Education evenings 2016

Practical introduction to groundwater modelling

Computer exercises
02 01 A more complex model

Purpose

In this example, we will

- ✓ create a more complex model, which uses data from Shapefiles to define the layer boundaries,
- ✓ use parameters for defining a data set and a model feature, and
- ✓ use the Observations process in MODFLOW to define head observations and river observations.

About parameters

- ✓ Uncertain material or boundary condition properties
- ✓ Parameters in MODFLOW are listed together in the parameter value file
- ✓ External software (*e.g*. ModelMate and UCODE) can easily modify this parameter value file, to perform for example sensitivity analysis, parameter estimation or uncertainty quantification.
- ✓ Working with parameters requires setting up your model in a slightly different way. Think about which parameters you want to include before building your model!

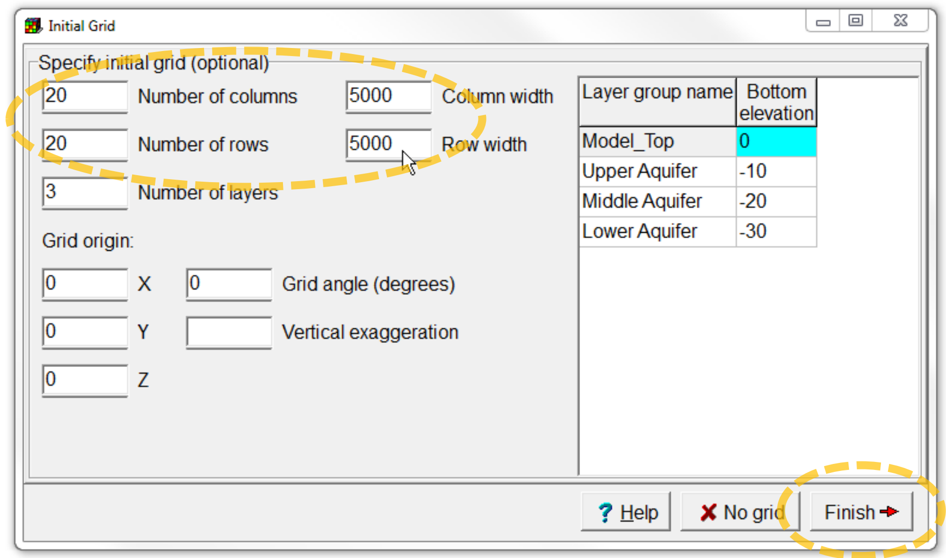
Parameters for data sets vs model features

- No mixture possible: either parameters for the whole data set, or no parameters at all!
- **Parameter value** is multiplied by a **multiplier array** (= data set; 1 everywhere by default), and/or only used in a **zone** (= data set; False by default).
- There is no time-dependency.

- Mixture is possible: features with parameters can be combined with similar features without parameters.
- **Parameter value** is multiplied by a **multiplier** defined for each of the features it relates to.
- This **multiplier** can change with time.

Initial Grid

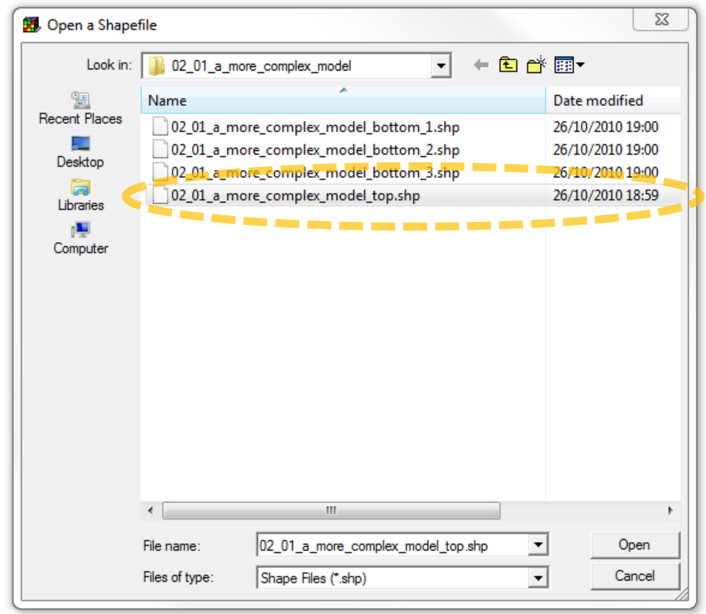
- ✓ Start a new model with 20 rows, 20 columns, and 3 layers. Make the rows and columns 5000 metres wide.
- ✓ You don't need to change the layer elevations now, so click **Finish**.



Import shape files (1/4)

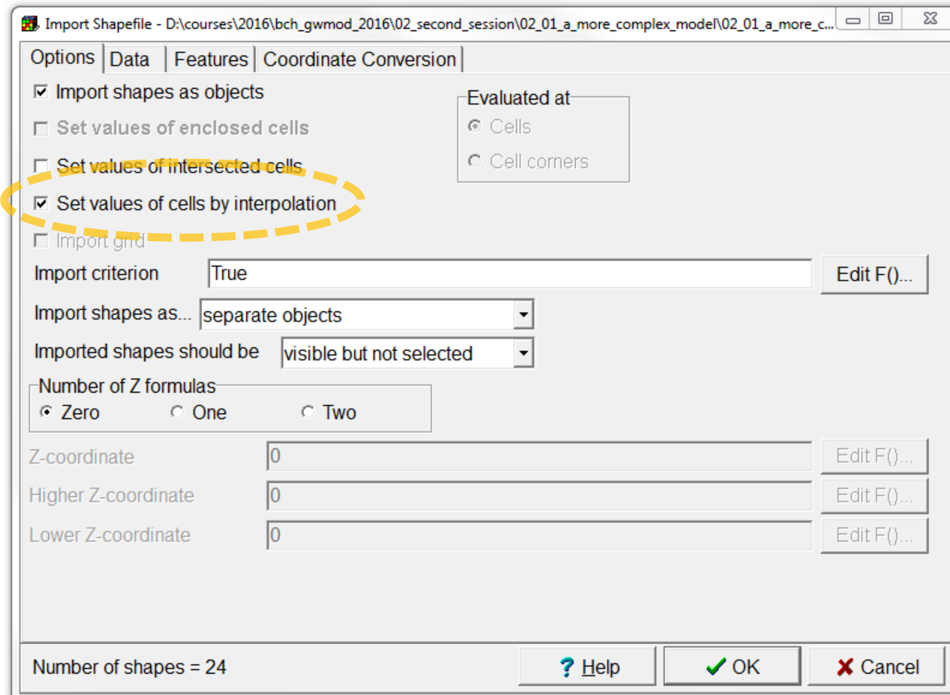
Next we will import the layer elevations from shape files.

- ✓ Select **File|Import|Shapefile** and select /02_01_a_more_complex_model/02_01_a_more_complex_model_top.shp.



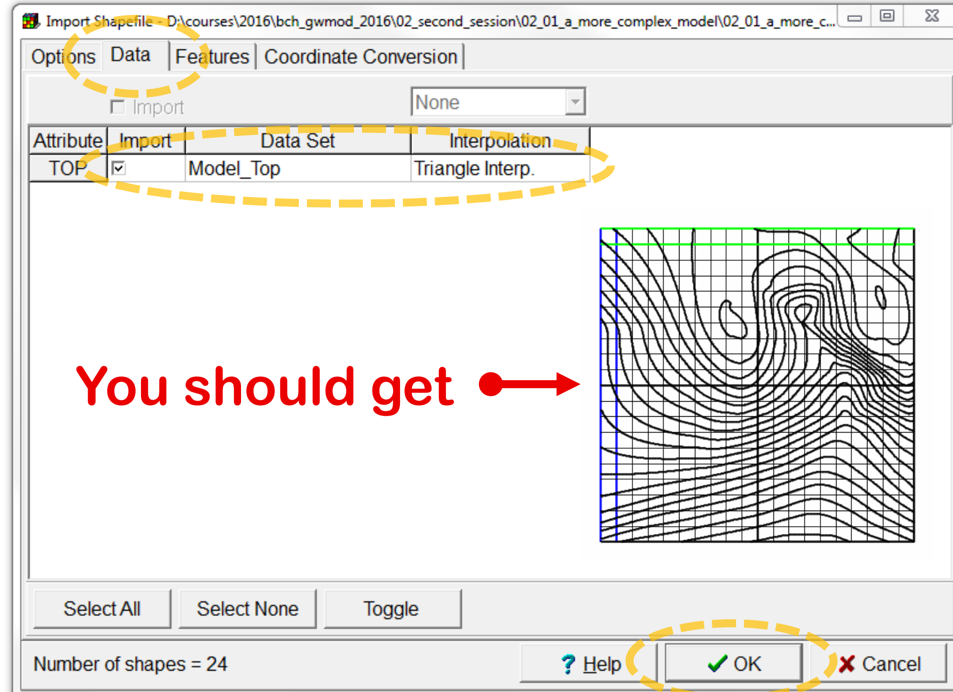
Import shape files (2/4)

- ✓ Check **Set values of cells by interpolation**.



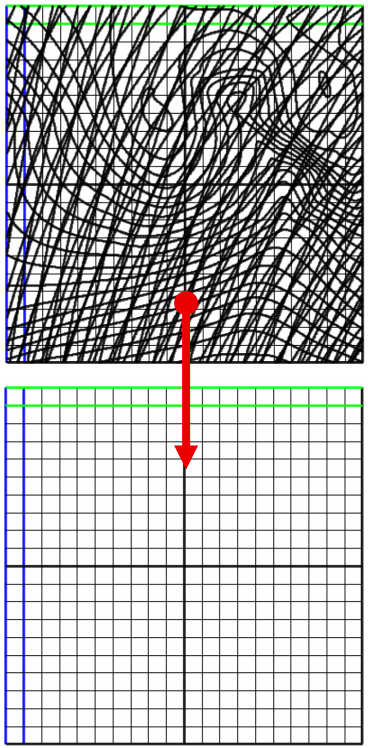
Import shape files (3/4)

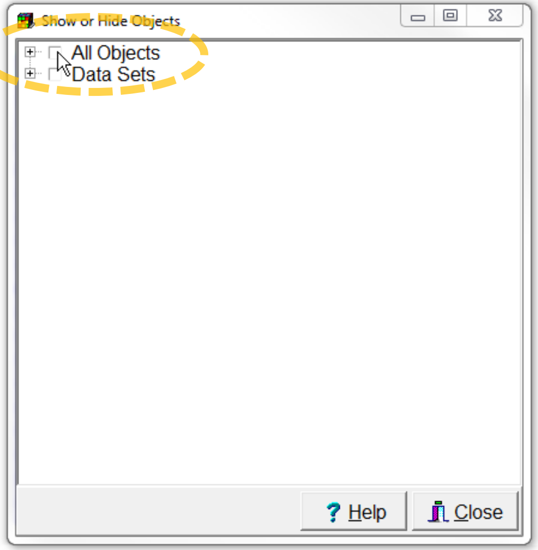
- ✓ On the **Data** tab, check the **Import** check box for the **TOP** attribute,
- ✓ change the **Data Set** to **Model_Top**,
- ✓ and change the interpolation method to **Triangle Interp**.
- ✓ Then click **OK**.



