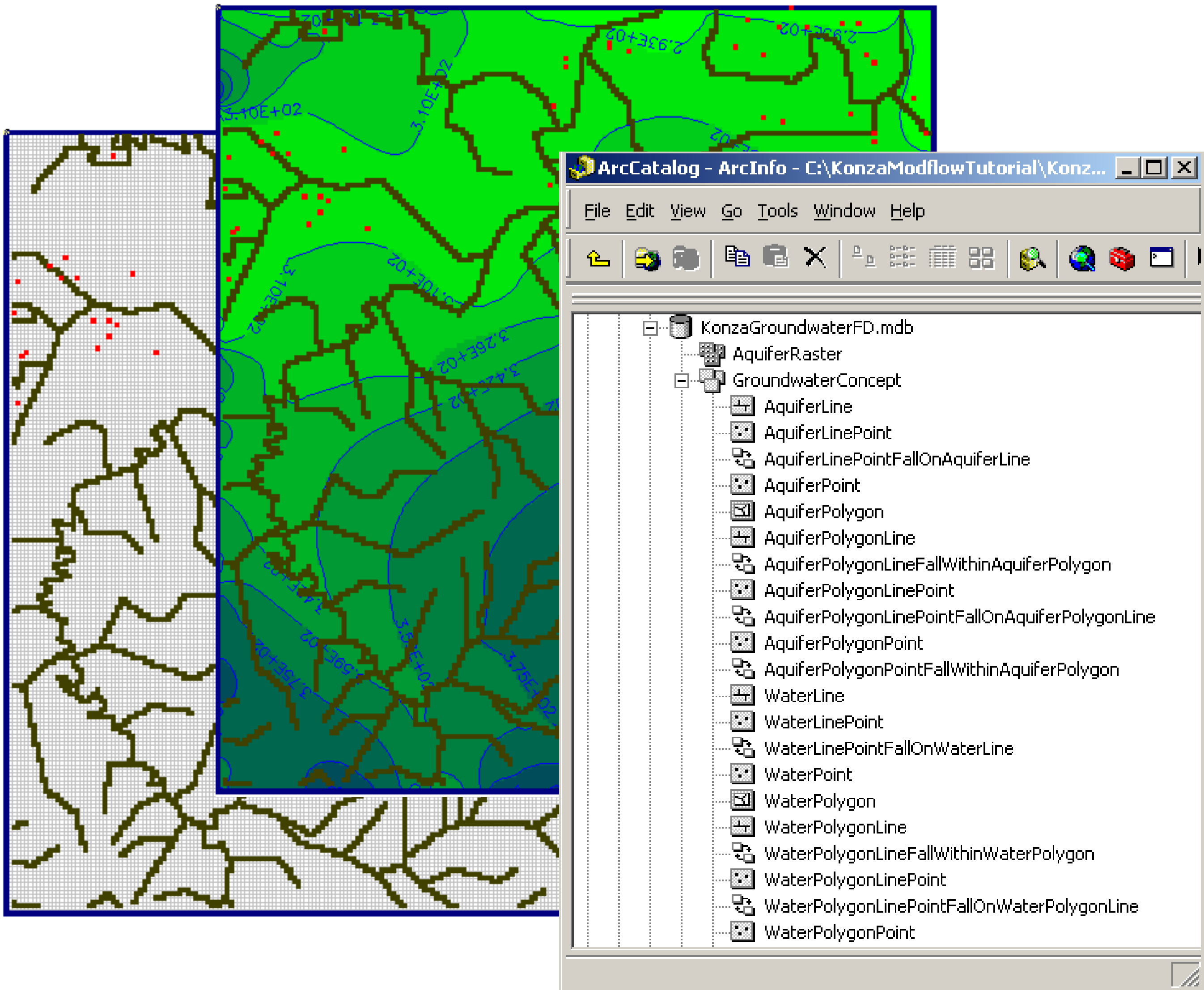
Using Conceptual Groundwater Data Model to Model Groundwater Flow with PMWIN



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2009

Introduction

This document is designed to teach the basics of creating a Groundwater Geodatabase based on the conceptual groundwater data model and extracting the data from the geodatabase to develop a Finite Difference groundwater model with PMWIN. It illustrates the procedures of data preparation and the Finite Difference groundwater model development for the Konza Prairie regional groundwater system in a step-by-step manner. Through the course of the document, you will be working with Arc Map, Arc Catalogue, Arc Toolbox and PMWIN (Processing MODFLOW for Windows). PMWIN is a simulation system for modeling ground-water flow and transport processes with MODFLOW (Chiang 2001). PMWIN 5.3 can be downloaded freely at http://www.pmwin.net/pmwin5.htm.

The following data files have been provided to allow you to work through the tutorial:

1. dem: The raster dataset on the surface elevation of the Konza region.
2. ConceptualGroundwaterDataModel.xml: The XML schema for the conceptual groundwater data model.
3. FourCounties.shp: The shapefile on the extent of the four counties surrounding Konza prairie.
4. GroundwaterDataModelForModflow.tbx: The toolbox containing tools and models created for working with the conceptual groundwater geodatabase.
5. KonzaBoundary.shp: The shapefile on the boundary of Konza prairie.
6. KansasRiverBed.shp: The shapefile on the boundary of Kansas River Bed
7. KonzaWells.mdb: The Arc Hydro Groundwater Geodatabase containing the well pumping records in Konza region.
8. NHDInThreeHUCs.shp: The shapefile on the national hydrograph river segments in three 8-HUC watersheds surrounding Konza prairie.

It is recommended that you create a new folder for saving the above data files as well as your work on this tutorial. In this tutorial, the working folder is C:\KonzaModflowTutorial.

Chapter 1: Creating the Conceptual Groundwater Geodatabase

Konza Prairie, which is an experimental nature preserve owned by the Nature Conservancy and Kansas State University, is operated for environmental research, education and preservation by Kansas State University Division of Biology. It covers more than 34 square kilometers in the tall grass prairie of the Flint Hills in northeastern Kansas, near the city of Manhattan.

The first step in groundwater modeling is to establish the modeling purpose and formulate the conceptual view of the groundwater system. The adequacy of the groundwater system conceptual view dictates the resulting groundwater models' performances. In this tutorial, the Konza groundwater system is conceptualized as a single unconfined aquifer layer consisting of two areas with different hydrogeological properties: the alluvial aquifer underlying Kansas River bed with a higher hydraulic conductivity and the fractured limestone/shale aquifer with a lower hydraulic conductivity (Figure 1).

