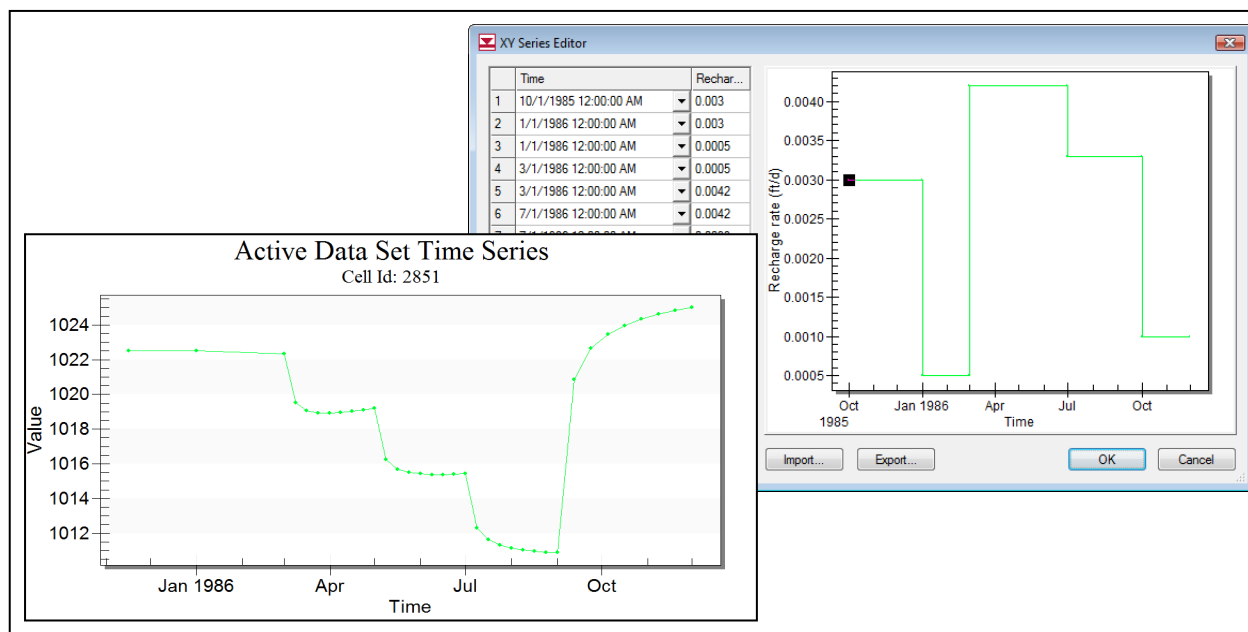


GMS 9.1 Tutorial

MODFLOW – Managing Transient Data

Creating transient MODFLOW models with time-varying inputs



Objectives

GMS provides a powerful suite of tools for inputting and managing transient data. These tools allow all data to be managed using a date/time format that eliminates much of the extra data processing that is often required with modeling projects. This tutorial illustrates how these tools are used.

Prerequisite Tutorials

- MODFLOW - Conceptual Model Approach

Required Components

- Grid
- Map
- MODFLOW

Time

- 30-60 minutes

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2 Introduction

Building a transient simulation typically requires the management of large amounts of transient data from a variety of sources including pumping well data, recharge data, river stages, and water levels in observation wells. Gathering and formatting such data can be very tedious. GMS provides tools for importing time series data and converting that data to inputs for MODFLOW models.

2.1 Outline

This is what you will do:

1. Open a MODFLOW model and solution.
2. Enter transient data.
3. Import well pump data file.
4. Set up stress periods and define additional inputs.
5. Run MODFLOW.
6. Create an animation.

3 Description of Problem

The model we will be using in this tutorial is the same model used in the **MODFLOW - Model Calibration** tutorial. We will use the computed heads from the steady-state calibrated flow model as the starting heads for our transient simulation. Transient recharge and pumping conditions will be modeled. The recharge rates will be manually entered but the pumping rates will be imported from a text file.


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 Reading in the Project

First, we will read in the project:

1. Select the *Open* button .
2. Locate and open the **Tutorials\MODFLOW\trans** directory.
3. Open the file entitled **start.gpr**.

You should see a MODFLOW model with a solution and a set of map coverages. Two of the coverages are the source/sink and hydraulic conductivity coverages used to define the conceptual model. The active coverage is the recharge coverage.

