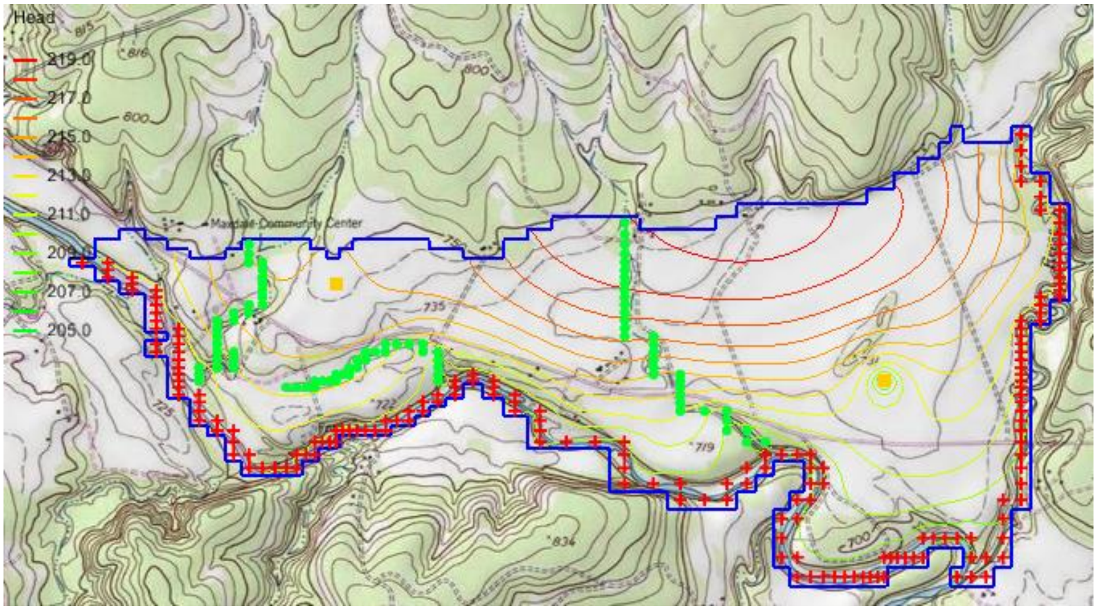
GMS

v. 10.2

GMS 10.2 Tutorial

MODFLOW – Conceptual Model Approach I

Build a basic MODFLOW model using the conceptual model approach



Objectives

The conceptual model approach involves using the GIS tools in the Map module to develop a conceptual model of the site being modeled. The location of sources/sinks, model boundaries, layer parameters (such as hydraulic conductivity), and all other data necessary for the simulation can be defined at the conceptual model level without a grid.

Prerequisite Tutorials

- Feature Objects
- MODFLOW – Grid Approach

Required Components

- Grid Module
- Map Module
- MODFLOW

Time

- 40–60 minutes

AQUAVEO™

1 Introduction ... 2
1.1 Getting Started ... 3
2 Importing the Background Image ... 4
2.1 Importing the Image ... 4
3 Saving the Project ... 4
4 Defining the Units ... 5
5 Defining the Boundary ... 5
5.1 Create the Coverage ... 5
5.2 Create the Arc ... 6
6 Building the Local Source/Sink Coverage ... 6
6.1 Defining the Specified Head Arcs ... 7
6.2 Defining the Drain Arcs ... 8
6.3 Building the Polygons ... 10
6.4 Creating the Wells ... 11
6.5 Grid Refinement ... 11
7 Delineating the Recharge Zones ... 12
7.1 Copying the Boundary ... 12
7.2 Assigning the Recharge Values ... 12
8 Defining the Hydraulic Conductivity ... 13
8.1 Copying the Boundary ... 13
8.2 Assigning Values ... 13
9 Defining the Layer Elevations ... 13
9.1 Copying the Boundary ... 13
9.2 Assigning the Elevation ... 14
10 Setting up the Grid ... 14
10.1 Locating the Grid Frame ... 14
10.2 Creating the Grid ... 15
11 Preparing for the MODFLOW Model Run ... 15
11.1 Initializing the MODFLOW Data ... 15
11.2 Defining the Active/Inactive Zones ... 16
11.3 Converting the Conceptual Model ... 16
11.4 Defining the Starting Head ... 17
11.5 Checking the Simulation ... 17
12 Saving and Running MODFLOW ... 17
13 Viewing the Solutions ... 18
13.1 Viewing the Water Table in Side View ... 18
13.2 Viewing the Flow Budget ... 18
14 Conclusion ... 19

1 Introduction

Two approaches can be used to construct a MODFLOW simulation in GMS: the grid approach or the conceptual model approach. The grid approach involves working directly with the 3D grid and applying sources/sinks and other model parameters on a cell-by-cell basis. The steps involved in the grid approach are described in the tutorial entitled “MODFLOW – Grid Approach”.

The conceptual model approach involves using the GIS tools in the Map module to develop a conceptual model of the site being modeled. The location of sources/sinks, layer parameters (such as hydraulic conductivity), and all other data necessary for the simulation can be defined at the conceptual model level. Once this model is complete, the grid is generated, the conceptual model is converted to the grid model, and all of the cell-by-cell assignments are performed automatically. This tutorial describes the steps involved in performing a MODFLOW simulation using the conceptual model approach.

The problem this tutorial will be solving is illustrated in Figure 1. The site is located in eastern Texas in the United States of America.

