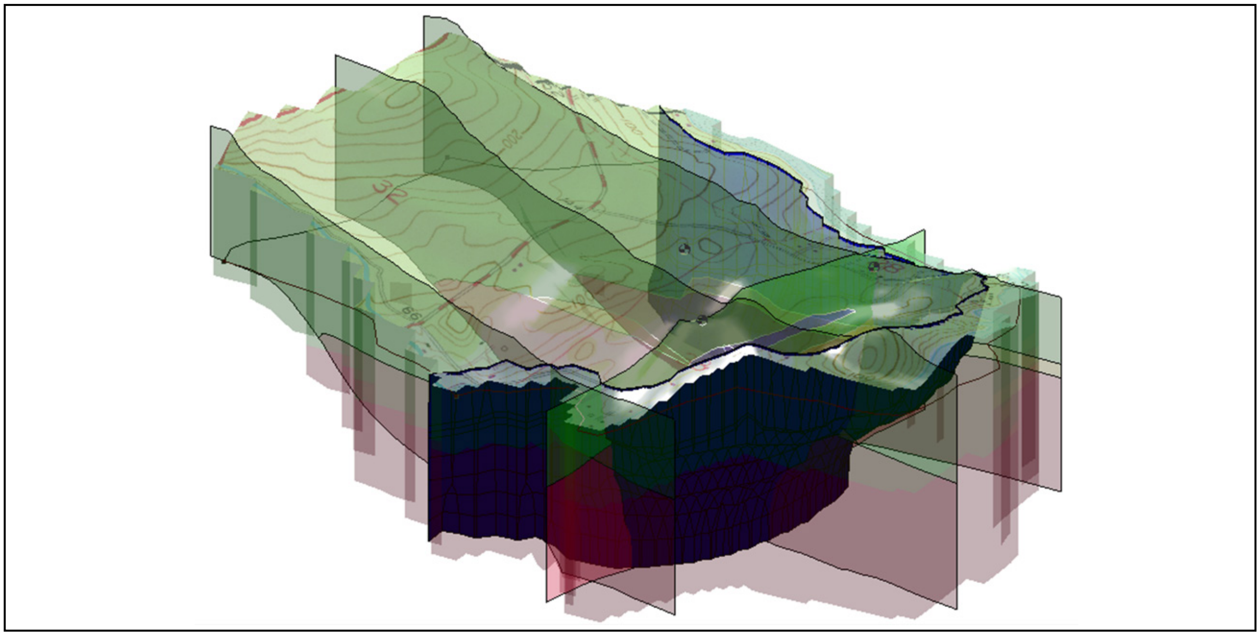
GMS

v. 9.2

GMS 9.2 Tutorial

SEAWAT – Conceptual Model Approach

Create a SEAWAT model in GMS using the conceptual model approach



Objectives

Create a SEAWAT model in GMS using the conceptual model approach which 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, model boundaries, 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.

Prerequisite Tutorials

- MODFLOW - Conceptual Model Approach
- MT3DMS - Conceptual Model Approach

Required Components

- Grid
- Map
- MODFLOW
- MT3DMS
- SEAWAT

Time

- 30-60 minutes

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1 Contents

2 Introduction

"SEAWAT is a generic MODFLOW/MT3DMS-based computer program designed to simulate three-dimensional variable-density groundwater flow coupled with multi-species solute and heat transport. The program has been used for a wide variety of groundwater studies including those focused on brine migration in continental aquifers as well as those focused on saltwater intrusion in coastal aquifers. SEAWAT uses the familiar structure of MODFLOW and MT3DMS."[1]

This tutorial explains how to perform a SEAWAT simulation within GMS using the conceptual model approach. If you have not done so already, it is recommended that you complete the *MODFLOW – Conceptual Model Approach* and *MT3DMS – Conceptual Model Approach* Tutorials prior to completing this tutorial.

2.1 Outline

This is what you will do in this tutorial:

1. Import an existing MODFLOW simulation and conceptual model.

2. Create a SEAWAT model to simulate the effects of pumping on salt water intrusion.

3. Run the simulation and view the results in 3D.

3 Description of the Problem

The site in this model is a small coastal aquifer with three production wells with variable pumping rates. The no flow boundary on the upper left corresponds to a parallel flow boundary and the no flow boundary on the left corresponds to a thinning of the aquifer due to a high bedrock elevation. A stream provides a specified head boundary on the lower left and the remaining boundary is a coastal boundary simulated with a specified head boundary condition.

