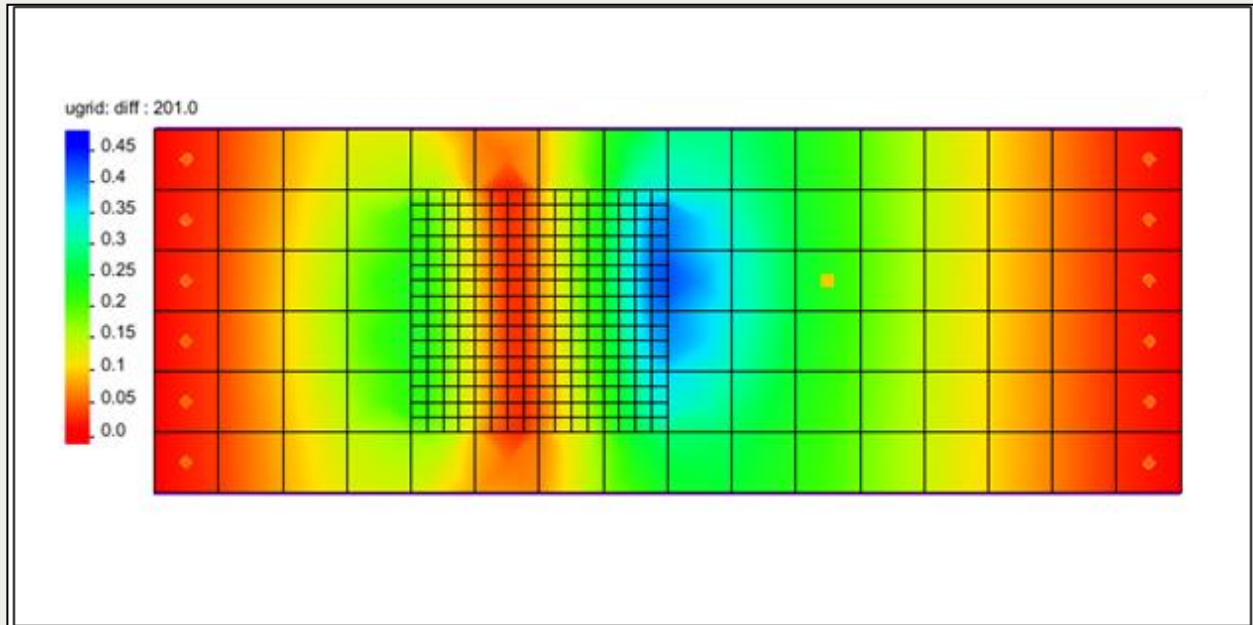




## GMS 10.9 Tutorial

### **MODFLOW-USG Transport – TVM Package**

Use the Time-Variant Materials package (TVM) in GMS



### Objectives

Learn how to use the Time-Variant Materials package (TVM) with MODFLOW-USG Transport.

#### Prerequisite Tutorials

- MODFLOW-USG Transport

#### Required Components

- GMS Core
- MODFLOW-USG Transport

#### Time

- 20–30 minutes

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## 1 Introduction

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The Time-Variant Materials package (TVM) works with MODFLOW-USG Transport. The TVM package allows hydraulic conductivity and storage values to be changed as a step function between stress periods or in a continuous manner through a transient simulation.

This tutorial demonstrates how the TVM package can be used with a MODFLOW-USG Transport simulation.

The problem in this tutorial consists of a two layer unstructured grid (UGrid) with a MODFLOW-USG Transport simulation. The UGrid contains a well on the second layer set with a constant pumping rate.



This tutorial will demonstrate the following topics:

1. Opening an existing MODFLOW-USG Transport simulation.
2. Creating a transient conductivity coverage and dataset.
3. Activating the TVM package.
4. Running the simulation and examining the results.

## 2 Getting Started

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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.
3. Click **Open**  (or *File* | **Open...**) to bring up the *Open* dialog.
4. Browse to the data files for this tutorial and select “start.gpr”.
5. Click **Open** to import the file and close the *Open* dialog.
6. In the Project Explorer, select the “ Head” dataset.