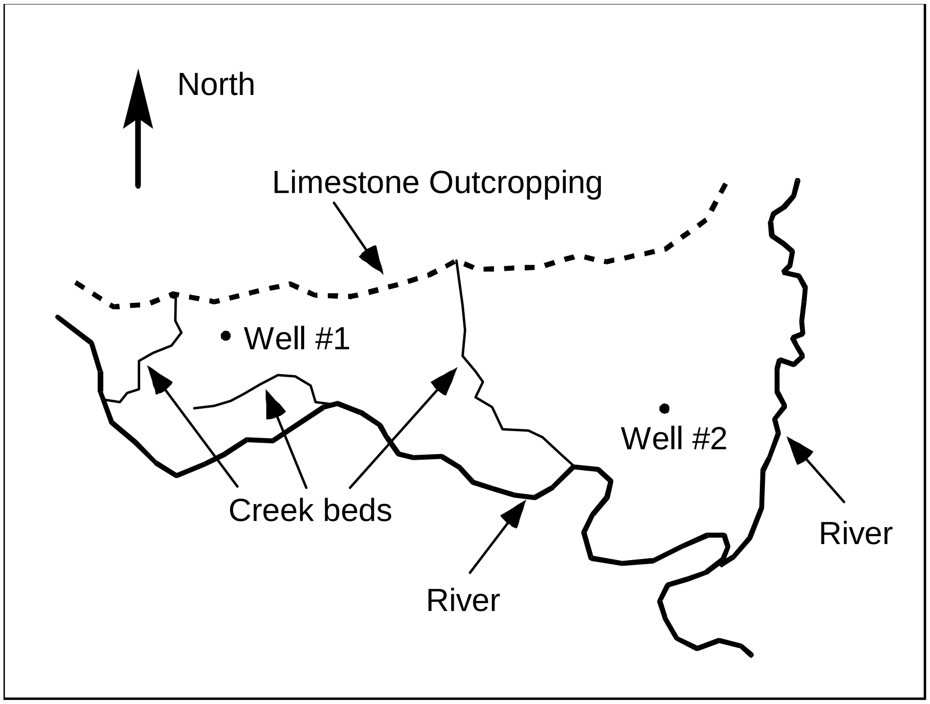


Figure 1 Plan view of site to be modeled

This project will be modeling the groundwater flow in the valley sediments bounded by the hills to the north and the two converging rivers to the south. The boundary to the north will be a no-flow boundary and the remaining boundary will be a specified head boundary corresponding to the average stage of the rivers.

It is necessary to assume that the influx to the system is primarily through recharge due to rainfall. There are some creek beds in the area which are sometimes dry but occasionally fill up due to influx from the groundwater. These creek beds will be represented using drains. Two production wells in the area will also be included in the model.

This tutorial will discuss and demonstrate importing a background image, creating and defining coverages, mapping the coverages to a 3D grid, converting the conceptual model to MODFLOW, checking the simulation and running MODFLOW, and viewing the results.

1.1 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.

2 Importing the Background Image

The first step in setting up the simulation is to import a digital image of the site being modeled. This image was created by scanning a portion of a USGS quadrangle map on a desktop scanner. The image was imported into GMS, registered, and a GMS project file was saved. Once the image is imported to GMS, it can be displayed in the background as a guide for on-screen digitizing and placement of model features.

2.1 Importing the Image

Import the image by doing the following:

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 *Tutorials\MODFLOW\modfmap* directory and select “start.gpr”.
4. Click **Open** to import the project file and close the *Open* dialog.

The Main Graphics Window will appear as in Figure 2. All other objects in GMS are drawn on top of the image. The image will only appear in plan view.

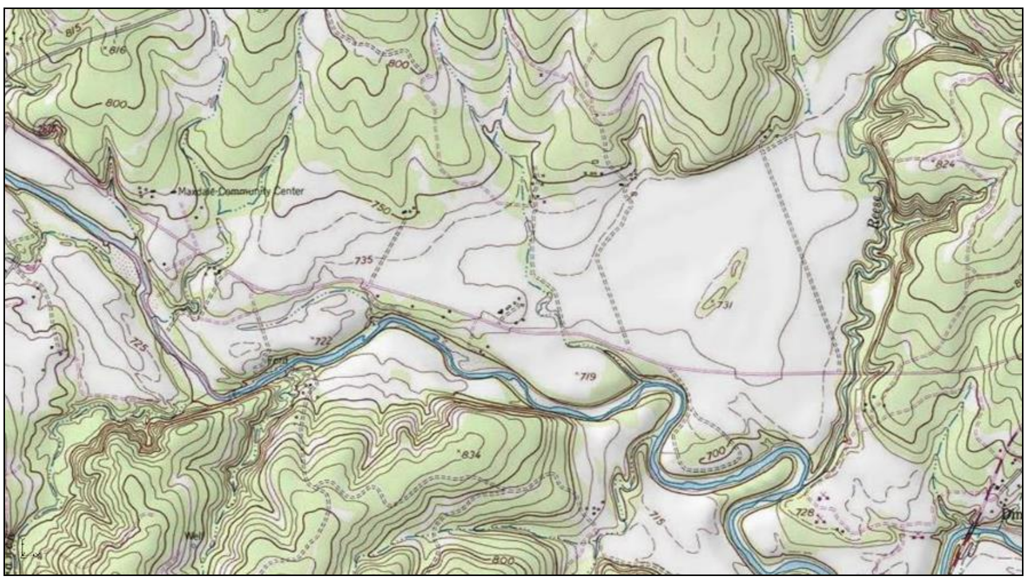


Figure 2 The imported map

3 Saving the Project

Before making any changes, save the project under a new name.

1. Select *File* | **Save As…** to bring up the *Save As* dialog.
2. Select “Project Files (*.gpr)” from the *Save as type* drop-down.
3. Enter “easttex.gpr” for the *File name*.
4. Click **Save** to save the project under the new name and close the *Save As* dialog.

While working through the tutorial, it is recommended to use the **Save** button periodically. This is a good habit to develop when working on projects.

4 Defining the Units

The units used in the conceptual model should now be defined. The chosen units will be applied to edit fields in the GMS interface to indicate the proper units for each parameter.

1. Select *Edit* | **Units…** to bring up the *Units* dialog.
2. Click the button to the right of the *Length* field to bring up the *Display Projection* dialog.
3. In the *Horizontal* section, select *Global projection* and click the **Set Projection…** button to bring up the *Select Projection* dialog.
4. Select "METERS" from the *Planar Units* drop-down and click **OK** to close the *Selection Projection* dialog.
5. In the *Vertical* section, select "Meters" from the *Units* drop-down.
6. Click **OK** to close the *Display Projection* dialog.
7. Select "d" from the *Time* drop-down. This indicates the *Time* units will be in days. The other units can be ignored because they are not used for flow simulations.
8. Click **OK** to close the *Units* dialog.

5 Defining the Boundary

The first step is to define the outer boundary of the model. This will be done by creating an arc which forms a closed loop around the site.

5.1 Create the Coverage

1. Right-click on the empty space in the Project Explorer and select *New* | **Conceptual Model** to bring up the *Conceptual Model Properties* dialog.
2. Enter "East Texas" for the *Name*.
3. Select "MODFLOW" from the *Type* drop-down.
4. Click **OK** to close the *Conceptual Model Properties* dialog.
5. Right-click on the " East Texas" conceptual model and select **New Coverage…** to bring up the *Coverage Setup* dialog.
6. Enter "Boundary" for the *Coverage name*.
7. Enter "213" as the *Default elevation*.
8. Click **OK** to close the *Coverage Setup* dialog.