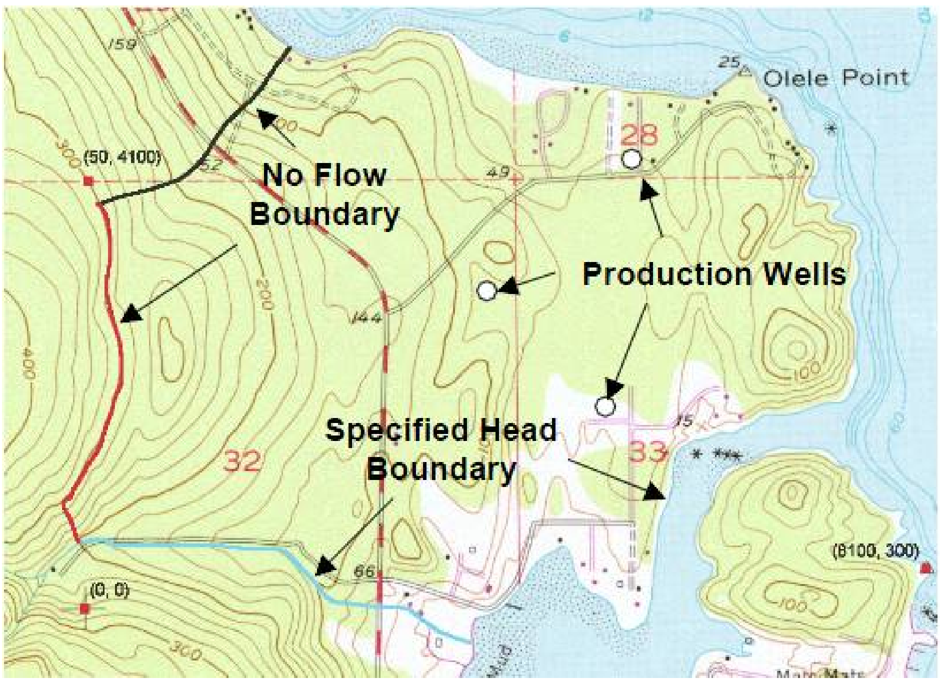

Figure 1. Site map of SEAWAT model.

The stratigraphy of the site consists mainly of an upper and lower aquifer. The upper aquifer has a hydraulic conductivity of 1.5 m/day and the lower aquifer has a hydraulic conductivity of 5.0 m/day. The model also has some areas with confining units. The production wells extend to the lower aquifer.

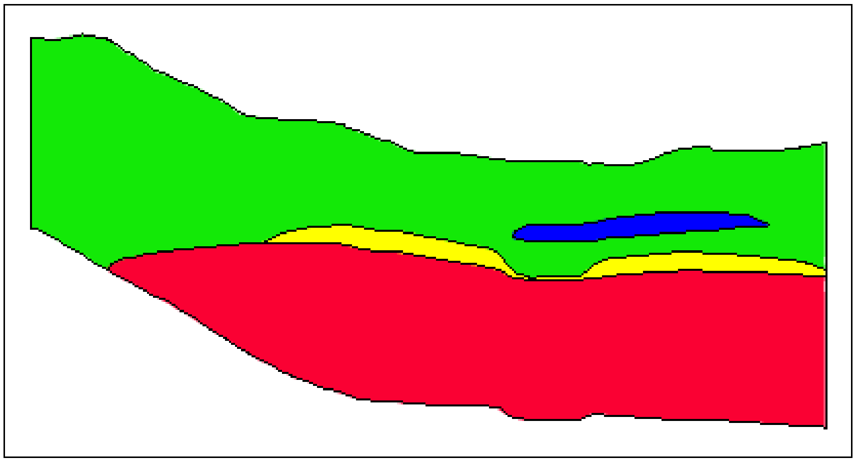

Figure 2. Cross-section through model domain.