Import shape files (4/4)

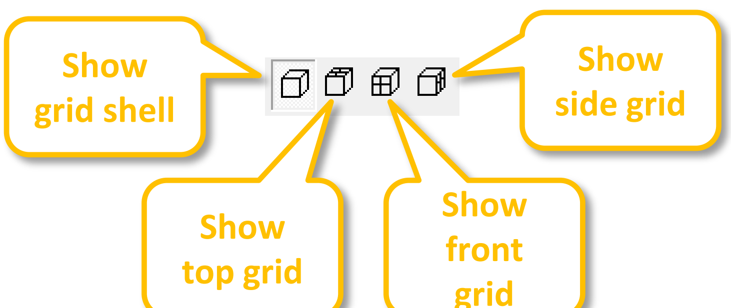
- ✓ Repeat steps 2-4 with the Shapefiles 02_01_a_more_complex_model_bottom_1.shp, *_bottom_2.shp and *_bottom_3.shp. Use them to set the bottoms of the upper, middle, and lower aquifer respectively.
- ✓ Then select **Object|Show-or Hide Objects** and uncheck the check box for "**All Objects**" to hide all the objects.

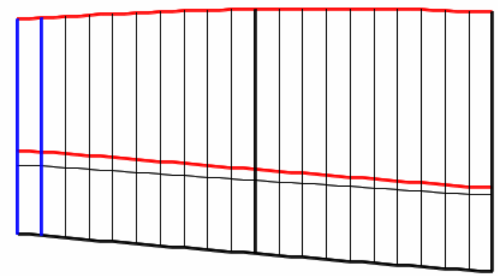


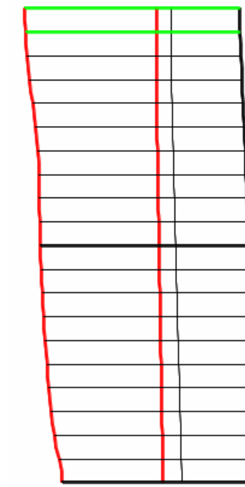


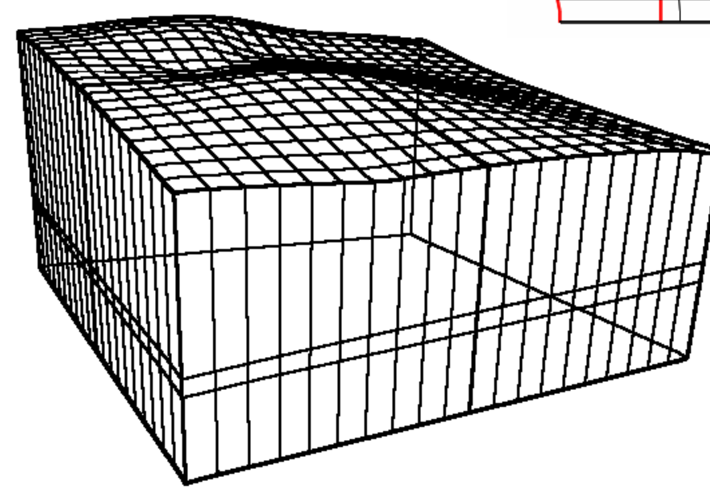
Check layer geometries

- ✓ Have a look at the front, side and 3D views to see if the layer geometry was set correctly.
- ✓ Use the grid buttons to reveal more layer details on the 3D view.





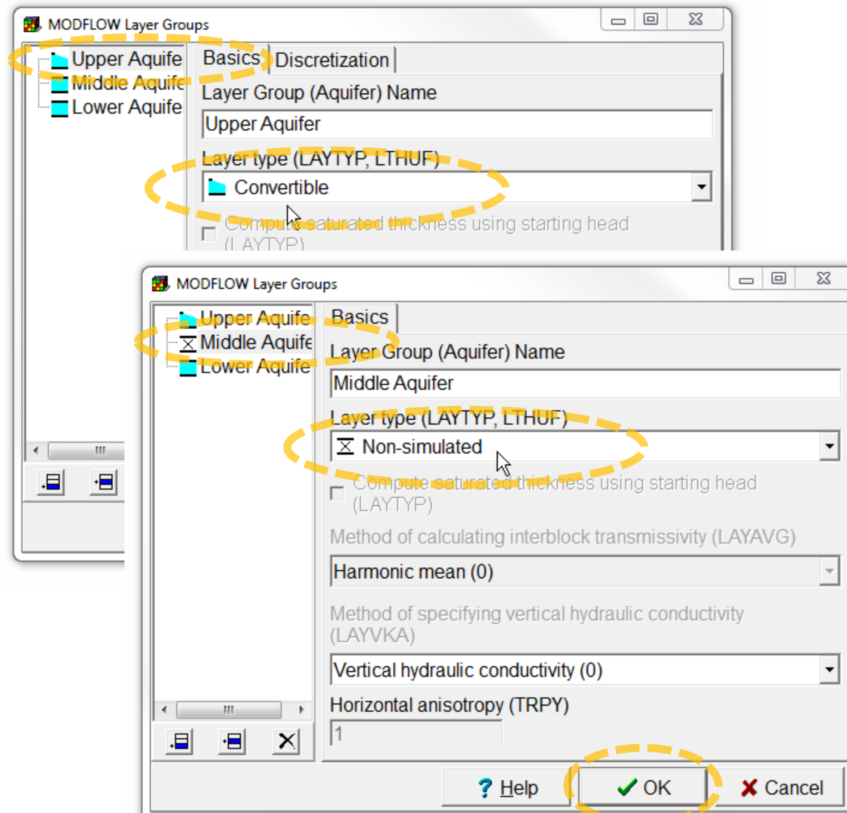




Define layer types

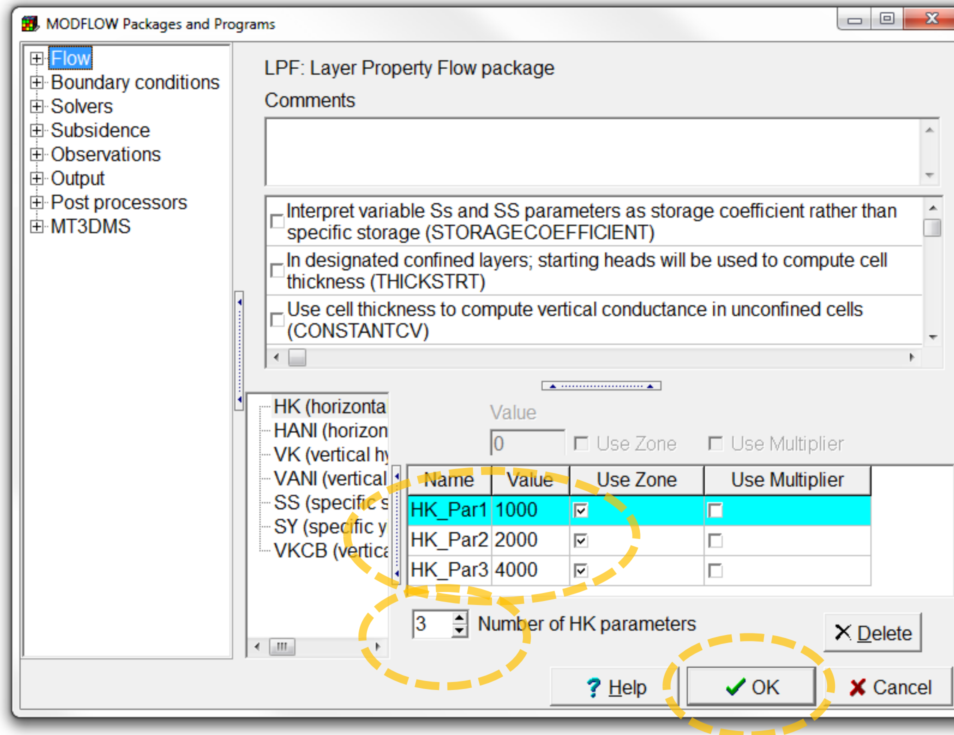
At this point, the elevations of the layers have been defined. The next step is to define the layer types:

- ✓ Select **Model|MODFLOW Layer Groups...**
- ✓ Select the **Upper Aquifer** and change its layer type to **Convertible**
- ✓ Select the **Middle Aquifer** and change its layer type to **Non-simulated** (= Quasi-three-dimensional confining bed in MODFLOW) and
- ✓ click **OK.**



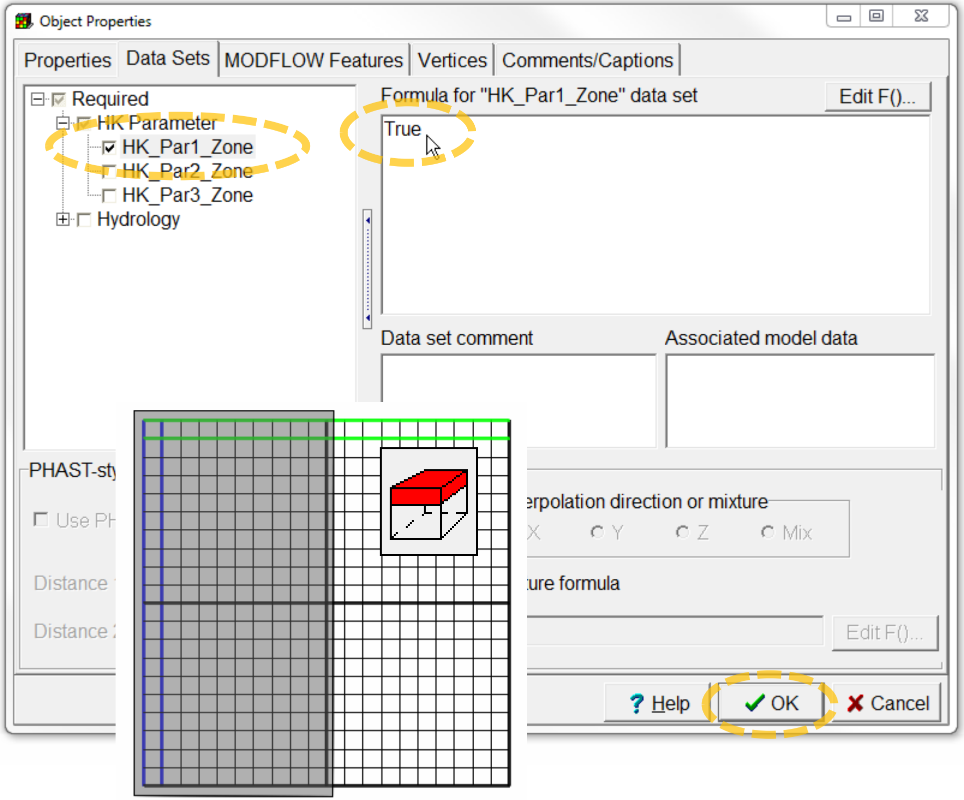
Set Kx with parameters and zones (1/4)

- ✓ Select **Model|MODFLOW Packages and Programs...**
- ✓ The **LPF package** is active by default. In it change the **Number of HK parameters** to 3.
- ✓ Set the values of the parameters to 1000, 2000, and 4000 respectively.
- ✓ Check the check box for **Use Zone** for all three parameters,
- ✓ and then click **OK**.



