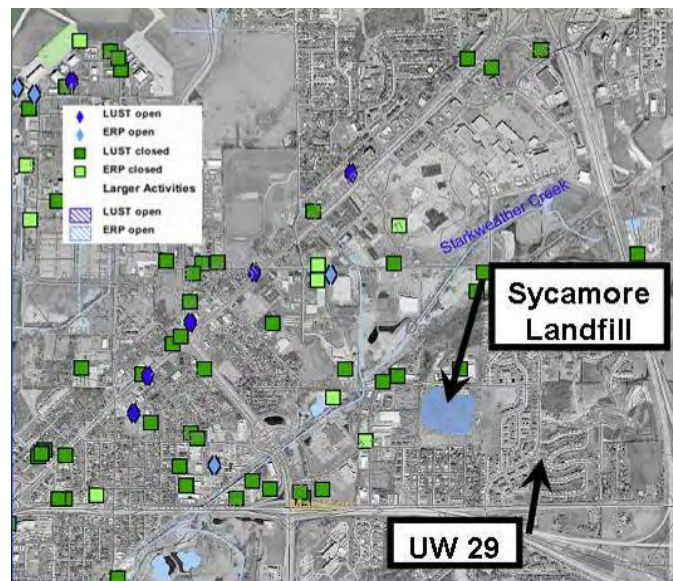


Figure 2. Potential Contaminant Sources.

The nearest potential contaminant source of organic loading is Sycamore Landfill located approximately 1,500 feet to the west (downgradient) of Well 29.

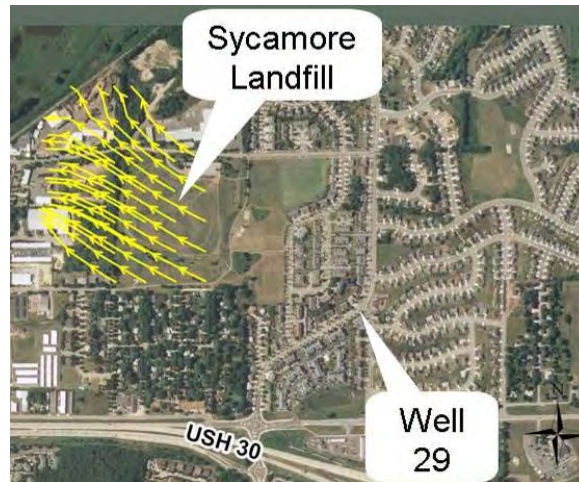


Figure 3. Particle Flow from Sycamore Landfill.

Particles were inserted in layer two (upper bedrock aquifer) underneath the landfill. The bottom of the affected groundwater beneath the landfill was reported to be at an approximate elevation of 830 ft msl at the eastern edge dropping to 810 ft msl at the western edge (City of Madison, 1996). Particles were inserted at an approximate elevation of 780 ft msl to 760 ft msl or approximately 50 feet below the affected groundwater. The model results indicate that the particles from layer two will track to the northwest and will not be captured by Well 29 pumping 2,100 gpm, the maximum design capacity.

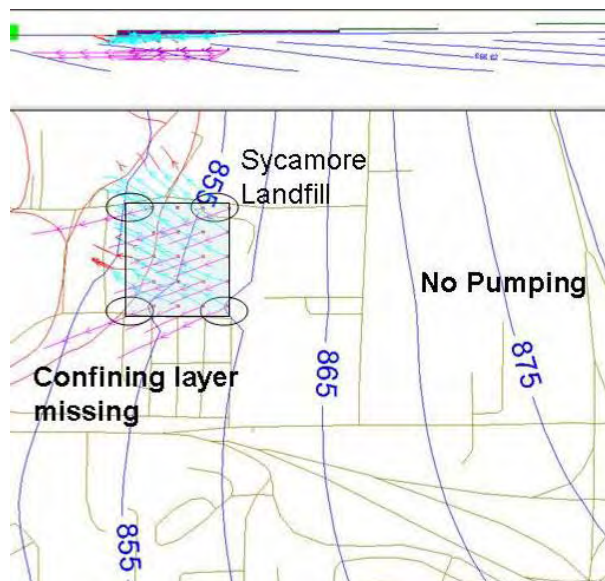


Figure 4. Particle Tracking when the confining Layer (Eau Claire shale) is absent.

