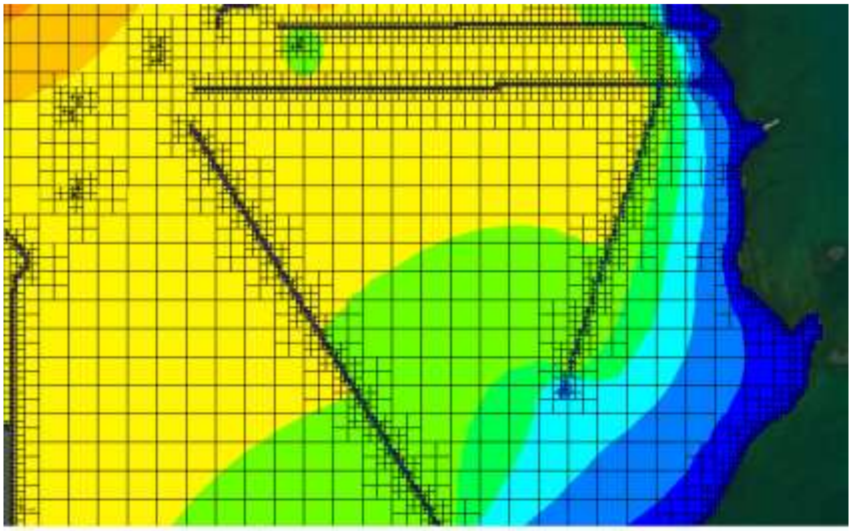
GMS

v. 10.0

GMS 10.0 Tutorial

MODFLOW–USG - Quadtree

Create a MODFLOW-USG with a locally refined Quadtree UGrid using GMS



Objectives

GMS supports building MODFLOW-USG models with Quadtree UGrids. This tutorial shows how to generate a smoothed Quadtree UGrid for a complex model.

Prerequisite Tutorials

- MODFLOW – Conceptual Model Approach I
- UGrid Creation

Required Components

- Map Module
- MODFLOW-USG

Time

- 25–40 minutes

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1 Introduction

As mentioned in the MODFLOW-USG documentation, MODFLOW-USG was developed to allow for a wide variety of grid geometries including the ability for increased grid resolution around rivers, wells, and other areas of interest.[1] One such type of unstructured grid (UGrid) is a smoothed Quadtree UGrid. In a smoothed Quadtree UGrid, the largest sized cell is refined near areas of interest by splitting each successive neighboring cell into 4 cells until the desired cell size is reached.

GMS has the ability to easily generate smoothed Quadtree UGrids from a conceptual model. Areas of interest can be identified on specific conceptual model objects including points, arcs, and polygons.

1.1 Outline

Here are the steps to this tutorial:

1. Read in an existing GMS project containing model shapefiles.

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1. Panday, Sorab, Langevin, C.D., Niswonger, R.G., Ibaraki, Motomu, and Hughes, J.D. (2013). MODFLOW–USG version 1: An unstructured grid version of MODFLOW for simulating groundwater flow and tightly coupled processes using a control volume finite-difference formulation: U.S. Geological Survey Techniques and Methods. Book 6, chap. A45, 66 p., http://pubs.usgs.gov/tm/06/a45.

2. Create a conceptual model using the shapefile geometry.
3. Turn on refinement for grid generation.
4. Create a Quadtree UGrid.
5. Create a MODFLOW-USG model.
6. Perform the **Map → MODFLOW** command.
7. Run the model and examine the results.

2 Description of Problem

The problem in this tutorial is illustrated in **Error! Reference source not found.**. The model is based on the Quadtree example problem included with MODFLOW-USG.[2] The model consists of a specified head boundary along the ocean to the right of the model. It also includes a network of canals modeled using the RIV package and wells modeled using the WEL package. The locations of the boundary conditions are provided by shapefiles and the elevations by raster files. The generated grid will be 1 layer thick and contain base cells (the largest cells) that are 800 m by 800 m. At specified head and river boundary conditions, the cells will be refined down to 100 m; and at wells, the cells will be refined down to 50 m.