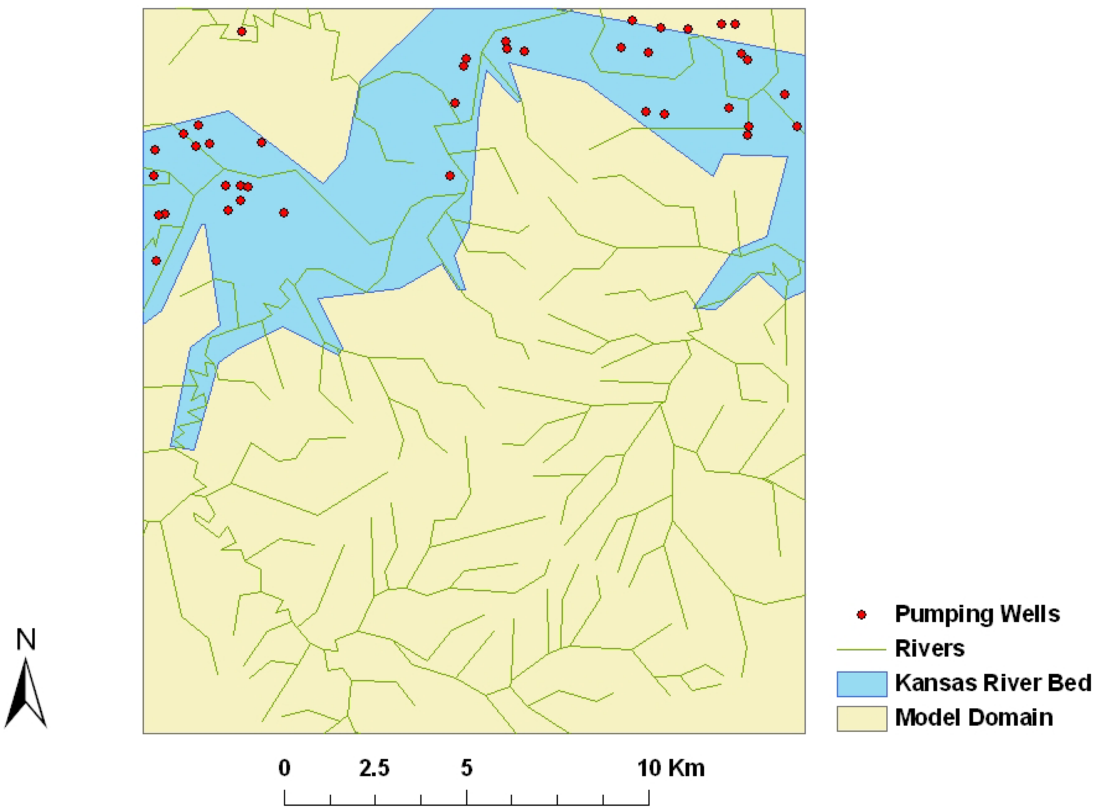
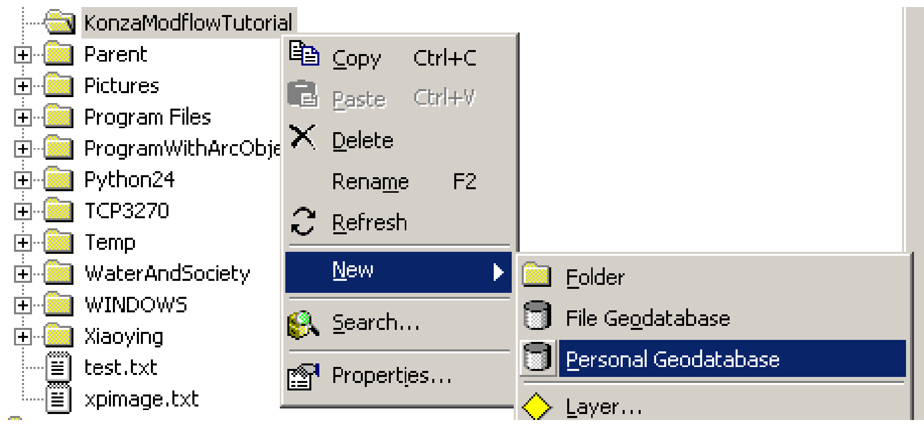


Figure 1 Conceptual View of the Konza Groundwater System

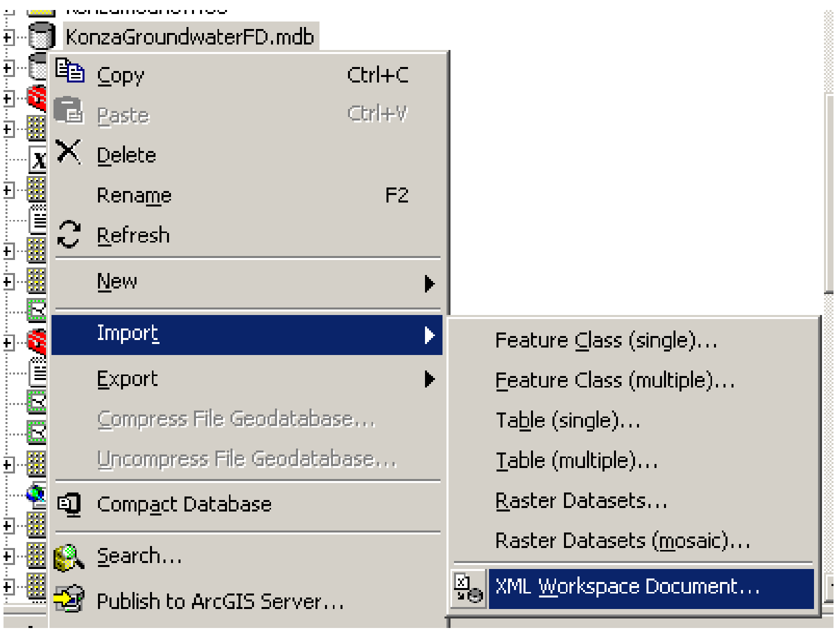
The conceptual groundwater data model is fully capable of storing the groundwater system conceptual view. In the following, we will show you how to create a new geodatabase based on the conceptual groundwater data model and how to store the Konza groundwater system conceptual view in the geodatabase.