The confining layer (layer 3) at the four corners of the landfill was simulated as missing by increasing the vertical hydraulic conductivity from 7.2×10^{-4} ft/day to 1.0 ft/day. When there is no pumping at UW 29, model results show that particles move to the northwest in layer 2 (aqua) and eventually move upward into layer 1. Particles inserted in layer 3 move down to layer 4 (pink) and to the southwest.

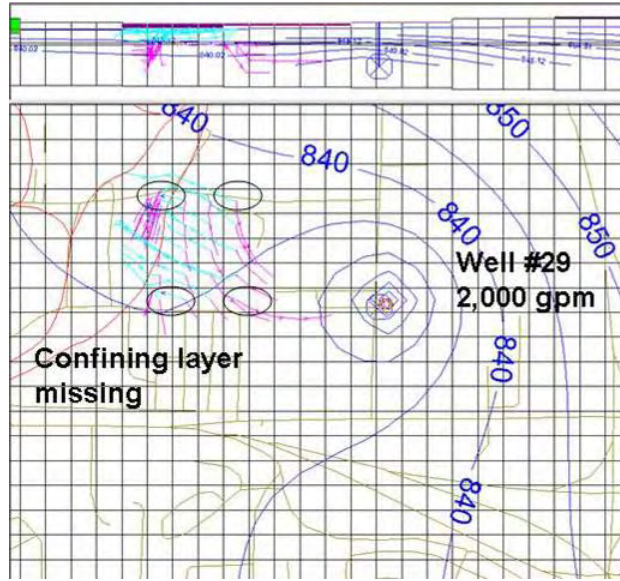


Figure 5. Particle tracking for 20 years when the confining Layer (Eau Claire shale) is absent and well is open only to the deep aquifer.

The confining layer (layer 3) at the four corners of the landfill was simulated as missing by increasing the vertical hydraulic conductivity from 7.2×10^{-4} ft/day to 1.0 ft/day. Model results show that particles will be captured by Well 29 after approximately twenty years. Layer 3 particles where the Eau Claire shale is still present also start moving toward Well 29 indicating that the deeper the contaminants are the more likely they are to be captured.

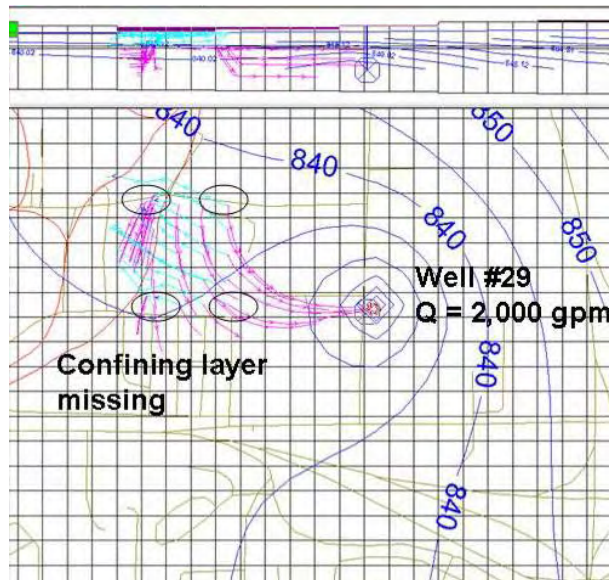


Figure 6. Particle tracking for 30 years when the confining layer (Eau Claire shale) is absent and well is open only to the deep aquifer. Same scenario as above except tracking is for 30 years.