2. Ibid.

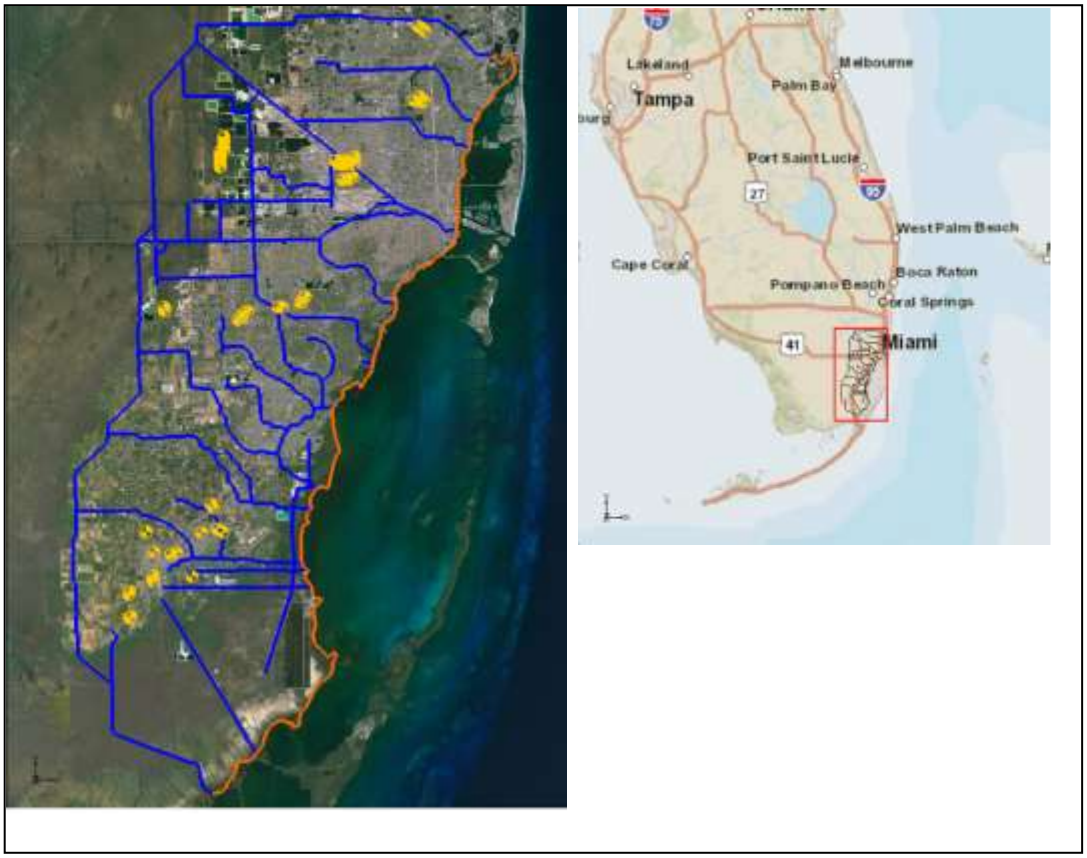

Figure 1 Problem to be solved

3 Getting Started

Do the following to get started:

1. If necessary, launch GMS.
2. If GMS is already running, select the *File* | **New** command to ensure that the program settings are restored to their default state.

4 Open the Starting Project

The user will start by opening a GMS project that already has the shapefiles that contain the model geometry.

1. Select the **Open** button.
2. Locate and open the directory entitled *Tutorials\MODFLOW-USG\Quadtree*.

3. Select the file entitled “start.gpr.”
4. Click **Open**.

5 Save with a Different Name

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

1. Select the *File* | **Save As** command.
2. Change the project name to “biscayne.gpr.”
3. Click **Save**.

Now select the **Save** button periodically to save the work as it develops.

6 Create the Conceptual Model

The user will begin by creating a conceptual model.

1. Right-click in the blank space in the Project Explorer.
2. Select *New* | **Conceptual Model** to open the *Conceptual Model Properties* dialog.
3. Change the *Name* to “Biscayne.”
4. Click **OK**.

6.1 Create the Areal Coverage

For the first part of setting up the conceptual model, the user will create a coverage with horizontal conductivity and recharge areal properties.