6 Save the Project With a New Name

Before we continue, let's save the project with a new name.

1. Select the *File | Save As* command.
2. Save the project with the name **trans1.gpr**.

It's a good idea to save your work periodically as you proceed.

7 Transient Data Strategy

When entering the time values associated with transient data, MODFLOW requires that the time be entered as scalar time values relative to a time value of zero at the beginning of the simulation. Furthermore, the times must be compatible with the time unit selected

for the model. This approach can be time-consuming since transient data must be converted from a date/time format to relative time format. The strategy used in GMS for managing transient data makes it possible to enter all time values using a simple date/time format. Transient data are entered in the conceptual model using date/time values. The time at the beginning of the first MODFLOW stress period is the reference time. This represents the date/time corresponding to time=0.0 in the simulation. When the model is converted from the conceptual model to the grid model, the time values in the conceptual model are automatically mapped to the appropriate time values corresponding to the MODFLOW stress periods. When the MODFLOW model is saved to disk, the date/time values are converted to the appropriate relative time values.

In addition to ease of use, another advantage of the transient data strategy used in GMS is that both the spatial and temporal components of the conceptual model are defined independently of the discretization used in both the grid spacing and the stress period size. The user can change the stress period spacing and regenerate the model from the conceptual model in seconds.

8 Entering Transient Data in the Map Module

The first step in setting up our transient model is to associate our transient data with the feature objects in the Map Module.

8.1 Assigning the Transient Recharge Rate

First, we will assign the transient recharge rate for the recharge zones. The recharge zones are shown in Figure 1. There are four recharge zones defined by five polygons. We will leave the recharge rate for zone 1 at zero. We will assign a transient recharge rate to the other three zones.

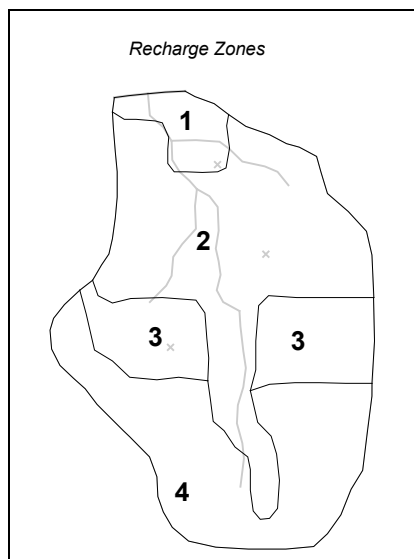








Figure 1. Recharge zones.

To assign the recharge data:

1. Expand the *BigVal* conceptual model  item in the *Project Explorer*.
2. Select the *Recharge* coverage  to make it active.
3. Choose the *Select Polygon* tool .
4. Select the polygon corresponding to recharge zone 2 in Figure 1.
5. Select *Properties* button .
6. For the *Recharge rate*, click the down arrow  button and select the **<transient>** option from the drop down list.
7. Now click the  button for the *Recharge rate* to bring up the *XY Series Editor*.
8. Select the *Use dates/times* toggle.
9. Enter the following date/times and recharge rates:

Date/Time	Recharge (ft/day)	Rate
Oct 1, 1985 12:00:00 AM	0.001	
Jan 1, 1986 12:00:00 AM	0.001	
Jan 1, 1986 12:00:00 AM	0.0005	
Mar 1, 1986 12:00:00 AM	0.0005	
Mar 1, 1986 12:00:00 AM	0.006	
July 1, 1986 12:00:00 AM	0.006	
July 1, 1986 12:00:00 AM	0.005	
Oct 1, 1986 12:00:00 AM	0.005	
Oct 1, 1986 12:00:00 AM	0.001	
Dec1, 1986 12:00:00 AM	0.001	