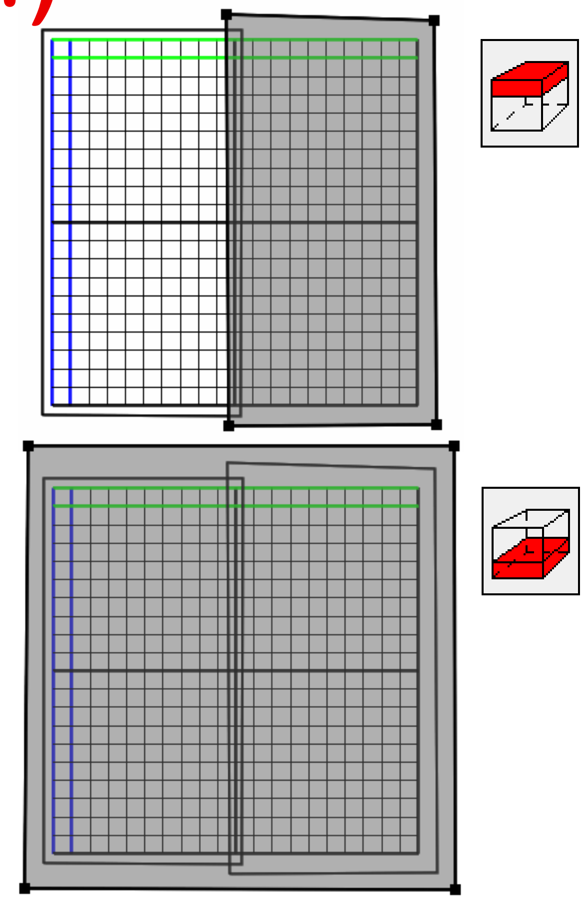
Set Kx with parameters and zones (2/4)

- ✓ Make sure that layer 1 is the active layer and draw a polygon around the left half of the model.
- ✓ On the **Data Sets** tab of the Object Properties dialog box, expand **Required|HK Parameter** and check the check box for **HK_Par1_Zone**.
- ✓ Then set the formula to **True** and close the dialog box,
- ✓ and press **OK**.



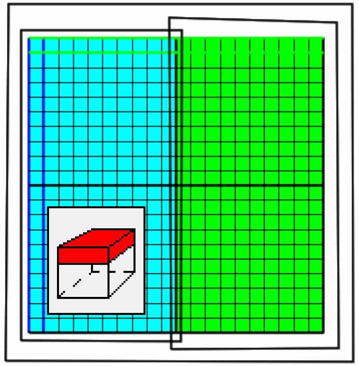
Set Kx with parameters and zones (3/4)

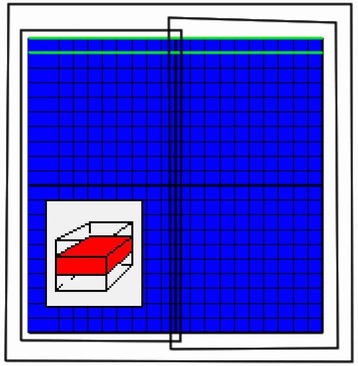
- ✓ Draw another object on the right half of the model and use it to set **HK_Par2_Zone** to **True**.
- ✓ Change the active layer to layer 3, and draw an object completely surrounding the grid. Use it to set the value of **HK_Par3_Zone** to **True**.

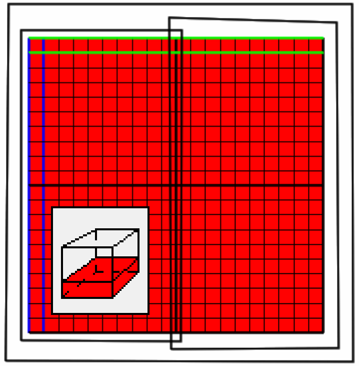


Set Kx with parameters and zones (4/4)

- Colour the grid with the Kx data set. ModelMuse will use a formula that reproduces how MODFLOW assigns values to cells.
- Try moving one of the objects that set the zones in the first layer, so that the zones overlap.
- What is the hydraulic conductivity where the zones overlap?
- Use the undo button to move the objects back to their original locations.

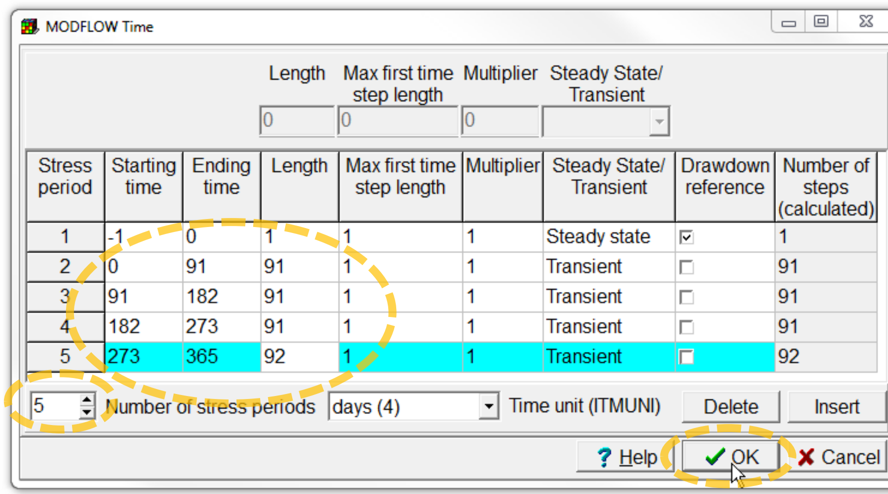






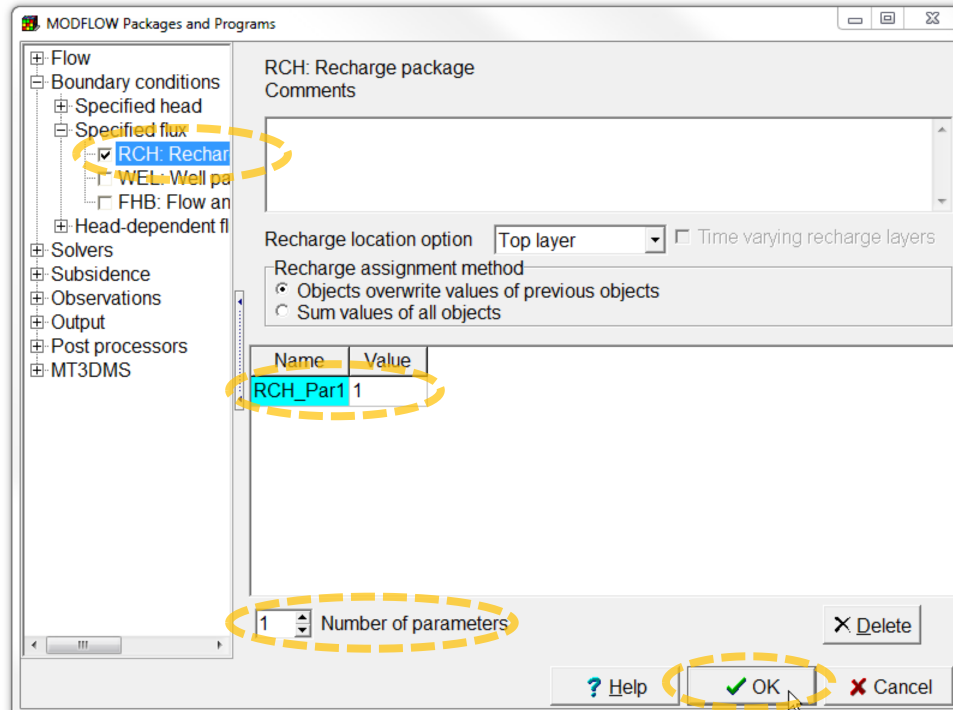
Define MODFLOW stress periods

- ✓ Next select **Model|MODFLOW Time...**
- ✓ and set up the stress periods as shown on the right.
- ✓ Then click **OK**.