We will use this model to simulate the effect of the pumping wells on salt water intrusion. The initial heads and concentrations were created by running a SEAWAT model for a very long time with steady state flow model.

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 an existing MODFLOW Model

We will start with an existing MODFLOW model and make the necessary modifications to run SEAWAT.

1. Select the *Open* button.
2. Locate and open the directory entitled ***Tutorials\SEAWAT\Coastal***
3. Select the file entitled ***coastal.gpr*** and select the *Open* button.

The imported model shows a MODFLOW grid on top of a back ground topo map. The contours on the grid are the heads computed by the "long" SEAWAT run with a steady state flow model.

5.1 Viewing the Initial Concentration

Now we will view the initial concentration that will be assigned to the SEAWAT model.

1. Expand the **3D Grid Data** folder and the **grid** item in the *Project Explorer*.

2. Select the **Salt Initial Concentration** data set.

3. Expand the **Display Themes** folder in the Project Explorer.

4. Select the **Fresh-water Isosurface** display theme.

You should now see an image similar to the figure shown below. Use the Rotate tool to move around the view to see how the fresh water interface looks. You should also see cross sections through the stratigraphy at the site. You can also select the **Isosurface Animation** display theme; this theme only shows the isosurface and the 3D grid faces.

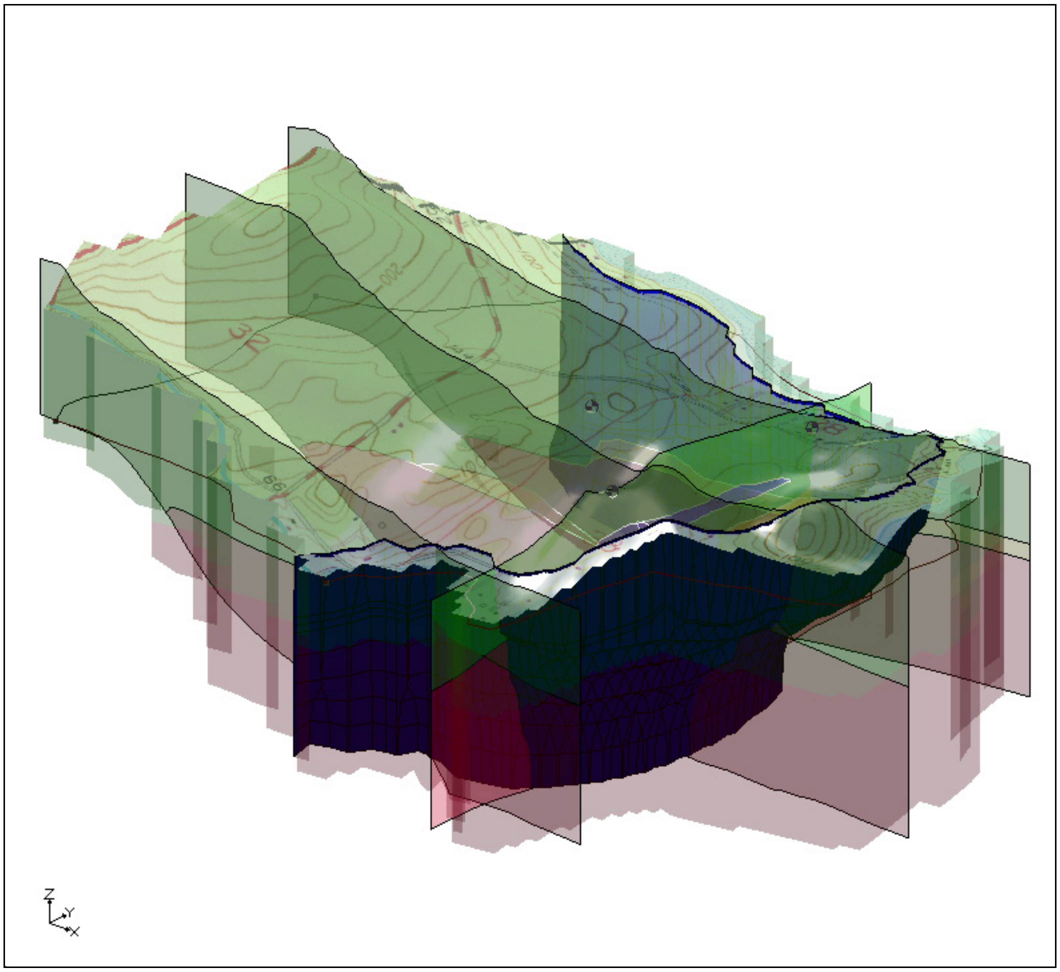

Figure 3. Display of the fresh-water isosurface.

