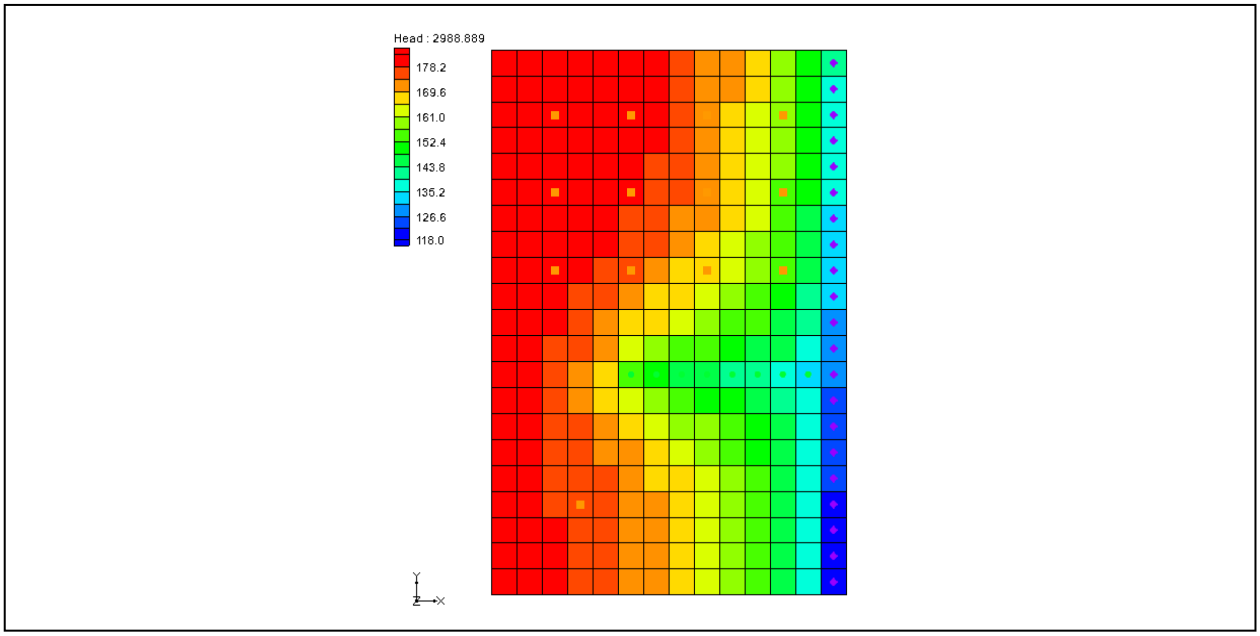
GMS

v. 9.2

GMS 9.2 Tutorial

MODFLOW – MNW2 Package

Use the MNW2 package with the sample problem and a conceptual model



Objectives

Learn how to use the MNW2 package in GMS and compare it to the WEL package. Both packages can be used at the same time if desired. Examine the sample MNW2 model that comes with MODFLOW and then examine a different model that uses the conceptual model approach.

Prerequisite Tutorials

- None

Required Components

- Map
- Grid
- MODFLOW

Time

- 30-60 minutes

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1 Contents

2 Introduction

This tutorial is very similar to the MNW1 tutorial. The MNW1 sample problem was converted to MNW2 using the USGS program mnw1to2.exe.

The Multi-Node Well (MNW2) package was created to replace the MNW1 package. Both packages were developed to more accurately model wells that are completed in multiple aquifers or in a single heterogeneous aquifer, partially penetrating wells, and horizontal wells that can be affected by the effects of dynamic changes in the distribution of pumping or intraborehole flow that can significantly alter groundwater flow.[1]

2.1 Outline

This is what you will do in this tutorial:

1. Import an existing MODFLOW simulation.
2. Run the simulation and examine the results to understand the MNW2 package options.
3. Modify a conceptual model to use MNW2 instead of the WEL package.

3 Description of Problem

The problem we will be solving in this tutorial is the same as the model used in the MNW1 documentation.

> The system consists of two aquifers that are separated by a 50-foot-thick confining unit. The upper aquifer is unconfined, has a hydraulic conductivity of 60 ft/d, and has a uniform base of 50 ft above the datum. The lower aquifer is confined and has a transmissivity of 15,000 ft^2/d. Storage coefficients of 0.05 and 0.0001 were assigned to layers 1 and 2, respectively. The 66-mi^2 area of the test problem was divided into 21 rows of 14 columns. Uniform, square cells that measured 2,500 ft on a side were used throughout the simulated area. Specified heads and drains are assigned in layer 1 and are maintained at the same elevations for all stress periods.[1]

