

Education evenings 2018

*Practical introduction
to groundwater modelling*

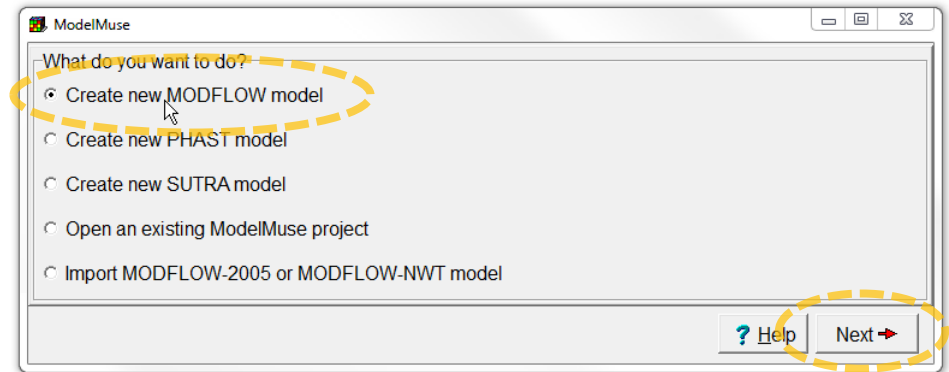
Computer exercises
01 03 Our first MODFLOW model

Purpose

- ✓ In this exercise, we will use ModelMuse to set up, run, and visualize the results of a very simple MODFLOW model.
- ✓ We will also introduce visualizing model output with GW_Chart and Model Viewer.

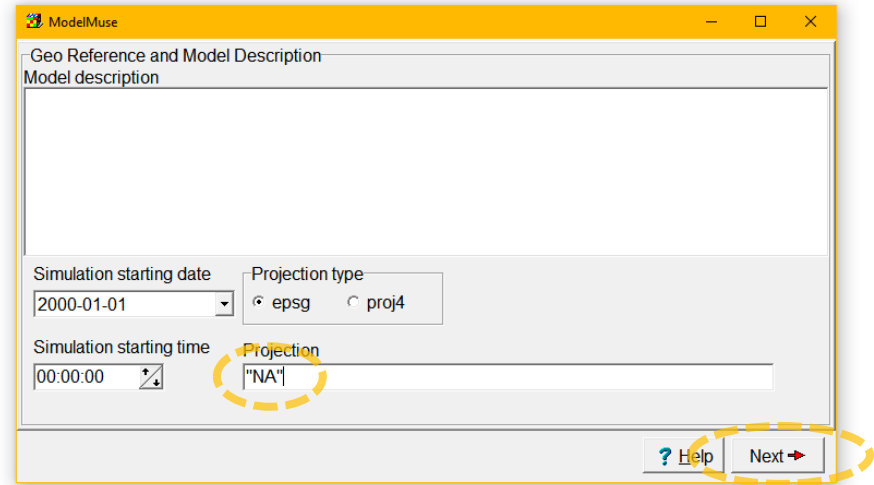
Create new model

- ✓ Start ModelMuse by double-clicking on its icon.
- ✓ Choose **Create new MODFLOW model** and click **Next**.



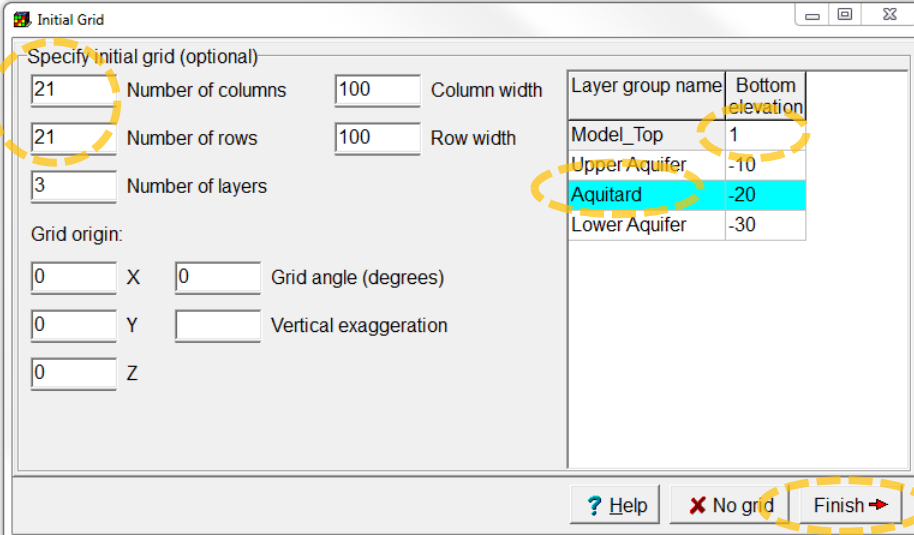
Set the projection

- ✓ We will not be working with projections in this course, so set **Projection** to "NA".
- ✓ Click **Next**.



Initialize model grid

- ✓ Change the number of columns and rows each to 21.
- ✓ Set the **Model_Top** to 1,
- ✓ change the middle layer name to “Aquitard”, and
- ✓ then click **Finish**.



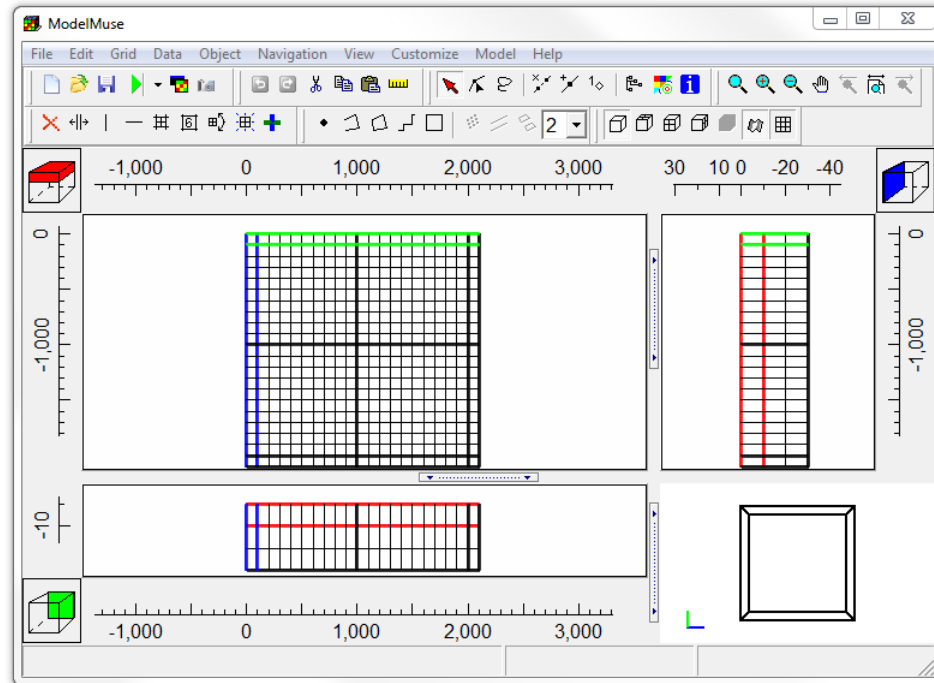
The screenshot shows the 'Initial Grid' dialog box with the following settings and annotations:

- Specify initial grid (optional):**
 - Number of columns: 21 (circled in yellow)
 - Number of rows: 21 (circled in yellow)
 - Number of layers: 3
 - Column width: 100
 - Row width: 100
- Grid origin:**
 - X: 0
 - Y: 0
 - Z: 0
 - Grid angle (degrees): 0
 - Vertical exaggeration: (empty)
- Layer group name / Bottom elevation table:**

Layer group name	Bottom elevation
Model_Top	1
Upper Aquifer	-10
Aquitard	-20
Lower Aquifer	-30

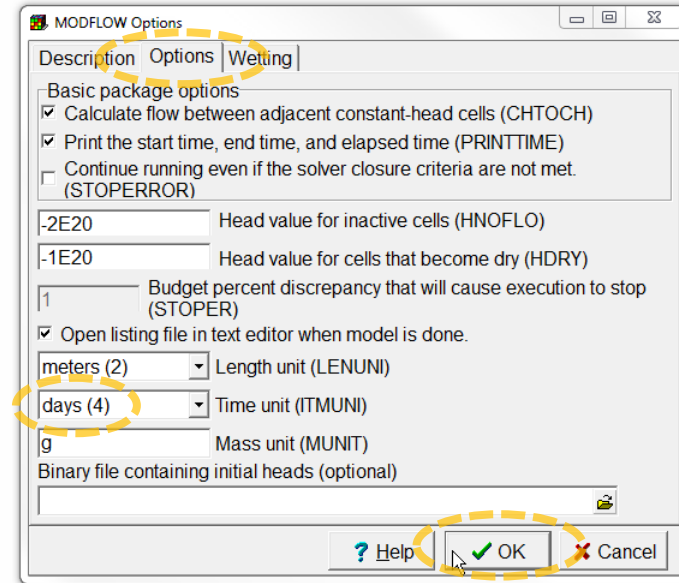
The 'Aquitard' row is highlighted in blue, and the 'Bottom elevation' column header is circled in yellow.
- Buttons:**
 - ? Help
 - X No grid
 - Finish → (circled in yellow)

This is what you should get



Change model units

- ✓ Select **Model | MODFLOW Options...**,
- ✓ switch to the **Options** tab,
- ✓ change the time unit to “days”,
- ✓ and click **OK**.



