Modeling of the Silver River Watershed

Angela Quillo
Doug Moore
Jeff Thompson
Lindsay Bussell
Ben Drenth

Executive Summary

Keweenaw Bay Indian Community (KBIC) has hired the Aqua Terra Tech Enterprise team to study the groundwater resources of the L'Anse region of Baraga County. As part of this study, Aqua Terra Tech is currently working on developing a model of the hydrogeology of the lower Silver River watershed. The phases involved in creating and running the model were to define the boundary of the watershed, collect applicable data for the model with respect to hyrdrogeologic and hydraulic conditions, to create a conceptual model, then finally transform the conceptual model into a numeric model by assigning parameters obtained through various processes. A conceptual model was created, and a first attempt at a numeric model was undertaken. Unfortunately, a lack of data in some areas resulted in some undesirable effects and hindered the model's capability to work. At the present time, a 2-layer model is nearly ready to run simulations, but much refinement will be necessary to make this model accurate and comprehensive. It is believed that with additional data collection in the fall of 2002 that a good working model of the lower portion of the Silver River watershed will be created.

Acknowledgements

This project was done under the guidance of J. S. Gierke, Associate Professor of Geological and Environmental Engineering, Department of Geological Engineering and Sciences, Michigan Technological University. We acknowledge the financial and other support provided by the Natural Resources Department of the Keweenaw Bay Indian Community. Specifically, we would like to thank Micah Petoskey, water quality specialist, and Michael Donofrio, tribal natural resources director, and Mike Duschene, formerly water quality specialist for their work and logistical support. This project is part of Aqua Terra Tech within Michigan Technological University's Enterprise program

Table of Contents

List of Figures

List of Tables

1 Introduction

1.1 Background

Keweenaw Bay Indian Community (KBIC) has hired the Aqua Terra Tech Enterprise team to study the groundwater resources of the L'Anse region of Baraga County. As part of this study, Aqua Terra Tech is currently working on developing a model of the hydrogeology of the lower Silver River watershed (Figure 1). This portion of the Silver River watershed is about 14 square miles in size and consists of rural, forested land. Geologically, the watershed is composed of thin glacial till overlying metamorphic rocks and sandstone. The Silver River itself is located in the central portion of its lower watershed and is fed by numerous small streams.

The data used to create the model has come from published well logs, geophysical surveys, and pump tests. This report discusses how the model was developed, from the collection of field data to the compilation and processing of that data, and then discusses the model itself.

Figure 1: Location map of lower Silver River watershed, outlined in blue.

1.2 Previous work

A preliminary GMS model in the Little Silver River (Zeba Creek) was generated last year. This project was also part of the Aqua Terra Tech Enterprise. The information obtained from their progress was used as a guide for the formation of the Lower Silver

River watershed model. Much of the data used in creating the Lower Silver River model was collected in the fall of 2001 by the Aqua Terra Tech Enterprise program.

2 Objectives and Scope

2.1 Objectives

Eight major tasks were defined for the project. These were to prepare geological cross-sections, analyze pump test data to determine transmissivities, review geophysical data and well logs, contour bedrock topography and water table topography, delineate the river course and elevation, develop a model to simulate annual flows and steady state conditions, attempt to simulate monthly conditions for the calendar year 2000, and evaluate the sensitivity of the model to grid resolution. Several of these initial tasks were either altered or redefined as the project progressed. The modeling was simplified into a conceptual model and creation of a numerical model for later simulations.

2.2 Scope

Data collection was limited to areas with good roads or in locations where people have a well. Well log information was present for most, but not all of the wells. The exact location of many of the wells was not known; the best information for the location was a portion of a section and the position of the wells for use in the model was determined using a topographic map and Digital Elevation Model (DEM) data.