1.1.Create an Empty Conceptual Groundwater Geodatabase

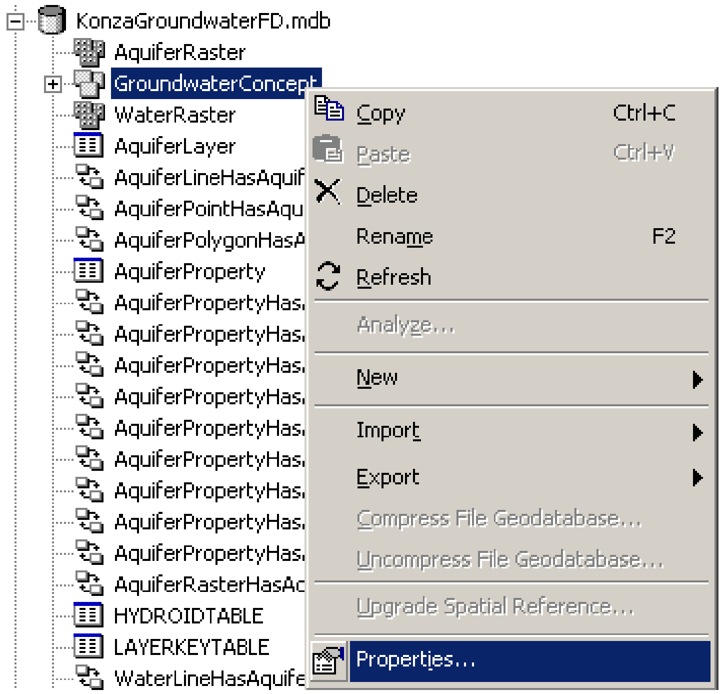
(1) Open up ArcCatalog, right click your working folder, and click "**New – Personal Geodatabase**." Name the new personal geodatabase "***KonzaGroundwaterFD.mdb.***"



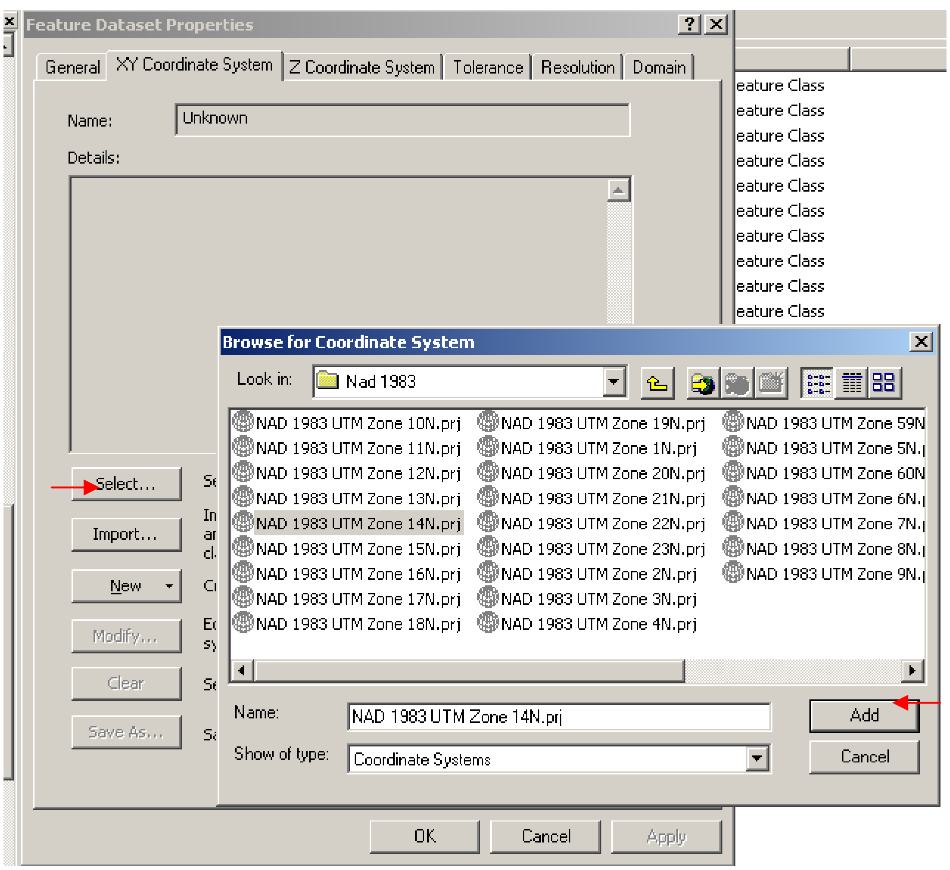
(2) Right click the empty geodatabase "***KonzaGroundwaterFD.mdb***", and click "**Import – XML Workspace Document ….**" This will import the feature dataset, feature classes, object classes, raster catalog, and relationship classes defined in the conceptual groundwater data model to our geodatabase.



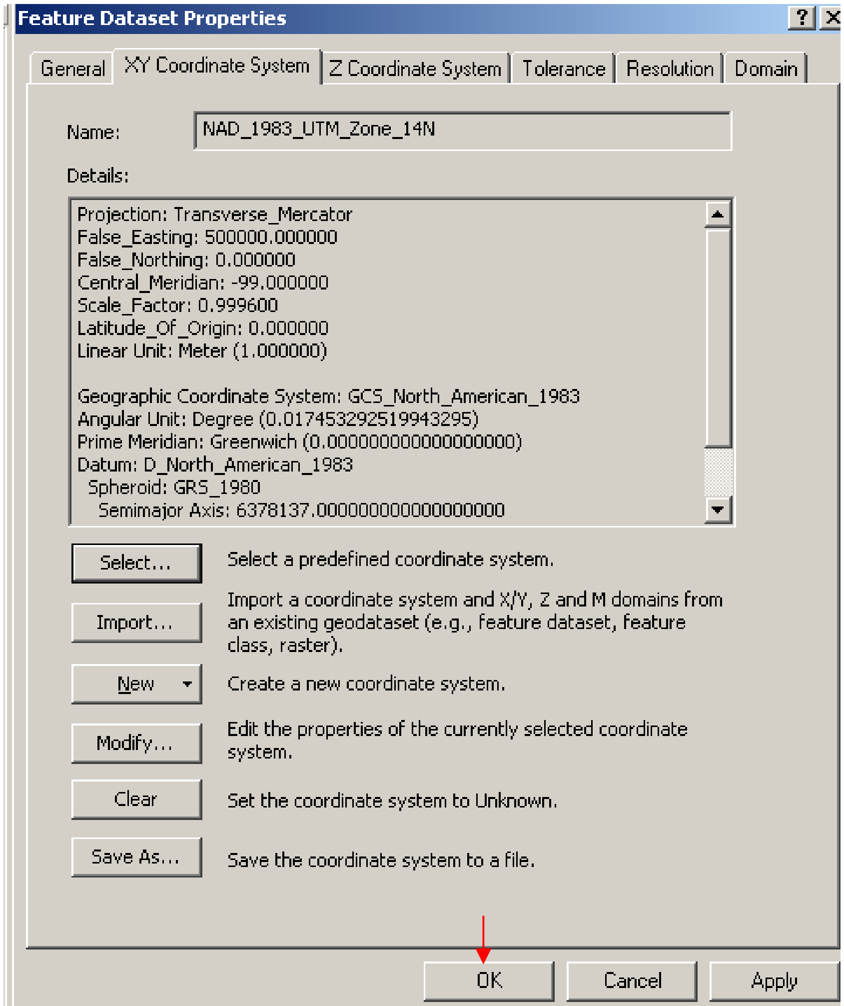
(3) Define the coordinate system for the GroundwateConcept feature dataset. Right click the GroundwaterConcept feature dataset, and click "**Properties…**"