1. Right-click on the “Biscayne” conceptual model in the Project Explorer.
2. Select **New Coverage** to open the *Coverage Setup* dialog.
3. Set the *Coverage name* to “Areal.”
4. In the *Areal Properties* section, turn on *Recharge rate* and *Horizontal K*.
5. Toggle on *Use to define model boundary*.
6. Click **OK** to create the coverage.
7. Expand the “GIS Layers” folder in the Project Explorer.

8. Toggle on the "Biscayne.shp" shapefile in the Project Explorer.
9. Make sure "Wells.shp" shapefile is toggled off.
10. Right-click on "Biscayne.shp."
11. Select *Convert To* | **Feature Objects**.
12. In the dialog that pops up, select **Yes** to map all visible shapefiles to feature objects.
13. Click on **Next** twice.
14. Then click on **Finish** to create the feature objects.
15. Select the "Areal" coverage in the Project Explorer.
16. Select the **Build Polygons** macro.
17. Right-click on the "Areal" coverage in the Project Explorer.
18. Select the **Attribute Table** menu item to open the *Attribute Table* dialog.
19. From the *Feature type* dropdown, select "Polygons."
20. In the *All* row, enter "1.0e-4" for the *Recharge rate* value.
21. In the *All* row, enter "400" for the *Horizontal K* value.
22. Click **OK** to save the values and close the dialog.

6.2 Setup the Sources and Sinks Coverage

Now the user will create a coverage containing the specified head, river, and well boundary conditions.

1. Right-click on the "Biscayne" conceptual model in the Project Explorer.
2. Select **New Coverage**.
3. Set the *coverage name* to "Sources-Sinks."
4. In the *Sources/Sinks/BCs* section, turn on the following options:
   - *Wells*
   - *Specified Head (IBOUND)*
   - *River*

5. Click **OK** to create the coverage.

Now it is possible to copy the specified head, river, and well geometry from the shapefile to the coverage.

6. Toggle on “Wells.shp” in the Project Explorer.
7. Right-click on “Wells.shp.”
8. Select the *Convert To* | **Feature Objects** command.
9. In the dialog that pops up, select **Yes** to map all visible shapefiles to feature objects.
10. Click on **Next** three times.
11. Then click on **Finish** to create the feature objects.
12. Turn off the “Biscayne.shp” and “Wells.shp” files in the Project Explorer.

6.3 Assign Specified Head

Now it is necessary to set the arc types. First the user will set up the specified head arcs.

1. Select the “Sources-Sinks” coverage in the Project Explorer.
2. Click on the **Select Arcs** tool.
3. Select the arcs along the coastline to the right by holding down the shift key, and clicking on each arc. The user may need to zoom in on certain areas while selecting. There are 14 arcs.
4. Right-click on one of the selected arcs and choose the **Attribute Table** command in the menu to open the *Attribute Table* dialog.
5. Change the arcs to specified head by selecting the “spec head (IBOUND)” in the *All* row of the *Type* column.
6. Click **OK** to save the values and close the dialog.
7. Do not unselect the arcs.

The map should now look like the following image. If necessary, select an arc that was missed and assign the boundary condition.

Figure 2 Specified head boundary condition applied to arcs on coastline

6.4 Assign Rivers

Now the user will set up the river arcs. To simplify the tutorial, the user will set the conductivity of all of the arcs to the same value.

1. With the coastal arcs still selected, change the selection to the river arcs by selecting the *Edit* | **Invert Selection** menu item.
2. Open the *Attribute Table* dialog by right-clicking on the "Sources-Sinks" coverage in the Project Explorer and selecting **Attribute Table**.
3. In the *All* row, change the arc *Type* to "river."
4. In the *All* row, change the *Cond.* value to "5000.0."
5. From the *Feature type* dropdown, select "Nodes."
6. From the *BC type* dropdown, select "river."

To set the river stage and bottom elevation, the user will use the rasters that were included in the starting project.

