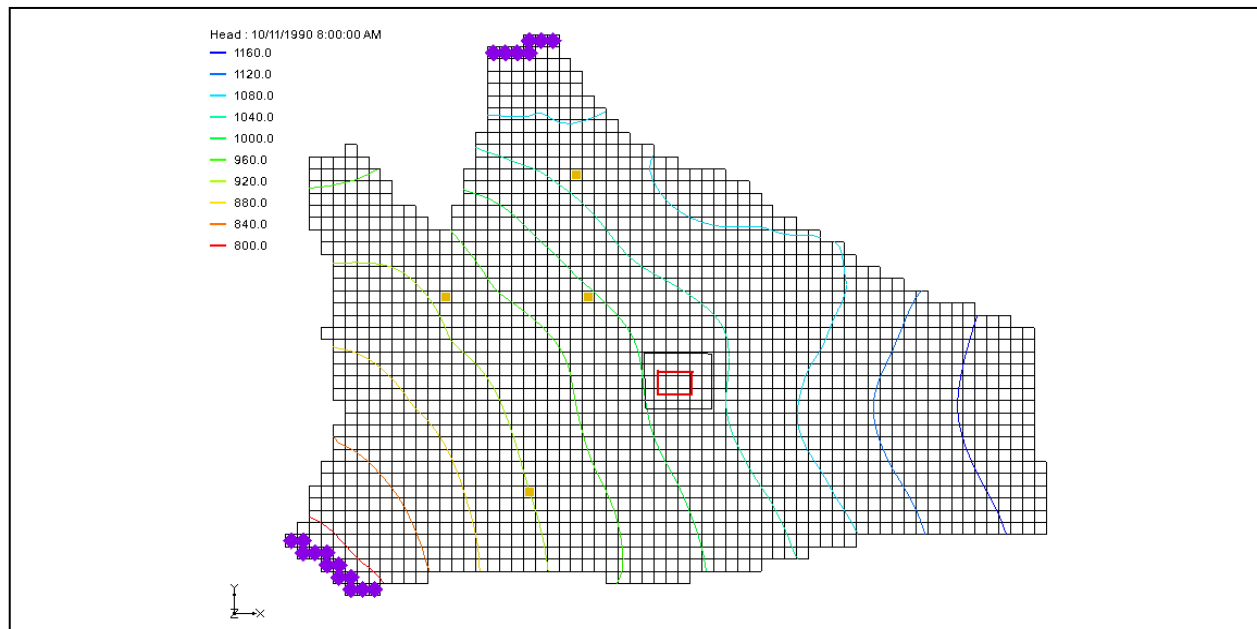


GMS 10.5 Tutorial

MODFLOW – Regional to Local Model Conversion, Steady State

Create a local model from a regional model using convenient tools provided in GMS



Objectives

This tutorial will use the convenient tools provided in GMS to perform the steps involved in a typical regional to local model conversion. This tutorial uses a steady state model. A transient example is provided in the “MODFLOW – Regional to Local Model Conversion, Transient” tutorial.

Prerequisite Tutorials

- MODFLOW – Conceptual Model Approach II

Required Components

- Grid Module
- Geostatistics
- Map Module
- MODFLOW
- MODAEM

Time

- 25–40 minutes



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1 Introduction

For many modeling studies, determining an appropriate set of boundary conditions can be difficult. It is often the case that classical boundaries such as rock outcroppings, rivers, lakes, and groundwater divides may be located at a great distance from the site of interest. In such cases, it is often convenient to perform the modeling study in two phases.

In the first phase, a large, regional scale model is constructed, and the model is extended to well-defined boundaries. During the second stage, a second, smaller, local scale model is constructed that occupies a small area within the regional model. The groundwater elevations computed from the regional model are applied as specified head boundary conditions to the local scale model.

The layer data, including elevations and transmissivities, are also interpolated from the regional to the local model. A more detailed representation of the local flow conditions, including low-capacity wells and barriers not included in the regional flow model can be constructed in the local scale model. Regional to local model conversion is often referred to as “telescopic grid refinement”.

GMS provides a convenient set of tools that can be used for regional to local model conversion. This tutorial describes the steps involved in a typical regional-to-local model conversion using MODFLOW.

The site modeled in this tutorial is shown in Figure 1. The main features of the regional model are shown. Most of the boundaries are no-flow boundaries corresponding to groundwater flow divides, bedrock outcroppings, and natural flow boundaries. A river runs through the left side of the model. The narrow regions where the river enters and exits the model are modeled as specified head boundaries. There are four major

production wells in the region. The site will be modeled using two layers: a lower confined layer and an upper unconfined layer.

The local site is situated in the interior of the model. The local site corresponds to a chemical plant with a small spill. Once the regional model is completed, a local scale model is to be developed and then used to analyze a number of injection/extraction well placement scenarios. The wells are part of a treatment system that is being designed.