Specify time discretization

- ✓ Select **Model | MODFLOW Time...**
- ✓ Increase the number of stress periods to two,
- ✓ change **Starting time** to 0,
- ✓ Ending time to 1000,
- ✓ the length of the first time step to 10 and
- ✓ choose a transient stress period.
- ✓ Then click **OK**.

The screenshot shows the 'MODFLOW Time' dialog box. At the top, there are summary fields for Length (0), Max first time step length (0), Multiplier (0), and a dropdown for Steady State/Transient. Below this is a table with columns: Stress period, Starting time, Ending time, Length, Max first time step length, Multiplier, Steady State/Transient, Drawdown reference, and Number of steps (calculated). The table has two rows: Row 1 (Stress period 1) has values -1, 0, 1, 1, 1, 1, Steady state, checked, and 1. Row 2 (Stress period 2) has values 0, 1000, 1000, 10, 1, Transient, unchecked, and 100. The values 0, 1000, 1000, 10, 1, and Transient in Row 2 are highlighted with a yellow dashed box. Below the table, the 'Number of stress periods' is set to 2 (highlighted with a yellow dashed box), 'days (4)' is selected in the time unit dropdown, and 'Time unit (ITMUNI)' is also highlighted with a yellow dashed box. At the bottom, the 'OK' button is highlighted with a yellow dashed box.

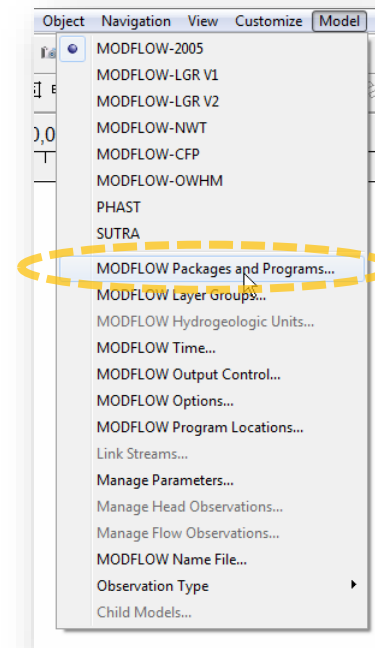
Stress period	Starting time	Ending time	Length	Max first time step length	Multiplier	Steady State/Transient	Drawdown reference	Number of steps (calculated)
1	-1	0	1	1	1	Steady state	<input checked="" type="checkbox"/>	1
2	0	1000	1000	10	1	Transient	<input type="checkbox"/>	100

2 Number of stress periods days (4) Time unit (ITMUNI) Delete Insert

Convert time units ? Help OK Cancel

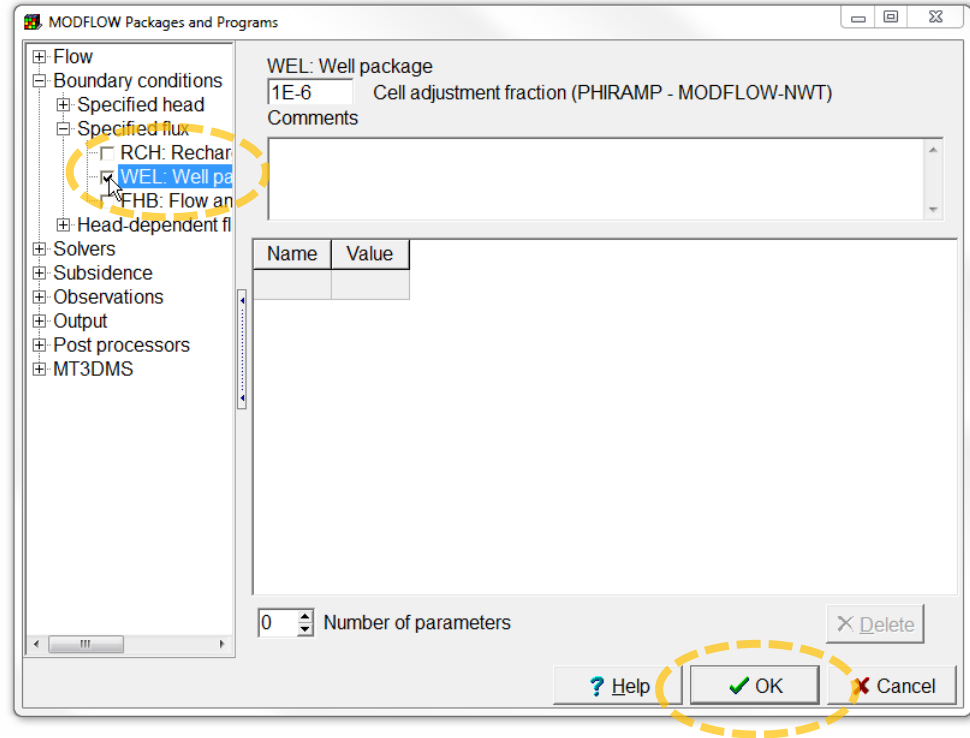
Add well to model (1/4)

- ✓ The **MODFLOW Packages and Programs** dialog box is where you activate any of the optional packages in MODFLOW that you want to use. Select **Model | MODFLOW Packages and Programs...**



Add well to model (2/4)

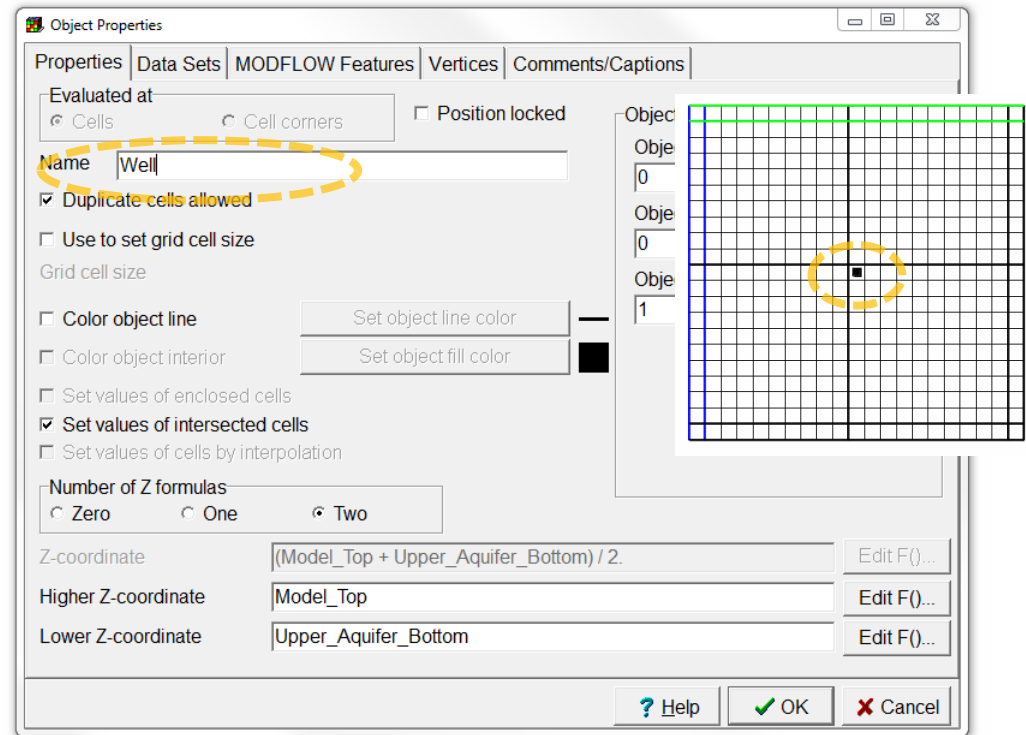
- ✓ The packages are listed in a tree control on the left. To activate a package check the checkbox or radio-button next to its name. Then set any other options for the package in the part of the dialog box to the right of the tree control. Check the checkbox for the Well package. Then click **OK**.