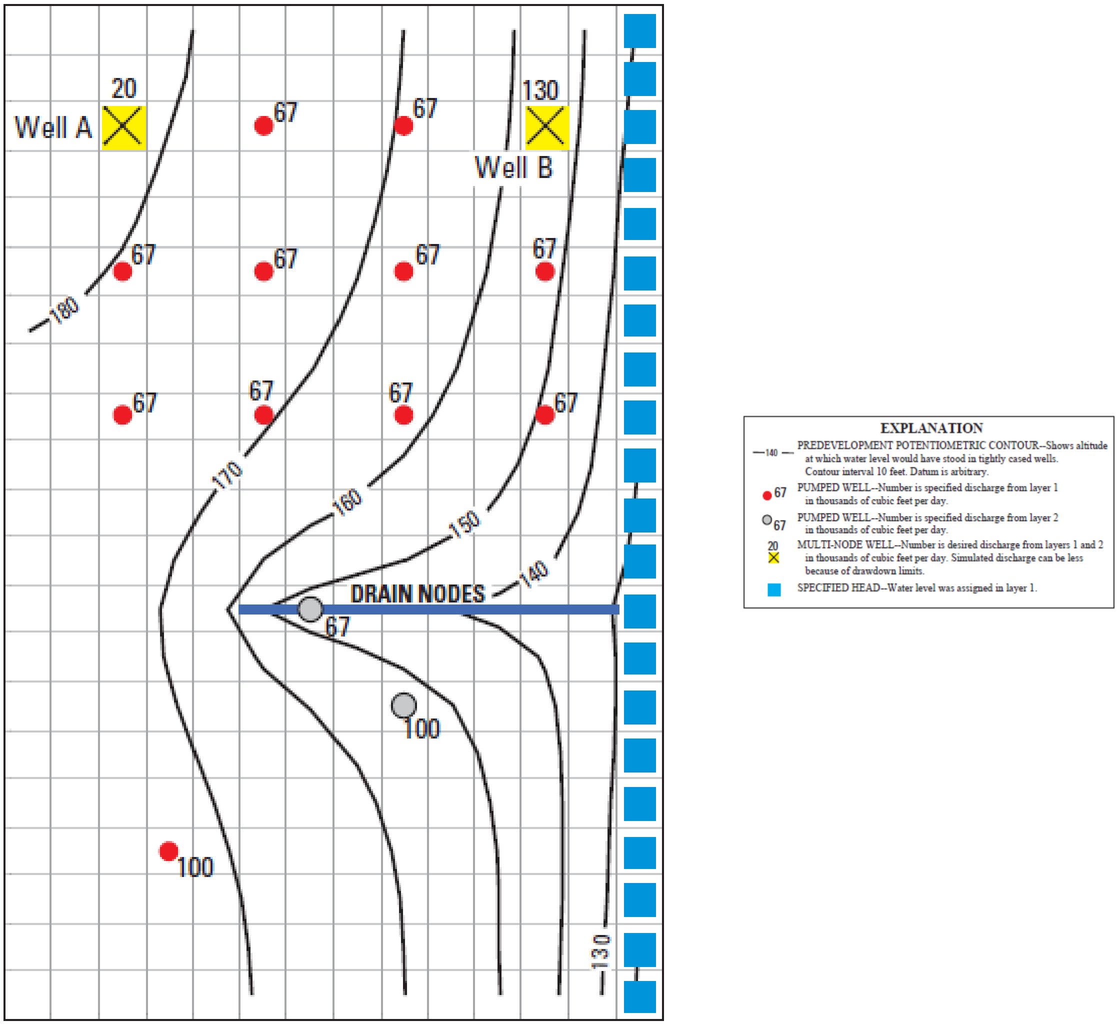

Figure 1. Flow model from MNW2 documentation.[1]

A period of 1,000,970 days was simulated with 5 stress periods. The first two stress periods simulated steady-state conditions, which were achieved by having each stress period be 500,000 days long. Recharge during stress periods 1 and 2 was a uniform 7 inches per year (in./yr). No pumpage was extracted during stress period 1 but multi-node wells were simulated. About 950,000 ft^3/d of pumpage was extracted during stress period 2; this is about 35 percent of the total volumetric budget. Transient conditions were simulated during stress periods 3, 4, and 5, which were periods of 60, 180, and 730 days, respectively. Uniform recharge rates of 2, 0, and 12 in./yr, respectively, were applied during stress periods 3, 4, and 5. In addition to the simulation of two multi-node wells (wells A and B), there are 15 other single-node wells that have a combined discharge of 935,350 ft^3/d for stress periods 2 through 5. [1]

4 Getting Started

Let's get started.

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

5 Importing the existing model

We will start with a MODFLOW model that has already been created.

1. Select the *Open* button (or the *File* | *Open* menu command).
2. Browse to the **\Tutorials\MODFLOW\mnw2** folder.
3. Change the *Files of type* popup menu to *All Files*.
4. Select the *mnw2.nam* file and click *Open*.

A dialog should alert you that the model needs to be translated into GMS format.

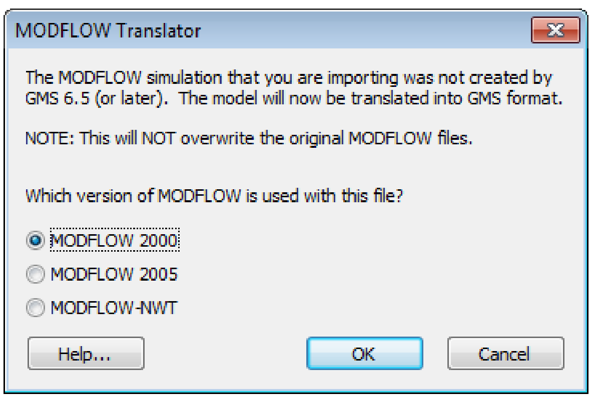

Figure 2. MODFLOW Translator dialog.

5. Click *OK* to translate the model.

Now the MODFLOW Translator runs and ends with a message saying "MODFLOW 2000 terminated successfully".