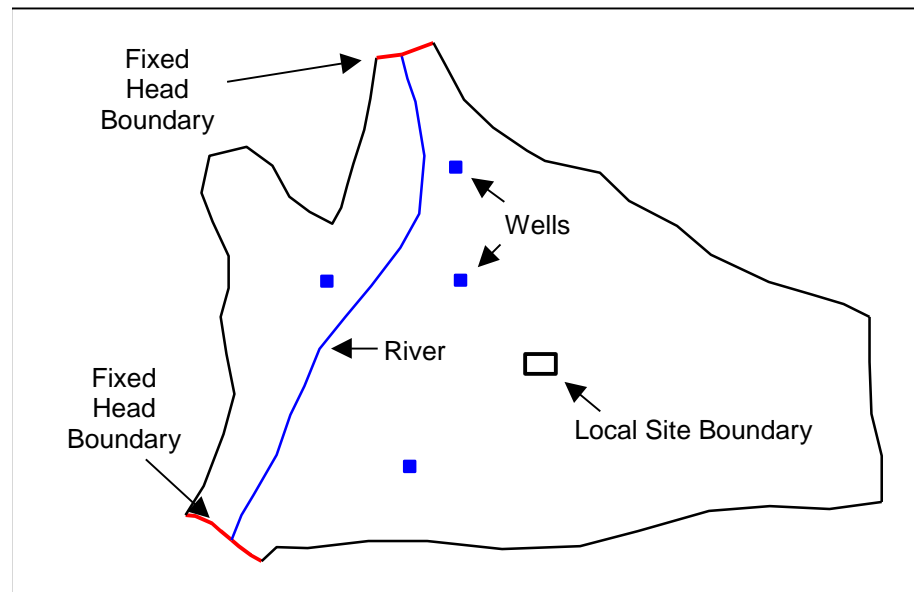


Figure 1 Regional model

The basic goal of the regional to local model conversion process is to create a 2D scatter point set containing the heads and layer data arrays from the regional model, create the local model, and interpolate the heads and layer data to the local model. A 2D scatter point set is used since the MODFLOW arrays should be interpolated on a layer-by-layer basis using 2D interpolation. GMS provides a set of tools that greatly simplify this process. The basic steps are as follows:

1. Generate the regional model and compute a solution.
2. Use the **MODFLOW Layers** → **2D Scatter Points** command to create the scatter point set with the layer and head data from the regional model.
3. Create the 3D grid for the local scale model.
4. Interpolate the heads and layer data values from the scatter points to the MODFLOW layer arrays for the local scale model.

Each of these steps will be described in more detail below.

1.1 Outline

This tutorial will demonstrate and discuss the following:

1. Opening a regional conceptual model.

2. Converting the layer data to a scatter point set.
3. Building a local conceptual model and mapping it to a 3D grid.
4. Mapping the conceptual model to a MODFLOW simulation.
5. Interpolating the layer data.
6. Running MODFLOW.
7. Running MODAEM.
8. Using the MODAEM head instead of the specified head, and rerunning MODFLOW.


1.2 Getting Started

Do the following to get started:

1. If necessary, launch GMS.
2. If GMS is already running, select *File / New* to ensure that the program settings are restored to their default state.
3. If asked to save changes, click **Don't Save** to close the dialog and restore GMS to a default state.

2 Importing the Regional Model

The first step in the model conversion process is to build a regional model. Since the focus of this tutorial is primarily on the conversion process, a previously constructed model will be imported.

1. Click **Open**  to bring up the *Open* dialog.
2. Select “Project Files (*.gpr)” from the *Files of type* drop-down.
3. Browse to the *reg2loc_ss\reg2loc_ss* directory and select “regmod.gpr”.
4. Click **Open** to import the project and close the *Open* dialog.

The top layer of the two-layer model is now being viewed (Figure 2). The arrow buttons in the Mini Grid Toolbar can be used to view the bottom layer. The wells are located in the bottom layer. When finished, return to the top layer.

This model was constructed using the conceptual model approach. The boundary of the local site is indicated with a red rectangle. The conceptual model consists of three coverages. The coverage being viewed is for the sources and sinks. There is also a coverage defining recharge zones and a coverage defining hydraulic conductivity zones for the top layer. The imported project includes the solution for the regional model with visible contours of computed head.