5.2 Create the Arc

1. Select the new " Boundary" coverage to make it active and to switch to the Map module.
2. Using the **Create Arc** tool, click out an arc beginning at point (a) in Figure 3, following the river southeast as shown (b), then northeast from the convergence (c), then along the foot of the limestone outcroppings on the north (d) until back at the start point (e). Don't worry about the spacing or the exact location of the points; just use enough points to define the approximate location of the boundary.
3. To end the arc, click on the starting point.

If a mistake is made while clicking on the points, press the *Backspace* key to backup. If wanting to abort the arc and start over, press the *Esc* key.

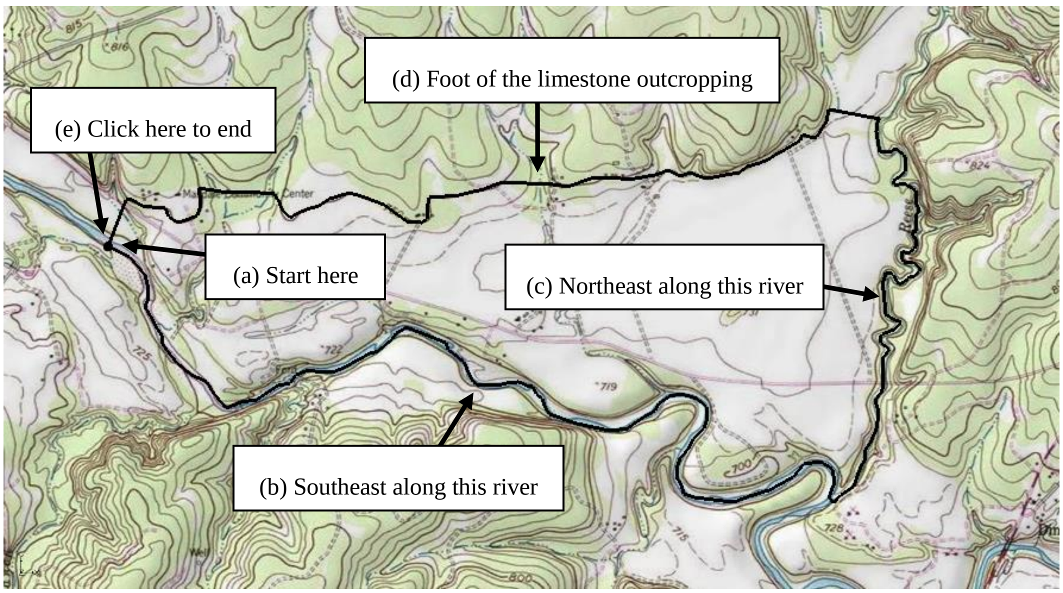


Figure 3 Creating the boundary arc

6 Building the Local Source/Sink Coverage

The next step in building the conceptual model is to construct the local sources/sinks coverage. This coverage defines the boundary of the region being modeled and defines local sources/sinks including wells, rivers, drains, and general head boundaries.

The properties that can be assigned to the feature objects in a coverage depend on the conceptual model and the options set in the *Coverage Setup* dialog. Before creating the feature objects, it is necessary to change these options.

1. Right-click on the " Boundary" coverage and select **Duplicate** to create a new " Copy of Boundary" coverage.
2. Right-click on the new coverage and select **Properties** to bring up the *Properties* dialog.
3. For the *Coverage name*, enter "Sources & Sinks" and press the *Enter* key.
4. Click **OK** to close the *Properties* dialog.

5. Right-click on the " Sources & Sinks" coverage and select **Coverage Setup** to bring up the *Coverage Setup* dialog.
6. In the *Sources/Sinks/BCs* column, turn on *Wells*, *Refinement*, *Specified Head (CHD)*, and *Drain*.
7. Near the bottom right of the dialog, turn on *Use to define model boundary (active area)*.
8. Click **OK** to close the *Coverage Setup* dialog.

6.1 Defining the Specified Head Arcs

The next step is to define the specified head boundary along the south and east sides of the model. Before doing this, however, it is necessary to first split the arc that was just created into three arcs. One arc will define the no-flow boundary along the top and the other two arcs will define the two rivers. An arc is split by selecting one or more vertices on the arc and converting the vertices to nodes.

1. Select " Sources & Sinks" in the Project Explorer to make it active.
2. Using the **Select Vertices** tool, select the two vertices shown in Figure 4 by selecting one of them, then holding down the *Shift* key and selecting the other one. Vertex #1 is located at the junction of the two rivers. Vertex #2 is located at the top of the river on the east side of the model.
3. Right-click on one of the selected vertices and select **Vertex → Node** to change them into nodes.

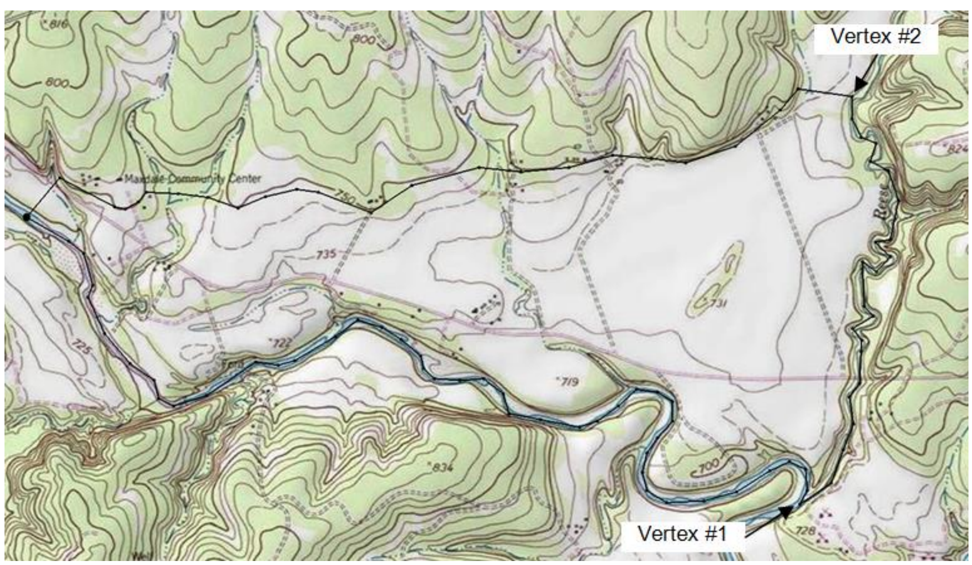


Figure 4 Convert vertices to nodes

Now that the three arcs have been defined, the two arcs on the rivers should be classified as specified head arcs.