6. Press *Done*.

This imports the model. You should see a grid with symbols representing wells, drains, and specified head boundary conditions similar to the figure below.

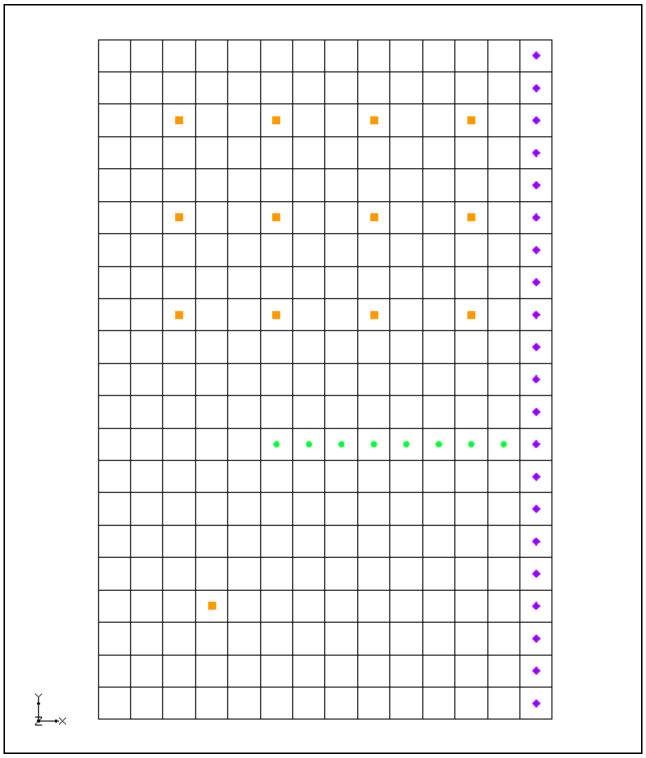

Figure 3. Imported MODFLOW model.

6 Saving the model with a new name

We're ready to start making changes. Let's save the model with a new name.

1. Select the *File* | *Save As* menu command.
2. Make sure the project file name is **mnw2.gpr**.
3. Save the project by clicking the *Save* button.

7 Viewing the MNW2 boundary conditions

Before running the simulation we'll view the MNW2 boundary conditions.

7.1 Opening the MNW2 Package Dialog

1. Select the *MODFLOW* | *Optional Packages* | *MNW2 - Multi-Node Well* to open the MNW2 Package dialog.

This dialog is used to add and edit MNW2 wells and to change options associated with the MNW2 package.

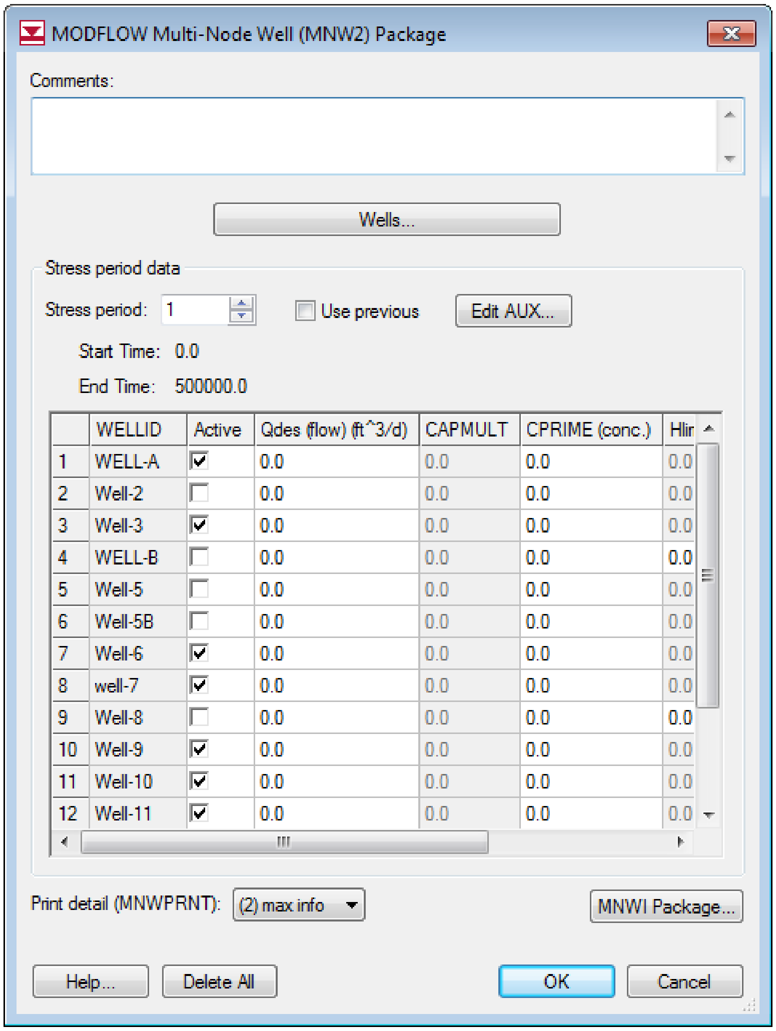

Figure 4. MNW2 Package dialog.

It is recommended that the user review the MNW2 documentation for more information on each input option. MNW2 documentation can be found at the following URL: http://pubs.usgs.gov/tm/tm6a30/.