3 Approach

3.1 Data Collection

3.1.1 Surface Information

Data collection from the surficial group included constructing geological maps, locating wells and determining land use and vegetation for the Silver River watershed. The group consisted of five individuals who divided these important tasks among themselves. Joseph Kraft and Jacob Lobremeier were the key individuals who performed the field reconnaissance of the watershed area. These individuals divided the watershed into sectors A through F and completed the reconnaissance in two intense mapping sessions. The first mapping session (sectors A & B) occurred in the north section and "the main features mapped were the lower Silver River channel and basin, the oxbow lake (unnamed), the northwest intermittent tributary, Kallio Creek, the overland mapping along Skanee Road and the overland hillside regions" (Kraft, 2001). The second major mapping session (sectors C-F) occurred in the southern and western sections and "the major features mapped included the upper parts of the Silver River channel and basin, Silver River Falls, the Third Lake area, the Bella Lake area, Dakota Creek, Commanche Creek, Page Creek and the overland hillside and marsh areas to the east and west of the river" (Kraft, 2001).

The three remaining individuals, Mellisa Le, Jessica Tuomi and Angela Quillo, worked to locate wells in the watershed. Well logs from the area provided the township and range of wells. This information was used in conjunction with a topographic map to locate wells. Some wells were visited on-site and a Trimble Global Positioning System (GPS) unit was used to ascertain the Universal Transverse Mercator (UTM) coordinates for the wells. The overall results of the surficial group can be recorded in the *Surface Study Report: Silver River Watershed (Lower).*

3.1.2 Bedrock information:

In order to determine the subsurface geology, several methods were employed. The first source of information was well logs provided by the Keweenaw Bay Indian Community and the Baraga County Health Department. These give information on the stratigraphy and static water level for a water well. Some seismic refraction surveys were also available. These surveys were used to determine the thickness of the unsaturated and saturated glacial till and the depth to the bedrock. Field mapping by the Surface group in the fall of 2001 provided information about bedrock outcrops. Finally a geologic map was used for comparison and to give a better idea of the underlying geology.

Well logs are an excellent source of information about the geology of an area. The well logs contain a general location in terms of portion of a section and a verbal description or schematic map. The importance of well logs is that they contain stratigraphic information, in terms of depth and thickness of each geologic unit and the lithology. In order to determine the location of the well for modeling purposes, UTM easting and northing were determined by using either topozone.com or the Digital Elevation Model (DEM) with NAD27 as the datum. Elevation data were determined using the DEM data.

The bedrock group completed seismic refraction surveys in the fall of 2001. A total of 18 seismic surveys were done in various areas of the watershed. Descriptions of survey technique and results are presented by Decleene et al (2001). In addition, GPS coordinates were obtained at the survey locations.

The final two sources included data from the Surface group and a geologic map. Outcrop data collected by the Surface group in the fall of 2001 were used (Kraft et al, 2001). The UTM location and elevation of these data were determined using DEM data. Finally, a geological map (Figure 2) provided information on the distribution of the geological units. This map was used to show the distribution of bedrock types and used to indicate where better delineation of units is required.

Once the bedrock information was gathered and organized, it was put into GMS with the borehole editor and then made into geologic units. This procedure is discussed in the TINs to Solids modeling section later on. Once this was done, geological cross-sections were generated and a diagram of cross-sections was created using GMS.