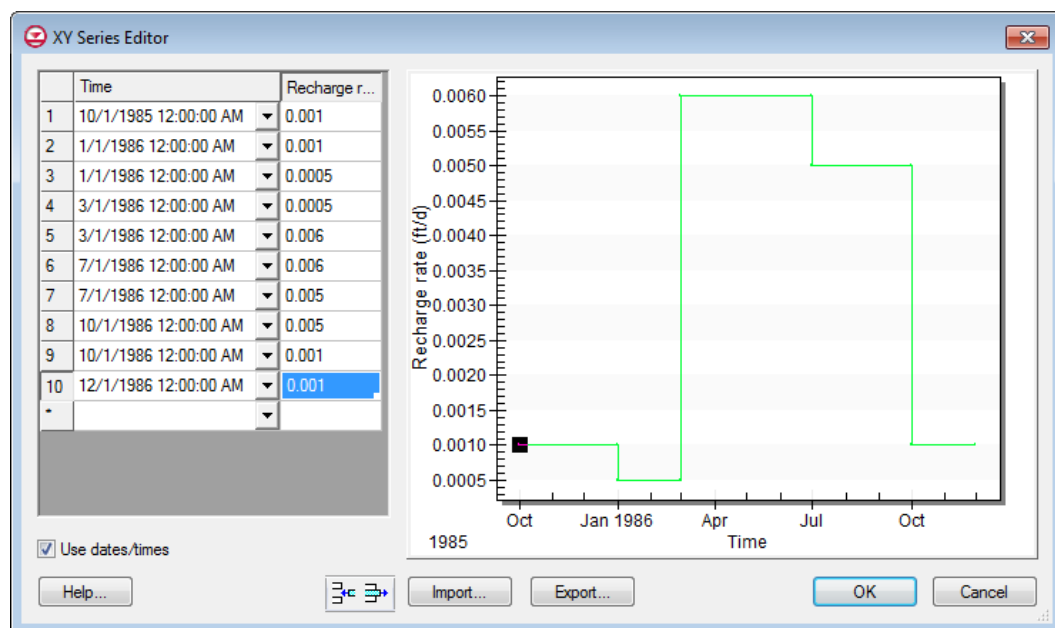


Figure 2. XY Series Editor showing recharge rate.

10. Select the *OK* button twice to exit both dialogs.


NOTE: Depending on your computer settings you dates may be formatted differently than shown in the figure above. Those shown above are formatted *month/day/year*.

8.2 Importing Transient Recharge Data

Instead of repeating this same procedure for the other recharge zones we will import the data from a text file. Transient data can be imported for polygons, arcs, points, or nodes. The format for the text files is shown below.

Name	Date	Recharge
zone 3	Dec 3, 1999	0.0005
zone 3	Jan 30, 2000	0.001
zone 4	Mar 27, 2000	0.002
...		

In the case above we only have a date field; GMS also supports specifying both a date and a time. Later in this tutorial we will import pumping data that has both a date and a time specified. The *Name* column is used to match the *Date* data with a particular polygon.

1. Select the *Open* button .
2. In the *Open* dialog, change the *Files of type* selection to **Text Files (*.txt)**.
3. Select the file named **trans_recharge.csv** and click *Open*.

You should now see the Text Import Wizard. It should look similar to the next figure. This Wizard is used to import text data into a GMS project.