Add well to model (3/4)

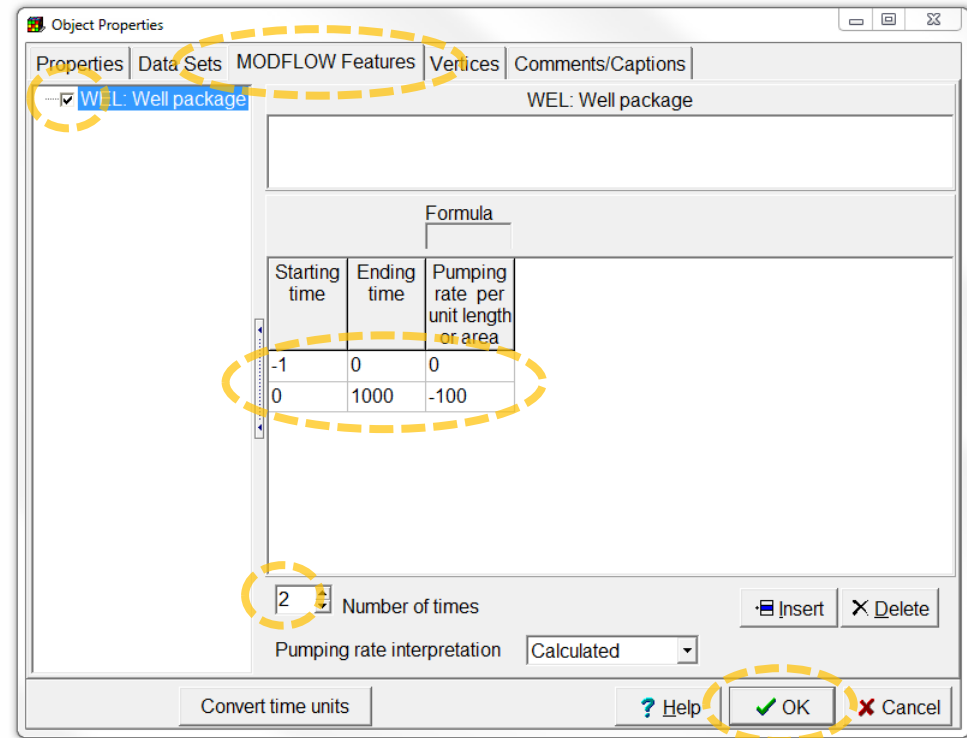
- ✓ Objects are used to specify the locations of things like wells, rivers, and drains. They are also used to set up spatially varying properties of data sets. In this case, we will use an object to define a well. Select **Object | Create | Point** and then click in the center of the grid (row 11, column 11).
- ✓ The **Object Properties** dialog box will appear. Change the object name into “Well”.

Create
point
object



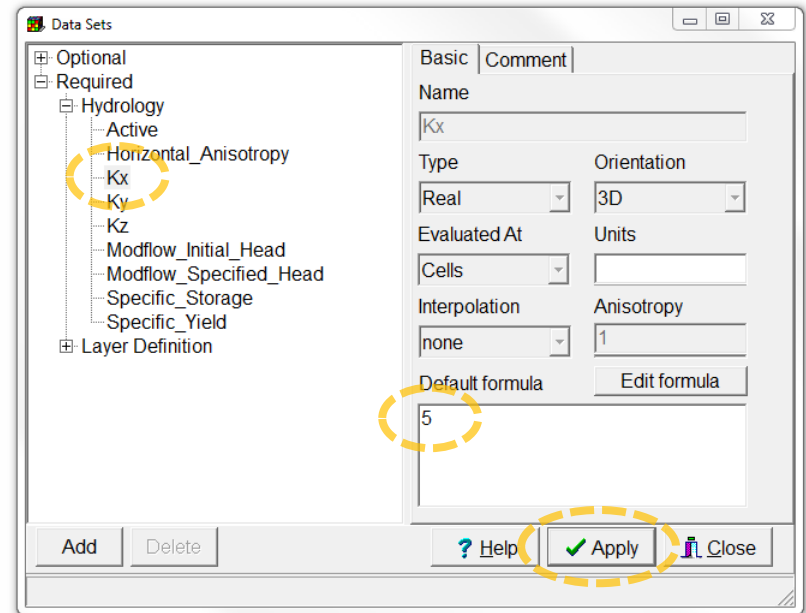
Add well to model (4/4)

- ✓ Switch to the **MODFLOW Features** tab.
- ✓ Check the **Well package** check box.
- ✓ Increase the Number of times to 2,
- ✓ Enter a starting time of -1,
- ✓ an ending time of 0,
- ✓ and a pumping rate of 0 for the steady state stress period, and
- ✓ 0, 1000 and -100 for the transient one.
- ✓ Then click **OK**.



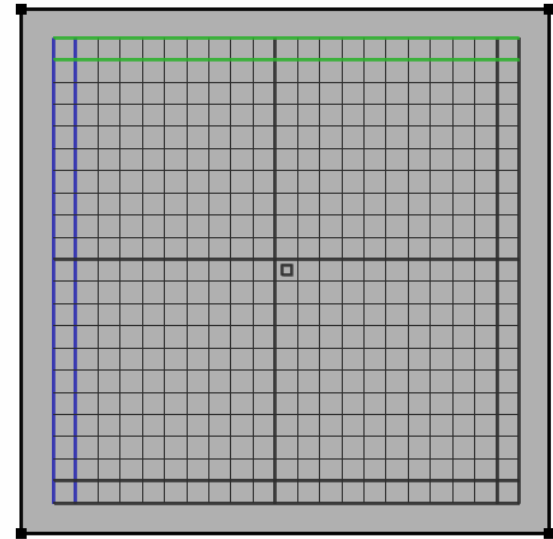
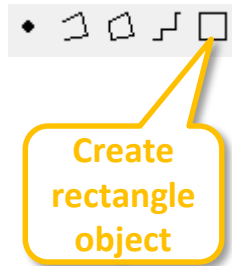
Set default Kx

- ✓ The aquifer properties, layer elevations and other similar data are specified by data sets. Select **Data | Edit Data Sets...**
- ✓ Then select the **Kx** data set under **Required | Hydrology** and change its default formula to 5.
- ✓ Press **Apply**.



Modify Kx Aquitard (1/3)

- ✓ Select **Object | Create | Rectangle** or use the corresponding button, and
- ✓ draw a rectangle in the top view, surrounding the entire grid.



Modify Kx Aquitard (2/3)

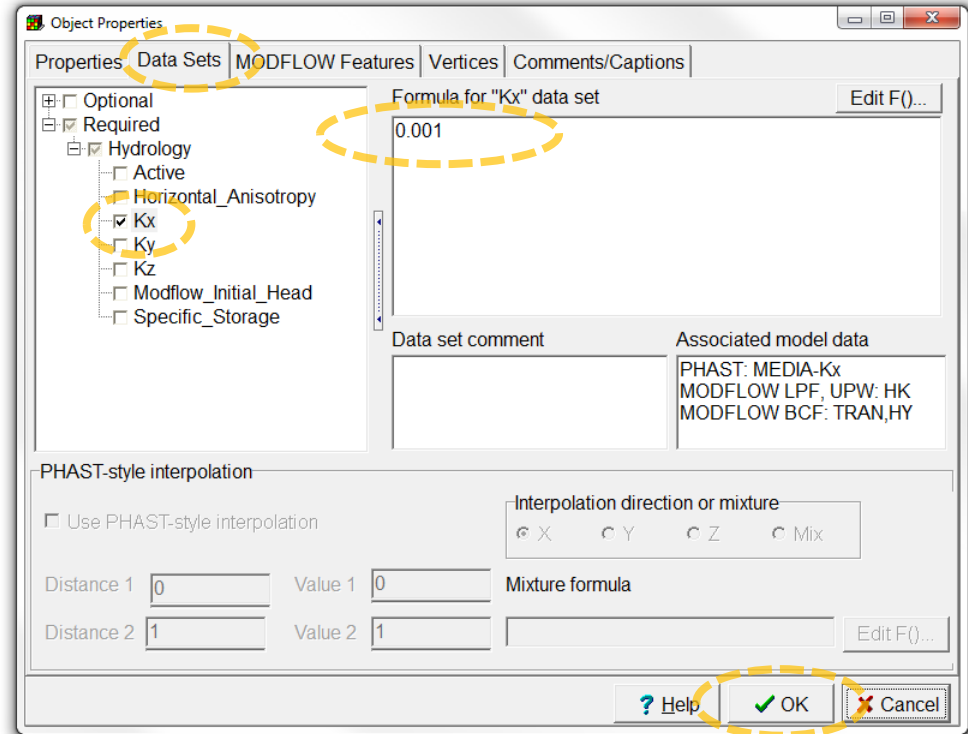
- ✓ In the **Object Properties** dialog box, change the **Higher Z-coordinate** to “Upper_Aquifer_Bottom”, and
- ✓ the **Lower Z-coordinate** to “Aquitard_Bottom”