4. Using the **Select Arcs** tool, select the arcs on the south and east sides (right and bottom) of the model by selecting one arc and holding down the *Shift* key while selecting the other arc.

5. Right-click on one of the selected arcs and select **Attribute Table** to bring up the *Attribute Table* dialog.
6. On the *All* row, select “spec. head (CHD)” from the drop-down in the *Type* column. This will change the types for both arcs.
7. Click **OK** to close the *Attribute Table* dialog.
8. Click anywhere on the model other than on the arcs to unselect them. Notice that the color of the arcs has changed to indicate the arc type.

The next step is to define the head at the nodes at the ends of the arcs. The head along a specified head arc is assumed to vary linearly along the length of the arc.

1. Using the **Select Points/Nodes** tool, double-click on the western (left) node of the arc on the southern (bottom) boundary to bring up the *Attribute Table* dialog.
2. Enter “212.0” on row *1* in the *Head-Stage (m)* column.
3. Click **OK** to close the *Attribute Table* dialog.
4. Using the **Select Points/Nodes** tool, double-click on the southern (bottom) node where the rivers converge to bring up the *Attribute Table* dialog.
5. Enter “208.0” on row *2* in the *Head-Stage (m)* column.
6. Click **OK** to close the *Attribute Table* dialog.
7. Using the **Select Points/Nodes** tool, double-click on the northern (top) node of the arc on the east (right) boundary to bring up the *Attribute Table* dialog.
8. Enter “214.0” on row *3* in the *Head-Stage (m)* column.
9. Click **OK** to close the *Attribute Table* dialog.

6.2 Defining the Drain Arcs

At this point, it is possible to enter the arcs at the locations of the creek beds to define the drains.

1. Using the **Create Arc** tool, create arc #1 as in Figure 5. Start by clicking on the bottom arc, then clicking points along the creek bed, and ending by clicking on the top arc.

Notice that when clicking in the vicinity of a vertex on an existing arc or on the edge of an arc, GMS automatically snaps the arc being created to the existing arc and makes a node at the junction of the two arcs.

2. Create the arc labeled arc #2 in Figure 5 by clicking on the bottom arc, clicking points along the creek bed, and then double-clicking at the end of the creek bed.
3. Create arc #3 in Figure 5 the same way that arc #1 was made.

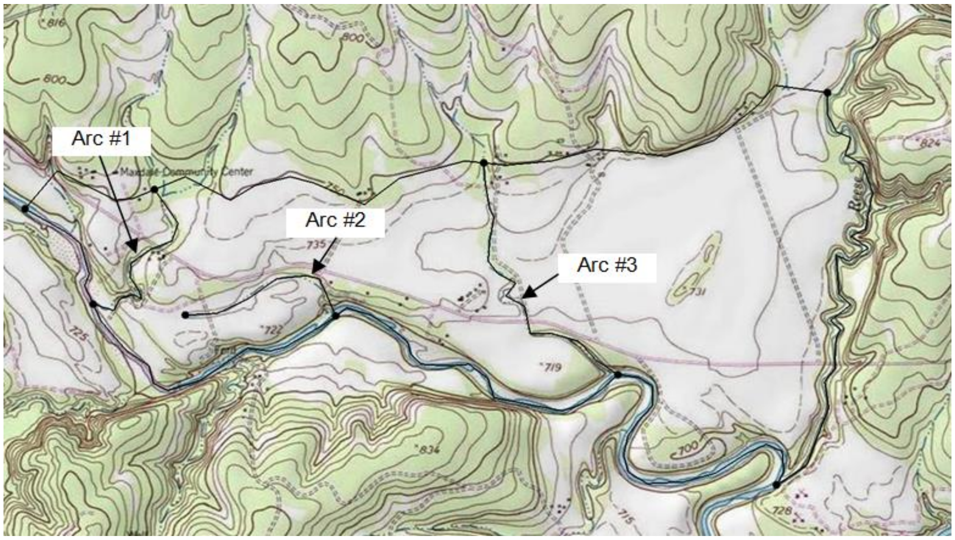


Figure 5 The drain arcs

Next, define the arcs as drains and assign the conductance and elevation to the arcs.

4. Using the **Select Arcs** tool and while holding down the *Shift* key, select all three drain arcs.
5. Right-click on one of the selected arcs and select **Attribute Table** to bring up the *Attribute Table* dialog.
6. In the *All* row, select “drain” from the drop-down in the *Type* column.
7. Enter “555.0” in the *Cond. (m^2/d)/(m)* column.

Conductance is calculated using the following formula:

$$C = \frac{kA}{L}$$

Where *k* is the hydraulic conductivity, *A* is the gross cross-sectional area, and *L* is the flow length. In this tutorial, assume that the hydraulic conductivity is 12 m/day, the drain width is 9.25 m, and the flow length is 0.2 m. This will give a conductance of 555 (m^2/day)/(m).

This represents a conductance per unit length value. GMS automatically computes the appropriate cell conductance value when the drains are assigned to the grid cells.

8. Click **OK** to close the *Attribute Table* dialog.

The color of the drain arcs should change to show they are now recognized as drains by GMS.

The elevations of the drains are specified at the nodes of the arcs. The elevation is assumed to vary linearly along the arcs between the specified values.

9. Using the **Select Points/Nodes** tool, double-click on Node 1 as shown in Figure 6 to bring up the *Attribute Table* dialog. Notice that this node has two properties associated with it since it is attached to two arcs of different types.
10. On the *drain* row, enter “221” in the *Bot. elev.* column. Do not change anything on the other row.

11. Click **OK** to close the *Attribute Table* dialog.

Repeat steps 9–11 to assign the drain elevations from the list below to the rest of the nodes shown in Figure 6. Be sure to change only value in the *Bot. elev.* column on the *drain* row. Do not change anything on the other rows.