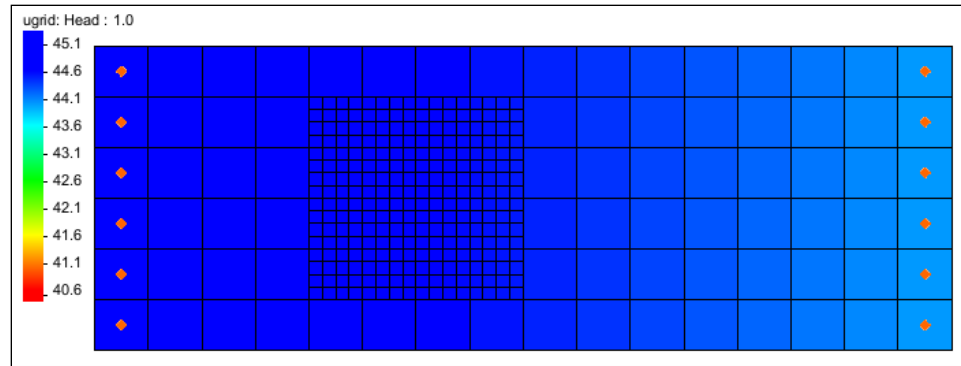


Figure 1 Imported MODFLOW-USG Transport model

The Graphics Window should appear as in Figure 1. This model has a two layer UGrid with a refined zone. General heads have been set at each end. There is a well on the second layer.

Before continuing, save the project with a new name.

7. Select **File | Save As...** to bring up the **Save As** dialog.
8. Browse to the directory for this tutorial.
9. Enter “model-tvm.gpr” as the *File name*.
10. Select “Project Files (\*.gpr)” from the *Save as type* drop-down.
11. Click **Save** to save the project file and close the **Save As** dialog.

### 3 Changing the Conductivity

Before activating the TVM package, start with creating a time-variant dataset for the refined area of the UGrid. This will be done using a separate map coverage which will then be added to the model.

1. Right-click on the “ model” conceptual model and select **New Coverage...** to bring up the **Coverage Setup** dialog.
2. Enter “tvm\_hk” for the *Coverage name*.
3. In the *Areal Properties* column, turn on *Datasets*.
4. Click the **Datasets** button to open the **Datasets** dialog.
5. Click the **Insert Row** button.
6. In the new row, enter “TVM\_HK”.
7. Click **OK** to close the **Datasets** dialog.
8. Click **OK** to close the **Coverage Setup** dialog.

With the new “ tvm-hk” coverage created, time-variant data needs to be added to the refined area of the UGrid.

9. Make certain the “ tvm-hk” coverage is active in the Project Explorer.
10. Using the **Create Arc** tool, create four arcs around the refined area of the UGrid as in Figure 2 below.

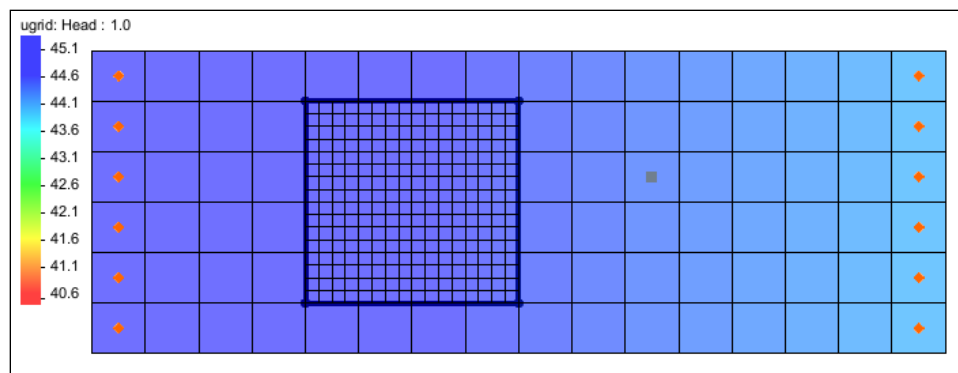





Figure 2 Arcs drawn around refined area of the UGrid

11. Select the **Build Polygons**  macro.
12. Using the **Select Polygons**  tool, double-click on the polygon to open the *Attribute Table* dialog.
13. Using the drop-down, change the *TVM\_HK* column to be "<transient>".
14. Click the  button in the *TVM\_HK* column to open the *XY Series Editor*.
15. Enter the values in Table 1 below to create a time series:

Time (d)	TVM_HK
0.0	1.5
1.0	1.5
1.0	3.0
101.0	3.0
101.0	6.0
201.0	6.0


Table 1 Time series


16. Click **OK** to close the *XY Series Editor*.
17. Click **OK** to close the *Attribute Table* dialog.

The "tvm\_hk" coverage now contains time-variant material data that can be added to the MODFLOW-USG Transport simulation.

## 4 Map to MODFLOW

The data added in the conceptual model needs to be mapped to the UGrid model.


1. Right-click on the  "model" conceptual model and select **Map To | MODFLOW/MODPATH** to open the *Map → Model* dialog.
2. Check *All applicable coverages* and click **OK** to close the *Map → Model* dialog.

A new dataset,  "TVM\_HK", should appear in the Project Explorer in the MODFLOW simulation.

## 5 Activating the TVM Package

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With the horizontal conductivity data available, the TVM package can now be activated and added to the MODFLOW simulation. To activate the TVM package:

1. Switch to the **UGrid**  module.
2. Select **MODFLOW | Global Options...** to bring up the *MODFLOW Global/Basic Package* dialog.
3. Click **Packages...** to bring up the *MODFLOW Packages / Processes* dialog.
4. In the *Optional packages / processes* section, turn on **TVM – Time Varying Materials**.
5. Click **OK** to exit the *MODFLOW Packages / Processes* dialog.
6. Click **OK** to exit the *MODFLOW Global/Basic Package* dialog.

## 6 Defining the TVM Package

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With the time-varying dataset mapped to the simulation and the TVM package activated, the parameters for the TVM package can now be defined.

1. Select **MODFLOW | Optional Packages | TVM – Time Varying Materials...** to bring up the *TVM Package* dialog.
2. In the list on the left, select **HK**.
3. Select **Dataset to Array** to bring up the *Select Dataset* dialog.
4. Under *Solution*, select “ TVM\_HK”.
5. Turn on *All time steps*.
6. Click **OK** to close the *Select Dataset* dialog.
7. Click **OK** to close the *TVM Package* dialog.