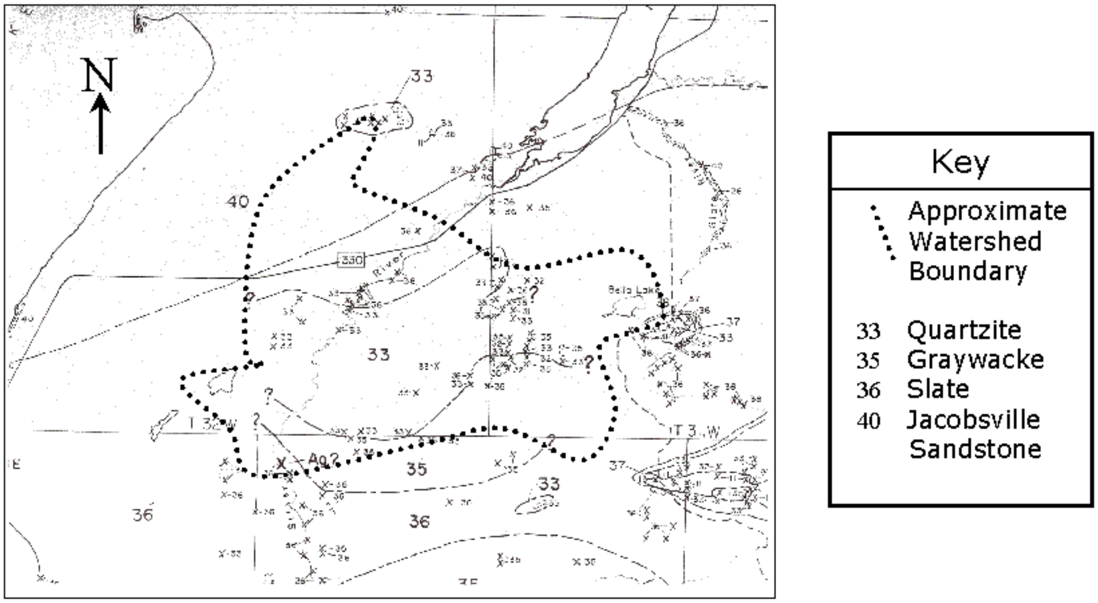

Figure 2: Generalized Geologic map of the Lower Silver River area (modified from Bodwell 1972).

3.1.3 Aquifer properties from pumptest

The pumptest data was modeled using GMS software. First, the data collected by Dr. Gierke was analyzed. The drawdown curves, including pump-down and recovery, were plotted on a graph. A grid was created in GMS by incorporating the parameters of the pump test. Initially, values for hydraulic conductivity and specific yield were estimated and entered into GMS. After the appropriate parameters were entered, MODFLOW was run in GMS and the output file was examined. Drawdown values and their corresponding times from the output file were plotted, creating a model drawdown curve. This model drawdown curve was compared to the observed drawdown curve from the pump test data. This was done for the recovery periods as well. Values for hydraulic conductivity and specific yield were subsequently changed to match the model curve to the observed curve. The values corresponding to the model curve that most accurately matches the observed curve were retained. A complete pump test report can be found in John S. Gierke's Interim Report on a Pumptest at the Leo Niemala Residence, Silver River Watershed, Baraga County, Michigan, 2002.

3.2 Computer Modeling with Groundwater Modeling System (GMS) and MODFLOW

3.2.1 Conceptual Model of the Lower Silver River Watershed

Groundwater Modeling System (GMS) was used in designing a conceptual model of the Lower Silver River Watershed. The conceptual model uses a 3-D grid approach to model the watershed. Different coverages can be used to apply necessary parameters for different aspects of the model. Parameters such as hydraulic conductivity, transmissivity, and specific yield are applied to each block of the 3-D grid once the model is complete. A

MODFLOW simulation is run once the model is concluded and may be altered for desired outcomes. The MODFLOW simulations allows the head contours, water table and flow budget to be viewed using GMS as well.

Modeling began with importing a background image of the Lower Silver River Watershed. The background image consisted of a topography acquired from topozone.com. Sources/sinks, layer 1, layer 2 and recharge coverages were then created by applying special properties to each coverage. The sources/sink coverage includes the delineated river, drains and constant head lakes as well as the conductance of the streams. Layer 1 and layer 2 coverages include vertical and horizontal hydraulic conductivities, specific yield and storage and conductance. The recharge coverage includes the recharge value. All of the coverages include the watershed boundaries and a three-dimensional grid as well.

3.2.2 TIN to Solids Modeling

In order to create a more accurate model, the compiled information from the well logs, seismic surveys, and outcrop data were input into a borehole file. In order to aid in the creation of a borehole file for GMS, a spreadsheet format was used for data input. This spreadsheet was then converted to a borehole file for use in GMS. The borehole file requires units to be numbered and thickness of each unit reported. For modeling purposes in the Lower Silver River watershed, four main units were used. These are glacial deposits, sandstone, slate, and quartzite. Other unusual occurrences as noted on well logs were also put into the borehole file, although they may not be used in the model creation. Once the borehole file was created, the borehole module of GMS was used to pick unit contacts and these contacts were made into triangular irregular networks (TINs). TINs were made for the ground surface, the base of the glacial drift, the top and bottom of the sandstone, and for the top of the slate and quartzite. For the purposes of the initial model, the slate and quartzite were grouped together due to the limited amount of well data for the distribution of quartzite and the fact that these two units have more similar properties as compared to the sandstone or the glacial deposits. Once the TINs were created, they were used to create solids. The solids that were created were the glacial drift, sandstone, and slate, which included quartzite. The use of these solids in the model will be discussed later.