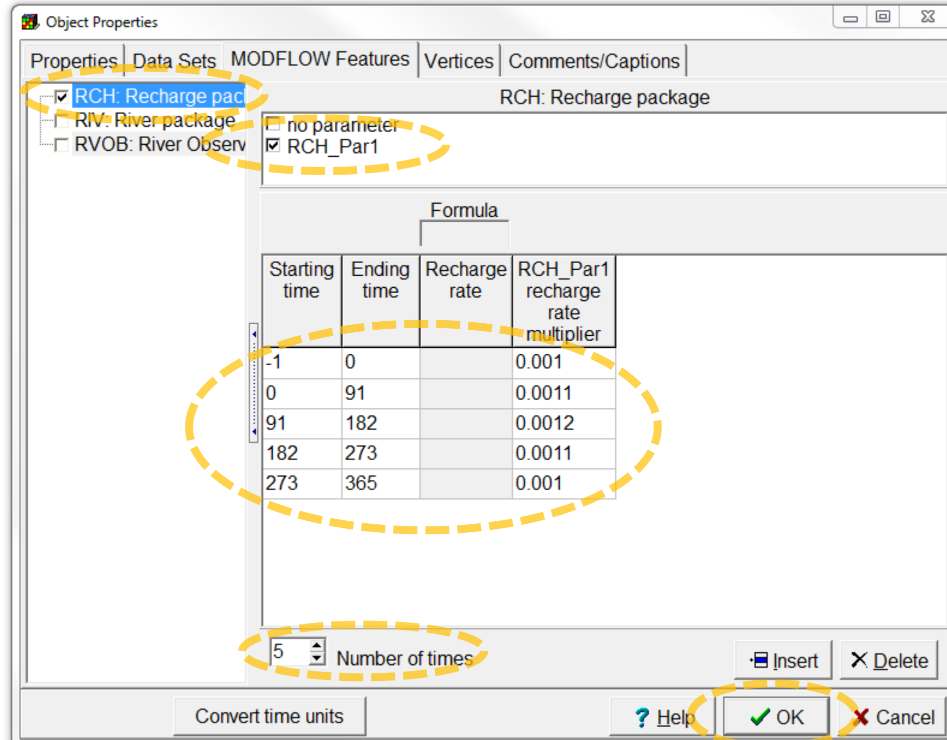
Set Recharge with a parameter and multipliers (1/2)

- ✓ Select **Model|MODFLOW Packages and Programs...**,
- ✓ expand **Boundary conditions|Specified flux** and check the check box for the **Recharge package**.
- ✓ Change the **number of parameters** to 1,
- ✓ and set the value of the parameter to 1.
- ✓ Click **OK** to close the dialog box.



Set Recharge with a parameter and multipliers (2/2)

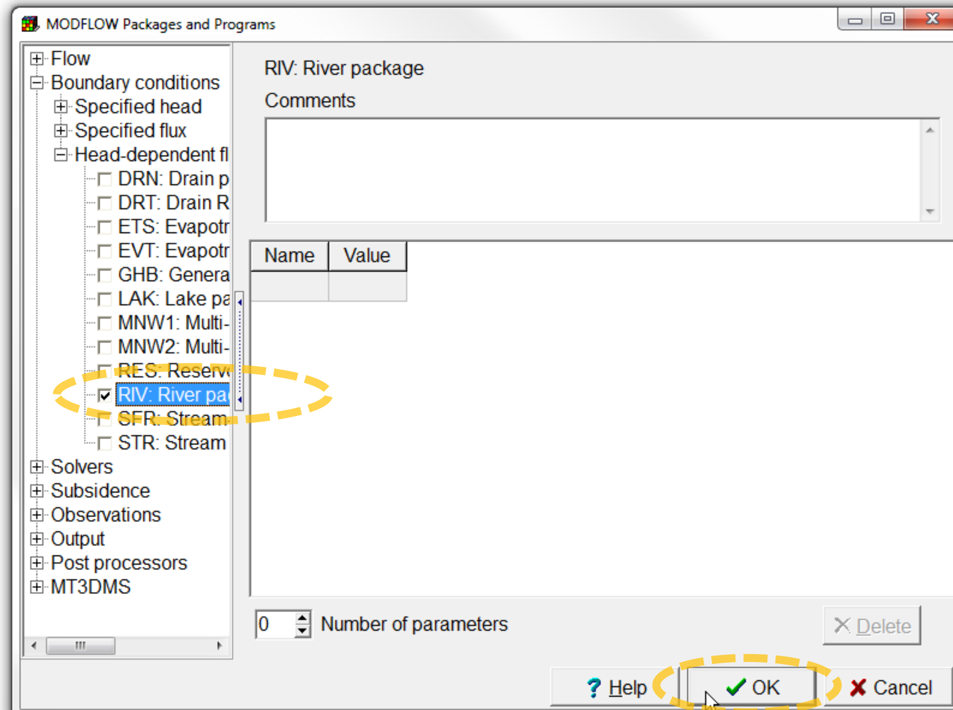
- ✓ Hide the existing objects, and draw another object that completely surrounds the grid.
- ✓ In the **Object Properties** dialog box, check the checkbox for the **Recharge package** on the **MODFLOW Features** tab and check the check box for the recharge parameter **RCH_Par1**.
- ✓ This will cause a new column to appear in which you specify the recharge rate multiplier for that parameter. Fill in the rate multipliers as shown on the right.
- ✓ Then click **OK** to close the **Object Properties** dialog box.



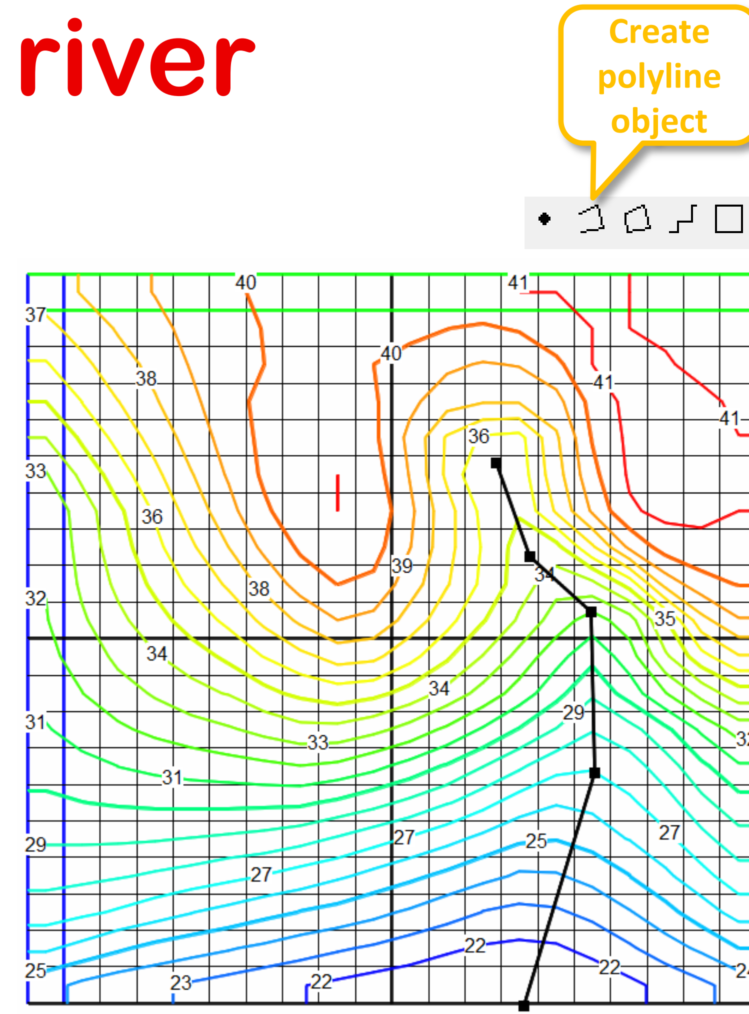
Enable the River package

In this model, all the water leaves through a river. We will now define the river.

- ✓ Select **Model|MODFLOW Packages and Programs...**,
- ✓ expand **Boundary conditions|Head-dependent flux** and check the check box for the **River package**.
- ✓ Then click **OK** to close the **Object Properties** dialog box.



Draw a river

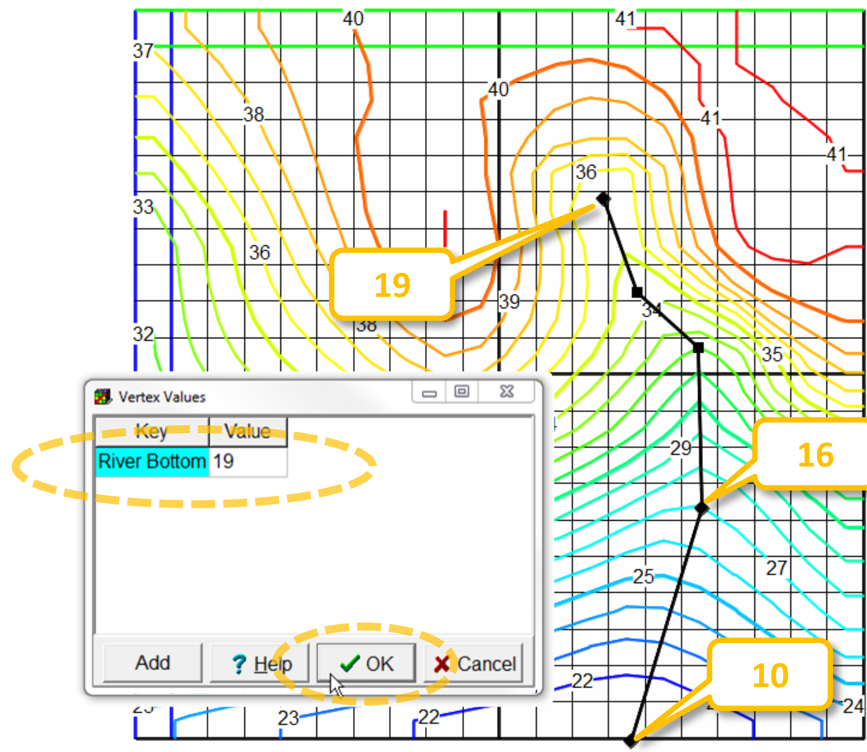


In order to help see where the river should be located, we will contour the top of the model and then draw the river down the middle of the valley.

- ✓ Select **Data|Color Grid**, select **none**, and click **Apply**.
- ✓ Select **Contour Data**, select the **Model_Top** data set, and again click **Apply**.
- ✓ Then make the top layer the active layer and draw an object as shown on the right.