- **Node 1**: 221
- **Node 2**: 210
- **Node 3**: 220
- **Node 4**: 209
- **Node 5**: 221
- **Node 6**: 208

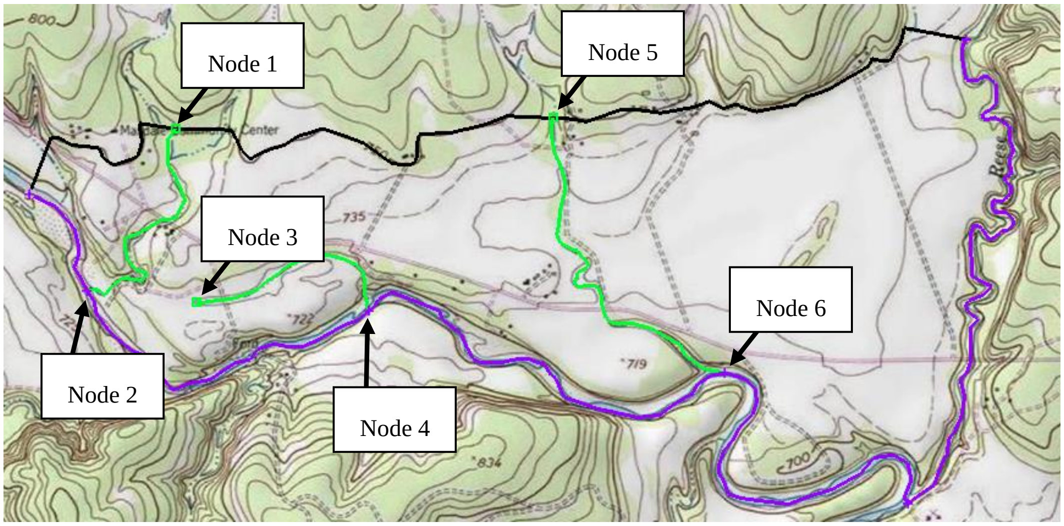


Figure 6 Locations of the drain nodes

6.3 Building the Polygons

With the local sources/sinks type coverage, the entire region to be modeled must be covered with non-overlapping polygons. This defines the active region of the grid. In most cases, all of the polygons will be variable head polygons (the default). However, other polygons may be used.

For example, to model a lake, a general head polygon can be used. The simplest way to define the polygons is to first create all of the arcs used in the coverage and then select the **Build Polygons** command. This command searches through the arcs and creates a polygon for each of the closed loops defined by the arcs. These polygons are of type "NONE" by default but may be converted to other types by selecting the polygons and using the **Properties** command.

Now that all of the arcs in the coverage have been created, it is possible to construct the polygons. All of the polygons will be variable head polygons.

1. Click the **Build Polygons** macro. Notice that the polygon are now filled.
2. If desired, change the view of the polygons by selecting *Display* | **Display Options** and changing the option in the *Display Options* dialog.

6.4 Creating the Wells

The final step in creating the local sources/sinks coverage is to define the two wells. Wells are defined as point type objects.

1. Using the **Create Point** tool, create a point at the approximate location of Well #1 in Figure 7.
2. While the new point is selected, enter the coordinates "613250" for *X* and "3428630" for *Y* at the top of the GMS window, pressing the *Tab* key after each.
3. Click **Properties** to bring up the *Attribute Table* dialog.
4. In the table, select "well" from the drop-down in the *Type* column.
5. Enter "-50.0" in the *Flow rate* column.
6. Click **OK** to close the *Attribute Table* dialog.
7. Repeat steps 1–2 for Well #2, entering "615494" for *X* and "3428232" for *Y*.
8. Repeat steps 3–6 for Well #2, entering "-300.0" for step 5 when in the *Attribute Table* dialog.

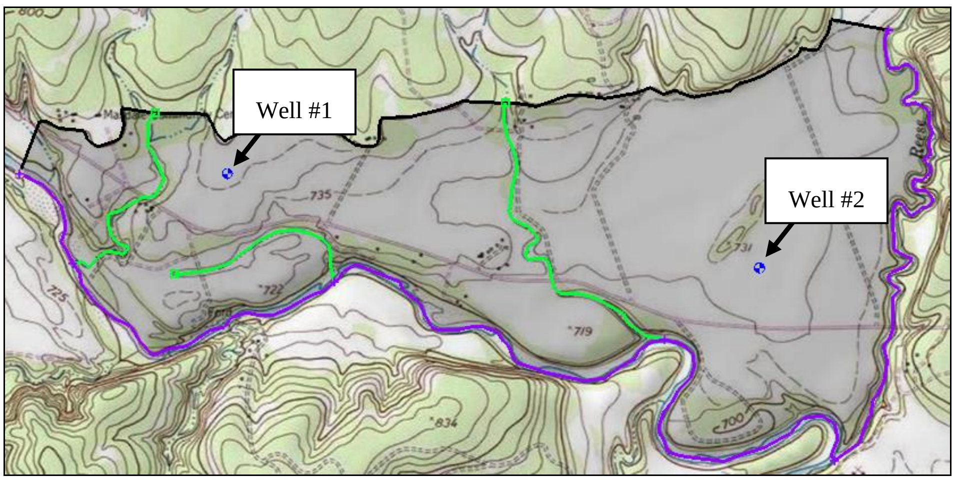


Figure 7 Location of the wells

6.5 Grid Refinement

A well represents a point of convergence in the groundwater flow and causes steep gradients in the head near the well. In order to accurately model the flow near wells, the grid is typically refined in the vicinity of the wells. This type of refinement can be performed automatically in GMS by assigning refinement data directly to the wells in the conceptual model.

1. Using the **Select Points/Nodes** tool and while holding down the *Shift* key, select both wells.
2. Click **Properties** to bring up the *Attribute Table* dialog.
3. Scroll to the right until the *Refine* column is visible and check the box in the *All* row. This turns on refinement for both points.

4. Enter the following into the *All* row: "25.0" for the *Base size*, "1.1" for the *Bias*, and "150.0" for the *Max size*. Press *Tab* after each entry.
5. Click **OK** to close the *Attribute Table* dialog.

7 Delineating the Recharge Zones

The next step in constructing the conceptual model is to construct the coverage that defines the recharge zones. Assume that the recharge over the area being modeled is uniform.

7.1 Copying the Boundary

Create the recharge coverage by copying the boundary coverage:

1. Right-click on the " Boundary" coverage and select **Duplicate** to create a new " Copy of Boundary" coverage.
2. Right-click on " Copy of Boundary" and select **Properties…** to bring up the *Properties* dialog. Notice that *Coverage name* is the only property which can be modified in this dialog.
3. Enter "Recharge" as the *Coverage name* and click **OK** to close the *Properties* dialog.
4. Right-click on " Recharge" and select **Coverage Setup…** to bring up the *Coverage Setup* dialog.

Notice that the *Coverage name* can be modified in this dialog as well.

5. In the *Areal Properties* column, turn on *Recharge rate*.
6. Click **OK** to close the *Coverage Setup* dialog and finish defining the recharge coverage arcs.
7. Click **Build Polygons** to build the polygon on the "Recharge" coverage.