3.2.3 Numerical Modeling

Parameters based on data and observation were used to define the coverages. A three dimensional grid was constructed with 528 ft east-west by 528 ft north-south and the third dimension varried. With the completion of the TIN to solid method, MODFLOW simulations will be performed for the watershed.

4 Experimental Results and Discussion

4.1 Initial results

4.1.1 Cross-sections

The compiled bedrock data was used to generate several cross-sections and a diagram of multiple interconnected cross-sections. Figures 3a through 3c are cross-sections and Figure 3d is a diagram of cross-sections. Figure 3a is an east-west cross-section at the south end of the watershed, Figure 3b is an east-west cross-section at the north end of the watershed near Ford Farm Road, Figure 3c is a north-south cross-section from near Pinery Road to north of Ford Farm Road. Due to limited well log data with quartzite, the Slate and Quartzite were left together since they are both metamorphic rocks, they are part of the same formation and they have more similar hydrologic characteristics than the sandstone or glacial drift. However, the Quartzite will most likely have a lower hydraulic conductivity.

Figure 3a shows that there is a thin glacial drift (black) overlying slate and quartzite (yellow). This glacial drift is thicker at the east side of the cross-section. Figure 3b shows Jacobsville sandstone overlying the slate/quartzite with a thin layer of Glacial drift over everything. An artifact of the creation of the solids is shown where the Jacobville sandstone appears to be above the glacial drift. Figure 3c indicates an area where the glacial drift is substantially thicker than other areas. This is near the Third Lake area and is confirmed by well log data. Figure 3d shows an oblique view of several cross-sections.

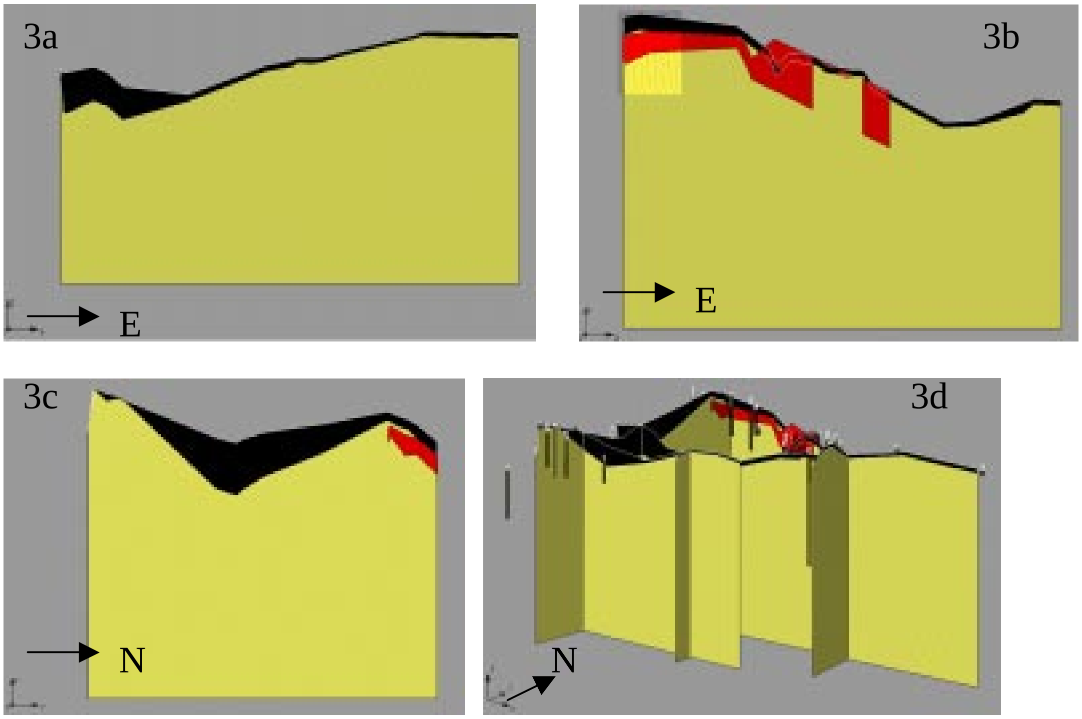

Figure 3: Cross-sections (a-c) and a geologic fence diagram (d) of the Lower Silver River watershed area. Black is glacial drift, Red is Jacobsville Sandstone, and Yellow is slate and quartzite.