The screenshot shows the 'Object Properties' dialog box for an object named 'Aquitard_Kx'. The 'Properties' tab is active. The 'Evaluated at' section has 'Cells' selected. The 'Name' field contains 'Aquitard_Kx'. The 'Duplicate cells allowed' checkbox is checked. The 'Grid cell size' is set to 100. The 'Color object line' and 'Color object interior' checkboxes are unchecked. The 'Set values of enclosed cells' checkbox is checked. The 'Number of Z formulas' is set to 'Two'. The 'Z-coordinate' field contains the formula $(Model_Top + Upper_Aquifer_Bottom) / 2$. The 'Higher Z-coordinate' field contains 'Upper_Aquifer_Bottom'. The 'Lower Z-coordinate' field contains 'Aquitard_Bottom'. The 'Object information (not editable)' section shows 'Object length' as 9496.12403100775, 'Object area' as 5635956.97373956, and 'Object order' as 1. The 'Convert time units' button is at the bottom left, and 'Help', 'OK', and 'Cancel' buttons are at the bottom right.

Property	Value
Name	Aquitard_Kx
Evaluated at	Cells
Duplicate cells allowed	Checked
Grid cell size	100
Color object line	Unchecked
Color object interior	Unchecked
Set values of enclosed cells	Checked
Set values of intersected cells	Unchecked
Set values of cells by interpolation	Unchecked
Number of Z formulas	Two
Z-coordinate	$(Model_Top + Upper_Aquifer_Bottom) / 2$
Higher Z-coordinate	Upper_Aquifer_Bottom
Lower Z-coordinate	Aquitard_Bottom
Object length	9496.12403100775
Object area	5635956.97373956
Object order	1

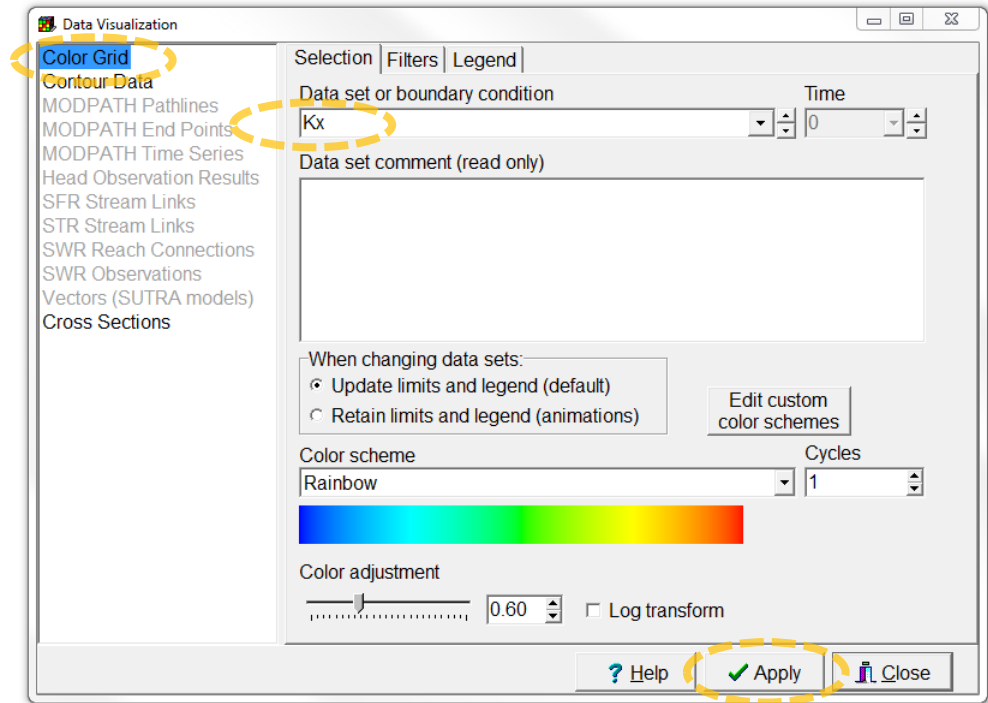
Modify Kx Aquitard (3/3)

- ✓ Switch to the **Data Sets** tab, and
- ✓ change the formula for the **Kx** data set to 0.001.
- ✓ Then press **OK**.

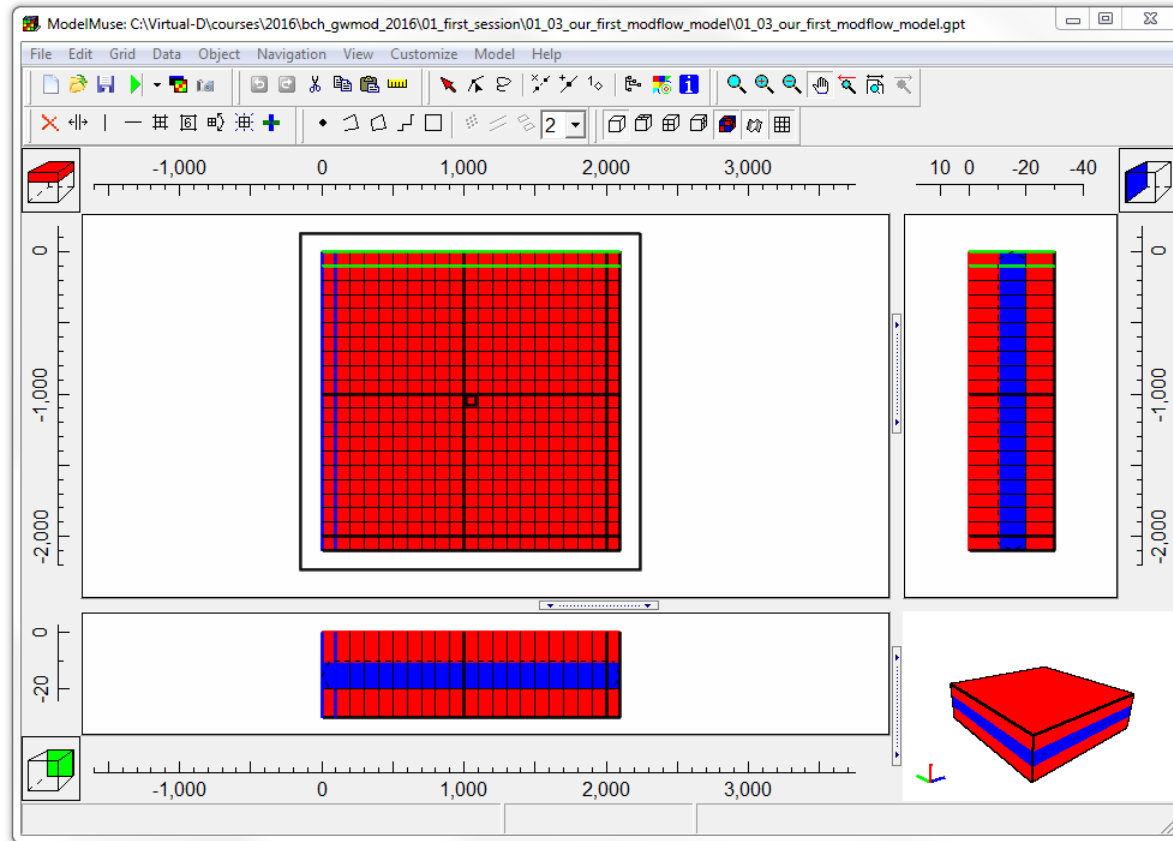


Visualize Kx data set

- ✓ Choose **Data | Data visualization**.
- ✓ Select **Color Grid**, and the **Kx** data set and
- ✓ press **Apply**.