Assign river elevations

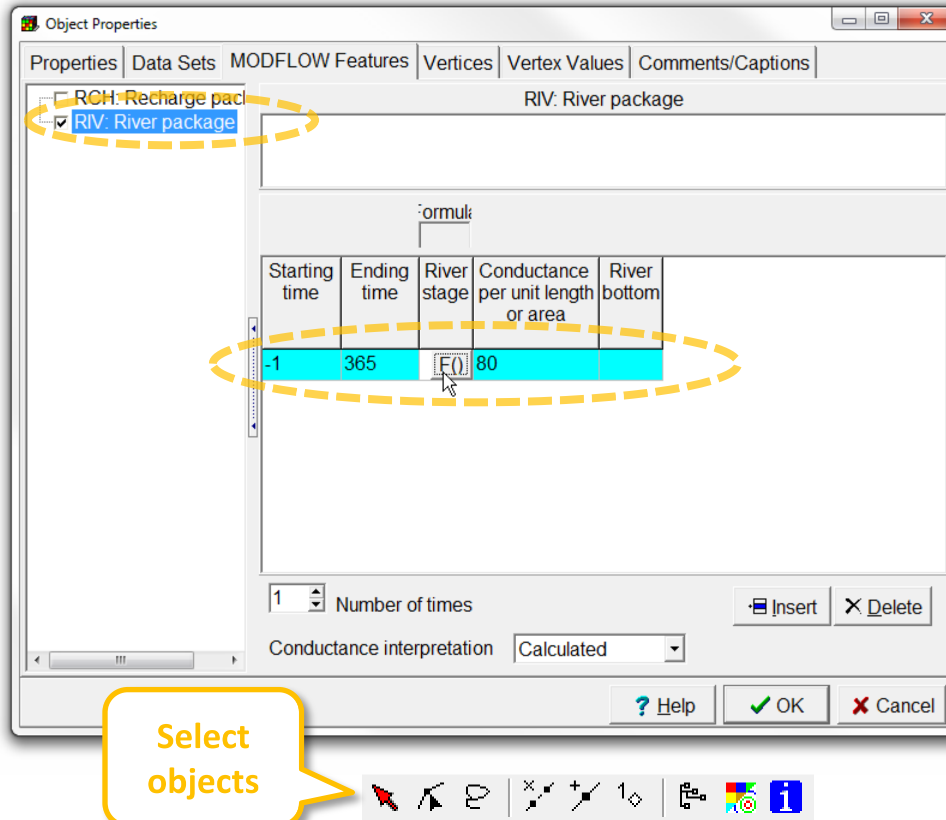
- ✓ Select **Object|Edit|Vertex Values** and double click on the vertex at the upstream end of the river.
- ✓ In **the Vertex Values** dialog box enter "River Bottom" as the key and 19 as the value.
- ✓ Then click **OK**. Note that the symbol for the vertex has changed from a square to a diamond.
- ✓ Repeat the above steps for the two other vertices indicated on the right.



Specify river conductance, bottom and stage formulas (1/2)

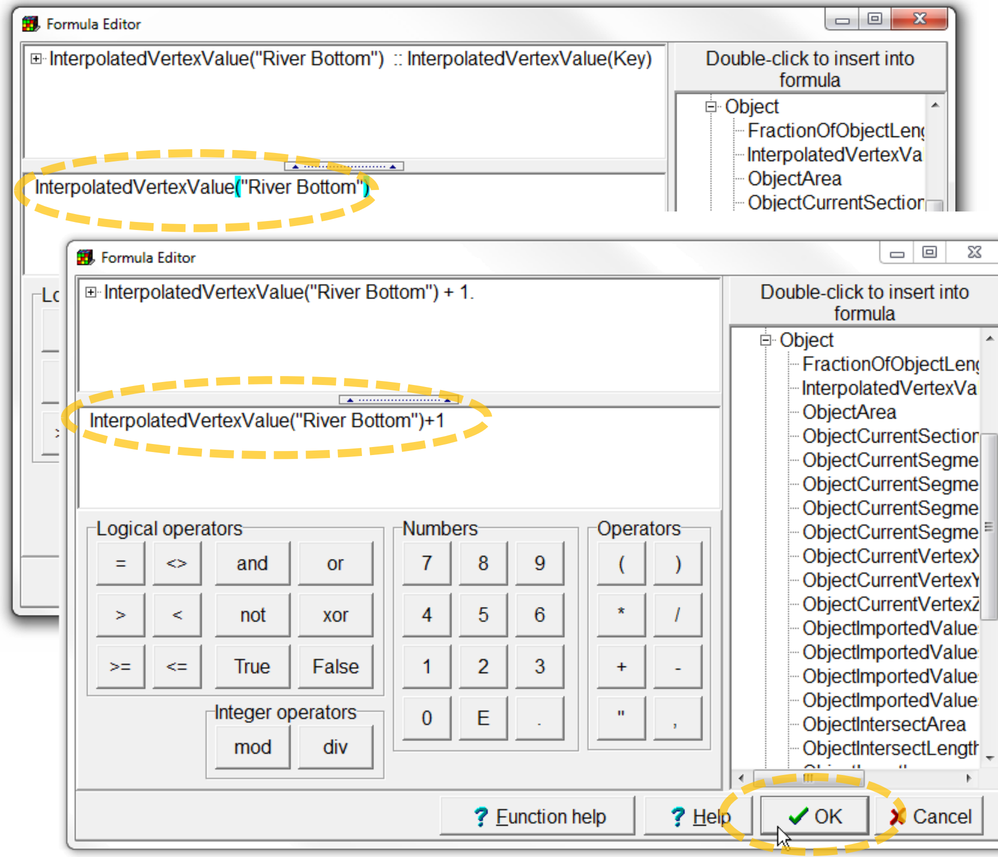
At this point we have defined the river elevations but we need to do one more thing to apply them to the river:

- ✓ Select the **Select objects** button and double click on the object that defines the river to open the **Object Properties** dialog box.
- ✓ On the **MODFLOW Features** tab, check the check box for the **River package** and enter **-1** as the **Starting time**, **365** as the **Ending time** and **80** as the **Conductance per unit length**.



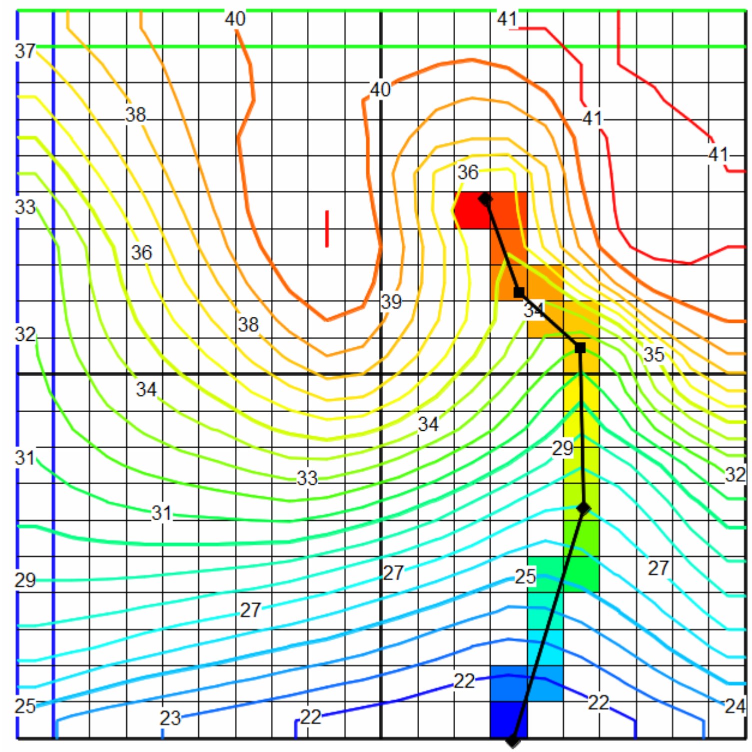
Specify river conductance, bottom and stage formulas (2/2)

- ✓ Click in the cell in the table where **River bottom** is defined.
- ✓ Click on the **F()** button that appears in the table to open the Formula Editor.
- ✓ In the list on the right, expand **Functions|Object** and double click on **InterpolatedVertexValue**.
- ✓ The formula will appear on the left. Replace "Key" with "River Bottom". Be sure to include the quotation marks around "River Bottom".
- ✓ Click **OK** to close the **Formula Editor**.
- ✓ Repeat the steps above for setting the formula for the **River stage** to **InterpolatedVertexValue("River Bottom") + 1**.
- ✓ Close the **Object Properties** dialog box.



Verify river stage

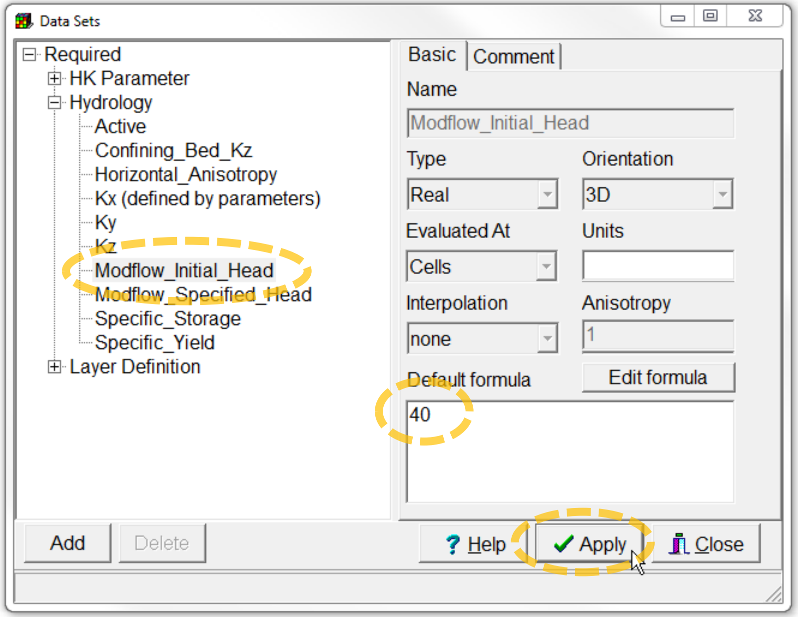
- ✓ To verify that the river stage has been assigned correctly, color the grid with the river stage.



Set initial heads

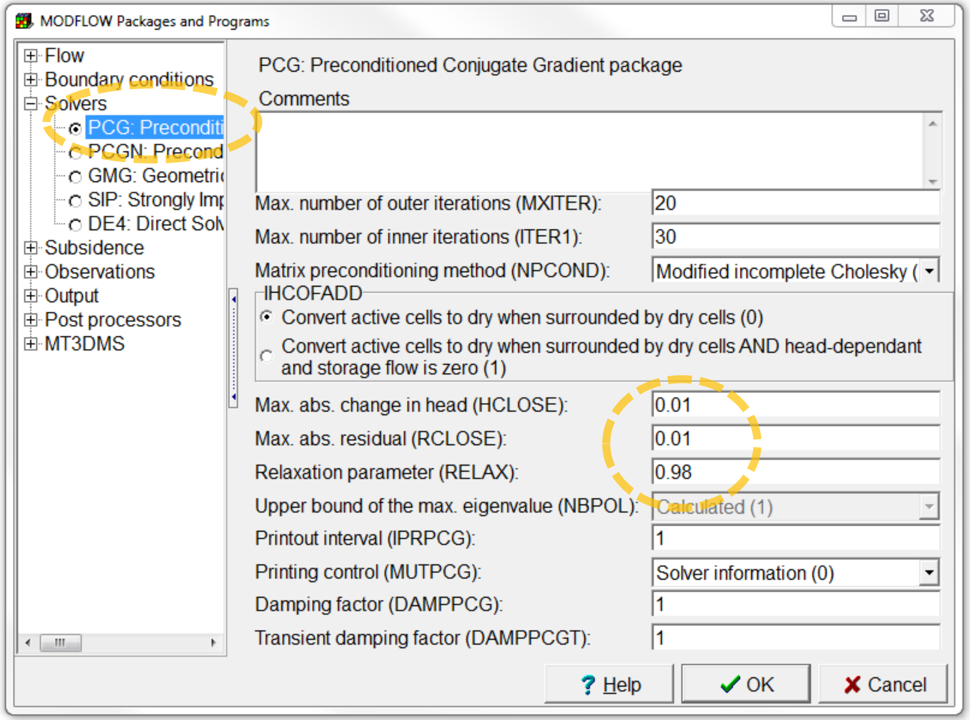
We still have a few more things we need to do before running the model. First set the initial head.