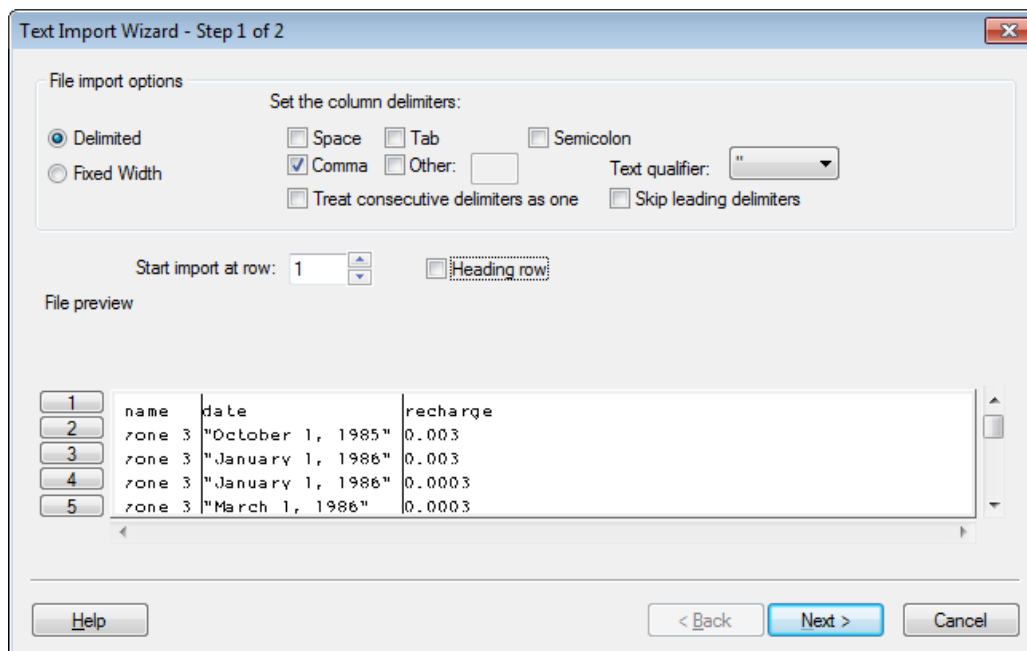


Figure 3. Text Import Wizard

4. Turn on the *Heading row* check box and click the *Next* button.
5. Near the top of the dialog, change the *GMS data type* to **Transient polygon data**. The dialog should look like the next figure.

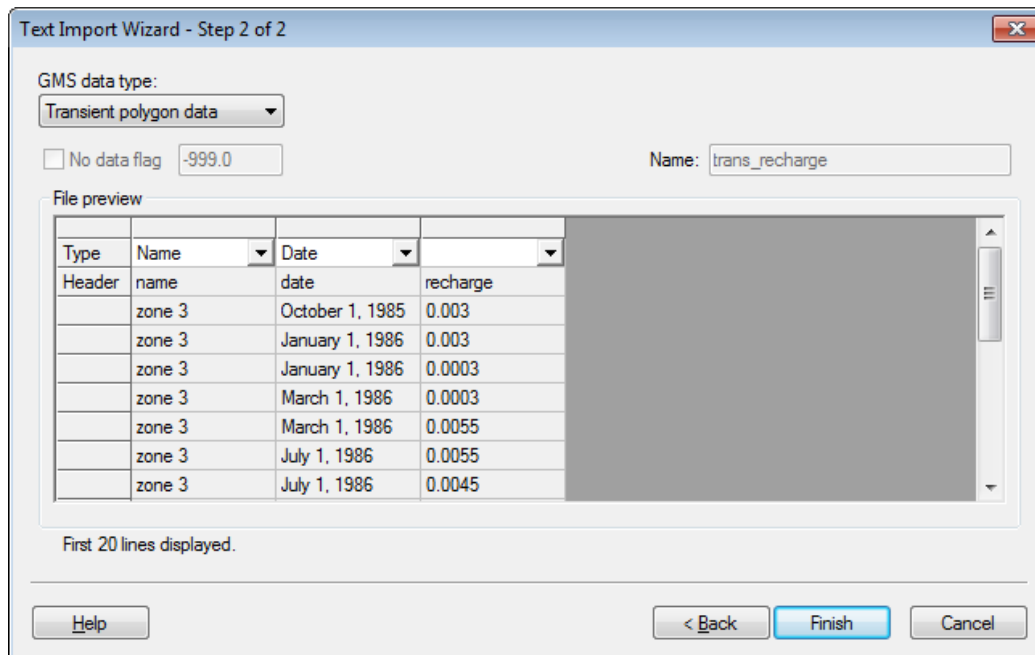



Figure 4. Step 2 of the Text Import Wizard

Notice that the Name and the Date columns were automatically recognized by GMS. Now we need to specify the field for the third column of data.

6. Select **Recharge rate TS** from the *Type* drop down box in the third column of the spread sheet.
7. Click on the *Finish* button.
8. Select *No* at the prompt.
9. Double click on any of the polygons in zone 3 or zone 4.
10. Now click the  button for the *Recharge rate* to bring up the *XY Series Editor*.

You should see a time series curve of the imported data.

11. Click OK twice to exit the dialogs.

8.3 Importing Pumping Well Data



In addition to the transient recharge data, our simulation will also contain a transient pumping schedule for the three wells in the model. Since our model only has three wells, the transient pumping schedules could easily be entered by hand. However, we will import the well data from a text file. This method is particularly useful for models with lots of wells and/or complicated pumping schedules.



Pumping well data is typically imported using two files. The first file contains the name, screen geometry, and xy coordinates of the wells. The second file contains the pumping schedules. Since the well locations are already defined, we only need to import the pumping schedules. The format for this file is as follows:

Name	date	time	Q
"well 1"	12/3/1999	18:00:00	625.0
"well 1"	1/30/2000	7:38:25	0.0
"well 1"	3/27/2000	18:00:00	200.0
"well 2"	12/3/1999	18:00:00	0.0
"well 2"	12/5/1999	14:48:32	100.0
...			