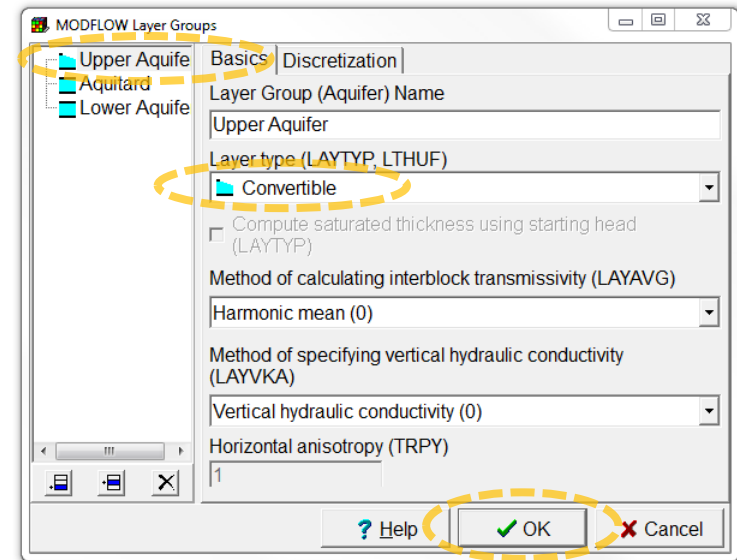


This is what you should get



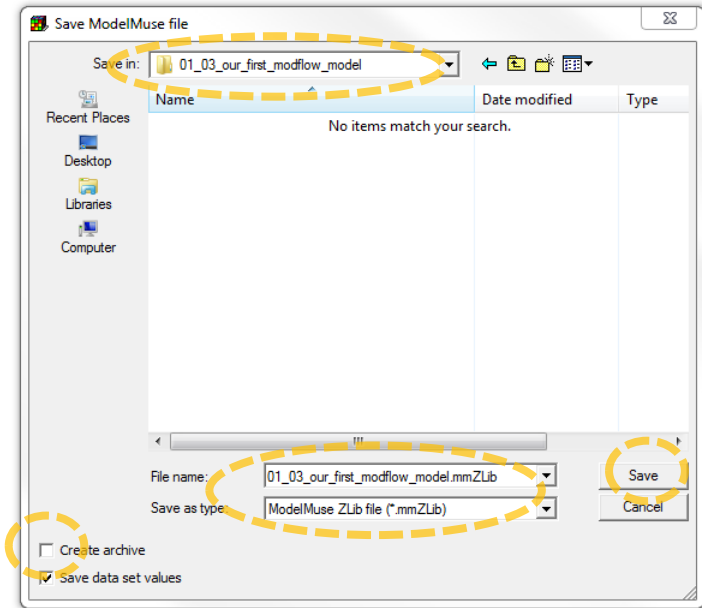
Change layer type

- ✓ Select **Model | MODFLOW Layer Groups...**
- ✓ Change the Upper Aquifer layer type to **Convertible**,
- ✓ and then click **OK**.



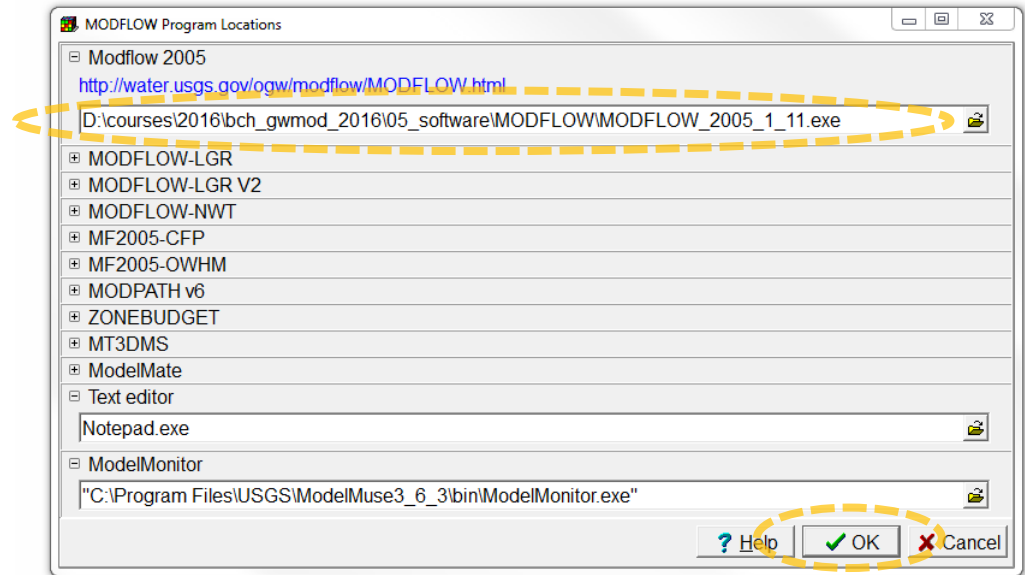
Save model

- ✓ Select **File | Save**, and
- ✓ select the folder ““/01-03_our-first-modflow-model/” and file name “01-03_our-first-modflow-model.mmZLib”.
- ✓ Deselect the **Create archive** checkbox, and
- ✓ **Save** the file.



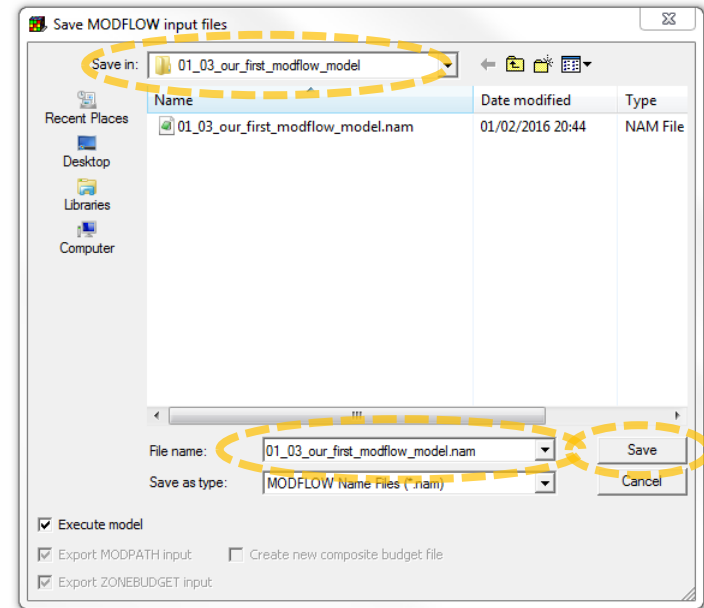
Set MODFLOW executable location

- ✓ Choose **Model | MODFLOW Program locations,**
- ✓ fill in the MODFLOW executable location
“.../bch_gwmod-2018/05_software/modflow/modflow-2005-1.12.exe”,
and
- ✓ click **OK.**



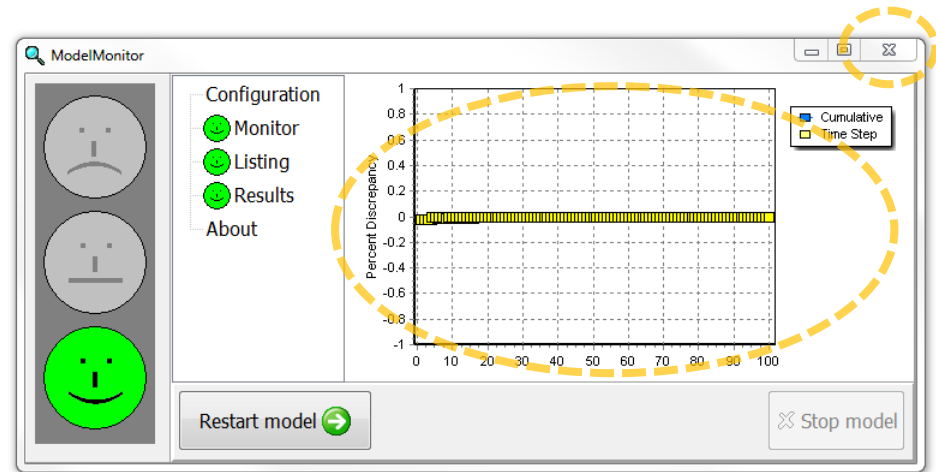
Run model (1/3)

- ✓ Select **File | Export | MODFLOW-2005 Input Files**,
- ✓ select a file name like “/01-03_our-first-modflow-model/ 01-03_our-first-modflow-model.nam”, and
- ✓ click **Save**. ModelMuse will create the MODFLOW input files and start running MODFLOW.