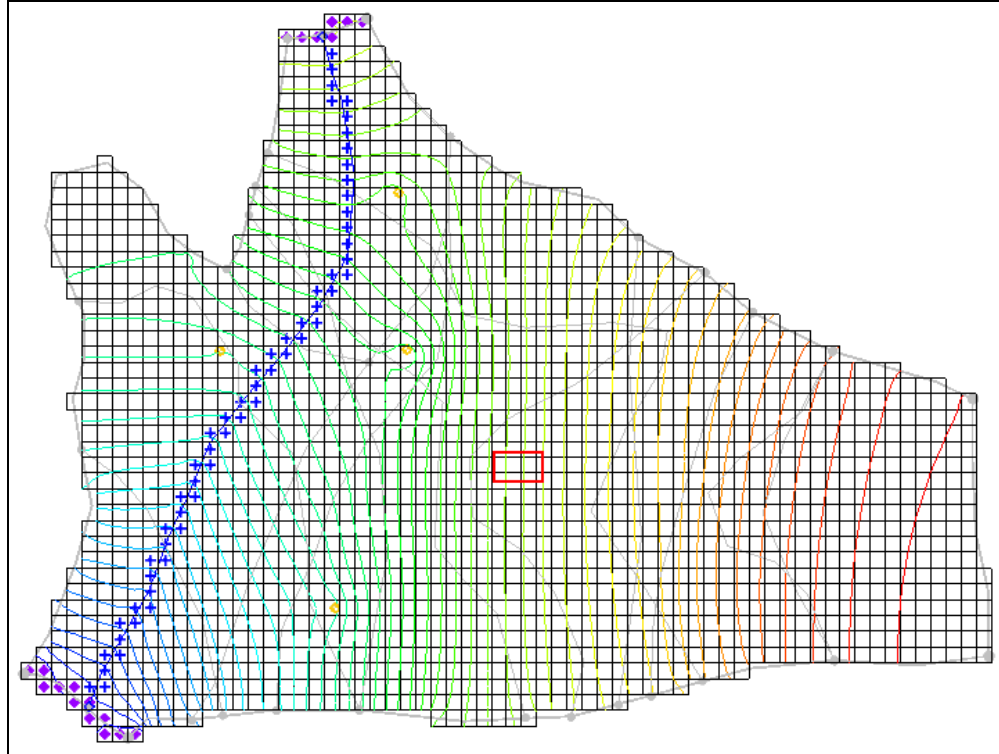



Figure 2 The initial view of the project

3 Converting the Layer Data to a Scatter Point Set

The first step in converting the regional model to a local model is to convert the MODFLOW layer data to a 2D scatter point set.

1. Select the “ 3D Grid Data” folder in the Project Explorer to make it active.
2. Select *Grid / MODFLOW Layers* → **2D Scatter Points...** to bring up the *MODFLOW Layers* → *Scatter Points* dialog.
3. Enter “Regional Data” as the *Scatter point set name*.
4. In the *Datasets* section, turn on *Layer elevations* and *Computed heads*.
5. Click **Select Dataset...** under *Computed heads* to bring up the *Select Dataset* dialog.
6. Select the “Head” dataset under the “regmod (MODFLOW)” solution.
7. Click **OK** to exit the *Select Dataset* dialog.
8. Click **OK** to exit the *MODFLOW Layers* → *Scatter Points* dialog.

A set of scatter points should appear at the location of the cell centroids (Figure 3). This scatter point set has a dataset for the computed heads and for the top and bottom elevations of the model layers.