- ✓ Select **Data|Edit Data Sets...**, Expand **Required|Hydrology** and select **Modflow_Initial_Head**.
- ✓ Change the formula to 40 and click **Apply**.



Choose a solver

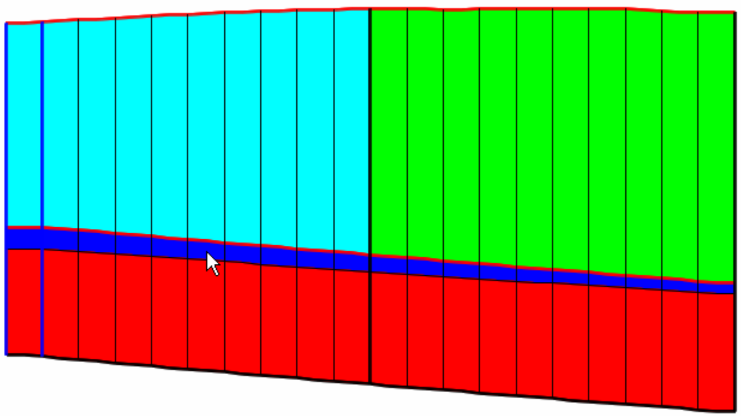
- ✓ Select **Model|MODFLOW Packages and Programs...**, expand **Solvers** and select the **PCG** package.
- ✓ Change both **HCLOSE** and **RCLOSE** to 0.01,
- ✓ and set **RELAX** to 0.98.



Set confining layer Kz (1/2)

- ✓ Color the grid with Kz.
- ✓ Note that in the middle confining layer, Kz is zero and that the formula used to define Kz is Kx/10. That needs to be fixed.

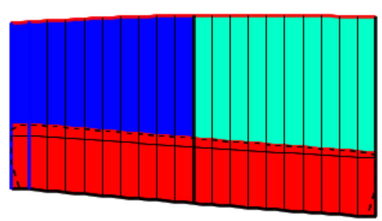
We could use another object to define Kz but in this case, we'll just adjust how Kx is defined.

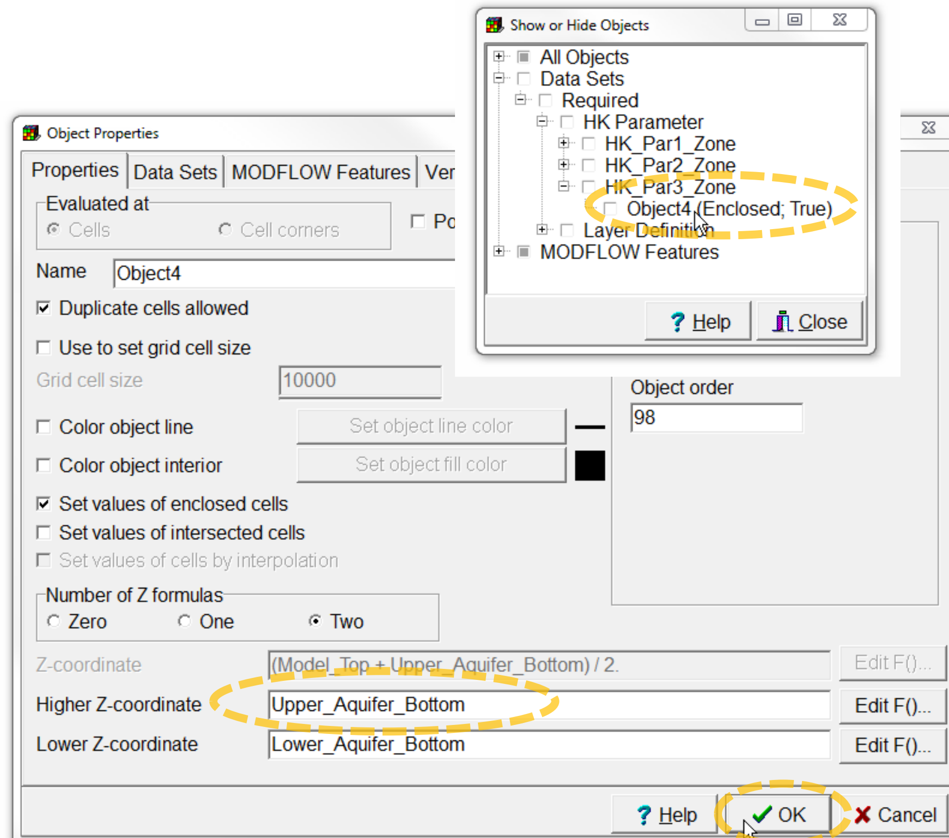


0: Kz; set via default formula: Kx / 10.

Set confining layer Kz (2/2)

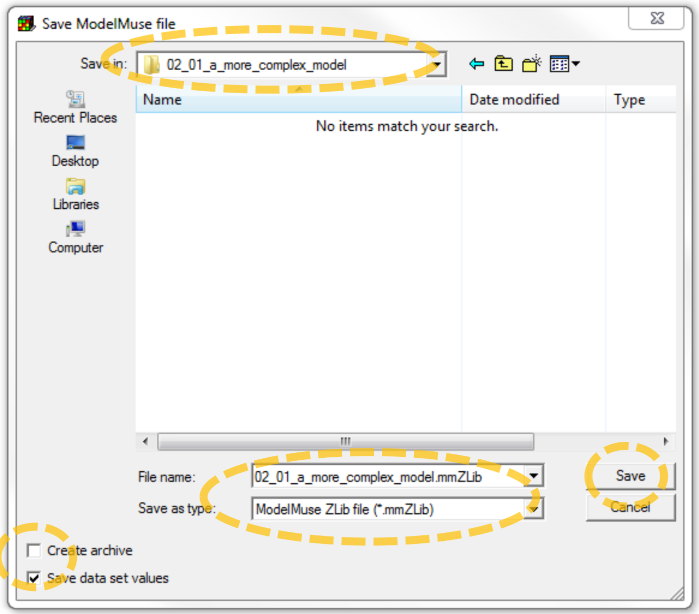
- ✓ Select **Object|Show or Hide Objects**, expand **Data Sets|Required|HK Parameter|HK_Par3_Zone** and double click on the object listed there.
- ✓ This opens the **Object Properties** dialog box. This object sets the zone for HK_Par3 to be the bottom layer. Change the formula for the Higher Z coordinate to "Upper_Aquifer_Bottom" so that the object applies to both the middle and lower layers.
- ✓ Click **OK** to close the dialog box. Now Kz for the middle layer should be 400.





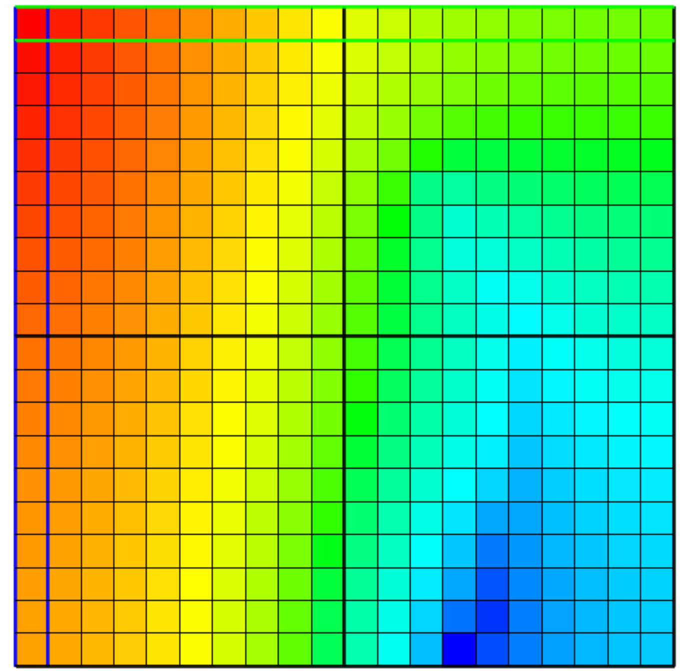
Save model

- ✓ Select **File|Save**, and
- ✓ select the folder ““/02_01_a_more_complex_model/” and file name “02_01_a_more_complex_model.mmZLib”.
- ✓ Deselect the **Create archive** checkbox, and
- ✓ **Save** the file.



Run model and import results

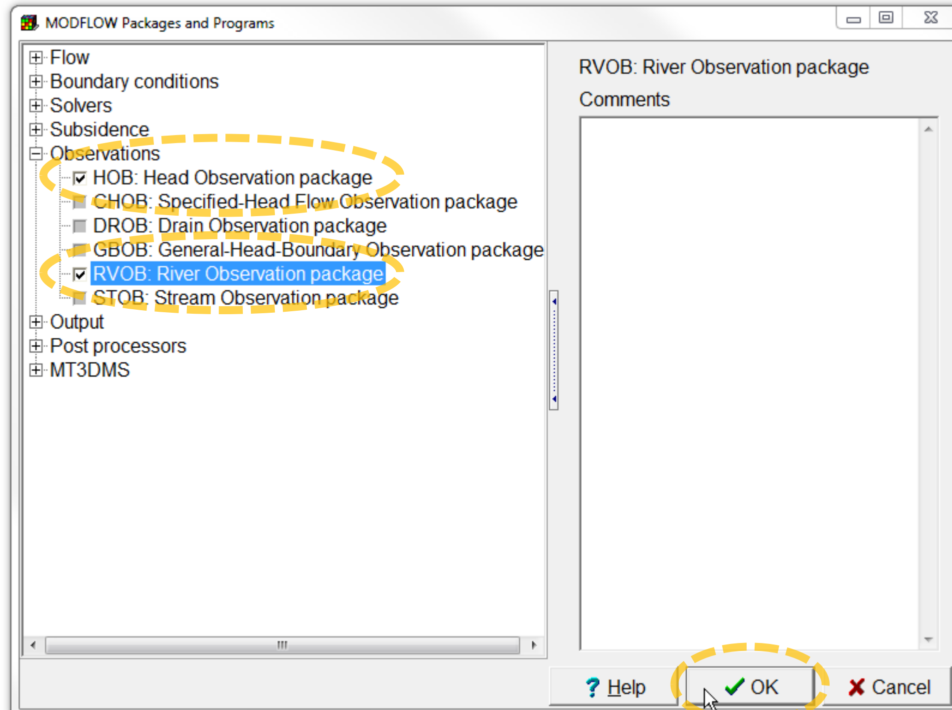
- ✓ To check that you've done everything correctly, try running the model now and then import the model results.
- ✓ The model should run to completion and the final imported heads should look like the ones on the right.