7.2 Assigning the Recharge Values

Now that the recharge zones are defined, it is possible assign the recharge values. This is done by assigning value to the polygon.

1. Using the **Select Polygons** tool, double-click on the polygon to bring up the *Attribute Table* dialog.
2. Enter "0.0001" as the *Recharge rate*.

This value was obtained by multiplying 30 inches of rainfall a year (.75 m) by 5% and dividing by 365.

3. Click **OK** to close the *Attribute Table* dialog.

8 Defining the Hydraulic Conductivity

Next, enter the hydraulic conductivity. In many cases, multiple polygons are defined by defining hydraulic conductivity zones. For the sake of simplicity, this tutorial will use a constant value for the entire grid.

8.1 Copying the Boundary

Create the layer coverage by copying the boundary.

1. Right-click on the " Boundary" coverage and select **Duplicate** to create a new " Copy of Boundary" coverage.
2. Right-click on " Copy of Boundary" and select **Coverage Setup…** to bring up the *Coverage Setup* dialog.
3. Enter "Layer 1" as the *Coverage name*.
4. In the *Areal Properties* column, turn on *Horizontal K*.
5. Click **OK** to close the *Coverage Setup* dialog.

8.2 Assigning Values

Assign a *K* value for the layer.

1. Select the " Layer 1" coverage in the Project Explorer to make it active.
2. Click **Build Polygons** to create a polygon on the "Layer 1" coverage.
3. Using the **Select Polygons** tool, double-click on the polygon to bring up the *Attribute Table* dialog.
4. Enter "5.5" in the *Horizonal K (m/d)* column.
5. Click **OK** to close the *Attribute Table* dialog.

9 Defining the Layer Elevations

The final step is to define the layer elevations of the model. In this tutorial, a constant elevation will be set for the top and bottom of the grid. Other tutorials instruct how to interpolate elevations from points to get more realistic layer elevations.

9.1 Copying the Boundary

Create the layer coverage by copying the boundary.

1. Right-click on the " Boundary" coverage and select **Duplicate** to create a new " Copy of Boundary" coverage.
2. Right-click on " Copy of Boundary" and select **Rename**.
3. Enter "Layer Elevations" and press *Enter* to set the new name.
4. Click **Build Polygons** to create a polygon on the "Layer Elevations" coverage.

9.2 Assigning the Elevation

Now assign values to the polygon.

1. Right-click on “ Layer Elevations” and select **Coverage Setup…** to bring up the *Coverage Setup* dialog.
2. In the *Areal Properties* column, turn on *Top elev.* and *Bottom elev.*
3. Click **OK** to close the *Coverage Setup* dialog.
4. Using the **Select Polygons** tool, double-click on the polygon top bring up the *Attribute Table* dialog.
5. Enter “230.0” in the *Grid Top elev.* column.
6. Enter “175.0” in the *Grid Bot. elev.* column.
7. Click **OK** to close the *Attribute Table* dialog**.**

10 Setting up the Grid

10.1 Locating the Grid Frame

Now that the coverages are complete, it is possible to create the grid. The first step in creating the grid is to define the location and orientation of the grid using the grid frame. The grid frame represents the outline of the grid. It can be graphically positioned on top of the site map.

1. In the Project Explorer, right-click on the empty space and select *New* | **Grid Frame**. A grid frame should appear in the Graphics Window and a new “Grid Frame” should appear in the Project Explorer.
2. Using the **Select Grid** tool, right-click on “ Grid Frame” and select **Fit to Active Coverage**. The grid frame will adjust to fit the active coverage entirely within it (Figure 8).

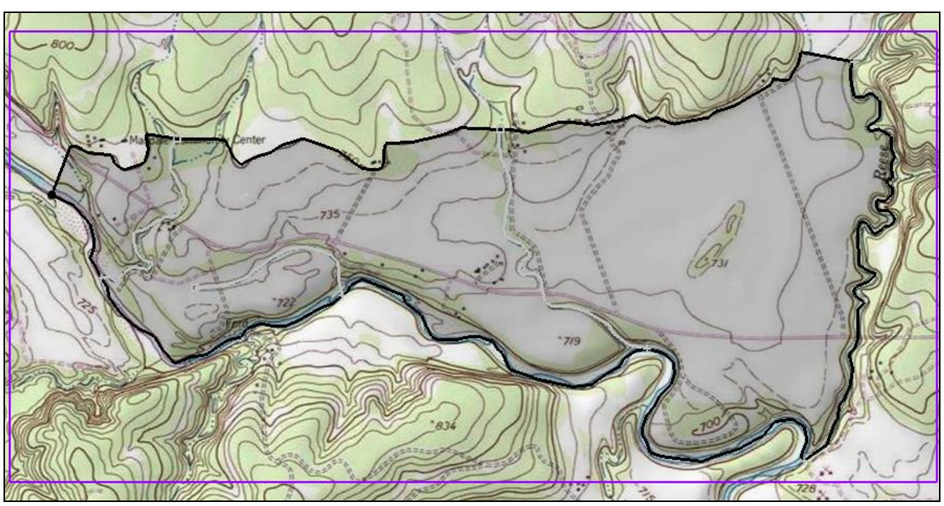


Figure 8 The grid frame is the purple box around the coverage

10.2 Creating the Grid

With the coverages and the grid frame created, it is now possible to create the grid.

1. Select the " Sources & Sinks" coverage in the Project Explorer to make it active.
2. Select *Feature Objects* | **Map → 3D Grid** to bring up the *Create Finite Difference Grid* dialog.

Notice that the grid is dimensioned using the data from the grid frame. If a grid frame does not exist, the grid is defaulted to surround the model with approximately 5% overlap on the sides. Also note that the number of cells in the *x* and *y* dimensions cannot be altered. This is because the number of rows and columns and the locations of the cell boundaries will be controlled by the refine point data entered at the wells.

3. Click **OK** to accept the defaults and close the *Create Finite Difference Grid* dialog.

A 3D grid will appear within the grid frame. Notice how the size of the cells is smaller when closer to the wells (Figure 9).