Under the "XYCoordinate System" tab, define the projection system to be "**NAD 1983 UTM Zone 14N**." Click the "**Select …**" button, and click through the path of **Projected Coordinate Systems – Utm – Nad 1983 – NAD 1983 UTM Zone 14N.prj** in the window of "Browse for Coordinate System."



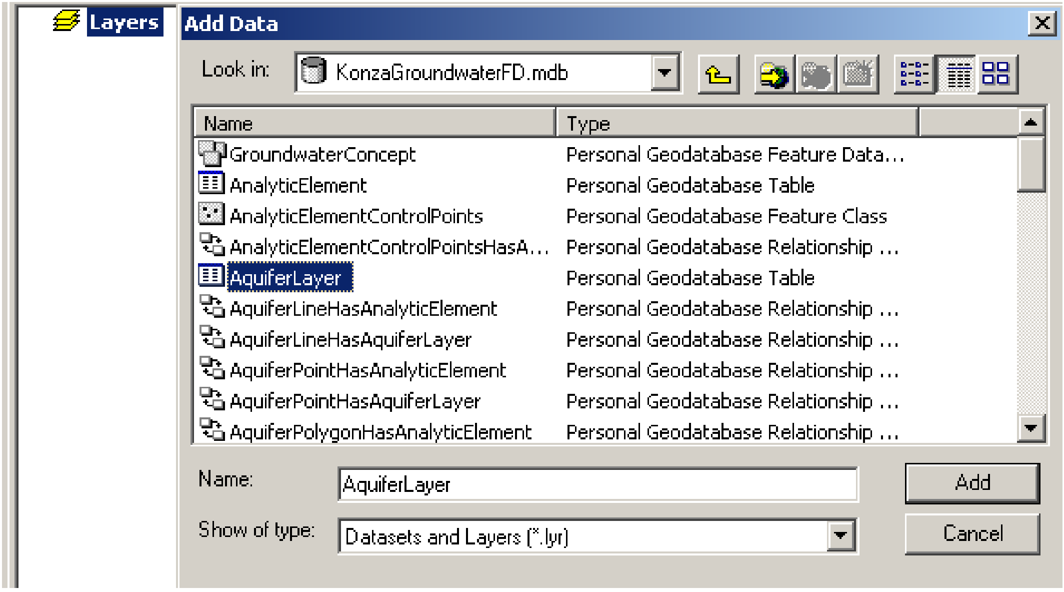
The defined XY Coordinate system should be like in the following figure. Click **OK** on the window of Feature Dataset Properties.



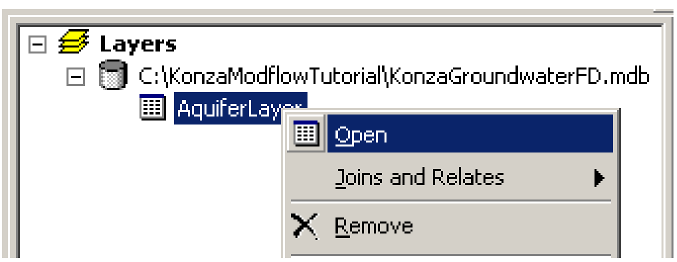
1.2.Define Aquifer Layer

Konza Prairie groundwater system is conceptualized as a single-layer system. Hence, we only need to add one record to the table ***AquiferLayer***.

(1) Open ArcMap, and add the ***AquiferLayer*** table from ***KonzaGroundwaterFD*** geodatabase.



(2) Start an edit session by selecting **Start Editing** on the **Editor** Toolbar. Then open the ***AquiferLayer*** table by right clicking it and clicking **Open**.



(3) Add a new record to represent the Konza Aquifer as the following:

(4) Click "**Editor – Save Edits**" to save the newly added record, and then click "**Editor – Stop Editing**" to exit the edit session.

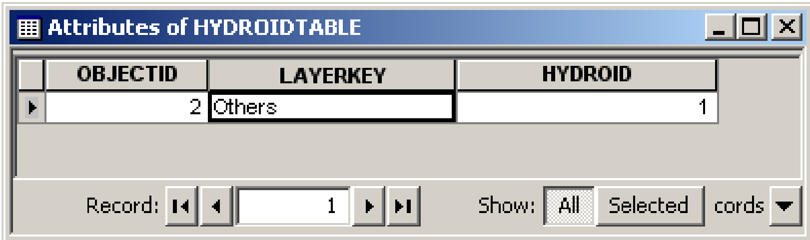
1.3. Modify the HydroIDTable

HydroIDTable is used by ArcHydro Toolbar to assign the unique **HydroID** value. Since we have just assigned **1** to the **HydroID** of the single aquifer layer, we need to update the table with the value.

(1) Add ***HydroIDTable*** to ArcMap.

(2) Start an edit session.

(3) Open ***HydroIDTable*** and make editions as shown in the following figure:



(4) Save the edits, and stop editing session.