5. Select the **Head Contours** display theme to return to the original view.

6 Saving the project

As you work in GMS it is a good idea to save often. Let's save the project under a new name so that we can save the project periodically as we work on it.

1. Select the *File* | *Save As* command.

2. Enter **seawat** for the name of the project and select the *Save* button.

Now we will create a SEAWAT model by modifying the existing MODFLOW model. We will do this by editing the conceptual model as well as setting up some options in the MODFLOW, MT3D, and SEAWAT interfaces.

7 Editing the MODFLOW simulation

The heads computed by SEAWAT simulation are different than the heads computed by a MODFLOW simulation (for more details see the SEAWAT documentation[3] p. 13). Our SEAWAT simulation will be transient so we will set the starting heads to be those computed by the prior long-term SEAWAT run. Also, we need to change our MODFLOW model to be transient and set up the stress periods. Our model will run for 730 days and each stress period will be 10 days long.

1. Select the *MODFLOW* | *Global Options* command.

2. Make sure the *Starting heads equal grid top elevation* toggle is turned off

3. Select the *Starting Heads* button.

4. Select the *3D Data Set → Grid* button.

5. Select the **Starting Heads** data set and select *OK* twice to return to the Global Options dialog.

6. In the *Model type* section of the dialog select **Transient**.

7. Select the *Stress Periods* button.

8. Select the *Initialize* button near the bottom of the dialog and select *OK* at the prompt.

9. Enter the values as shown in the following figure.

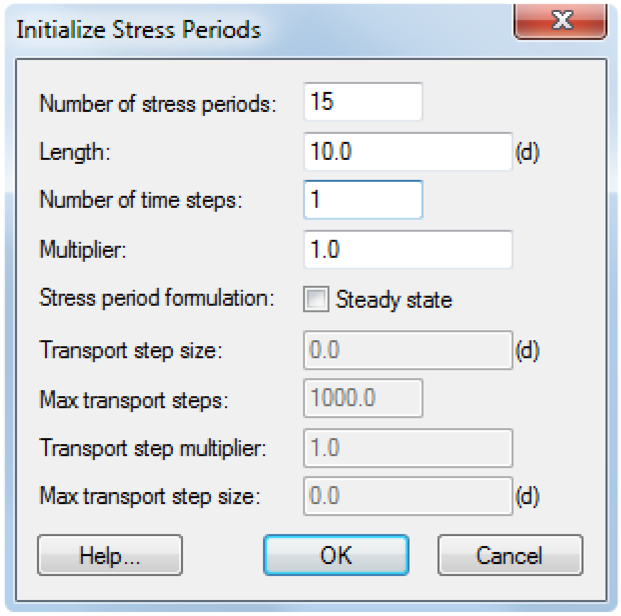

Figure 4. Initialize Stress Periods dialog.

10. Select OK until you return to the main GMS window.

8 Initializing MT3DMS

As stated earlier, SEAWAT uses the combination of MODFLOW and MT3DMS. We need to turn on the MT3DMS and SEAWAT menus. Now, we will initialize MT3DMS.

11. In the *Project Explorer*, right-click on the grid and select the *New MT3D* command. (You may need to expand the 3D Grid Data folder.)

12. Select the *Output Control* button.

13. Enter **40** for the **Print or save at specified interval** and select *OK* to exit the dialog.

14. Select the *Packages* button.

15. Turn on **Advection package** and **Source/sink mixing package** then select *OK* to exit the dialog.

16. Select the **Define Species** button.

17. Select the *New* button and change the name of the species to **Salt**; select *OK* to exit the dialog.

18. In the *Layer Data* section of the dialog turn on **Use materials for porosity and long. dispersivity**.

19. On the right side of the dialog select the **Salt** species in the spread sheet and click check the edit by cell button, click the "…" button.