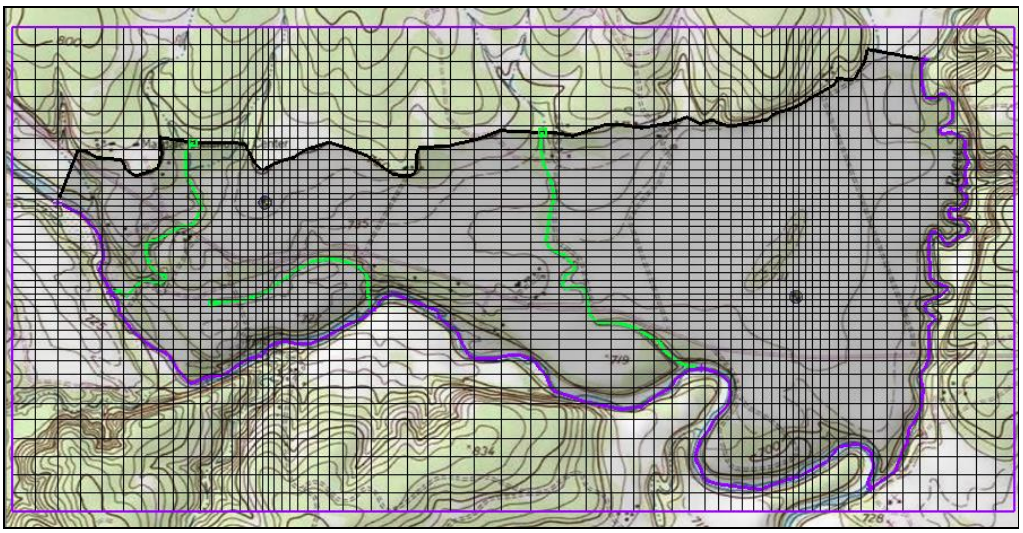


Figure 9 3D grid showing refined cell size near the wells

11 Preparing for the MODFLOW Model Run

11.1 Initializing the MODFLOW Data

Now that the grid is constructed, it is necessary to initialize the MODFLOW data before converting the conceptual model to a grid-based numerical model.

1. Right-click on the " grid" item in the Project Explorer and select **New MODFLOW…** to bring up the *MODFLOW Global/Basic Package* dialog.
2. Click **OK** to accept the defaults and close the *MODFLOW Global/Basic Package* dialog.

11.2 Defining the Active/Inactive Zones

With the grid constructed and MODFLOW initialized, the next step is to define the active and inactive zones of the model. This is accomplished automatically using the information in the local sources/sinks coverage.

1. Select the " Sources & Sinks" coverage in the Project Explorer to make it active.
2. Select *Feature Objects* | **Activate Cells in Coverage(s)**.

Each of the cells in the interior of any polygon in the local sources/sinks coverage is designated as active and each cell which is outside of all of the polygons is designated as inactive. Notice that the cells on the boundary are activated such that the no-flow boundary at the top of the model approximately coincides with the outer cell edges of the cells on the perimeter while the specified head boundaries approximately coincide with the cell centers of the cells on the perimeter (Figure 10).

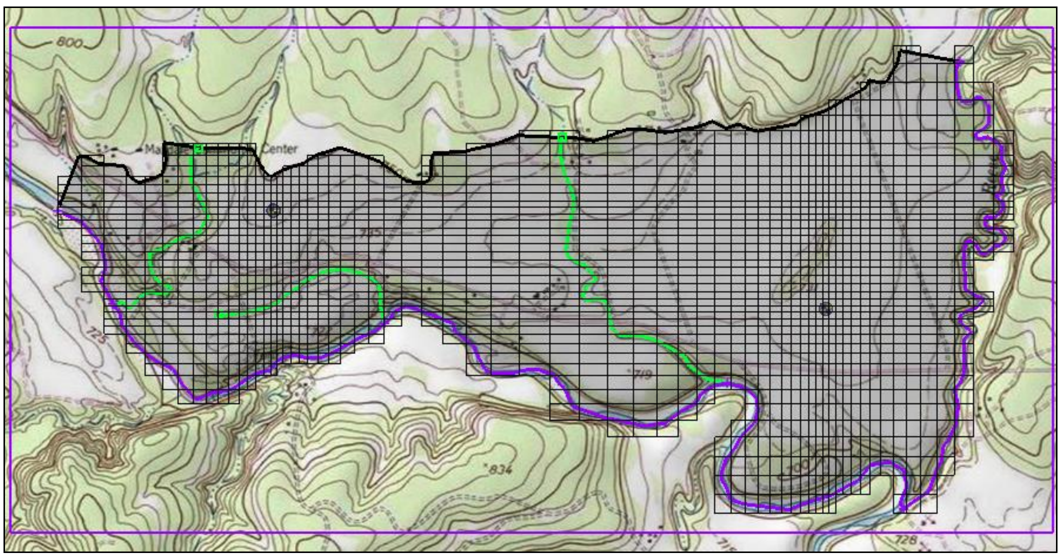


Figure 10 Only active cells are visible

11.3 Converting the Conceptual Model

It is now possible to convert the conceptual model from the feature object-based definition to a grid-based MODFLOW numerical model.

1. Right-click on the " East Texas" conceptual model 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. The Graphics Window should appear as in Figure 11.

Notice that the cells underlying the drains, wells, and specified head boundaries were all identified and assigned the appropriate sources/sinks. The heads and elevations of the cells were determined by linearly interpolating along the specified head and drain arcs. The conductances of the drain cells were determined by computing the length of the drain arc overlapped by each cell and multiplying that length by the conductance value assigned to the arc. In addition, the recharge and hydraulic conductivity values were assigned to the appropriate cells.

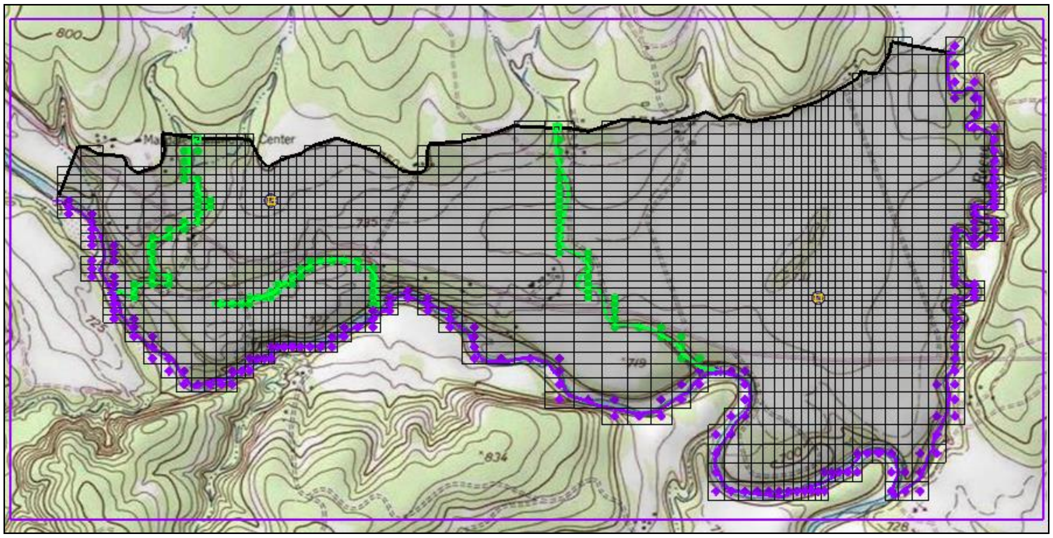


Figure 11 After the conceptual model is converted to MODFLOW

11.4 Defining the Starting Head

It is necessary to define the starting head before running MODFLOW. Because this tutorial is using the top elevation (230 m) as the starting head value, it is not necessary to make any changes because the starting heads are set to the grid top elevation by default.