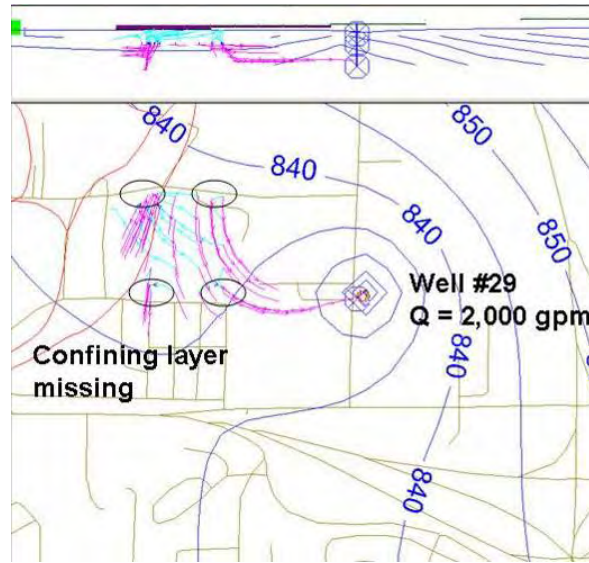


Figure 7. Particle tracking for 30 years when confining layer is absent and well is open to both upper and lower aquifers.

To simulate connectivity between the upper and lower bedrock aquifers (e.g. failure of well casing, missing Eau Claire shale, or the presence of continuous fractures) at the well site resulting in groundwater from the upper bedrock aquifer being captured by UW 29, the well was simulated as being open to layers 2, 3, and 4. The results are similar to previous runs in which the particles are captured by the well in about 25 years.

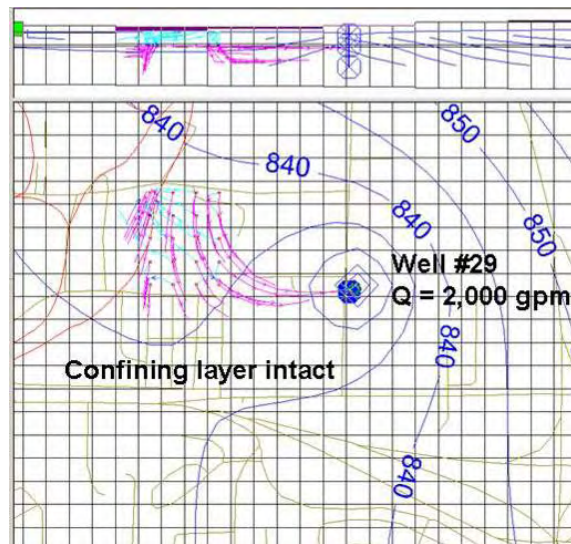


Figure 8. Particle tracking for 25 years when particles are beneath the landfill in the lower aquifer (layer 4) and the well is open only to the lower aquifer.

The model results indicate that particles inserted in the cells in the eastern landfill area are captured by the well and most of the particles that aren't yet captured are moving toward the south.

Conclusions

The results of the modeling indicate that impacted groundwater at a depth of 830 - 810 feet msl beneath the landfill will not be captured by UW 29 operating at proposed pumping rates given that the Eau Claire is present and continuous in this area. Particles emanating from the landfill would not be captured unless UW 29 were pumped at a rate of 2,000 gpm for approximately 25 years, the confining layer were breached or the particles were already in the deep aquifer.

Water Level Monitoring at Sycamore Landfill

Groundwater level monitoring was conducted at Sycamore Landfill to take advantage of the pumping being conducted at UW 29 during the manganese treatment pilot study. The purpose of this monitoring was to determine whether there were observable changes in head at the landfill during pumping at UW 29.

Two wells, MW 13B and MW 19B were selected for monitoring based on their positions closest to UW 29 (see figure below), their screened intervals being the deepest zone monitored at the landfill, and the hydraulic conductivity measured being approximately the highest values measured on the site.