20. Select the *3D Data Set → Grid* button.

21. Select the **Salt Initial Concentration** data set and select *OK* twice to exit the dialogs.

22. Select *OK* to exit the Basic Transport Package.

9 Initializing SEAWAT Simulation

With the MODFLOW and MT3DMS models ready, we can initialize the SEAWAT simulation

23. In the *Project Explorer*, right-click on the grid and select the *New SEAWAT…* command. (You may need to expand the 3D Grid Data folder.)

24. Turn on **Include transport in simulation** and **VDF. Variable-Density Flow**.

25. Select the *OK* button to exit the dialog.

9.1 Modifying the VDF Package

We can now enter the data necessary for the VDF package. The inputs to the VDF package control the density calculations performed by SEAWAT. In our example problem the concentration of seawater was defined as 19 g/l. Based on the units of our MODFLOW model our reference density will be 1000 kg/m^3. If the density of seawater is 1025 kg/m^3 then the linear relationship between concentration and density is defined with a factor of 1.315. You may wish to refer to SEAWAT manual[3] in page 20-21 for more information on these parameters.

1. Select the *SEAWAT | VDF Package* command

2. Enter all the values as given in the following figure:

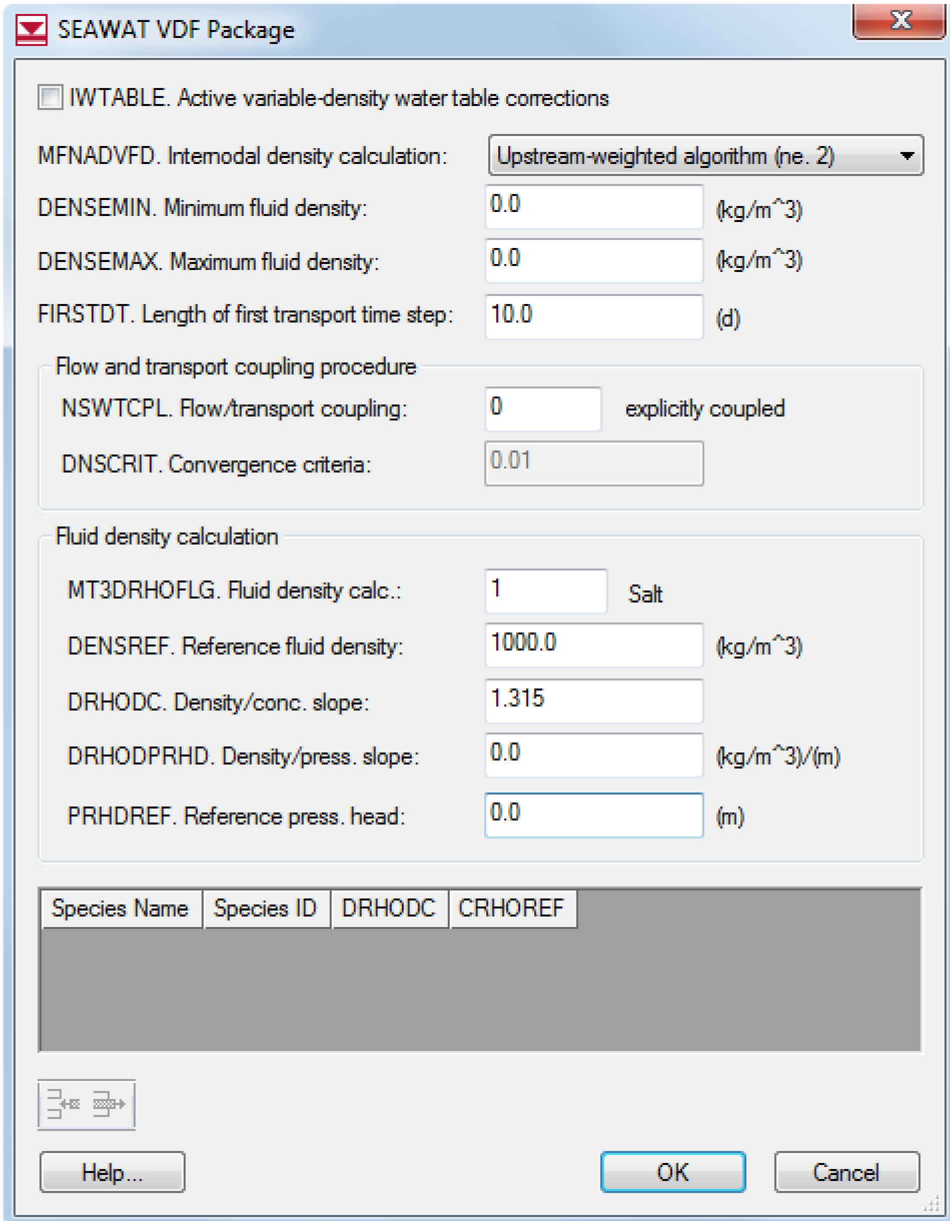

Figure 5. VDF Package inputs.

3. Select the *OK* button to exit the dialog.

10 Editing the Conceptual Model

Now we will adjust the conceptual model by assigning a concentration to the arc defining the coastline. In order to assign concentrations in our conceptual model we will turn on transport and define a species.

1. Expand the **Map Data** folder in the *Project Explorer*.

2. Right-click on the **MODFLOW_SEAWAT** conceptual model and select the *Properties* command from the menu.
3. Turn on *Transport*.
4. Make sure the transport model is **MT3DMS**.
5. Click the *Define Species* button.
6. Select *New* and change the species name to **Salt**.
7. Select *OK* twice to exit the dialogs.

10.1 Assign salt concentration at the coastline

Now that we have defined a species we can assign a concentration to the coast line arc.

1. Expand the **MODFLOW_SEAWAT** conceptual model and select the **Sources & Sinks** coverage in the *Project Explorer*.
2. Choose the *Select Arcs* tool .
3. Select the arc on the coastline.
4. Select the *Properties* button .
5. Enter **19.0** for starting concentration of salt.