7. In the *All* row, click on the *Head-Stage* dropdown.
8. Select "<Raster>" as shown in the next figure.

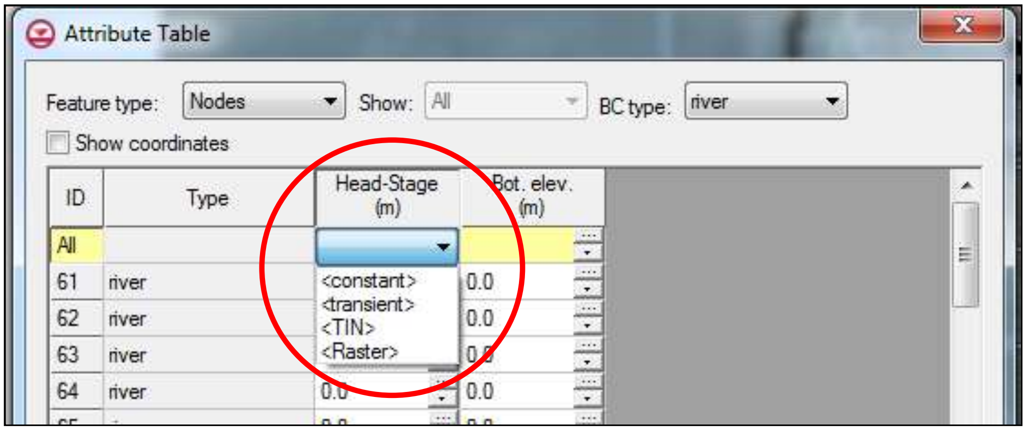

Figure 3 - Selecting a Raster for the River Stage

9. In the pop-up menu, select the "RiverStage.tif" raster.
10. Cick on **OK**.
11. In the *All* row, click on the *Bot. elev.* dropdown.
12. Select "<Raster>."
13. In the pop-up menu, select the "RiverBottoms.tif" raster.
14. Click on **OK**.

6.5 Assign Wells

Now assign the wells.

1. Open the *Attribute Table* dialog by right-clicking on the "Sources-Sinks" coverage in the Project Explorer and selecting **Attribute Table**.
2. From the *Feature type* popup menu select "Points."
3. In the *All* row, change the type to "well."
4. In the *All* row, set the flow rate to "-700."
5. Click **OK** to save the values and close the dialog.
6. Deselect the arcs by clicking on the map out in the ocean area away from any arcs.

The map should now look like the following figure.

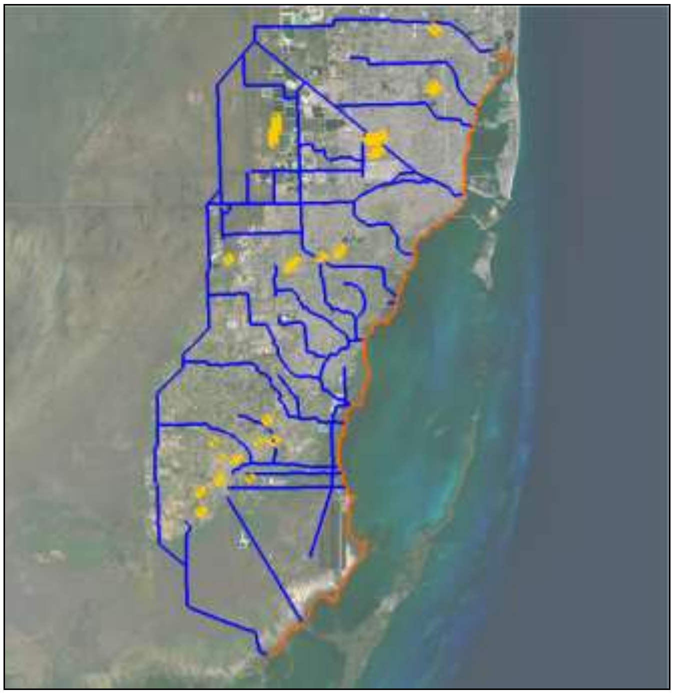

Figure 4 Biscayne conceptual model

6.6 Turn on Refinement for Grid Generation

To generate the Quadtree grid, it is necessary to turn on refinement for the areas of interest. For this model, the user will turn on refinement for the specified head and river boundary conditions to refine cells down to 100 m. For the wells, the user will set refinement to refine down to 50 m. First, it is necessary to turn on the *Refinement* option in the *Coverage Setup* dialog.