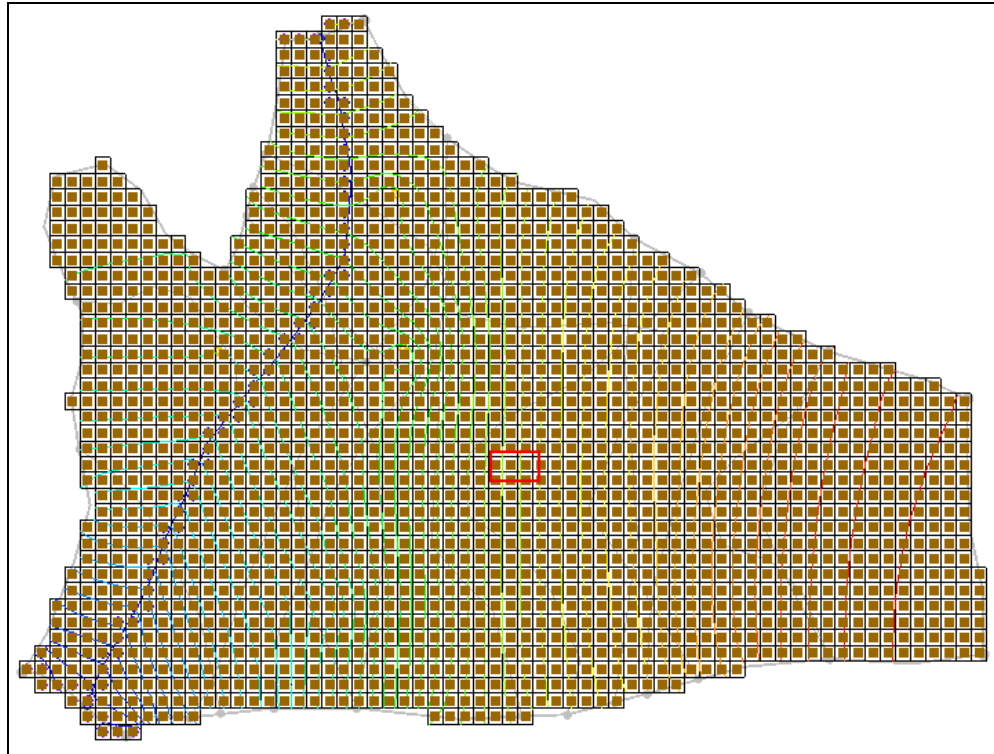






Figure 3 The layer data converted to scatter points

4 Building the Local Conceptual Model

There are numerous approaches to building the local model. A common approach is to mark the boundaries of the local model as specified head boundaries using the computed head values from the regional model. The following method accomplishes this objective:




A rectangular grid is constructed where two opposite boundaries are parallel to head contours from the regional model (i.e., a constant head value along each boundary). The other two boundaries are no-flow boundaries and are perpendicular to the head contours from the regional model.

The simplest way to build the local model is to create a conceptual model in the Map module. To do this, create a new conceptual model:

1. Expand the “ Map Data” folder in the Project Explorer.
2. Right-click on the “ Regional Model” item and select **Duplicate** to create a new “ Regional Model (2)” item.
3. Right-click on “ Regional Model (2)” and select **Properties...** to bring up the *Conceptual Model Properties* dialog.
4. Enter “Local Model” as the *Name*.
5. Click **OK** to close the *Conceptual Model Properties* dialog.



4.1 Creating a New Coverage

Next, to create a new source/sink coverage:


1. Expand the “ Local Model”, right-click on the “ ss” coverage, and select **Delete**.
2. Right-click on “ Local Model” and select **New Coverage...** to bring up the *Coverage Setup* dialog.
3. Enter “local ss” as the *Coverage name*.
4. In the *Sources/Sinks/BCs* column, turn on *Layer Range* and *Specified Head (CHD)*.
5. Change the *Default layer range* to be “1” to “2”.
6. Click **OK** to close the *Coverage Setup* dialog.

In this tutorial, the recharge and hydraulic conductivity coverages will be used to construct the local model. While the boundaries of the coverages are larger than they generally need to be, it is not necessary to change them here.

4.2 Creating the Boundary Arcs and the Polygon

1. Use the **Zoom**  tool to drag a box around the local site boundary (the red rectangle).
2. Select the “ local ss” coverage in the Project Explorer to make it the active coverage.

Now create the boundaries as follows:

3. Using the **Create Arc**  tool, create four arcs, two parallel to the contours, and two perpendicular to the contours as shown in Figure 4. Double-click on the corners to end each arc.

There should be a node at each corner and two vertices on each arc.

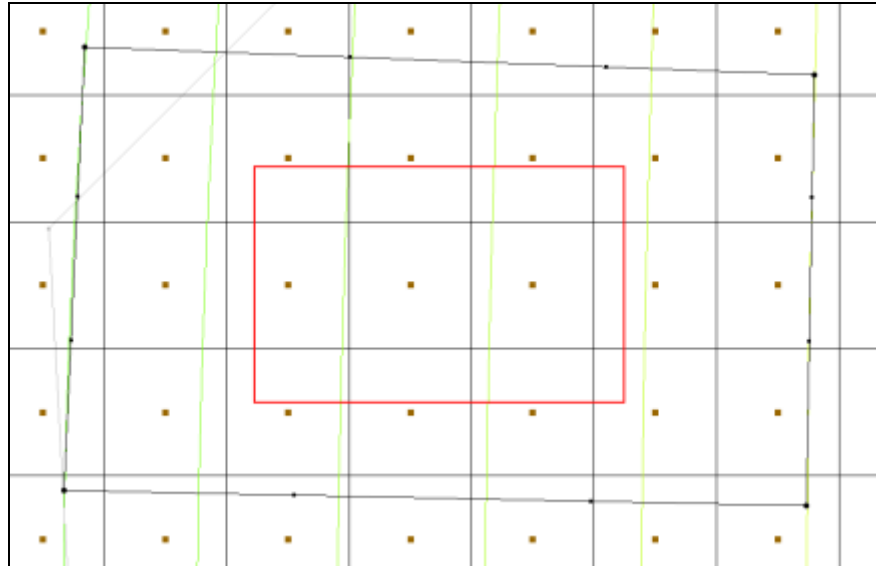



Figure 4 Boundary arcs to be created

Use the arcs to build a polygon defining the model domain.

4. Click **Build Polygons**  to create a polygon from the arcs. The polygon is indicated by the area within the arcs changing to a light gray (Figure 5).