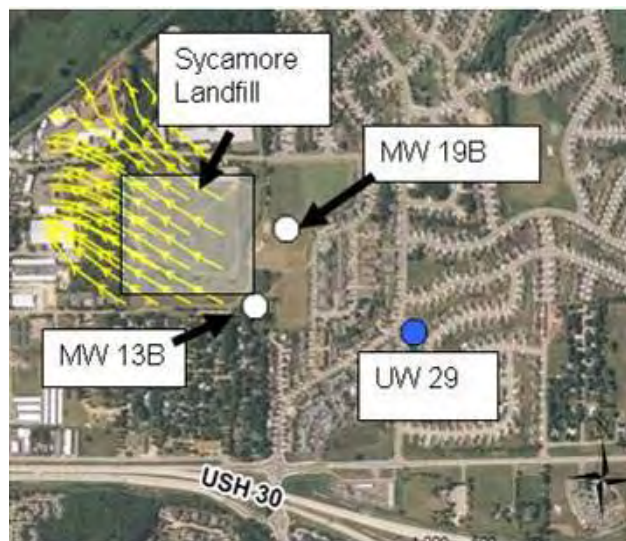


Figure 9. Location of Monitoring Wells at Sycamore Landfill.

Pressure transducers and loggers were placed in the monitoring wells after the dedicated pumps were removed by the City Health Department monitoring crew. The pressure transducers are unvented transducers with a data logger built into the transducer unit. Therefore, the well could be closed and locked, with no above ground device. However, this pressure transducer is unvented, so it measures changes in barometric pressure as well as water level changes. The records were then corrected by subtracting the changes in barometric pressure, as recorded at Dane County Regional Airport, from the time when the pressure transducers were installed in the wells. The figure below illustrates the changes in the raw data, the barometric pressure and the corrected water level changes.

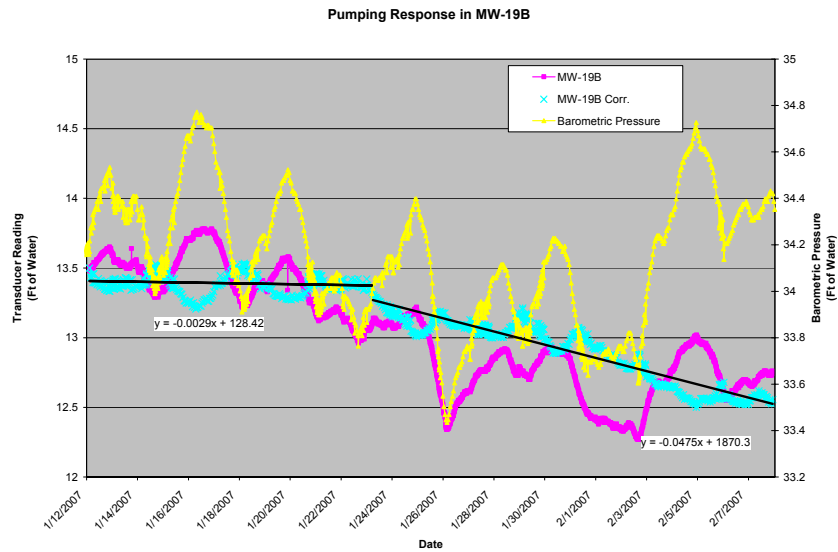


Figure 10. Raw Data for MW 19B.

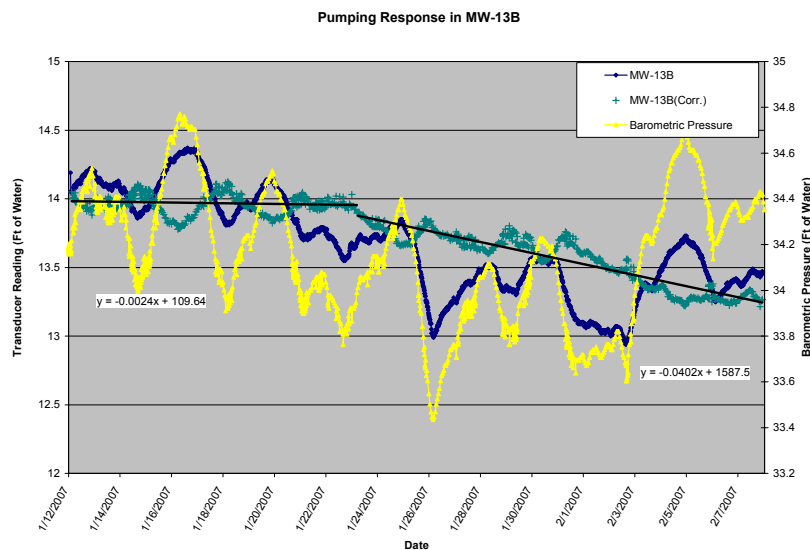


Figure 11. Raw Data for MW 13B.