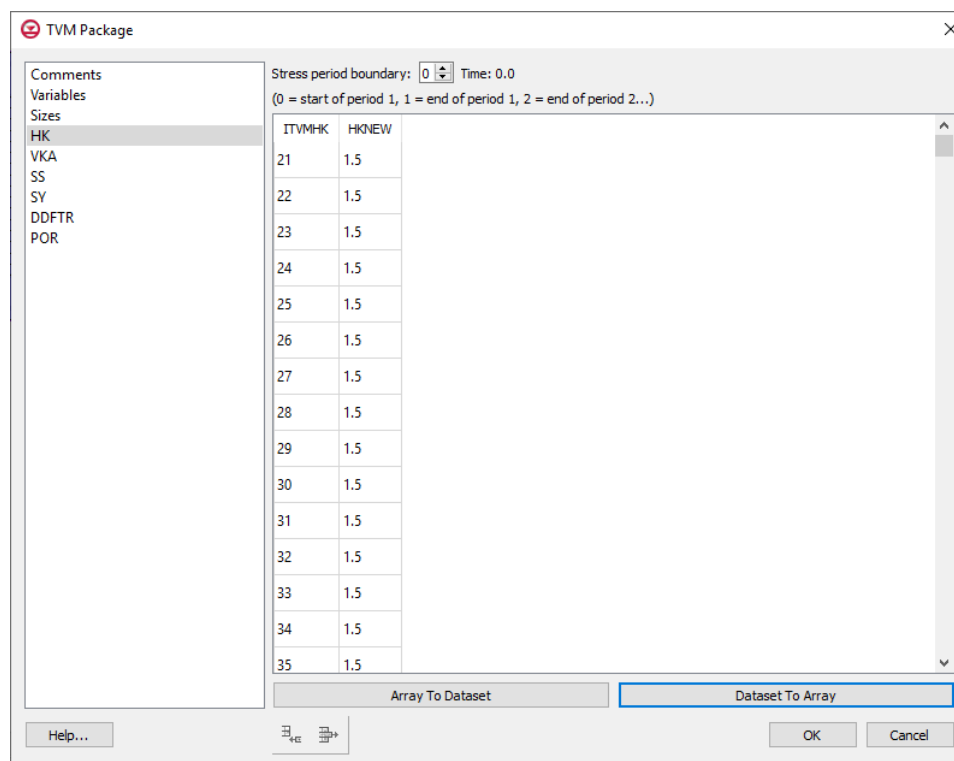





Figure 3 TVM Package dialog

## 7 Saving and Running MODFLOW




The changes should now be saved before running MODFLOW-USG Transport.




1. Click **Save**  to save the project.
2. Click the **Run MODFLOW**  macro in the toolbar to bring up the *MODFLOW* model wrapper dialog.
3. When MODFLOW finishes, check on the *Read solution on exit* and *Turn on contours (if not on already)* boxes.
4. Click **Close** to close the *MODFLOW* model wrapper dialog.
5. Click **Save**  to save the project with the new solution.

The solution set should appear in the Project Explorer.

## 8 Examining the Results

In order to more clearly see how the TVM package impacted the simulation, compare the results. This can be done by using the *Data Calculator* to create a dataset that compares the solution set with the TVM package to the previous solution set.

1. Click the **Data Calculator**  macro to open the *Data Calculator*.
2. In the *Datasets* section, select the “ Head” dataset under the “ start (MODFLOW)” folder.

3. Turn on *Use all time steps*.
4. Click **Add to Expression**.
5. Click the **minus (-)** button.
6. In the *Datasets* section, select the “ Head” dataset under the “ model-tvm (MODFLOW)” folder.
7. Click **Add to Expression**.
8. For *Result*, enter “diff”.
9. Click **Compute**.
10. Click **Done**.
11. Select the “ diff” dataset in the Project Explorer.
12. In the *Time Steps* window, use the down arrow key to step through the time steps and watch how the contours change.

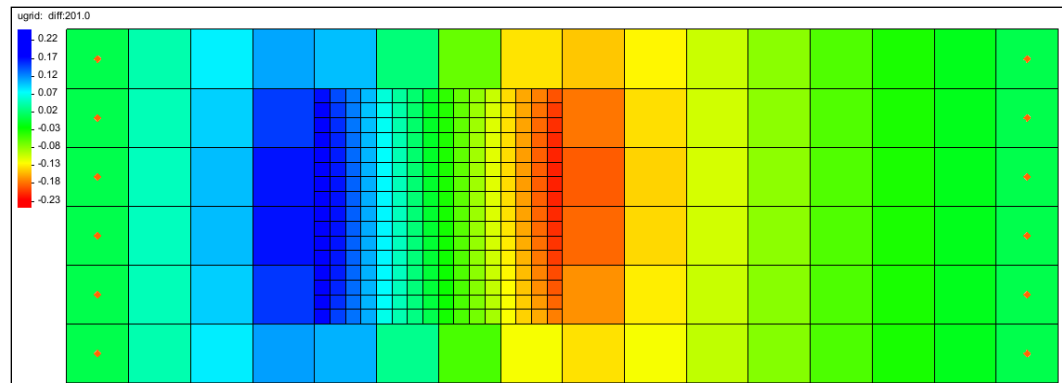


Figure 4 Last time step of the difference dataset showing the results of the TMV package.

## 9 Conclusion

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

- Using the TVM Package to add time-varying materials to a MODFLOW-USG Transport simulation.
- Creating a time-variant dataset using the Map module.
- Activating the TVM package for a MODFLOW simulation.