7.2 Stress period data

The MNW2 package allows certain things to vary per stress period, while other things are constant for all stress periods. For example, well definitions are constant for all stress periods - that is, wells cannot be defined for some stress periods and not for others, although they can be designated as active or inactive per stress period.

1. Change the current *Stress period* to 2.

Notice that nearly all of the wells have a specified pumping rate in this stress period except for "Well-5B".

7.3 Well definitions

The spreadsheet in the dialog shows the data that can vary per stress period, but to actually add and delete wells, you click on the *Wells* button.

1. Click on the *Wells* button.

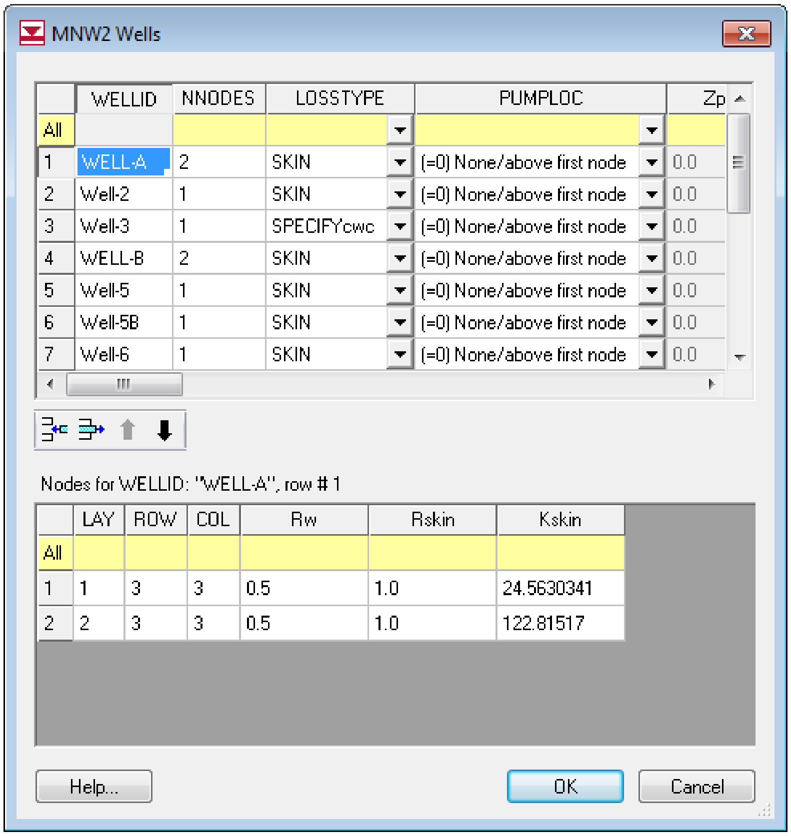

Figure 5. MNW2 Wells dialog.

You should see 16 MNW2 wells listed in the spreadsheet. Most of these are single node wells. However, the wells named “WELL-A” and “WELL-B” are multi-node wells (they have more than one node).

You can add, delete, reorder, rename, and change the options for the wells in this dialog. The nodes (cells) that are associated with each well are located in the bottom spreadsheet.

2. Click on the spreadsheet row for *WELL-A*.

Notice the nodes for Well-A are listed in the bottom spreadsheet, along with some other variables (Rw, Rskin, Kskin).

3. In the top spreadsheet, for WELL-A, change NNODES from 2 to **-1**.

Notice the change in the *Nodes* spreadsheet. Specifying a negative number for NNODES means the well is a vertical well and instead of specifying the nodes for the well, you specify the top and bottom elevations of the well screen. We'll continue and change Well-A to use a well screen.

4. In the *Nodes* spreadsheet, change *Ztop* to **400** and *Zbotm* to **10**.
5. Close both dialogs by pressing the *OK* button.

7.4 Examining the Well Screen for Well-A

Let's see what WELL-A looks like in the grid now that it's using a well screen.

1. Switch to the 3D Grid module by selecting the *3D Grid Data* item in the *Project Explorer*.
2. Select the 3D grid cell in the upper left with the well in it (the one highlighted in the figure below).

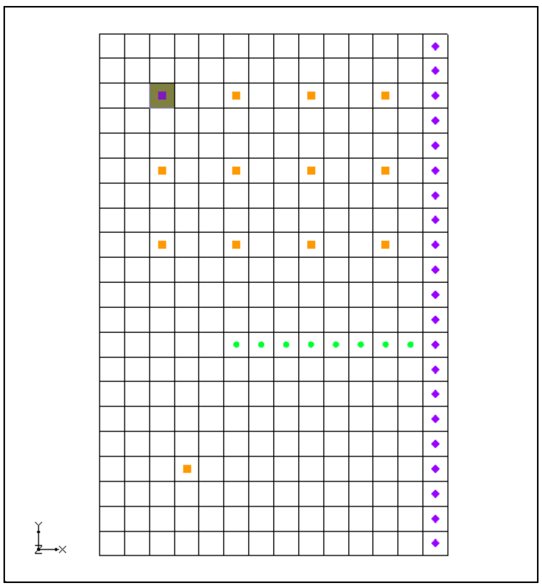

Figure 6. Selected MNW2 well cell.

3. Click the *Front View* button.

Now we're looking at a slice of the grid in front view, but we can't see much. We'll exaggerate the Z scale to see things better.