1. Right-click on the "Sources-Sinks" coverage in the Project Explorer.
2. Select **Coverage Setup** to open the *Coverage Setup* dialog.
3. In the *Sources/Sinks/BCs* section, turn on *Refinement*.
4. Click **OK** to close the dialog.

Now it is necessary to turn on refinement for each object. First the user will turn on refinement for the wells.

5. Right-click on the "Sources-Sinks" coverage in the Project Explorer.
6. Select the **Attribute Table** menu item to open the *Attribute Table* dialog.
7. From the *Feature type* dropdown, select "Points."
8. In the *All* row, turn on the *Refine* check box.

9. In the *All* row, set the *Base size* to “60.”

When the grid is generated, the cells that contain the wells will be sized to the first cell size below 60. To generate the grid, the cell size starts at the base cell size and then gets divided by two until the size is below 60. The base cell is 800 m, so a *Base size* of 60 m will result in cell refined to 400, 200, 100, and then 50 m.

Now the user will set the refinement for the specified head and river arcs. For the river arcs, it would be ideal for the cells to be refined to 100 m, so the user will set the size slightly above 100 m.

10. From the *Feature type* dropdown select “Arcs.”
11. In the *All* row, turn on the *Refine* toggle.
12. In the *All* row, set the *Base size* to “110.”
13. Click **OK** to close the dialog.

7 Create the Unstructured Grid

Now it is necessary to set the dimensions of the unstructured grid. The user will do this by using a grid frame. The Quadtree UGrid can be generated without a grid frame, but a grid frame gives more precise control over the size of the generated cells.

For this model, it would be ideal to set the base grid cell size (or largest cell size) to 800 m. To do so, the user will use a grid frame set with dimensions that are a multiple of 800 m.

1. Right-click in the blank space in the Project Explorer.
2. Select *New* | **Grid Frame**.
3. Right-click on the **Grid Frame** item in the Project Explorer.
4. Select **Fit To Active Coverage.**
5. Right-click on the **Grid Frame** item in the Project Explorer.
6. Select the **Properties** command to open the *Grid Frame Properties* dialog.
7. Set the *Origin* and *Dimensions* to the values in the following table:

Origin x:	543750.0
Origin y:	2793450.0
Origin z:	0.0
Dimension x:	44000.0
Dimension y:	79200.0
Dimension z:	10.0

8. Click **OK** the exit the dialog.

This gives the user a base grid with 44 columns and 99 rows.

Now it is possible to create the Quadtree UGrid. While a grid frame can be used to determine the dimensions of the grid cells, the polygons in the active coverage determine the boundary of the generated cells. If there are no polygons in the active coverage, the generated cells will fill the grid frame. For the grid, the user will use the polygons in the "Areal" coverage.

9. Select the "Areal" coverage in the Project Explorer to make it the active coverage.
10. Right-click on the *Grid Frame* in the Project Explorer.
11. Select *Map To* | **UGrid** to open the *Map → UGrid* dialog.
12. Change *UGrid type* to "Quadtree/Octree."
13. In the *X-Dimension* section, change the *Cell size method* to *Cell size.*
14. In the *X-Dimension* section, enter "800" for the *Cell size* value.
15. In the *Y-Dimension* section, change the *Cell size method* to *Cell size.*
16. In the *Y-Dimension* section, enter "800" for the *Cell size* value.
17. In the *Z-Dimension* section, change the *Number of cells* to "1."
18. The options in the *Map → UGrid* dialog should match those shown in Figure 5.