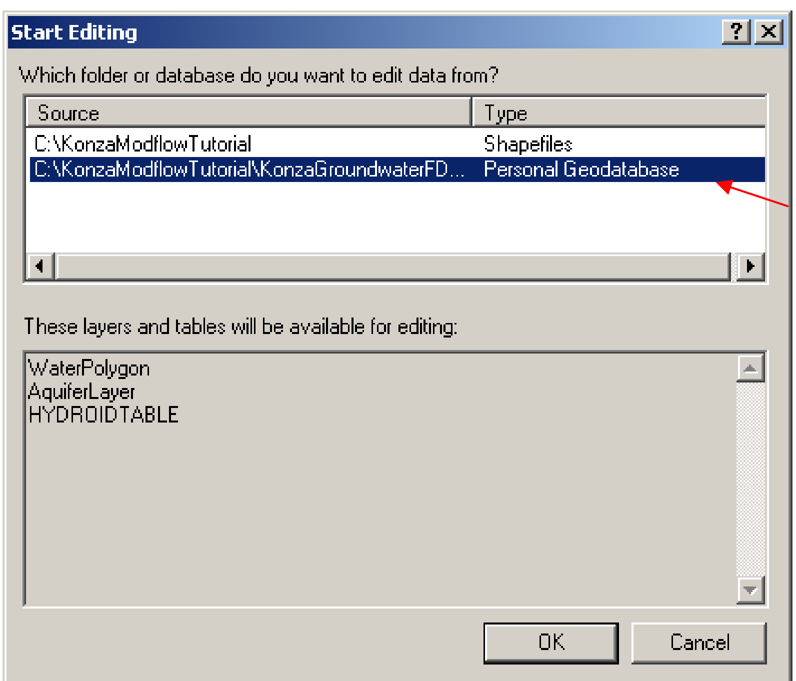
1.4.Define the Groundwater Model Domain

WaterPolygon feature class is used to store the regions with different boundary conditions. We will use the feature class to store the boundary of Konza groundwater model.

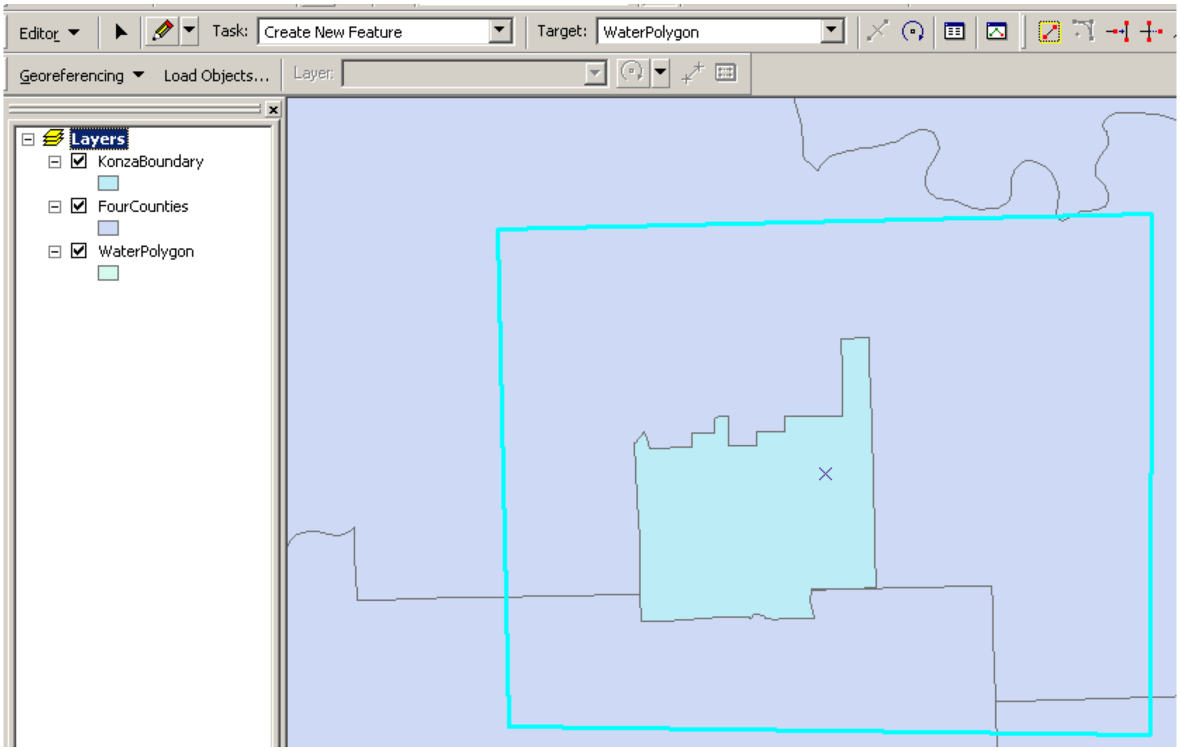
(1) Add the shapefiles "***FourCounties.shp***" and "***KonzaBoundary.shp***" to Arc Map.

(2) Add the ***WaterPolygon*** feature class to Arc Map. We will create a new polygon defining the model boundary and add it to the feature class.

(3) Zoom to the area surrounding Konza Boundary, and start an edit session. Make sure that you are editing data from the Personal Geodatabase.