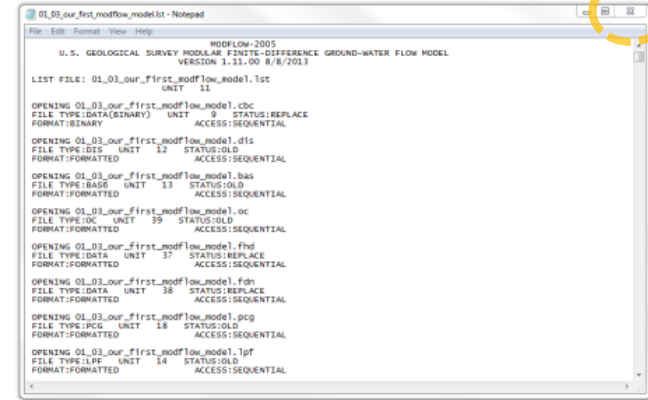
Run model (2/3)

- ✓ ModelMonitor will graph the percent discrepancy in the budget. If the percent discrepancy is larger than 1%, there is probably a problem with the model. However, smaller percent discrepancies do not guarantee that the model is OK.
- ✓ Close ModelMonitor when the model is done running.



Run model (3/3)

- ✓ The listing file will be opened in Notepad when you close ModelMonitor. You can close the listing file.
- ✓ There will also be a command line window that you can close.



```
MODFLOW-2005
U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER FLOW MODEL
VERSION 1.11.00 8/8/2013

LIST FILE: 01_03_our_first_modflow_model.lst
UNIT 11

OPENING 01_03_our_first_modflow_model.cbc
FILE TYPE:DATA(BINARY) UNIT 9 STATUS:REPLACE
FORMAT:BINARY ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.dfs
FILE TYPE:DIS UNIT 12 STATUS:OLD
FORMAT:FORMATTED ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.bas
FILE TYPE:BASE UNIT 13 STATUS:OLD
FORMAT:FORMATTED ACCESS:SEQUENTIAL

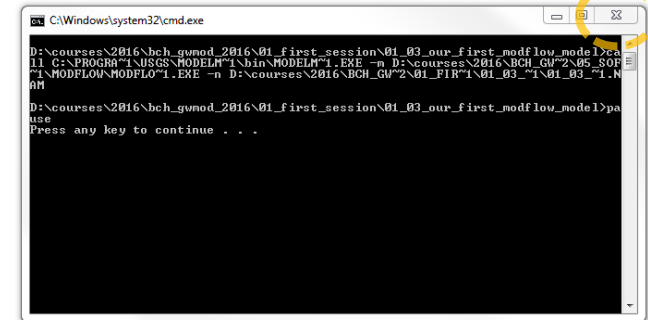
OPENING 01_03_our_first_modflow_model.mf
FILE TYPE:DC UNIT 39 STATUS:OLD
FORMAT:FORMATTED ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.fnd
FILE TYPE:DATA UNIT 37 STATUS:REPLACE
FORMAT:FORMATTED ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.fcn
FILE TYPE:DATA UNIT 38 STATUS:REPLACE
FORMAT:FORMATTED ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.pcg
FILE TYPE:PCG UNIT 18 STATUS:OLD
FORMAT:FORMATTED ACCESS:SEQUENTIAL

OPENING 01_03_our_first_modflow_model.lpf
FILE TYPE:LPF UNIT 14 STATUS:OLD
FORMAT:FORMATTED ACCESS:SEQUENTIAL
```



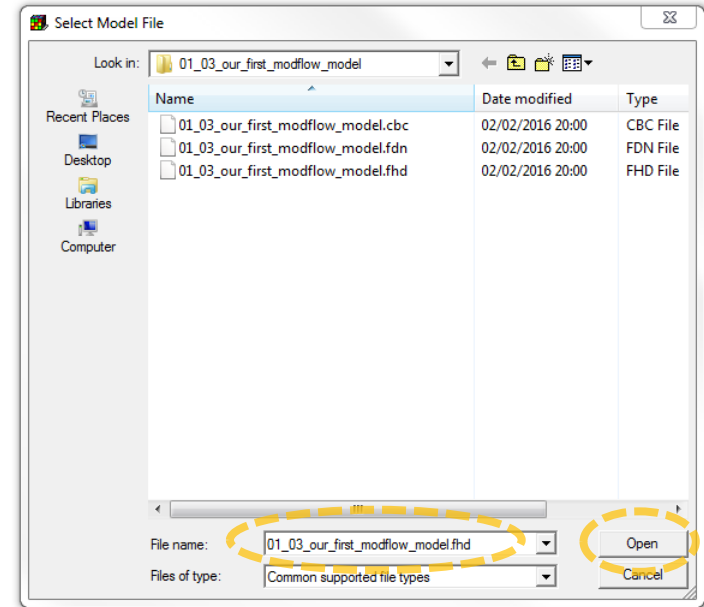
```
C:\Windows\system32\cmd.exe

D:\courses\2016\bch_gwmod_2016\01_first_session\01_03_our_first_modflow_model\ca11 C:\PROGRAM\USGS\MODELM\I\BIN\MODELM\I.EXE -n D:\courses\2016\BCH_GW\2\05_SOF\I\MODFLOW\MODFLOW\I.EXE -n D:\courses\2016\BCH_GW\2\01_FIR\I\01_03_our_first_modflow_model.lst

D:\courses\2016\bch_gwmod_2016\01_first_session\01_03_our_first_modflow_model>pa
use
Press any key to continue . . .
```

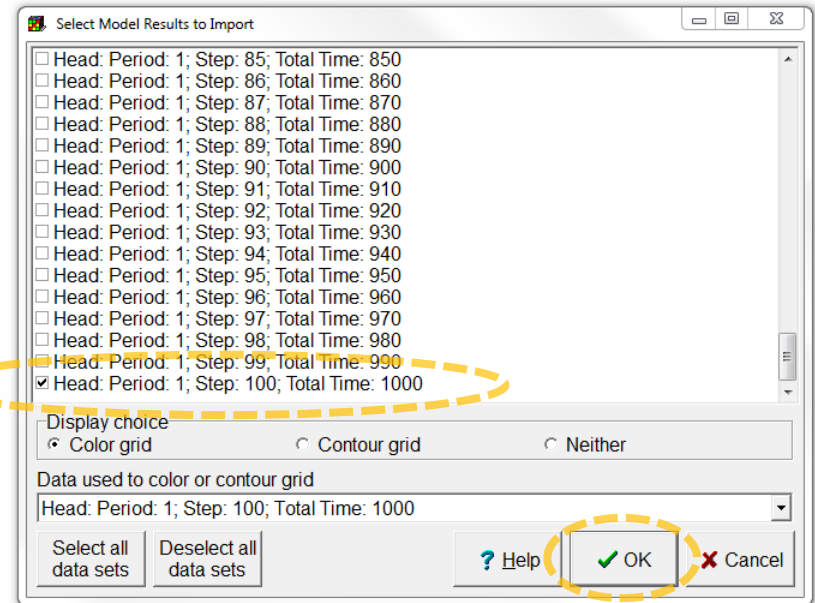

Import model results (1/2)

- ✓ Select **File | Import | Model Results...** The **Select Model File** dialog box should appear.
- ✓ The file containing the heads should already be selected by default so just click **Open**.



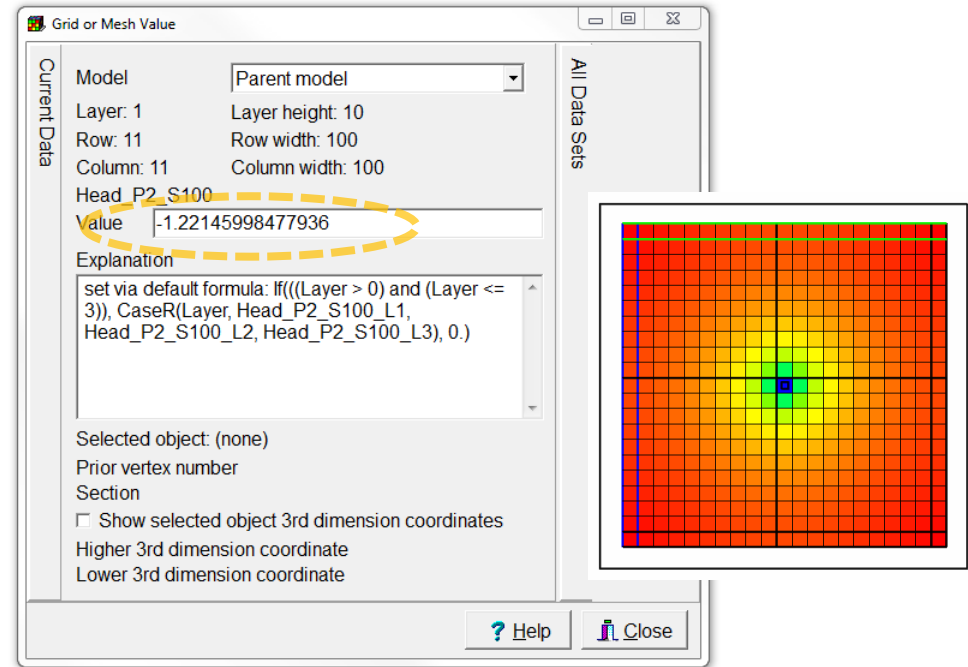
Import model results (2/2)

- ✓ In the **Select Model Results to Import** dialog box, the data for the last time step should already be selected, so just click **OK**.
- ✓ You can ignore the warning of Missing Geo Reference data, and **Close** the Errors and Warnings dialog box.