Enable Observation packages

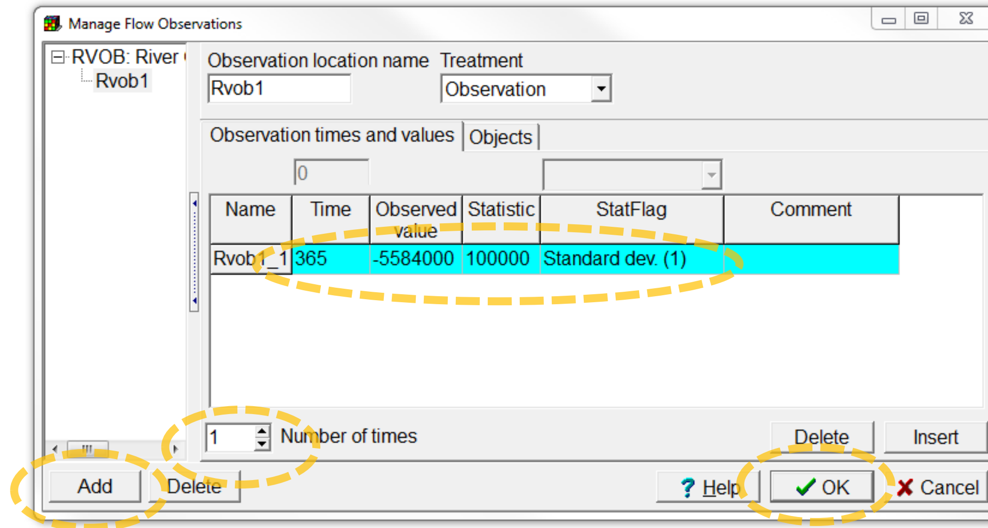
The next thing to do is to define some observations.

- ✓ Select **Model|MODFLOW Packages and Programs…** and expand **Observations**.
- ✓ Check the check boxes for the **Head Observation** and **River Observation** packages.
- ✓ Then click **OK**.



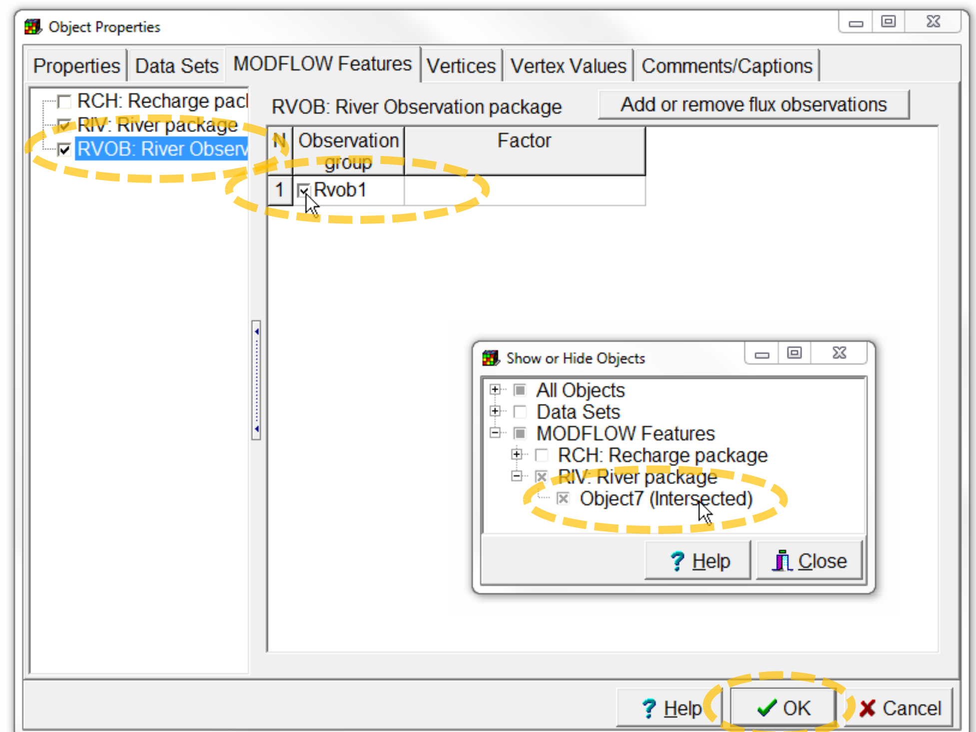
Define river observation (1/5)

- ✓ The **Manage Flow Observations** dialog box appears. Select the **river observation package** and click the **Add** button.
- ✓ Change the **number of times** to 1.
- ✓ Enter 365 for the **Time**,
- ✓ -5584000 for the **Observed value** (negative sign means that the water is leaving the aquifer and entering the river),
- ✓ 100000 for the **Statistic**, and
- ✓ **Standard dev. (1)** for the **StatFlag**.
- ✓ Then click **OK**.



Define river observation (2/5)

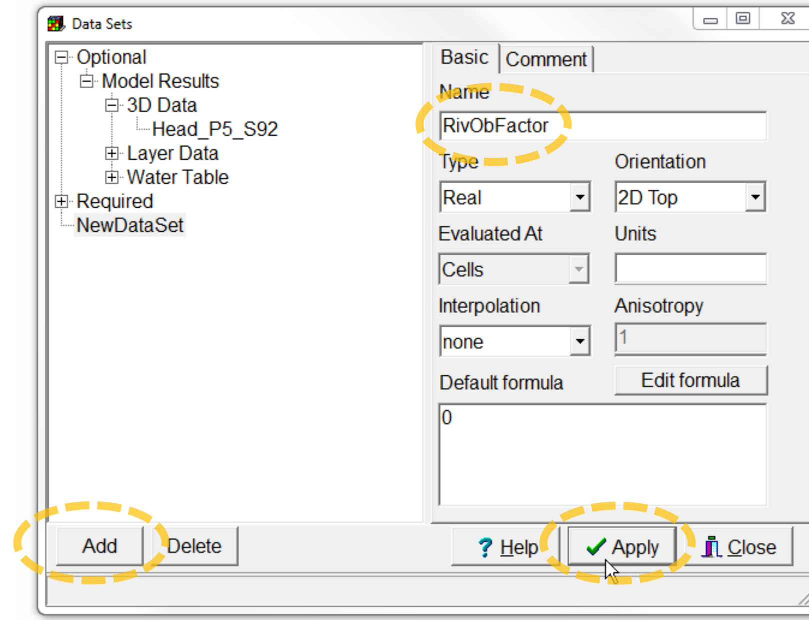
- Select **Object|Show or Hide Objects**, expand **MODFLOW Features|River package** and double click on the object listed there to open the **Object Properties** dialog box.
- On the **MODFLOW Features** tab, select the river observation package and check the check box for the **Rvob1** observation group. You can leave **Factor** blank for now.
- Then press **OK**.



Define river observation (3/5)

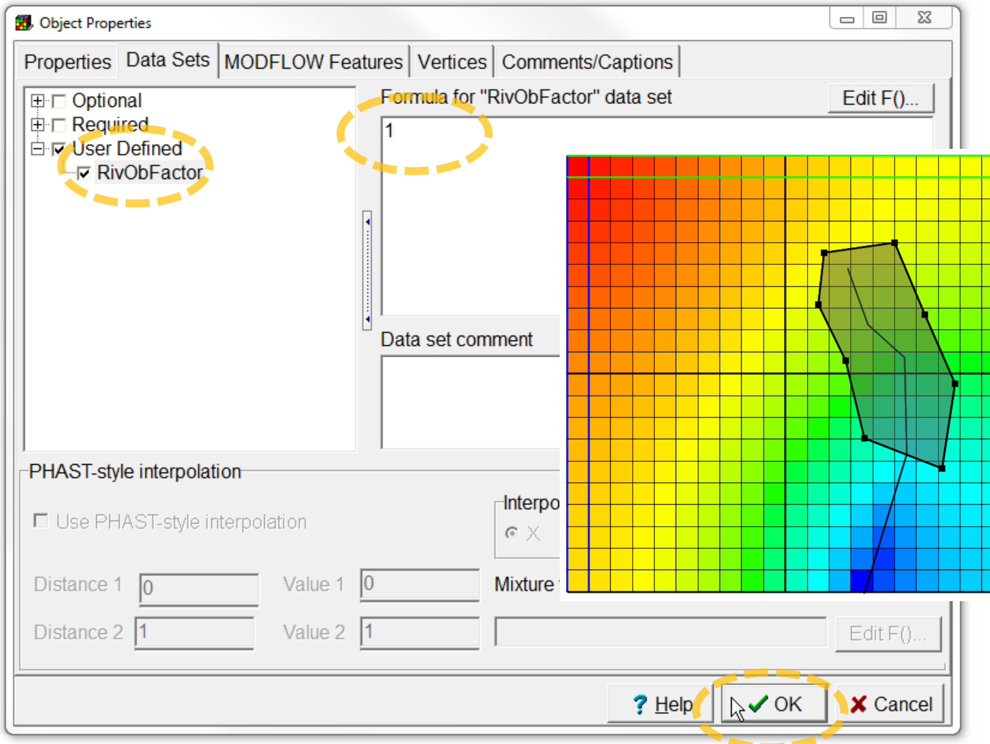
The observation doesn't apply to the whole object. If it did, we would just set Factor to 1. Instead, we will create a new data set that will have a value of 1 where the river cells are part of the river observation and 0 everywhere else.

- ✓ Select **Data|Edit Data Sets...** and click the **Add** button.
- ✓ Change the name of the new data set to **RivObFactor**.
- ✓ Note that the Default formula is 0.
- ✓ Then click the **Apply** button.