4. Select the *Display Options* button and set the *Z magnification* to **20**.
5. Select the *OK* button.

The display should look like this:

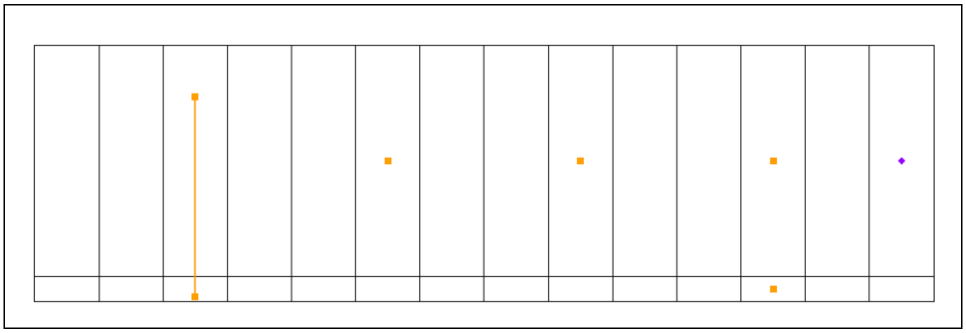

Figure 7. Front view of grid at Well-A.

Notice WELL-A (the one on the left) is drawn differently than the rest because it is a vertical well and uses a well screen. Square symbols are drawn at the top and bottom of the well screen with a line connecting them. The other wells are drawn with a symbol at the cell center. Notice the well on the right side that has symbols in the top and bottom layer. This is WELL-B and it has two nodes - one in each layer.

7.5 Opening the Source/Sinks Dialog

Now we'll see how MNW2 wells are handled by the *Sources/Sinks* dialog.

1. Select the 3D grid cell with WELL-A in it (on the left) as shown in the figure below.

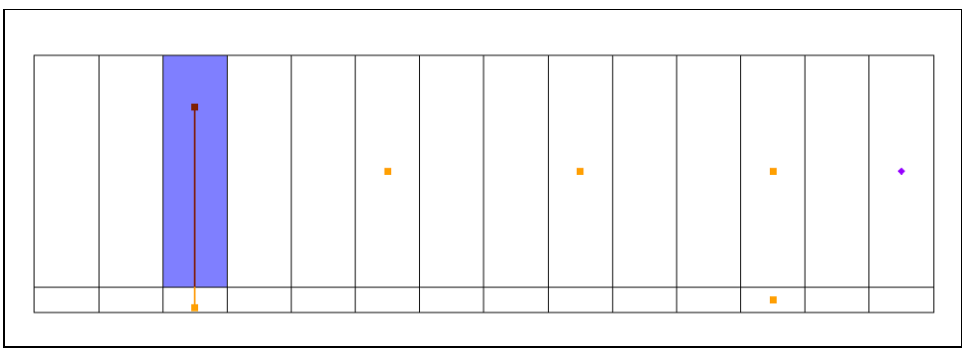

Figure 8. Selected MNW2 well cell.

2. Open the *MODFLOW Source/Sinks* dialog by right clicking on the selected cell and selecting the *Sources/Sinks* command.

The dialog should look like this:

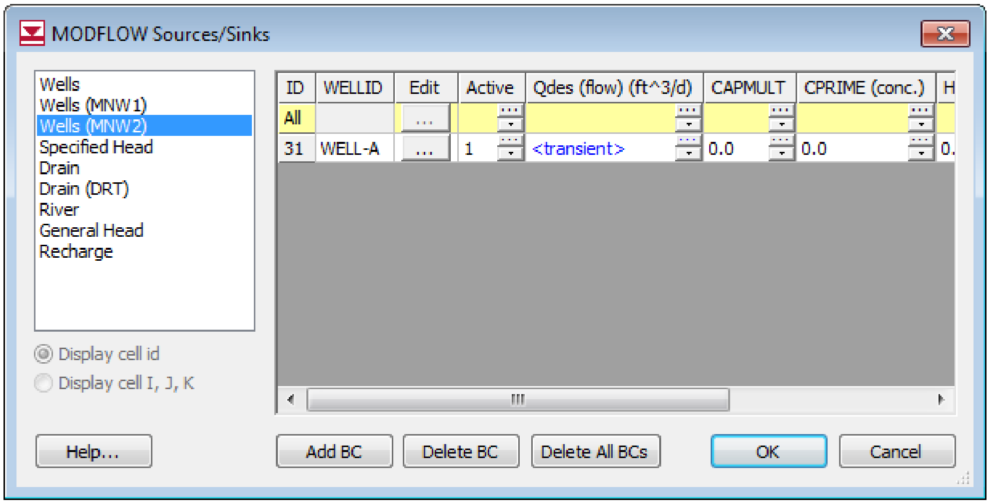

Figure 9. Sources/Sinks dialog.

This dialog lets you edit the properties of selected boundary conditions as well as add additional boundary conditions in the selected cells. With MNW2 wells, some things are defined with the well and remain constant while other things can vary per stress period. Only those things which can vary per stress period are shown in the spreadsheet. However, clicking on the button in the *Edit* column brings up the *MNW2 Wells* dialog allowing you to edit the well definition. This is the same dialog we saw earlier.

3. Select *OK* to exit the dialog.

4. Switch to plan view by clicking the *Plan View* button.

8 Running MODFLOW

Before running MODFLOW we need to change the output options to make it easier to see the results.