When importing text data for points, we need to indicate to GMS which point the date/time data goes with. This can be done using a name, an id, or an x,y coordinate. In the case above we are using a name. The first time an entry is found for a particular well, if the well is steady state, it is changed to transient and a pumping rate time series is created for the well. Each time a subsequent line is read with the same well name, GMS adds a point to the time series. The dates and times can be in any standard format.



To import the well pumping data file:

1. Select the **Sources & Sinks** coverage  from the *Project Explorer* to make it the active coverage.
2. Select the *Open* button .
3. In the *Open* dialog, change the *Files of type* selection to **Text Files (*.txt)**.

4. Select the file named **pumping.txt** and click *Open*.
5. In the *Import Wizard*, turn on the *Heading row* option and click *Next*.
6. Change the *GMS data type* to **Pumping data** and click *Finish*. In this case GMS automatically recognized all of the fields in the file.
7. Select *Yes* at the prompt to import the pumping data as a step function.
8. Select the *Select Points/Nodes* tool .
9. Double-click on any of the wells and note that the *Flow rate* says **<transient>**. You may want to click on the  button to see the curve.
10. Select *OK* to exit the dialog(s).

8.4 Assigning Specific Yield

Next, we need to assign the storage coefficient to the aquifer. Since this is a 1 layer unconfined aquifer, we need to assign the specific yield.

1. Double-click on the **Hydraulic Conductivity** coverage  in the *Project Explorer* to bring up the *Coverage Setup* dialog.
2. In the list of *Areal Properties*, turn on *Specific yield*.
3. Click *OK* to exit the dialog.
4. Select the *Select Polygon* tool .
5. Select the polygons labeled 1 and 2 in the figure below.

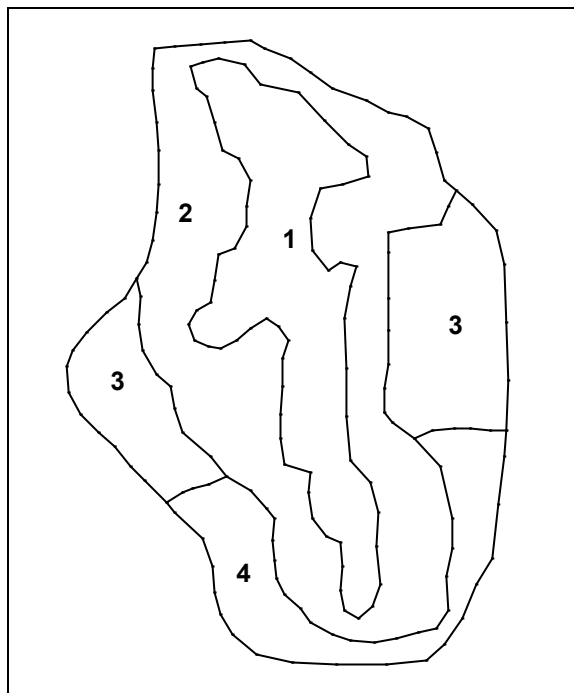



Figure 5. Hydraulic conductivity zones.



6. Select *Properties* button .
7. Assign a *Specific yield* value of **0.20** to both polygons and select the *OK* button to exit the dialog.
8. Repeat the same procedure with the polygons labeled 3 and 4 only this time assign a value of **0.15** for the specific yield.

9 Initializing MODFLOW Stress Periods

MODFLOW discretizes time using stress periods and time steps. A length of time is associated with each stress period, and boundary conditions (or stresses) can change at the beginning of a stress period. Stress periods are subdivided into time steps. Before converting our conceptual model we need to set up the stress periods.

9.1 Changing the MODFLOW Simulation to Transient

First, we will change the current MODFLOW simulation from a steady-state simulation to transient.

1. In the *Project Explorer* expand the *MODFLOW*  item located below the 3D Grid Data.
2. In the *Project Explorer* right-click on the *Global* package  and select the *Properties...* command.

3. In the *Model type* section, select the **Transient** option.

9.2 Setting up the Stress Periods

Now we will set up the stress period information for MODFLOW.