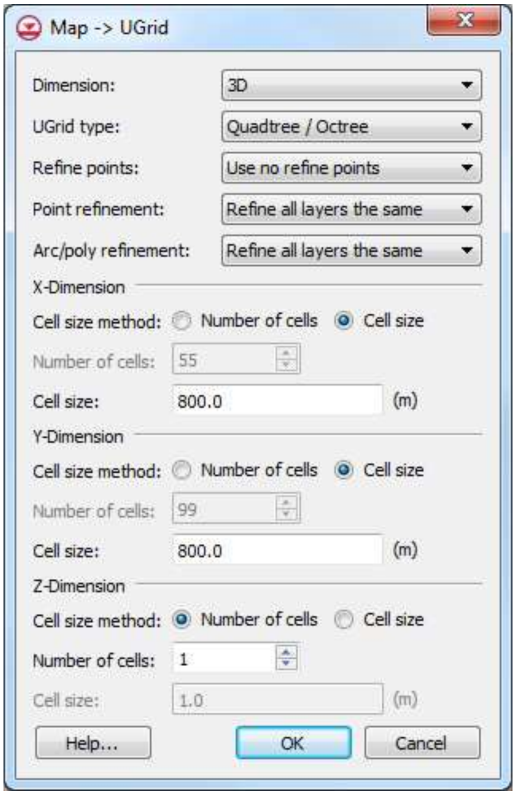

Figure 5 Map → UGrid dialog

19. Click **OK** to generate the unstructured grid.

The new Quadtree UGrid should appear similar to Figure 6 below.

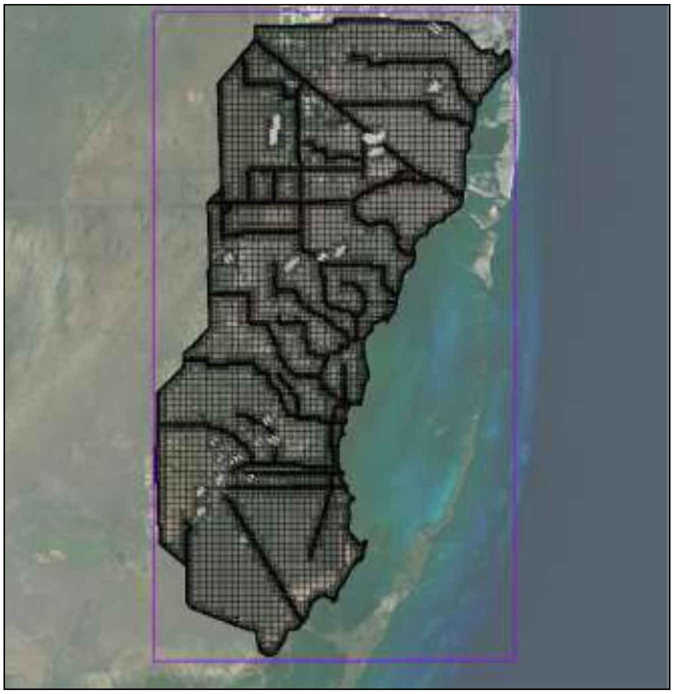

Figure 6 Quadtree grid

Check to see how many cells were generated.

20. Right-click on the **"**ugrid" item in the Project Explorer.

21. Select the **Properties** menu item to open the *UGrid Properties* dialog.

The generated unstructured grid has about 28,000 cells. Generating a structured grid for the same model using a cell size of 100 m results in a grid with about 185,000 cells.

22. Click **Done** to exit the dialog.

8 Create a MODFLOW-USG Model

Now it is possible to create the MODFLOW-USG model.

1. Select the *MODFLOW* | **New Simulation** menu item.

2. Click **OK** to exit the dialog.

9 Set Grid Elevations

The user also needs to set the top and bottom elevations for the model. This tutorial will use the *Interpolate to MODFLOW Layers* method and the rasters included in the project for the elevations.

1. Under the "GIS Layers" folder, right-click on the "Tops.tif" item in the Project Explorer.

2. Select *Interpolate To* | **MODFLOW Layers** menu item.

The "Tops.tif" has automatically been "mapped" to the Top Elevations of Layer 1 array. The user needs to map the "Bottoms.tif" to the Bottom Elevation of Layer 1 array.

3. In the *Rasters list*, select "Bottoms.tif."

4. In the *MODFLOW data* list, click on *Bottom Elevations Layer 1*.

5. Click on the **Map** button to add the mapping.

6. Click **OK** to interpolate the top and bottom values to the MODFLOW model.

10 Map to MODFLOW

Now assign the conceptual model values to the MODFLOW model.

1. Click on the "Biscayne" conceptual model in the Project Explorer.

2. Select the *Feature Objects* | **Map → MODFLOW** menu item.

3. In the *Map → Model* dialog, leave the values at their defaults.

4. Click on the **OK** button.

Boundary condition symbols for specified head, rivers, and wells should appear similar to the following figure.