4.1.2 Bedrock topography

The bedrock topography was contoured using GMS. The result is shown in Figure 4. Due to the area of sparse data in the central region of the watershed, the data in this region are suspect. In the southeast, southwest, and north (except for Pikes Peak) the results are what would be expected.

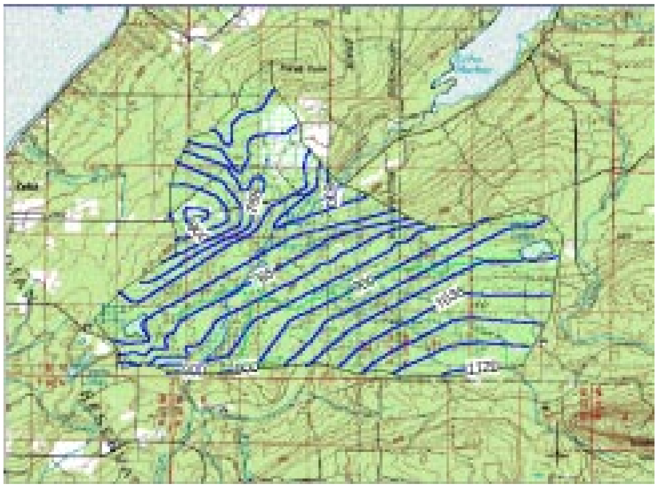

Figure 4: Bedrock Topography map. Contours of elevation of bedrock in feet above mean sea level.

4.1.3 Aquifer Properties

Figure 5 shows the plot containing the observed curves versus model curves. The corresponding values for hydraulic conductivity is 2.31E-03 ft/s and specific yield is 0.01. The model curves do not match up exactly with the observed curves, but they are reasonable. The large diameter of the well has a large effect on the drawdown values, and this was not completely accounted for. Due to this fact, the correlation of data at later near the end of the pumptest was emphasized instead of the early time data.

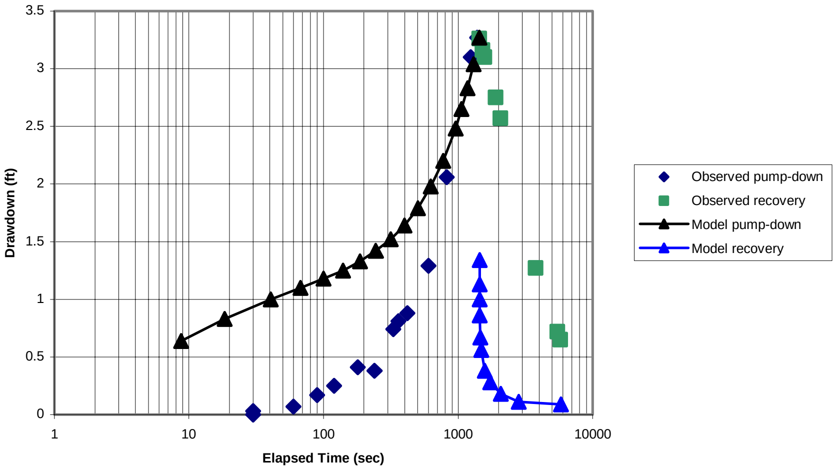

Figure 5: Plot showing observed and model drawdown curves.

4.2 Model results

4.2.1 Conceptual Model of the Lower Silver River Watershed

The conceptual model defined the watershed and its properties for use in MODFLOW simulations. Figure 6 defines the watershed as completed with the conceptual model. The black outlines the watershed boundary, the blue line represents the river, the green lines correspond to drains (intermittent streams), and the two smaller black outlined areas correspond to lakes with constant head.

Figure 6: Watershed boundaries with the delineated Silver River (blue), drains (green) and constant head lakes (black).

4.2.2 Numerical Model of the Lower Silver River Watershed

Parameters used in the numerical model are defined in Table 1 in Appendix A. A two-layer model was created with the first glacial drift and the second layer bedrock. A grid was constructed with 528 ft by 528 ft individual cells. To better define the subsurface geology, borehole data was implemented and used in GMS. With the completion of the TIN to solid method, MODFLOW simulations will be performed for the watershed.