1. Select the *MODFLOW* | *OC - Output Control* menu command.

2. From the *Output interval* section, select the *Output at last time step of each stress period* option.

3. Turn **on** the *Save cell by cell flow terms to *.ccf file* toggle.

4. Press the *OK* button to exit the *MODFLOW Output Control* dialog.

Now we are ready to save our changes and run MODFLOW.

5. Select the *Save* button (or the *File* | *Save* menu command).

6. Select the *Run MODFLOW* button.

7. When MODFLOW finishes, select the *Close* button.

Contours should appear on the grid similar to those shown in the following figure:

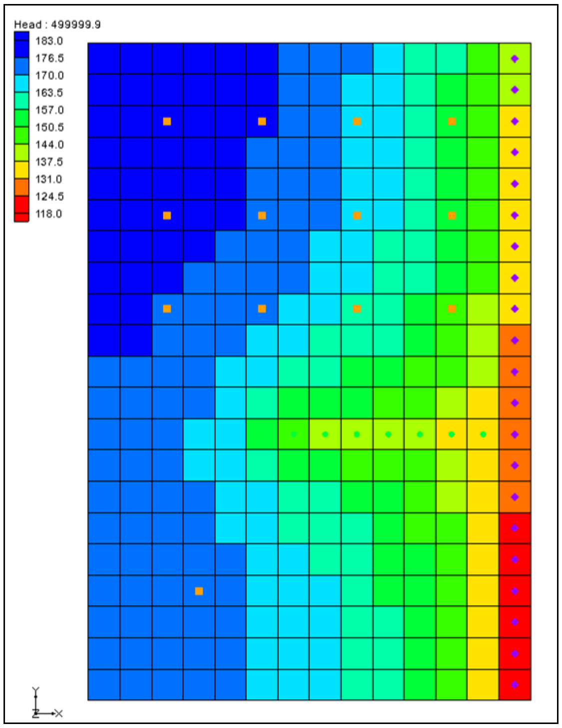

Figure 10. MODFLOW solution.

8. Select the *Save* button to save the project with the new solution.

9 Examining the Solution

Now we will look closely at the computed solution.

1. Re-select the grid cell containing WELL-A (as shown in Figure 6, the one containing the top-left well with Cell ID 31).

2. Click on the *Front View* button.

From this view, you can see the water table and the head contours. Notice that on the left side of the view the head is greater in the top layer of the model. In contrast, the head on the right side of the view, where the specified head boundary condition is located, is less in layer 1 than in layer 2 of the model. Notice that the head in the selected cell is about 180.

3. Select the cell in the second layer (Cell Id 325) just below the currently selected cell.

Notice that the head in the cell in the second layer is about 175.7. So there is a potential for flow from layer 1 to layer 2 at these particular cells. Now we will see what effect the MNW2 multi-node well has on these grid cells.

4. Right click on the *CCF* item in the *Project Explorer* and select the *CCF → Data Sets* command.

5. Select the data set named **MNW2**.

6. Click anywhere off the grid to unselect the grid cell.

Notice that flow is occurring between the multi-node well boundary conditions at these cells. This is an example of intraborehole flow that can occur when a well is completed in more than one aquifer. We can see the effect of the multi-node wells by looking at the *Flow Budget* dialog.

7. Select the two well cells on the left of the grid by clicking on one cell and then shift clicking on the other.

8. Select the *MODFLOW* | *Flow Budget* menu command.

Notice that the *Flow In* and the *Flow Out* are equal and opposite just as we would expect. A flow of about -11992 leaves the model cell in layer one and enters the model cell in layer 2.

9. Select the *OK* button to exit the *Flow Budget* dialog.

10 Changing the Active Flag for the Multi-node Well

Now we will see the effect of turning off the active flag for the multi-node well. Let's assume that "WELL-A" was not constructed until after the first stress period in our model. Therefore, we would not want to model the intraborehole flow or any pumping until after the first stress period. This can be accomplished by turning off the active flag for the boundary condition.

1. Select the *MODFLOW* | *Optional Packages* | *MNW2 - Multi-Node Well* command to open the *MNW2 Package* dialog.

2. Turn **off** the *Active* toggle box for "WELL-A" in the spreadsheet.

3. Change the value of the stress period to **2**.

Notice that "Well-A" is active in stress period 2.

4. Select *OK* to exit the dialog.

11 Running MODFLOW and Viewing the Solution

Now we will run MODFLOW to see how our solution has changed.

1. Select the *Run MODFLOW* button .

2. Select *Yes* at the prompt to save your changes.

3. When MODFLOW finishes, select the *Close* button.

4. Right click on the **CCF** item in the *Project Explorer* and select the *CCF → Data Sets* command.

5. Select the data set named **MNW2**.

Notice that there is no intraborehole flow now at "Well-A" during the first stress period.

12 Drawdown Limited Wells

The MNW2 package also allows for wells to be limited by the drawdown in the cell containing the well. This feature allows a well to stop pumping when the head in the cells drops below a specified elevation. We will now change the drawdown for one of the wells and see the effect on the solution. However, first we will change the active flag back to its original state for "WELL-A".

1. Select the *MODFLOW | Optional Packages | MNW2 - Multi-Node Well* command to open the *MNW2 Package* dialog.

2. Turn **on** the *Active* toggle box for "Well-A" in the spreadsheet.

3. Select *OK* to exit the dialog.

Now we will edit one of the MNW2 wells to illustrate the drawdown-limited feature.