6. Select OK to exit the dialog.

10.2 Map to MT3DMS

Now we can convert the conceptual model to our numerical model.

1. Select the *Feature Objects* | *Map* → *MT3DMS* command.
2. Select *OK* at the prompt.

Note that all the cells at the coastline are now assigned with new symbols representing the boundary condition in the MT3DMS source/sink mixing package.

10.3 Map to MODFLOW

At this point we also want to map over the wells and their pumping schedules.

1. Select the **Wells** coverage .

2. Right-click on the **Wells** coverage and select the *Map To → MODFLOW* command.

3. Select *OK* at the prompt.

11 Saving and running SEAWAT

We are ready to save our changes and run SEAWAT.

1. Select the *Save* button to save the project

2. Select the *SEAWAT* | *Run SEAWAT* command.

3. When SEAWAT finishes select the *Close* button.

12 Viewing the Solution

We will now view the results of the SEAWAT model run. We will examine how the fresh-water contour line changes with time.

1. Select the **MCL contour** display theme.

This display theme is set up to show one contour at a value of .25 g/l.

1. Select the **Salt** data set below the **seawat (MT3DMS)** solution in the *Project Explorer*.

2. In the time window select time **120.0**.

Notice that the MCL contour now encloses the northernmost and the southern most well.

12.1 Creating an animation

Now we will create an animation of the change in concentration over time. This will help us to see when this well begins pumping lower quality water.

1. Select the *Display* | *Animate* command.

The defaults will work fine for this animation.

2. Select *Next* on the first page and *Finish* on the second page.

After a few minutes an animation should begin playing. Notice how the MCL contour line eventually surrounds the northernmost pumping well. You can also see how the MCL contour line is moving near the southernmost well.

3. Close the *Play AVI Application* to return to GMS.

12.2 Creating a Time Series Plot of Concentration

Now we will make a plot of concentration verses time at the northern most well.

1. Select the Zoom tool and zoom in around the northernmost well.
2. Select the **grid** item in the *Project Explorer*.
3. Select the *Select Cell* tool.
4. Select the cell containing the well by click on the well.
5. Select the *Plot Wizard* button.
6. Select the **Active Data Set Time Series** plot and then the *Finish* button.