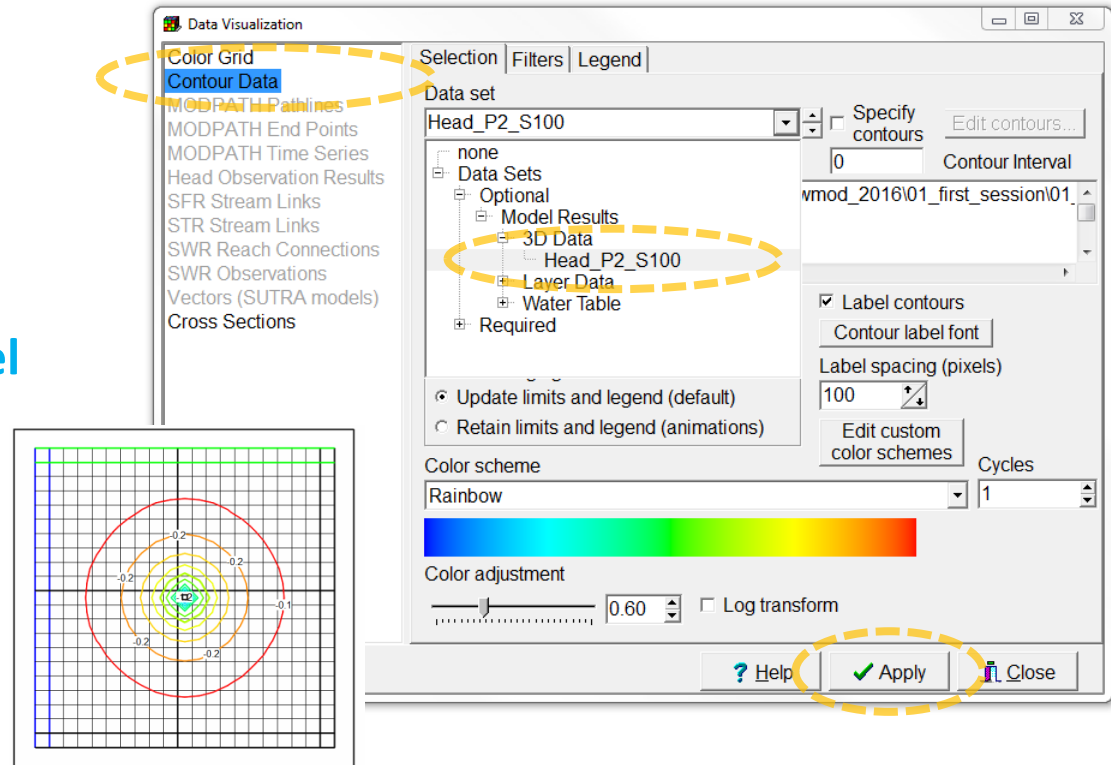
Check model results

- ✓ Select **Data | Show Grid Values**. Move the cursor over the model grid and observe the value displayed in the dialog box. This is one way to see what the data value is at a particular location.



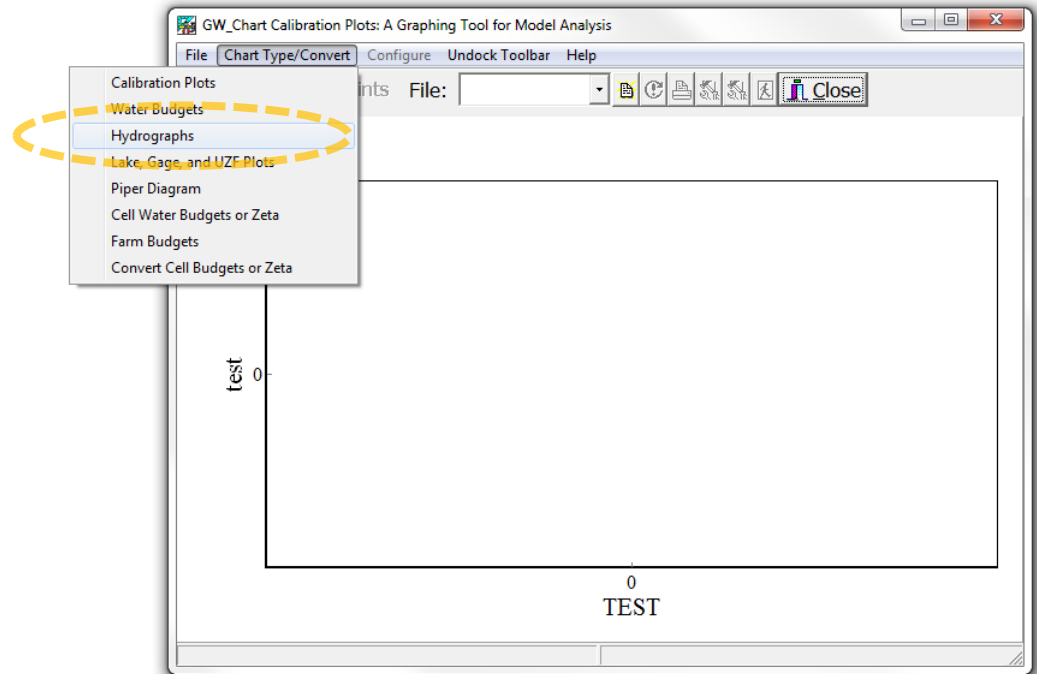
Change visualization type

- ✓ Select **Data | Data Visualization...**
- ✓ Set **Color Grid** to none, and
- ✓ **Contour Data** to **Data Sets | Optional | Model Results | 3D Data | Head_P2_S100**.
- ✓ Then click **Apply**.



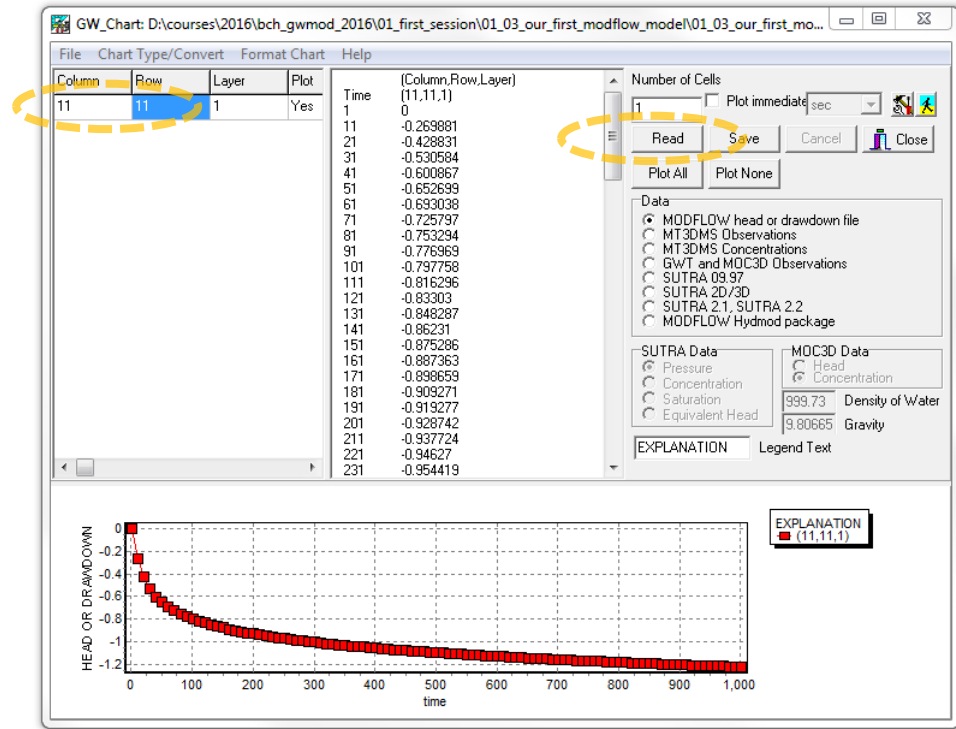
Plot hydrograph (1/2)

- ✓ Start GW_Chart and select **Chart Type/Convert | Hydrographs**.