11.5 Checking the Simulation

At this point, the MODFLOW data is completely defined and now ready to run the simulation. It is advisable to run the *Model Checker* to see if GMS can identify any mistakes that may have been made.

1. Select *MODFLOW* | **Check Simulation…** to bring up the *Model Checker* dialog.
2. Click **Run Check**. There should be no errors.
3. Click **Done** to exit the *Model Checker* dialog.

12 Saving and Running MODFLOW

Save the project before running MODFLOW.

1. Click the **Save** macro.

Saving the project not only saves the MODFLOW files but it saves all data associated with the project including the feature objects and scatter points.

2. Select *MODFLOW* | **Run MODFLOW** to bring up the *MODFLOW* model wrapper dialog. The model run should complete quickly.
3. When MODFLOW is finished, turn on *Read solution on exit* and *Turn on contours (if not on already).*
4. Click **Close** to close the *MODFLOW* model wrapper dialog.

Contours should appear (Figure 12). These are contours of the computed head solution.

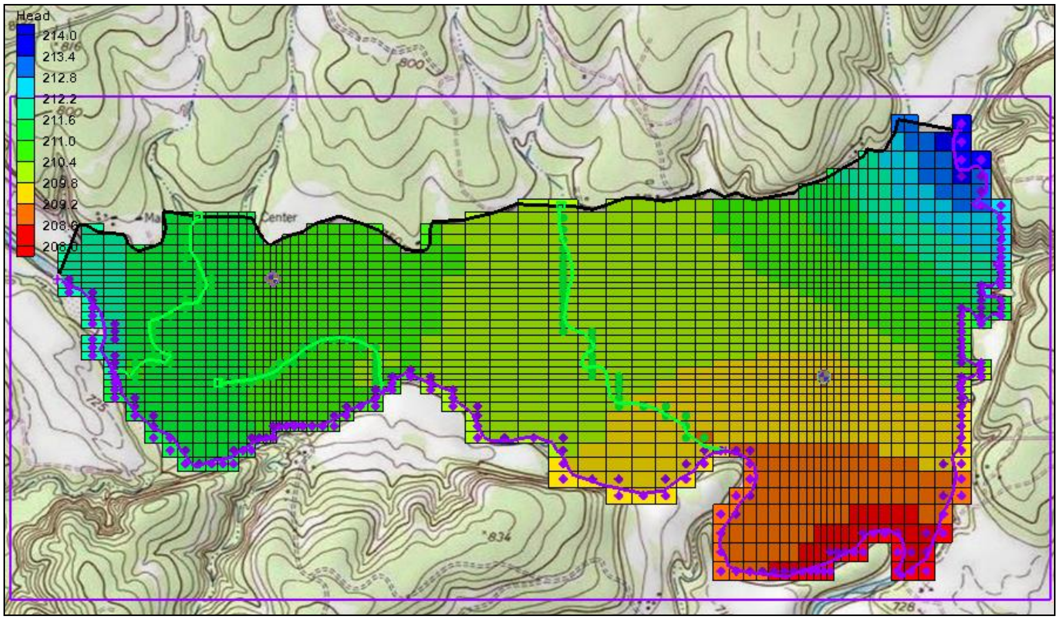


Figure 12 The contours are visible after the MODFLOW model run

13 Viewing the Solutions

13.1 Viewing the Water Table in Side View

Another interesting way to view a solution is in side view.

1. Turn off " Grid Frame" in the Project Explorer.
2. Select "MODFLOW" in the Project Explorer to switch to the 3D Grid module.
3. Using the **Select Cell** tool, select a cell somewhere near the well on the right side of the model.
4. Switch to **Side View** .
5. Click **Frame Image** .

Notice that the computed head values are used to plot a water table profile.

6. Use the arrow buttons in the main toolbar to move back and forth through the grid. A cone of depression should be seen at the well.
7. When finished, switch to **Plan View** .

13.2 Viewing the Flow Budget

The MODFLOW solution consists of both a head file and a cell-by-cell flow (CCF) file. GMS can use the CCF file to display flow budget values. To know if any water exited from the drains, simply click on a drain arc.

1. Select the " Map Data" folder in the Project Explorer.

2. Using the **Select Arcs** tool, select the rightmost drain arc.

Notice that the total flow through the arc is displayed in the strip at the bottom left of the window. Next, view the flow to the river.

3. Click on one of the specified head arcs at the bottom and view the flow.
4. Hold down the *Shift* key and select all of the specified head arcs.

Notice that the total flow is shown for all selected arcs. Flow for a set of selected cells can be displayed as follows:

5. Select the " 3D Grid Data" folder in the Project Explorer.
6. Select a group of cells by dragging a box around the cells.
7. Select *MODFLOW* | **Flow Budget...** to bring up the *Flow Budget* dialog.

The *Flow Budget* dialog shows a comprehensive flow budget for the selected cells.

8. Click **OK** to exit the *Flow Budget* dialog.
9. Click anywhere outside the model to unselect the cells.

14 Conclusion

This concludes the "MODFLOW – Conceptual Model Approach I" tutorial. Here are the Key concepts from this tutorial:

- A background image can be imported to help construct the conceptual model.
- It is usually a good idea to define the model boundary in a coverage and copy that coverage whenever it is necessary to create a new coverage.
- It is possible to customize the set of properties associated with points, arcs and polygons by using the *Coverage Setup* dialog.
- Some arc properties, like head, are not specified by selecting the arc but by selecting the nodes at the ends of the arc. That way the property can vary linearly along the length of the arc.
- A grid frame can be used to position the grid, but is not required.
- It is necessary to use the **Map → MODFLOW / MODPATH** command every time that conceptual model data is transferred to the grid.