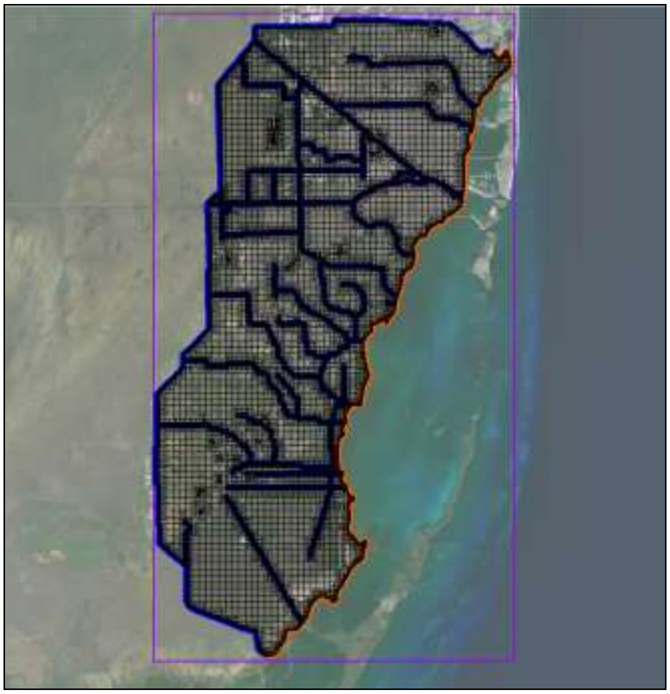

Figure 7 MODFLOW boundary conditions assigned from the conceptual model

11 Save and Run MODFLOW

Now it is possible to run MODFLOW.

1. Click the **Save** button.
2. Click the **Run MODFLOW** button.
3. When the model finishes, click **Close**.

GMS will read in the solution and display the contours similar to the figure below.

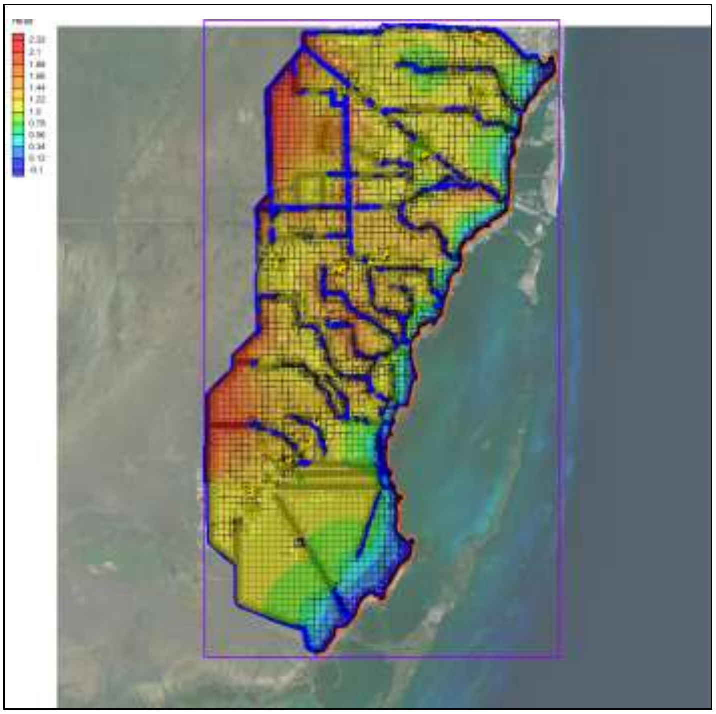

Figure 8 MODFLOW-USG head contours

12 Conclusion

This concludes the tutorial. Here are the key concepts in this tutorial:

- GMS supports generating smoothed Quadtree UGrids that can be used with MODFLOW-USG.
- The localized cell refinement for a generated grid can be controlled by turning on *Refinement* and setting the *Base size* in the conceptual model.
- Polygons in the active coverage determine the area in which cells are generated.
- A grid frame can be used to further control the size and position of the generated cells.