1. Select the *Stress Periods* button.
2. Make sure the *Use dates/times* option is turned on.

When the *Use dates/times* option is used, all input fields in the MODFLOW interface in the *3D Grid* module expect the date/time format for input. The date/time format is used to display time values such as the time step values when post-processing. If the option is not used, scalar time values (e.g., 100, 120, etc.) are displayed.

3. Change the *Number of stress periods* to **7**.

We want the stress periods to match the times where our input data in the map module changes. For example, the value for recharge changes at three different dates Jan 1, 1986, Mar 1, 1986, and July 1, 1986. Therefore, we need to make sure that we have stress periods that start at those times and at the time corresponding to changes in the pumping schedules.

4. Enter the following times and time steps for the stress periods.

	<i>Start</i>	<i>Num time steps</i>
1	Oct 1, 1985 12:00:00 AM	2
2	Jan 1, 1986 12:00:00 AM	1
3	Mar 1, 1986 12:00:00 AM	8
4	May 1, 1986 12:00:00 AM	4
5	June 1, 1986 12:00:00 AM	4
6	July 1, 1986 12:00:00 AM	8
7	Sept 1, 1986 12:00:00 AM	8
End	Dec 1, 1986 12:00:00 AM	


5. Make sure to uncheck the **Steady State** check box for the first stress period.

This check box is on by default so that our transient model starts from a steady state condition. You can either do this, or set your starting heads to the solution from a steady state run, or allow enough time at the beginning of the transient model for the heads to stabilize before applying any changes in stresses. Since we already have a steady-state model and solution, we'll use the solution as the starting heads for our transient model.

6. Select the *OK* button to exit the *Stress Periods* dialog.
7. Select the *OK* button to exit the *Global Package* dialog.





10 Converting the Conceptual Model

Now we will convert our conceptual model data to MODFLOW input data.

1. Right-click on the *BigVal* conceptual model  in the *Project Explorer* and select the *Map to | MODFLOW/MODPATH* command.
2. Select *OK* at the prompt to use *All applicable coverages*.
3. Select *OK* at the prompt to acknowledge that the xy series will be extrapolated to our numerical model.



11 Setting Starting Heads

As mentioned earlier, for transient models, you should either start off with a steady state stress period, or set the starting heads equal to the solution generated from a steady state model, or allow some time in the beginning of the transient model for the heads to stabilize before applying any changes in stresses (pumping rates, recharge rates etc.). We'll take the second approach.

1. In the *Project Explorer* expand the *Global* package  and double-click on the *Starting Heads* data set .
2. Click the *3D Data Set* → *Grid* button.
3. Expand the **grid**  item.
4. Expand the *start (MODFLOW)*  solution and select the **Head** data set.
5. Click *OK* twice to exit all dialogs.

12 Saving and Running MODFLOW

We are now ready to save the model and launch MODFLOW.

1. Select the *Save*  button.
2. Select the *Run MODFLOW*  button.
3. Once MODFLOW has finished, select the *Close* button to close the window and return to GMS.

The contours should change.

4. Expand the *trans1 (MODFLOW)* item  in the *Project Explorer* and select the *Head* data set .



5. Use the *Time Steps* window to cycle through the different time steps of the solution to see how the pumping schedules of the wells affect the computed heads.

13 Setting Up an Animation

Now we will observe how the head changes over time by generating an animation. To set up the animation:


1. Select the *Display | Animate* command.
2. Make sure the *Data set* option is on and click *Next*.
3. Make sure the *Display clock* option is on and select the *Finish* button.

You should see some images appear on the screen. These are the frames of the animation which are being generated.

4. After viewing the animation, select the *Stop*  button to stop the animation.
5. Select the *Step*  button to move the animation one frame at a time.
6. You may wish to experiment with some of the other playback controls. When you are finished, close the window and return to GMS.

14 Conclusion

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

- When you bring up the properties dialog for objects in the Map module, you can enter transient data by using the  button.
- You can import transient data for points, arcs, polygons, and nodes using the text import wizard. The points, arcs, polygons, and nodes must already exist in the active coverage.
- GMS can show dates and times as scalar values (0.0, 2.5 etc.) or in date/time format (12/03/2003).
- You must define your MODFLOW stress periods before you use the *Feature Objects | Map → MODFLOW / MODPATH* command with a transient simulation.