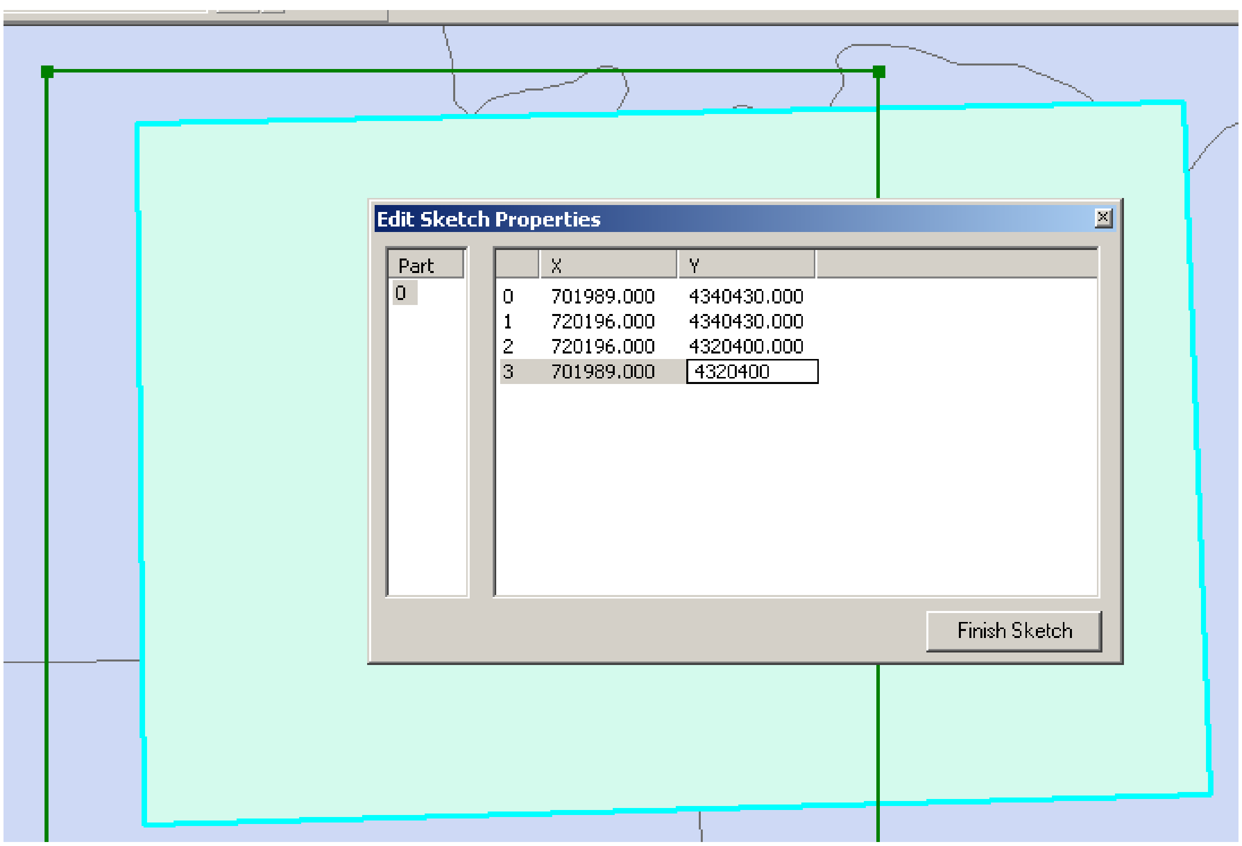


(4) Make sure that the target of editing is "***WaterPolygon***", and use the sketch tool  to draw a rectangle around Konza. Finish the sketch by double clicking the last vertex.



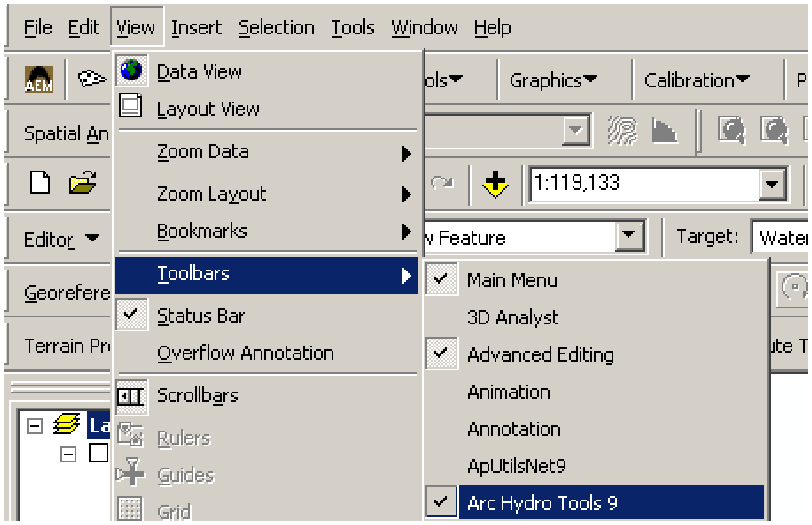
(5) Modify the coordinates of the newly sketched polygon. Use the **edit tool** to double click the newly sketched polygon, and its four vertices will show on the screen.

Click the **sketch properties button** . Change the X, Y coordinates on the "**Edit Sketch Properties**" window as shown in the following figure. Click **Finish Sketch** after you finish.

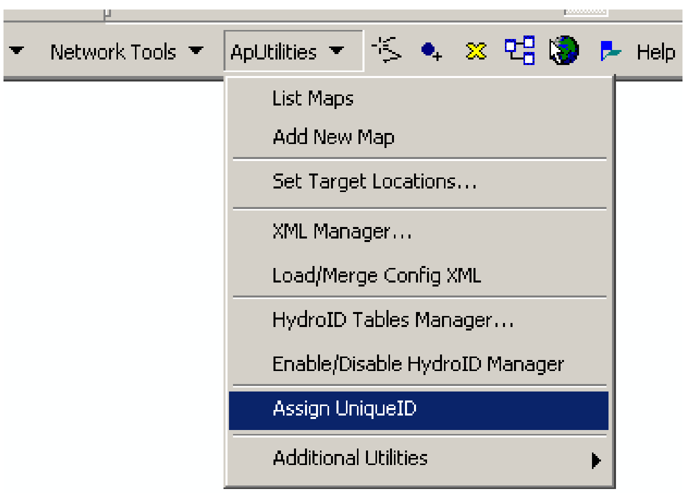


(6) Save the edits, and stop the edit session.

(7) If the ArcHydro toolbar is not already added, add it by clicking "**View – Toolbars – ArcHydro Tools 9**."



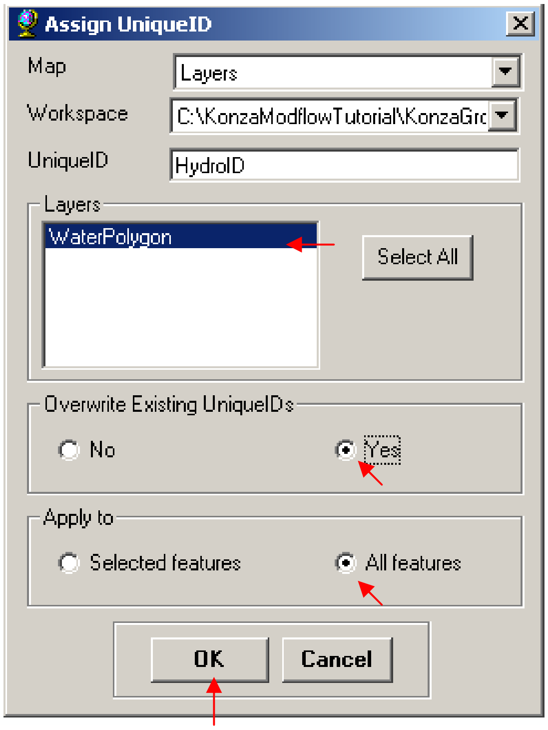
(8) On the ArcHydro toolbar, click "**ApUtilities – Assign UniqueID**."