You should see a plot similar to the figure below. You can see how the concentration increases when the well is pumping and then drops off when the well is turned off.

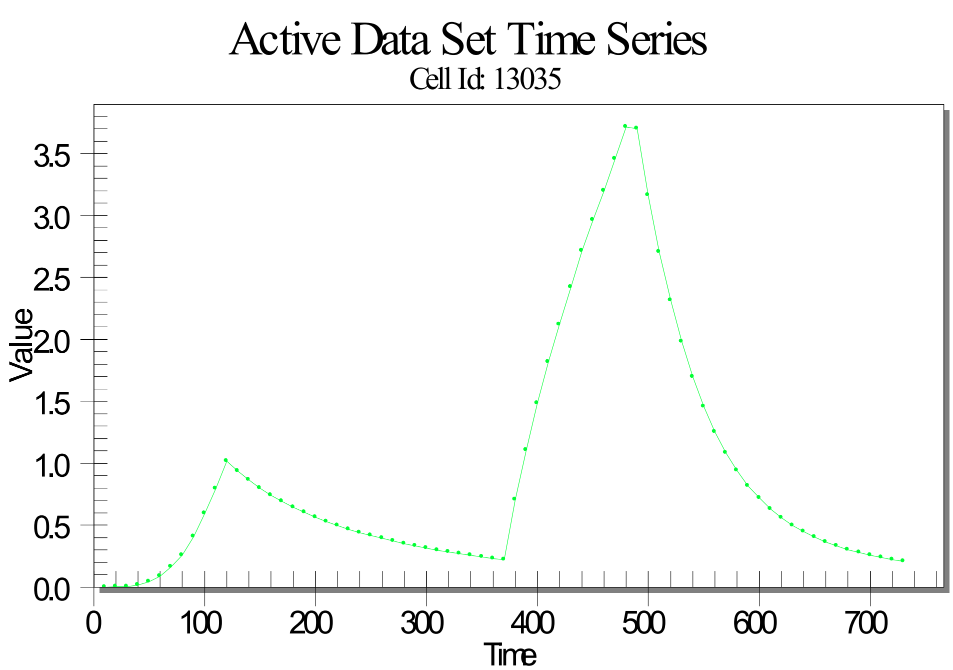

Figure 6. Time series plot of concentration.

Close the Plot window and maximize the Graphics Window before continuing.

12.3 Animating the Fresh-water Surface

Now we will animate the fresh-water isosurface over time. Close the Plot window and maximize the Graphics Window.

1. Select the **Isosurface Animation** display theme.

2. Select the *Select Material Zones* tool.

3. Select the *Edit* | *Select From List* command.

4. Toggle on the **lower_aquifer** and select *OK*.

You should now see the lower aquifer and the fresh-water isosurface. There will also be some circles that are visible. Those can be used to select material zones. Since we don't want the circles in our animation we will change our tool.

5. Select the *Select Cell* tool.

6. Select the Display | Animate command.

The defaults will work fine for this animation.

7. Select *Next* on the first page and *Finish* on the second page.

After a few minutes an animation should begin playing. Notice how the fresh-water surface is affected by the pumping wells. You can see how the fresh-water surfaces passes the northernmost well.

8. Close the *Play AVI Application* to return to GMS.

13 Conclusion

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

- SEAWAT combines MODFLOW and MT3DMS to solve variable density groundwater flow and solute transport problems.

- You can use the conceptual model approach with SEAWAT models.

- SEAWAT results can be visualized 3D in GMS.

14 Notes

1. http://water.usgs.gov/ogw/seawat/

2. Langevin, C.D., Shoemaker, W.B., and Guo, Weixing, 2003, MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model–Documentation of the SEAWAT-2000 Version with the Variable-Density Flow Process (VDF) and the Integrated MT3DMS Transport Process (IMT): U.S. Geological Survey Open-File Report 03-426, 43 p.

3. Langevin, C.D., Thorne, D.T., Jr., Dausman, A.M., Sukop, M.C., and Guo, Weixing, 2007, SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport: U.S. Geological Survey Techniques and Methods Book 6, Chapter A22, 39 p.