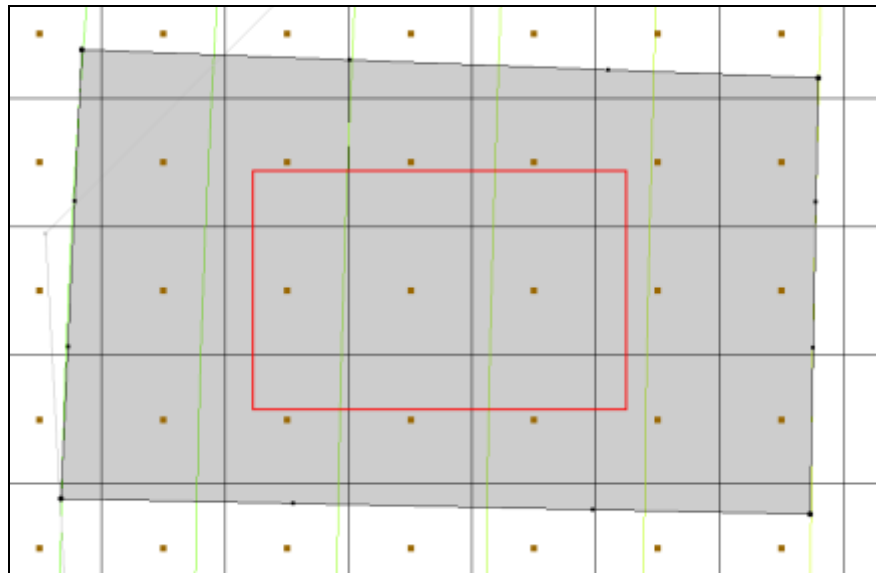




Figure 5 The polygon created from the boundary arcs



4.3 Marking the Specified Head Arcs

The specified head boundaries need to be marked next:

1. Using the **Select Arcs**  tool while pressing the *Shift* key, select the arcs on the left and right sides of the model.



2. Click **Properties**  to open the *Attribute Table* dialog.
3. In the *All* row of the spreadsheet, select “spec. head (CHD)” from the *Type* drop-down. This sets both arcs as specified head arcs.
4. Click **OK** to close the *Attribute Table* dialog.

At this point, select the nodes of the specified head arcs and assign a head value.

5. Using the **Select Points/Nodes**  tool, select the two nodes on the left side of the model by holding down the *Shift* key.
6. Click **Properties**  to open the *Attribute Table* dialog.
7. In the *Head-Stage (ft)* column, enter a head value of “1050.0” for the *spec. head (CHD)* rows for each node.
8. Click **OK** to close the *Attribute Table* dialog.
9. Repeat steps 5–8 for the two nodes on the right side of the model but assign a *spec. head (CHD)* value of “1100.0”.

5 Creating the Local MODFLOW Model

It is now possible to convert the conceptual model to a grid model. The first step in this process is to create a new grid frame that fits the local model.

1. In the Project Explorer, right-click on the empty space and select *New / Grid Frame* to create a new grid frame.
2. Right-click on “ Grid Frame” in the Project Explorer and select **Fit to Active Coverage**.
3. If desired, use the **Grid Frame**  tool to position the grid frame to better match the local grid boundary (Figure 6).

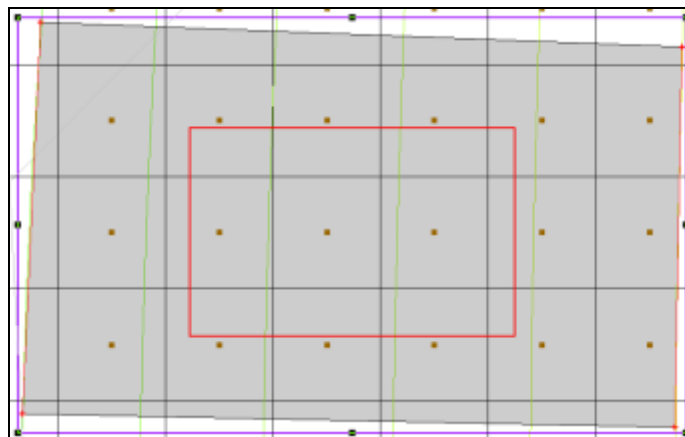




Figure 6 Grid frame encompassing the active coverage

5.1 Creating the Grid

Next, to create the grid:

1. In the Project Explorer, right-click on the “ Grid Frame” and select *Map To / 3D Grid* to bring up the *Create Finite Difference Grid* dialog.
2. Click **OK** to confirm deletion of the existing grid.
3. Click **OK** to confirm deletion of the current MODFLOW and MODPATH data.
4. In the *X-Dimension* section, enter “60” for the *Number of cells*.
5. In the *Y-Dimension* section, enter “50” for the *Number of cells*.
6. In the *Z-Dimension* section, enter “2” for the *Number of cells*.
7. Click **OK** to create the grid and close the *Create Finite Difference Grid* dialog.

A grid will appear (Figure 7).