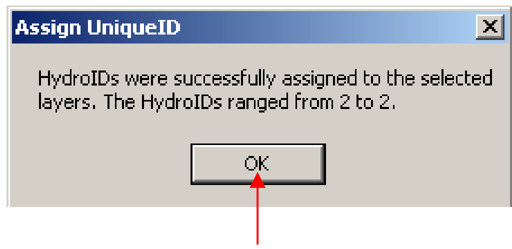


(9) On the "**Assign Unique ID**" window, specify the options as in the following figure:

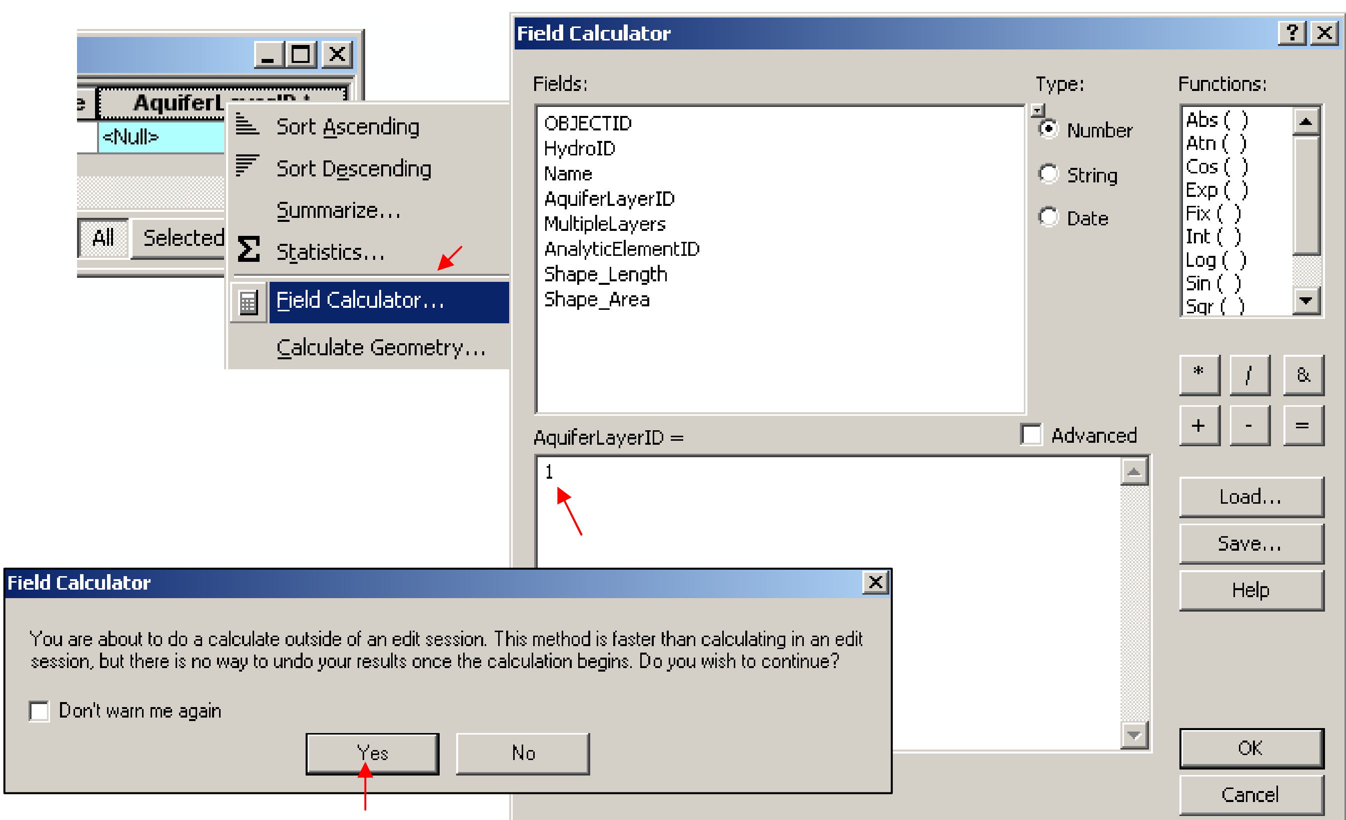
- Select the *WaterPolygon* layer
- Select the option of "yes" to overwrite existing unique IDs
- Select the option of applying to all features

Click **OK**. Then, click **OK** on the subsequent window to accept the assigned HydroID values.





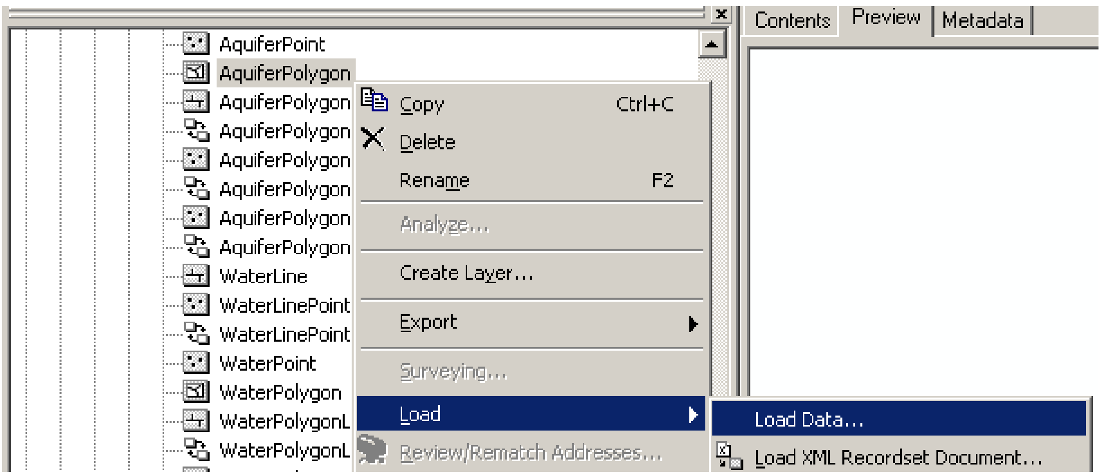
(10) Open the attribute table of ***WaterPolygon***. Calculate the field AquiferLayerID to be equal to **1**, which is the HydroID value of the single aquifer layer. Right click the field AquiferLayerID, and click "**Field Calculator…**" Click **OK** to accept calculating outside the edit session. Type "1" in the **Field Calculator** window, and click **OK**.