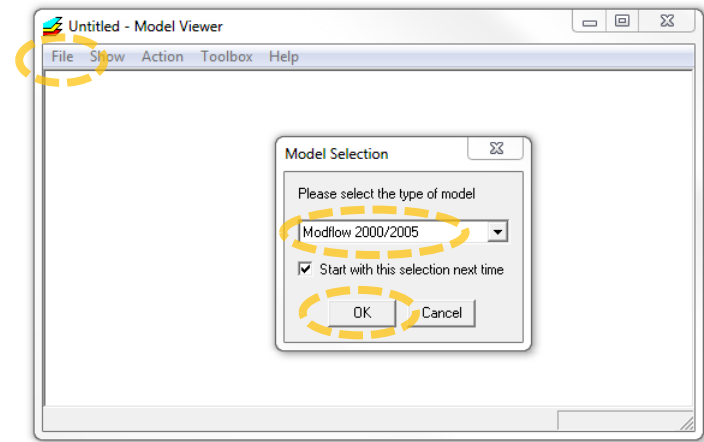
Plot hydrograph (2/2)

- ✓ Change the column and row to 11.
- ✓ Then click the **Read** button, and choose the file with heads for this exercise. GW_Chart will plot the change in head vs time.



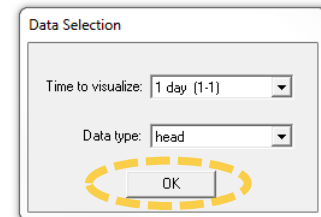
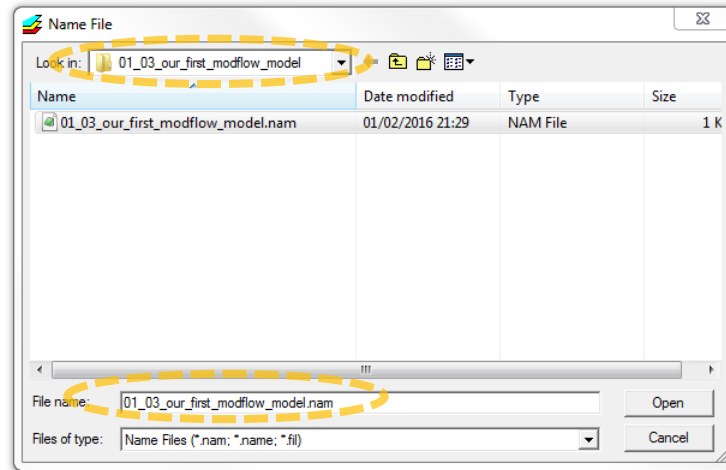
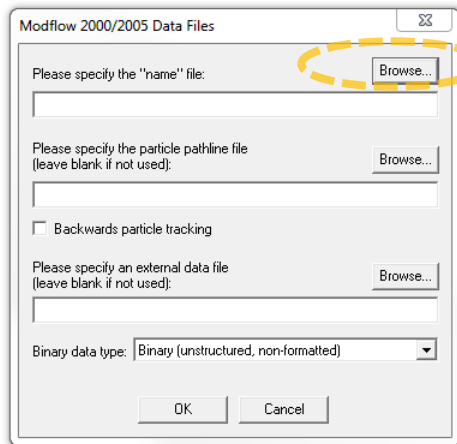
Animate in 3D (1/5)

- ✓ Start Model Viewer. Select **File | New** and set the model type to a MODFLOW 2000/2005 model.
- ✓ Then press **OK**.



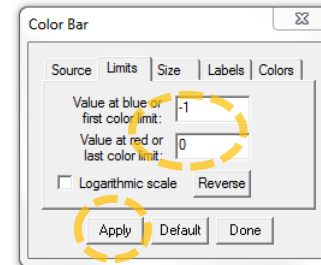
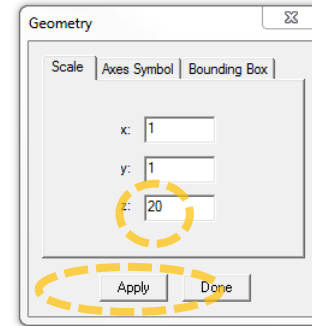
Animate in 3D (2/5)

- ✓ Select **Browse...**,
- ✓ choose the name file from the model and click **Open** and **OK**.
- ✓ Accept the defaults for the data selection, and click **OK**.



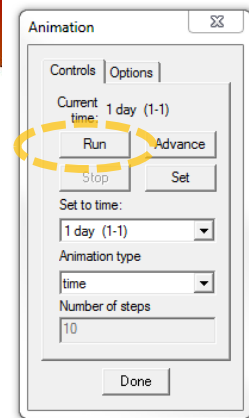
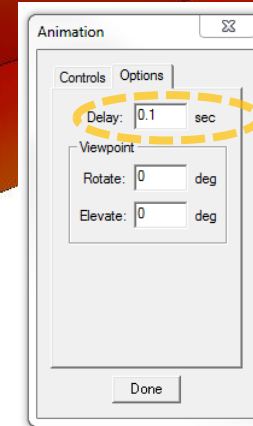
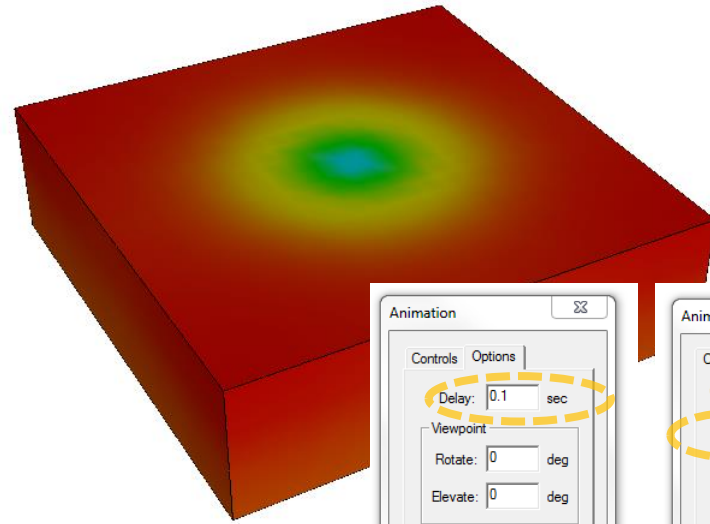
Animate in 3D (3/5)

- ✓ Select **Show | Solid**.
- ✓ Select **Toolbox | Geometry**, set the scale for z to 20, and click **Apply**.
- ✓ Select **Toolbox | Color Bar**, set the limits to -1 and 0, and click **Apply**.



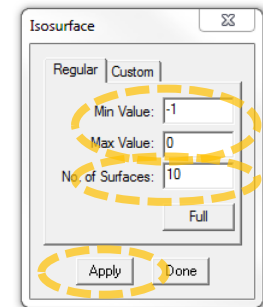
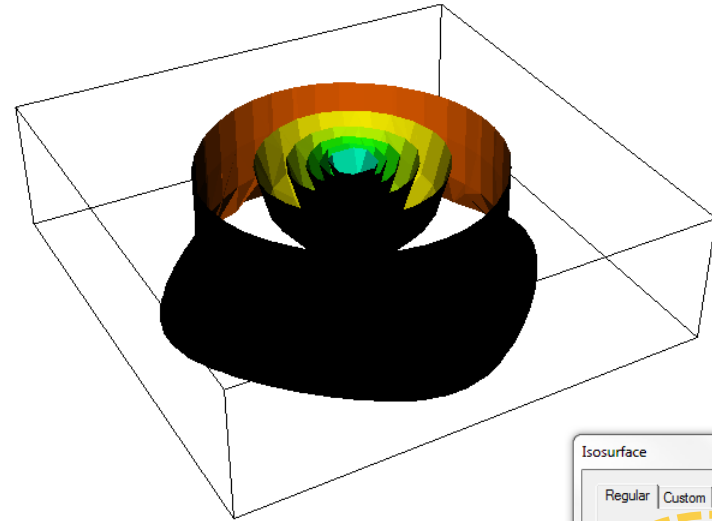
Animate in 3D (4/5)

- ✓ Then select **Toolbox | Animation**.
- ✓ Under the **Options** tab, set **Delay** to 0.1, and
- ✓ and click **Run** in the **Controls** tab.
- ✓ Try dragging with the mouse to rotate the view of the model.



Animate in 3D (5/5)

- ✓ Select **Show | Isosurfaces**.
- ✓ Select **Toolbox | Isosurface**,
- ✓ and set the limits again to -1 and 0.
- ✓ Also change the number of surfaces to 10,
- ✓ and press **Apply**.
- ✓ Now try animating the isosurfaces.



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*Questions? Found an error?
Please contact B. Rogiers at brogiers@sckcen.be.*