Pumping at well UW 29 for the manganese treatment pilot study began in mid January and continued into February. Results of the changes in water level indicate that groundwater elevations were approximately level prior to starting UW 29. After January 23rd, MW 13 and MW 19 showed declines in groundwater elevation of approximately 0.6 to 1.1 feet, respectively as shown below.

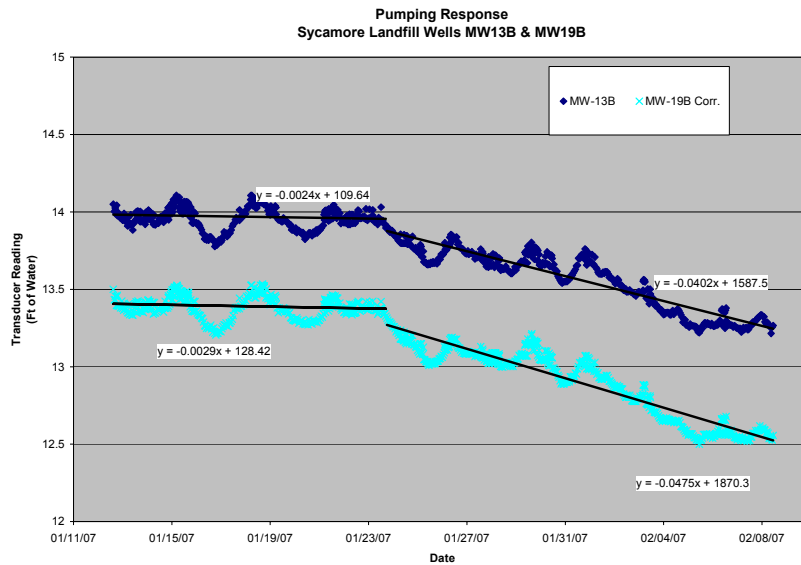


Figure 12. Pumping Response (corrected) for MW 13 and MW 19.

The groundwater model was run to simulate the drawdowns at the landfill (layer 2) as a result of pumping UW 29 during the manganese pilot test. The model predicted drawdowns at the eastern edge of the landfill were approximately 3 feet. The model was run for steady state conditions, so drawdowns of approximately 3 feet are consistent with the data measured (approximately 1 foot) for the short term manganese treatment test.

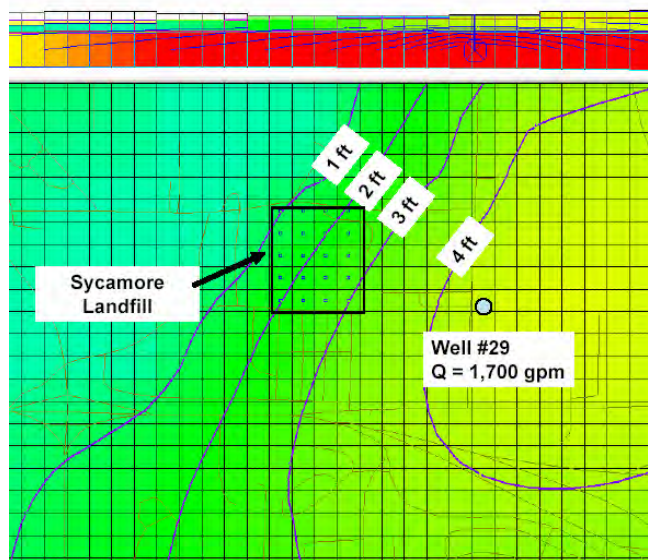


Figure 13. Modeled Drawdowns in the Upper Bedrock (Layer 2) at Sycamore Landfill.