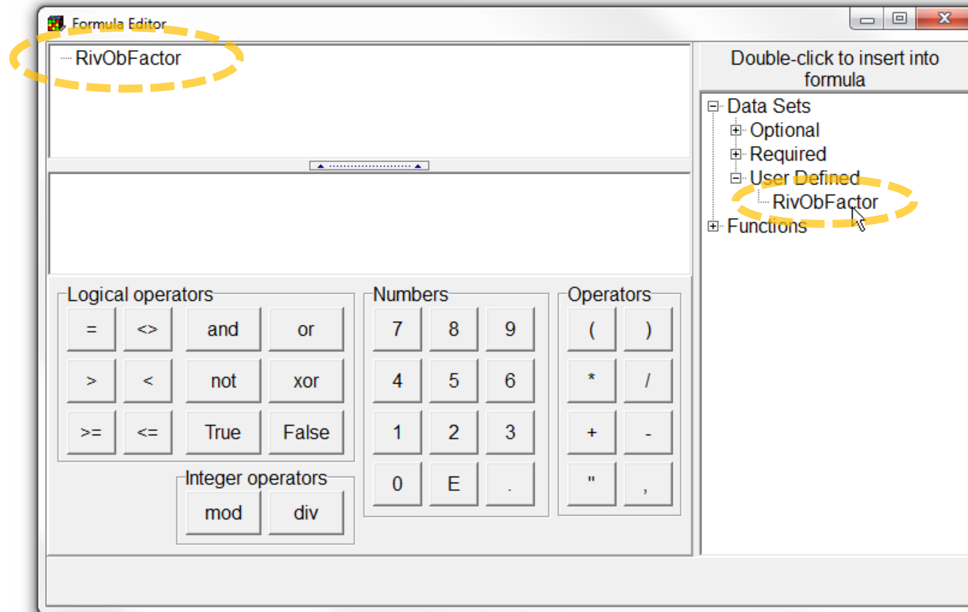
Define river observation (4/5)

- ✓ Now draw a polygon that surrounds the portion of the river object that extends from the upstream end down through the next to last vertex as illustrated on the right.
- ✓ In the **Object Properties** dialog box, go to the **Data Sets** tab and expand **User Defined**. Check the check box for **RivObFactor** and set the formula to **1**.
- ✓ Click **OK**.



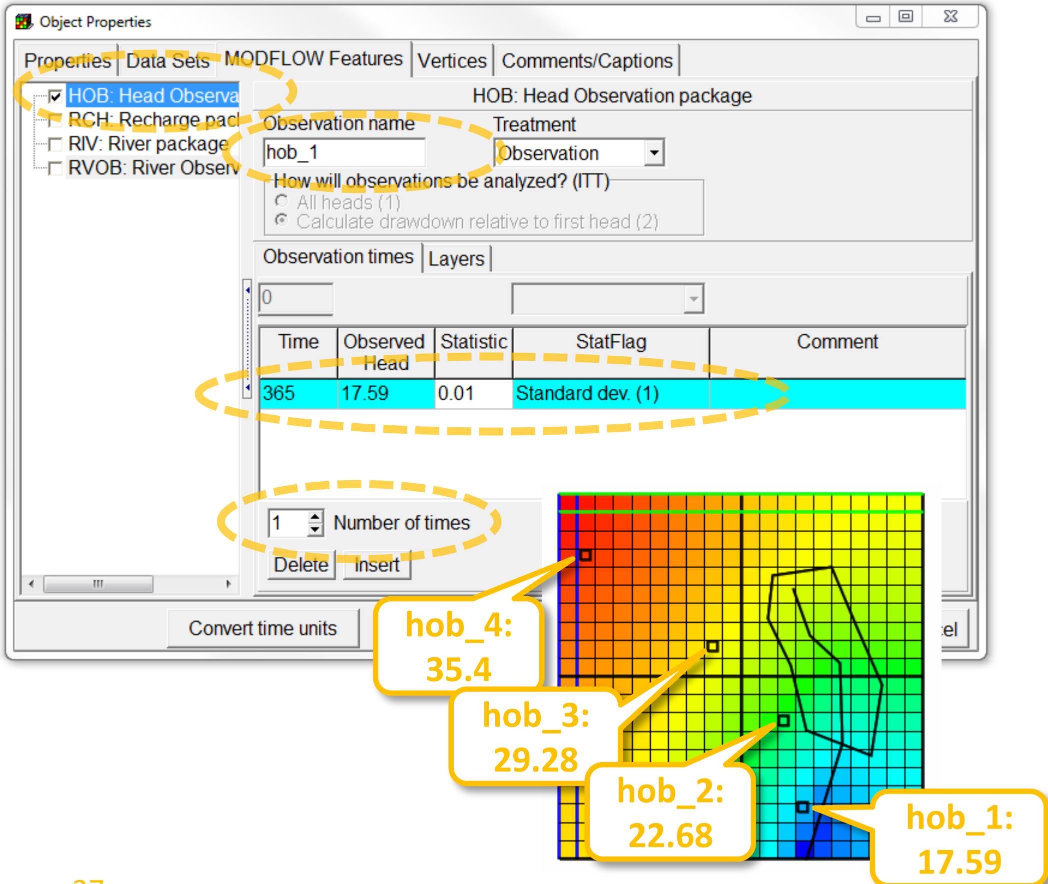
Define river observation (5/5)

- ✓ Now double-click on the object that defines the river and go back to the **River observation** on the **MODFLOW Features** tab.
- ✓ Change the factor to **RivObFactor**. Now only those cells for which RivObFactor equals 1 will be part of the observation.



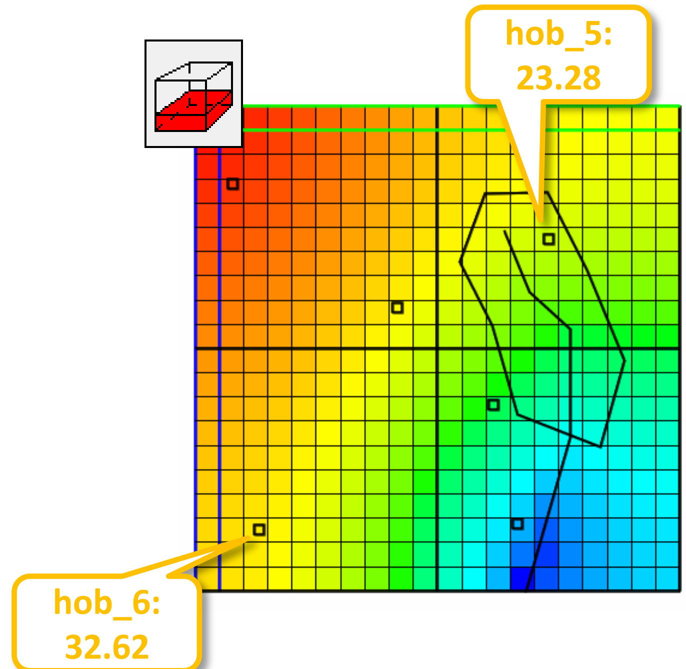
Define head observations (1/2)

- ✓ Next make sure layer 1 is the active layer and create four point objects as illustrated on the right.
- ✓ They will define the head observations in this layer. They all define observations at time 365, with a standard deviation of 0.01.
- ✓ The observed heads at each point are shown next to each object.
- ✓ Make sure to use observation names “hob_1” to “hob_4”



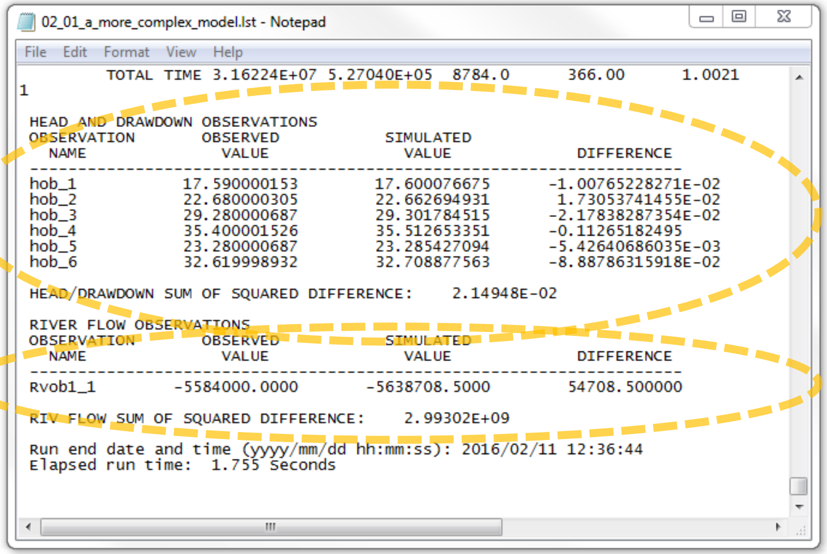
Define head observations (2/2)

- ✓ Next make sure layer 3 is the active layer and create two more point objects as illustrated on the right.
- ✓ They will define the head observations in the third layer. They again define observations at time = 365, with a standard deviation of 0.01.
- ✓ The observed heads at each point are shown next to each object.
- ✓ Make sure to use observation names “hob_5” and “hob_6”



Check model performance

- ✓ You can now run the model.
- ✓ At the end of the listing file, you can check and see how good the simulated values match the observed ones.



02_01_a_more_complex_model.lst - Notepad

File Edit Format View Help

```
         TOTAL TIME 3.16224E+07 5.27040E+05  8784.0       366.00       1.0021
1

 HEAD AND DRAWDOWN OBSERVATIONS
 OBSERVATION          OBSERVED            SIMULATED
   NAME                VALUE                VALUE                DIFFERENCE
 -------------------------------------------------------------------------------
 hob_1               17.590000153        17.600076675        -1.00765228271E-02
 hob_2               22.680000305        22.662694931         1.73053741455E-02
 hob_3               29.280000687        29.301784515        -2.17838287354E-02
 hob_4               35.400001526        35.512653351        -0.11265182495
 hob_5               23.280000687        23.285427094        -5.42640686035E-03
 hob_6               32.619998932        32.708877563        -8.88786315918E-02

 HEAD/DRAWDOWN SUM OF SQUARED DIFFERENCE:     2.14948E-02

 RIVER FLOW OBSERVATIONS
 OBSERVATION          OBSERVED            SIMULATED
   NAME                VALUE                VALUE                DIFFERENCE
 -------------------------------------------------------------------------------
 Rvob1_1            -5584000.0000        -5638708.5000        54708.500000

 RIV FLOW SUM OF SQUARED DIFFERENCE:     2.99302E+09

 Run end date and time (yyyy/mm/dd hh:mm:ss): 2016/02/11 12:36:44
 Elapsed run time:  1.755 Seconds
```

Education evenings 2016

Practical introduction
to groundwater modelling

Computer exercises
02 01 A more complex model

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