4. Switch to plan view by clicking the *Plan View* button.

5. Select and right-click the highlighted cell shown in the figure below.

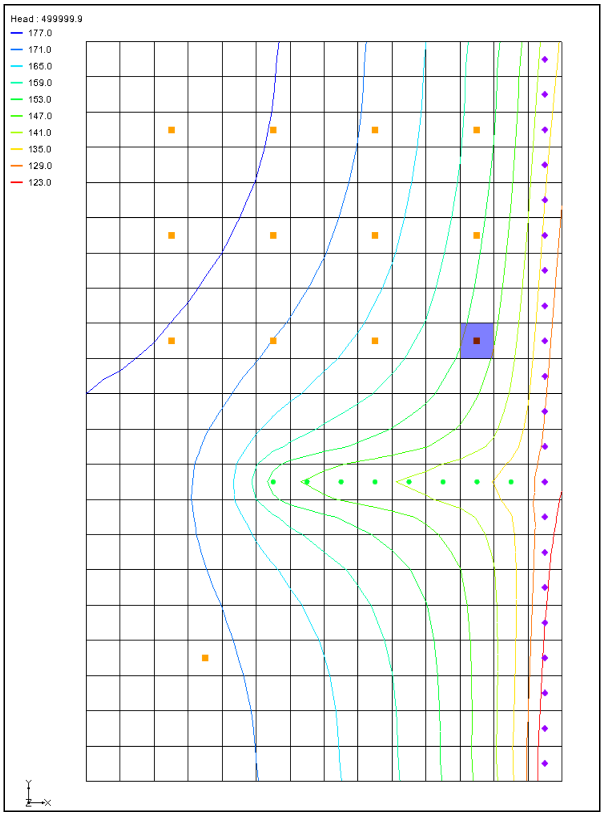

Figure 11. MNW2 boundary condition cell (IJK = 9,12,1, ID = 124)

6. Select the *Sources/Sinks* command from the pop-up menu.

7. If necessary scroll over in the spreadsheet to the *Hlim* column and select the button in the cell in the second row to edit the value of Hlim for the boundary condition.

8. Enter a value of **142.0** in each of the spreadsheet cells that currently have a value of 115.

9. Select *OK* twice to exit both dialogs.

13 Running MODFLOW and Viewing the Solution

Now we will run MODFLOW to see how our solution has changed.

1. Select the *Run MODFLOW* button.

2. Select *Yes* at the prompt to save your changes.

3. When MODFLOW finishes, select the *Close* button.

4. Right click on the **CCF** item in the *Project Explorer* and select the *CCF → Data Sets* command.

5. Select the data set named **MNW2** and change the active time step to the second time step listed in the *Time Step Window* below the *Project Explorer*. Notice that the flow at the cell that we edited is about -3127.

6. Select the **Head** data set. Notice that the head in this cell is about 142.7.

If you will remember, the desired flow rate (Qdes) that was specified for the well was -66850.0. Nevertheless, the computed flow for this drawdown limited well was only -3127. Now we will look at the head at the next output time.

7. Select the third time step listed in the *Time Step Window*. Notice that the head at the cell is about 141.6.

8. Change to the **MNW2** data set and notice that the flow in this time step is 0.0.

Even though the head value is high enough the well has been deactivated during this stress period. We can find out why by examining the well's settings in the *MNW2 Package* dialog.

9. Select the *MODFLOW | Optional Packages | MNW2 - Multi-Node Well* command to open the *MNW2 Package* dialog.

10. Change the stress period to stress period 2 and notice the *Hlim* settings for *Well 12*. You may want to make the dialog wider so you can see more columns.

11. Change to the next stress period.

Notice that for this stress period the QCUT value has been set to -1, which means percent, with a Qfrcmn value of 0.45 (45 percent). The Qfrcmn value is the minimum pumping rate required for the well to remain active. With a desired flow rate (Qdes) of -66850.0 we would need a flow rate of -30082.5 for the well to remain active. For the previous stress period QCUT was set to 0 (none) allowing the well to be active.

12. Select *OK* to exit the dialog.

14 Create a Conceptual Model

Now we'll examine how to use a conceptual model with MNW2 data. We'll do this by taking the finished model for the *MODFLOW – Conceptual Model Approach* tutorial and changing it to use the MNW2 package.

14.1 Open the Existing Conceptual Model

1. Before opening the conceptual model you may wish to save the grid based MNW2 model by selecting the *Save* button.

2. Select the *New* button.

3. Select the *Open* button.
4. Locate and open the directory entitled **Tutorials\MODFLOW\modfmap\sample**.
5. Open the file entitled **modfmap.gpr**.

Before we make any changes, lets save the project under a new name.

6. Select the *File | Save As* command.
7. Browse back to the **Tutorials\MODFLOW\mnw2** folder.
8. Save the project with the name **MNWmap.**

15 Examining the Existing Solution

Before changing to the MNW2 package lets look at the flow budget for the existing solution.

1. Select the *MODFLOW | Flow Budget* command.

Notice the flow budget for the Well package has a flow rate of -3510.0 (out of the model).

2. Press the *OK* button the exit the *Flow Budget* dialog.

16 Changing the Model to Use MNW2

To change to the MNW2 package first the WEL package needs to be removed from MODFLOW.