8. Using the **Zoom**  tool, drag a box around the grid to zoom in to just the grid area.

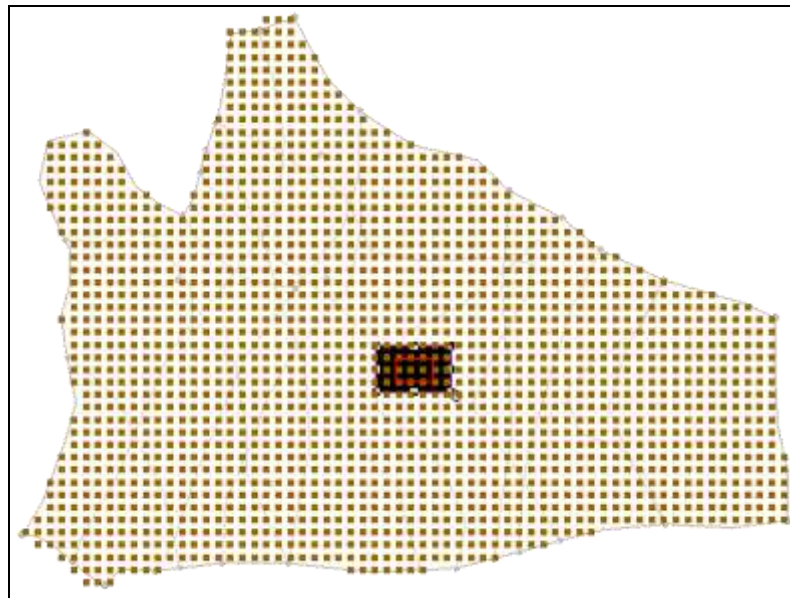




Figure 7 The finite difference grid

5.2 Activating the Cells

Next, to inactivate the exterior cells:


1. Select the “ 3D Grid Data” folder in the Project Explorer to make it active.
2. Select *MODFLOW | New Simulation...* to bring up the *MODFLOW Global/Basic Package* dialog.

3. Click **OK** to accept the defaults and close the *MODFLOW Global / Basic Package* dialog.
4. Select the “ Map Data” folder in the Project Explorer to make it active.
5. Select *Feature Objects* | **Activate Cells in Coverage(s)**.

If the arcs match the grid boundary closely, there may not be any cells inactivated. If the grid extends significantly beyond the arcs, some cells will be inactivated.

5.3 Mapping the Properties

Next, to convert the MODFLOW data to the grid:

1. Right-click on the “ Local Model” conceptual model in the Project Explorer and select *Map to / MODFLOW/MODPATH* to bring up the *Map → Model* dialog.
2. Select *All applicable coverages* and click **OK** to close the *Map → Model* dialog.

Note: At this point, the local scale model does not include the wells involved in the pump and treat system. These could be added at a later time.

5.4 Interpolating the Layer Data

The final step in the conversion process is to interpolate the regional data from the scatter points to the MODFLOW layer arrays.





1. Right-click on the “ Regional Data” scatter set in the Project Explorer and select *Interpolate To / MODFLOW Layers...* to bring up the *Interpolate to MODFLOW Layers* dialog.
2. Click **OK** to accept the defaults and close the *Interpolate to MODFLOW Layers* dialog.
3. Turn off the “ 2D Scatter Data” folder to make it easier to see the other information (Figure 8).



Figure 8 After the scatter point set is turned off

5.5 Saving and Running the Local Model

It is now possible to save the MODFLOW model and run the simulation.

1. Select the “ 3D Grid Data” folder in the Project Explorer to make it active.
2. Select *File* | **Save As...** to bring up the *Save As* dialog.
3. Select “Project Files (*.gpr)” from the *Save as type* drop-down.
4. Enter “locmod.gpr” as the *File name*.
5. Click **Save** to save the project under the new name and close the *Save As* dialog.
6. Select *MODFLOW* | **Run MODFLOW** to bring up the *MODFLOW* model wrapper dialog.
7. When the simulation is finished, turn on *Read solution on exit* and *Turn on contours (if not on already)*.
8. Click **Close** to close the *MODFLOW* model wrapper dialog.
9. **Zoom**  in the local model to see the contour lines within it.

A set of head contours, closely resembling the head contours from the regional model, are now visible (Figure 9). At this point, the local flow model is complete, and the injection and extraction wells could be added for the pump and treatment simulations.