5.0 Conclusions

Several areas of the model have much data while other areas have none. The conceptual model is nearly complete, but the numerical model needs much refinement for an accurate simulation to be attempted. An attempt at a steady state simulation was made, but the river and drain elevations were located beneath the first layer, so the model would not run. If these could be corrected, then a first approximation using the model could be attempted. Due to time constraints, the tasks of running simulations and testing grid sensitivity were not accomplished.

6.0 Recommendations

Despite the progress made on the model this year, one major problem is limiting its effectiveness and reliability to produce quality predictions: the model contains large central region where no bedrock or water table depths are known. The interpolation between points resulted in unrealistic scenarios. Correcting such errors is time-consuming and difficult.

For the refinement of the model, a three-layer model may be more effective due to the fact that the north end of the watershed contains wells that penetrate glacial till, sandstone, and slate. For the simulations to occur, the elevations of the river and stream need to be redefined since they are based on the DEM data which is of higher resolution than what is possible to obtain for the bedrock and glacial till. This causes the rivers and drains appear to be subterranean in many places.

Next year, more data needs to be collected, particularly in the central and eastern sections of the sub-watershed. As a general rule, any area that is not populated and does not have roads is extremely limited in the amount of existing data. Collecting data from these areas will probably require a higher ground clearance vehicle, preferably with 4-wheel drive. In addition, the data needs to be more evenly spaced instead of the concentrations of points that currently exist. This is to maximize the effectiveness of the data collection process and make accurate contouring easier. The first areas to concentrate on obtaining more data are on the road that connects Pinery Road to Skanee Road and the two tracks and roads in the Mead Paper on the east side of Silver River.

Finally, when this field data collection takes place next fall, a few procedures will make the process flow much more smoothly and prevent some of this year's pitfalls that wasted time. These procedures are outlined by Drenth (2002). Also, it is important that the same datum be used for every survey and the modeling aspect. Using an incorrect datum places the coordinates in the wrong place. In the fall of 2002, the North American Datum 1927 (NAD 27) should be used because the digital elevation data provided was in NAD 27 format.

7.0 References

Bodwell, W. A. (1972) "Geological Series, Map I: Marquette- L'Anse Region Baraga & Marquette Counties" Michigan Technological University

Dalton, K., M. Hieshetter, P. Strong, and J. Thompson (2001). Silver River Watershed Assessment Groundwater Work, Interim Progress Report, 18 December 2001.

Decleene, N. P., Kenzie, J. B., and Moore, D. E. (2001) Bedrock Group: Geophysics Report – Fall 2001, Resistivity and Seismic Refraction.

Drenth, B. J. (2002) "Proposal for Geophysical Studies in the Fall of 2002."

Kraft, J. E., Lobermeier, Jacob, (2001) "Surface Study Report: Silver River Watershed (Lower)" Fall Report.

Gierke, J.S. (2002). Interim Report on a Pumptest at the Leo Niemala Residence, Silver River Watershed, Baraga County, Michigan, 7 January 2002.

8 Appendix: Coverage Parameters

Table 1.- Coverage Parameters

Sources/Sinks Coverage	
River Conductance	10,000(ft^2/d)/ft
Drain Conductance	500 (ft^2/d)/ft
Northern River Elevation	635 ft
Southern River Elevation	772 ft
Eastern Drain Elevations	998 ft
Western Drain Elevation	814 ft
Bella Lake Elevation	997ft
Third Lake Elevation	840 ft

Layer 1 Coverage	
Horizontal Hydraulic Conductivity	39.372 ft/d
Vertical Hydraulic Conductivity	39.372 ft/d
Specific Storage	1.0*10^-7 1/ft
Specific Yield	0.05

Layer 2 Coverage	
Horizontal Hydraulic Conductivity	0.0028 ft/d
Vertical Hydraulic Conductivity	0.0028 ft/d
Specific Storage	1.0*10^-7 1/ft
Specific Yield	0.01
Bottom Elevation	500 ft

Recharge Coverage	
Recharge	0.06 ft/d