1. Select the *MODFLOW | Global Options* command.
2. Press the *Packages* button to bring up the *MODFLOW Packages* dialog.
3. Turn **off** the *Well (WEL1)* toggle to disable the WEL package.
4. Press the *OK* button twice to exit both dialogs.

16.1 Changing the Wells to MNW2

1. Expand the **East Texas** conceptual model in the *Project Explorer* and select the **Sources & Sinks** coverage.
2. Right click on the **Sources & Sinks** coverage and select *Coverage Setup*.

3. Turn **on** the *Wells (MNW2)* toggle in the *Sources/Sinks/BCs* section of the dialog.
4. Press the *OK* button to exit the *Coverage Setup* dialog.
5. Right-click on the **Sources & Sinks** coverage and select *Attribute Table*.
6. In the *All* row change the *Type* to **well (MNW2)**.
7. Change the *Qdes* of *well1*, the first well, to **–680.0.** You may need to scroll to the right to see these fields.
8. Change the *Qdes* of *well2*, the second well, to **–2830.0**.
9. Press the *OK* button to exit the *Properties* dialog.

The conceptual model is set up so now we can map it to the MODFLOW grid.

10. Select the *Map → MODFLOW* button.
11. Click *OK*.

17 Examine the MNW2 Package

Let's take a look at the data in MODFLOW that was mapped from the conceptual model.

1. Select the *MODFLOW* | *Optional Packages* | *MNW2 - Multi-Node Well* menu command.

Review the two MNW2 wells. These were created when we did *Map → MODFLOW*.

2. Click *OK* to exit the dialog.

18 Saving and running MODFLOW

We're ready to save our changes and run MODFLOW. First we need to adjust the Output Control.

1. Select the *MODFLOW* | *OC - Output Control* menu command.
2. Turn **off** the **.hff file for transport* option.
3. Select *OK* to exit the dialog.
4. Select the *Run MODFLOW* button.
5. Select *Yes* at the prompt to save your changes.
6. When MODFLOW finishes, select the *Close* button.

7. Select the *Save* button to save the project with the new solution.

19 Examining the Solution

Let's look at the flow budget for the new solution.

1. Select the *MODFLOW | Flow Budget* command.

Notice the flow budget for the MNW2 package has the same flow rate of -3510.0 (out of the model).

2. Press the *OK* button the exit the *Flow Budget* dialog.

20 Changing to a Multi-Node Well

Now we will create a multi-node well (a well with multiple nodes) from our map data.

1. Right-click on the **Sources & Sinks** coverage and select the *Attribute Table* command.
2. Change the *From layer* value to **1** for *well2* in the table.
3. Select *OK* to exit the dialog.

The conceptual model is set up so now we can map it to the MODFLOW grid.

4. Select the *Map→MODFLOW* button.
5. Click *OK*.

21 Examine the MNW2 Package

Let's take a look at the data in MODFLOW that was mapped from the conceptual model.

1. Select the *MODFLOW | Optional Packages | MNW2 - Multi-Node Well* menu command.
2. Click the *Wells* button.
3. Click on the row for *well2*.

Notice that well2 has 2 nodes.

4. Change the *LOSSTYPE* for *well2* to **THIEM**.

Wells that have more than one node must specify a LOSSTYPE other than NONE.

5. Click *OK* twice to exit both dialogs.

22 Saving and running MODFLOW

We're ready to save our changes and run MODFLOW. Before doing so we will need to adjust the parameters associated with our solver.

1. Select the *MODFLOW | PCG2 - Pre. Conj.-Gradient Solver* command.
2. Change *Maximum number of outer iterations (MXITER)* to **100** and *Relaxation parameter (RELAX)* to **0.5**.
3. Click *OK* to exit the dialog.
4. Select the *File* | *Save As* menu command.
5. Change the project name to **MNWmap2** and *Save*.
6. Select the *Run MODFLOW* button.
7. When MODFLOW finishes, select the *Close* button.

23 Viewing the Flow in the MNW2 Boundary Conditions

Now we will view the computed flow out of each of the MNW2 boundary conditions associated with well2.

1. Select the *Zoom* tool and zoom in around the well on the right side of the model.
2. Select the cell containing the well using the *Select Cell* tool.
3. Select the *MODFLOW* | *Flow Budget* command.

Notice that the flow out of the well in the top layer is about -1584. Now we will view the flow out of the well in the second layer.

4. Select *OK* to exit the dialog.
5. Change to view layer 2 of the grid by clicking the up arrow in the *Mini Grid* toolbar.
6. Select the cell containing the well using the *Select Cell* tool.
7. Select the *MODFLOW* | *Flow Budget* command.

Notice that the flow rate for this well is about -1246.

24 Conclusion

This concludes the tutorial. Here are the things that you should have learned in this tutorial:

- GMS supports the MNW2 package.
- The MNW2 package produces the same results as the WEL when there are no multi-node wells.
- MNW2 data can be viewed and edited in the MNW2 Package dialog.
- MNW2 wells can be created in the conceptual model and mapped to the grid.

25 Notes

1. User Guide for the Drawdown-Limited, Multi-Node Well (MNW) Package for the U.S. Geological Survey's Modular Three-Dimensional Finite Difference Ground-Water Flow Model, Versions MODFLOW-96 and MODFLOW-2000. K.J. Halford and R.T. Hanson. Open-File Report 02-293. 2002.