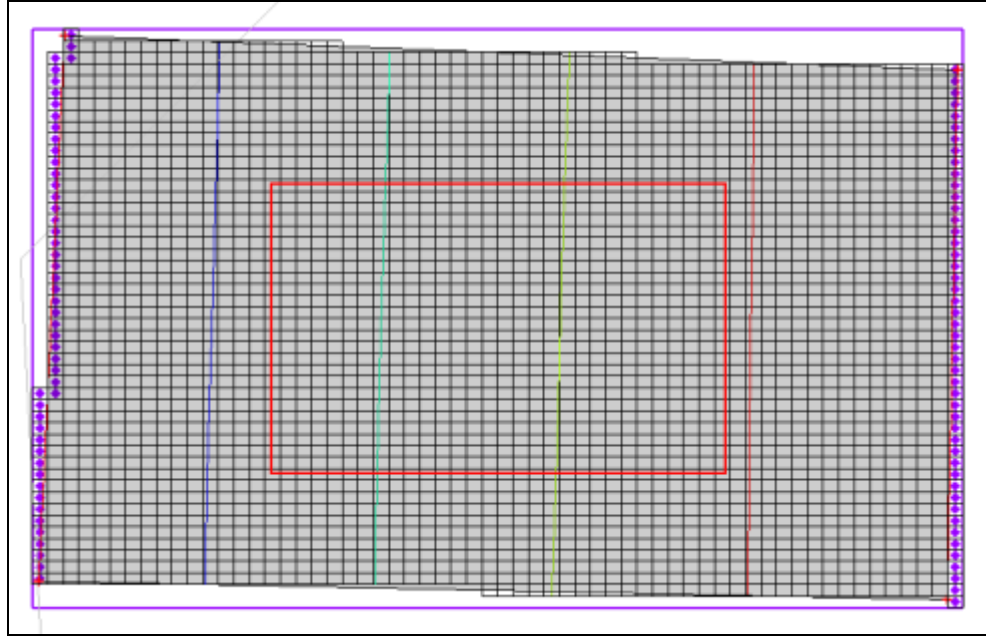





Figure 9 The local model showing contour lines





6 MODAEM Regional Model

A regional MODAEM model can also be used to create a local MODFLOW model. For a more detailed description of MODAEM see the “MODAEM” tutorial. Instead of using a specified head boundary in the “ local ss” coverage to assign heads to the MODFLOW model, use a MODAEM head boundary. A MODAEM head boundary condition is linked to a MODAEM conceptual model.


When the **Map** → **MODFLOW** command is selected, the locations of all of the cells associated with the MODAEM head boundary are found. Then a MODAEM model runs in the background and computes the head at the cell locations. MODAEM also computes the flow across the MODAEM head boundary. The MODAEM head boundary not only assigns heads to the MODFLOW model, but it also creates a flow observation.

6.1 Running MODAEM

Notice that there is now a “ Reg MODAEM” conceptual model in the “ Map Data” folder in the Project Explorer. The next step is to run the MODAEM model to see the head contours.

1. Expand the “ Reg MODAEM” conceptual model in the Project Explorer and select the “ ss” coverage within it to make it the active coverage.
2. Click **Run MODAEM**  to bring up the *MODAEM* model wrapper dialog. This runs the MODAEM model for the “ Reg MODAEM” conceptual model.

- When MODAEM is finished running, click **Close** to exit the *MODAEM* model wrapper dialog.

The head contours from the “ Reg MODAEM” conceptual model should now be visible (Figure 10).

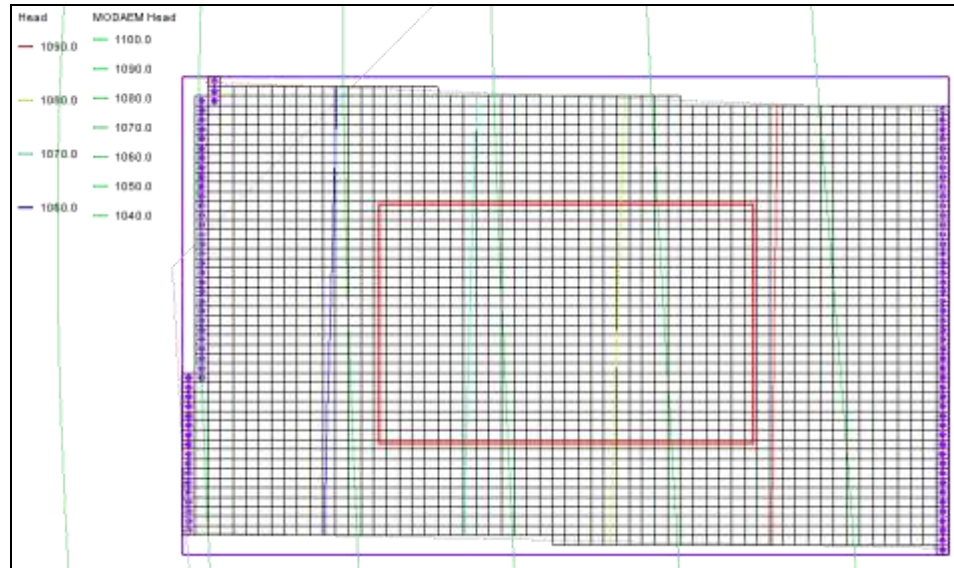







Figure 10 Local model after MODAEM run



6.2 Adjusting the Coverage Setup

Now to change the “local ss” coverage of the “Local Model” conceptual model to use a MODAEM head boundary instead of a specified head boundary:

- Expand the “ Local Model” conceptual model and select the “ local ss” coverage to make it active.
- Double-click on the “ local ss” coverage to bring up the *Coverage Setup* dialog.
- In the *Sources/Sinks/BCs* column, turn on *MODAEM head*.
- Select “Reg MODAEM” from the *MODAEM models* drop-down.
- Click **OK** to exit the *Coverage Setup* dialog.
- Using the **Select Arcs**  tool and while holding down the *Shift* key, select the two specified head arcs (the arcs on the left and right sides).
- Click **Properties**  to open the *Attribute Table* dialog.
- In the *Type* column on the *All* row, select “MODAEM head” from the drop-down.
- Click **OK** to exit the *Attribute Table* dialog.

6.3 Running the Local Model

It is now possible to convert the local conceptual model to the 3D grid.

1. Right-click on the “ Local Model” conceptual model in the Project Explorer and select *Map to / MODFLOW/MODPATH* to bring up the *Map → Model* dialog.
2. Select *All applicable coverages* and click **OK** to close the *Map → Model* dialog.
3. Select *File / Save As...* to bring up the *Save As* dialog.
4. Select “Project Files (*.gpr)” from the *Save as type* drop-down.
5. Enter “locmod2.gpr” as the *File name*.
6. Click **Save** to save the project under the new name and close the *Save As* dialog.
7. Select the “ 3D Grid Data” folder in the Project Explorer.
8. Select *MODFLOW / Run MODFLOW* to bring up the *MODFLOW* model wrapper dialog.
9. When the model finishes, turn on *Read solution on exit* and *Turn on contours (if not on already)*.
10. Click **Close** to exit the *MODFLOW* model wrapper dialog.

A set of head contours similar to the head contours from the regional model should now be visible (Figure 11). The head contours from the regional MODAEM model are slightly different from the MODFLOW regional model, so the sides of the local flow model that should represent parallel flow are most likely not perpendicular to the head contours from the MODAEM regional model. For this reason, the head contours do not match as well as they did for the conversion from the MODFLOW regional model.

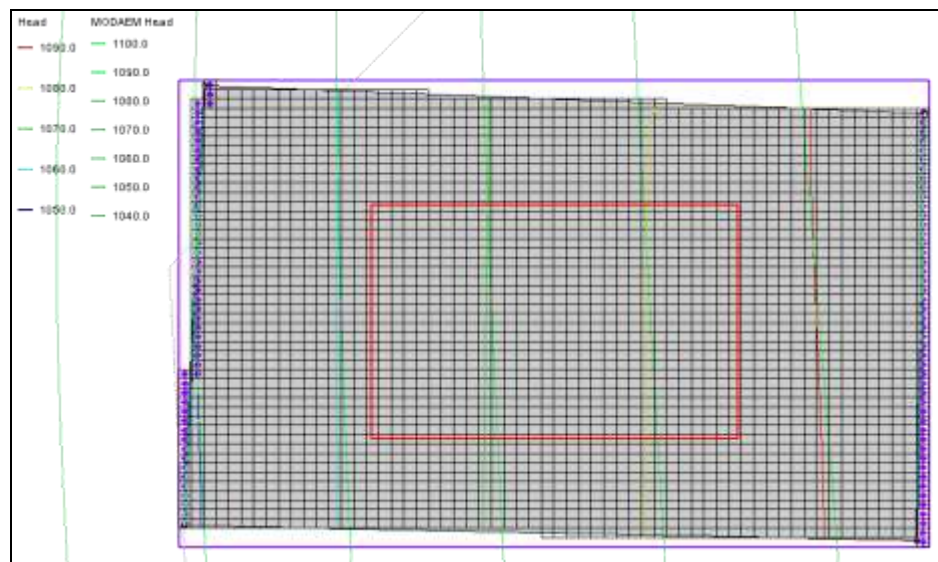


Figure 11 The local head contours are similar to the regional head contours

7 Conclusion

This concludes the “MODFLOW – Regional to Local Model Conversion, Steady State” tutorial. The following key concepts were discussed and demonstrated:

- The *Grid* | **MODFLOW Layers** → **2D Scatter Points** command converts the MODFLOW elevation data into scatter points.
- The basic steps for doing regional-to-local model conversion in GMS are:
 1. Generate the regional model and compute a solution.
 2. Use the **MODFLOW Layers** → **2D Scatter Points** command to create the scatter point set with the layer and head data from the regional model.
 3. Create the 3D grid for the local scale model.
 4. Interpolate the heads and layer data values from the scatter points to the MODFLOW layer arrays for the local scale model.
- A local MODFLOW model can be constructed from a regional MODAEM model.