1.5.Populate the AquiferPolygon Feature Class

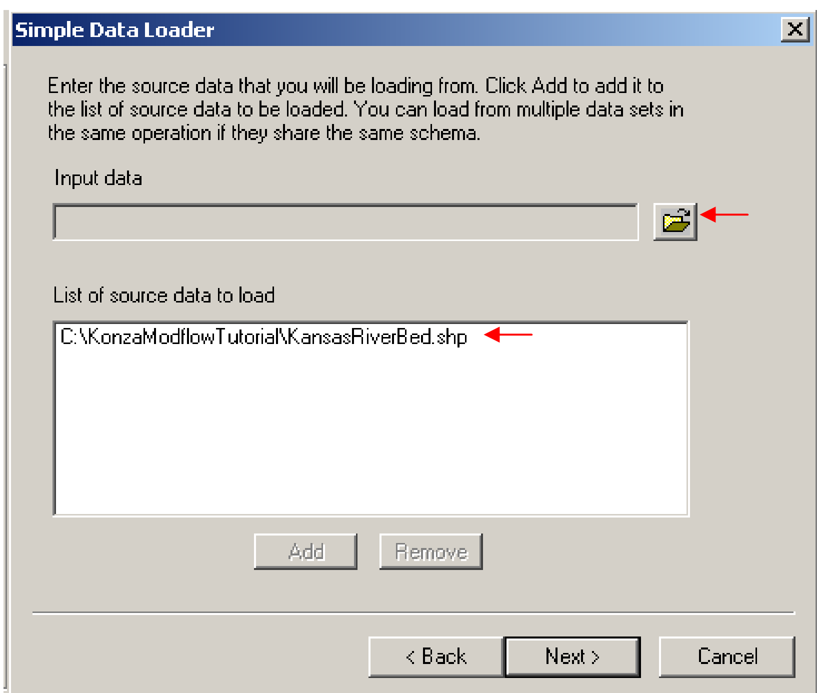
AquiferPolygon feature class is used to store the regions with different aquifer property values. In this case, the Kansas River bed has a higher hydraulic conductivity relative to the rest of the modeling area. We will add Kansas River bed to the ***AquiferPolygon*** feature class. For your convenience, we have provided the boundary of Kansas River bed (***KansasRiverBed.shp***).

(1) In Arc Catalog, right click the ***AquiferPolygon*** feature class, and click "**Load – Load Data**…."

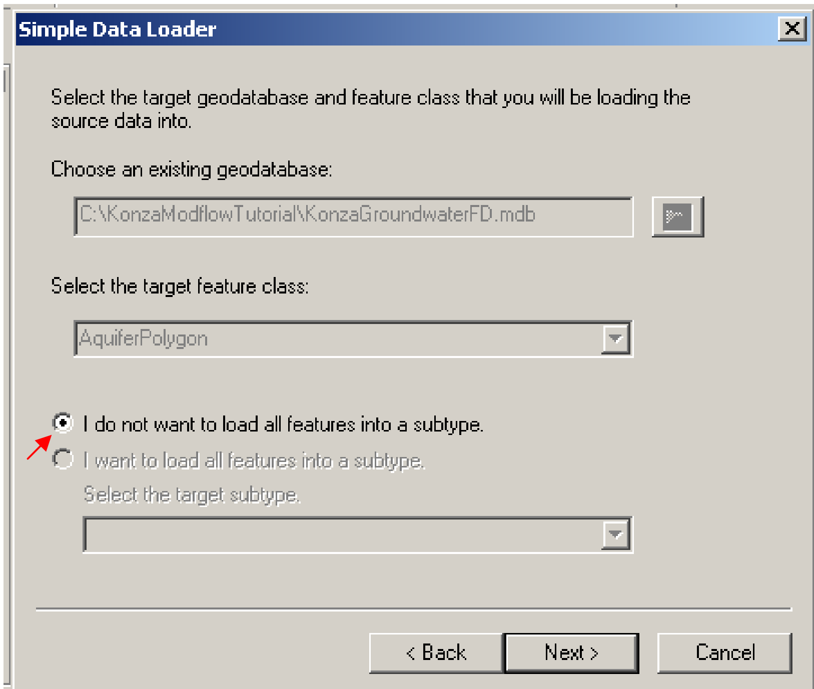


(2) Click **Next** on the first "**Simple Data Loader**" screen.

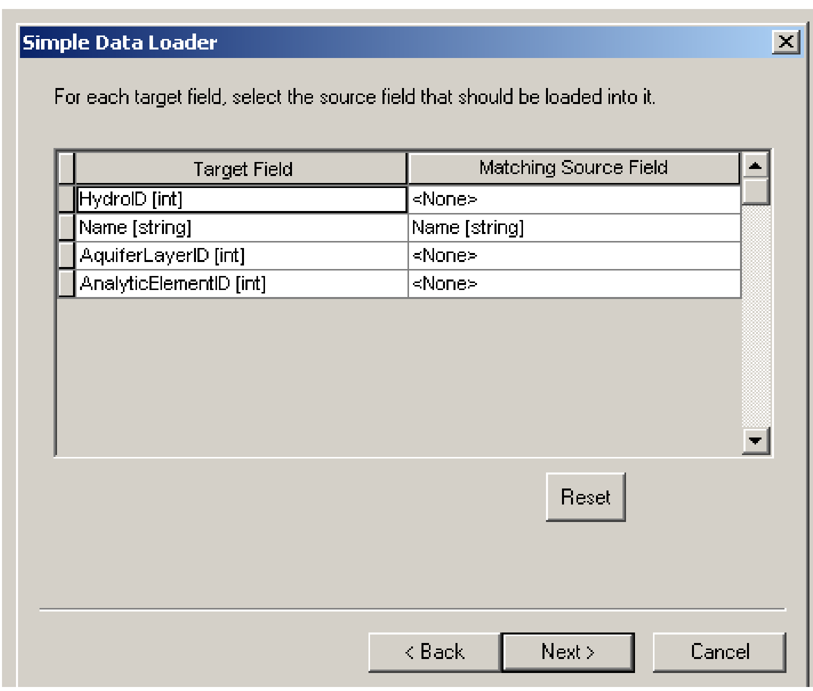
(3) On the first screen of "**Simple Data Loader**", browse to add the shapefile "***KansasRiverBed.shp***" for data loading. Click **Next**.



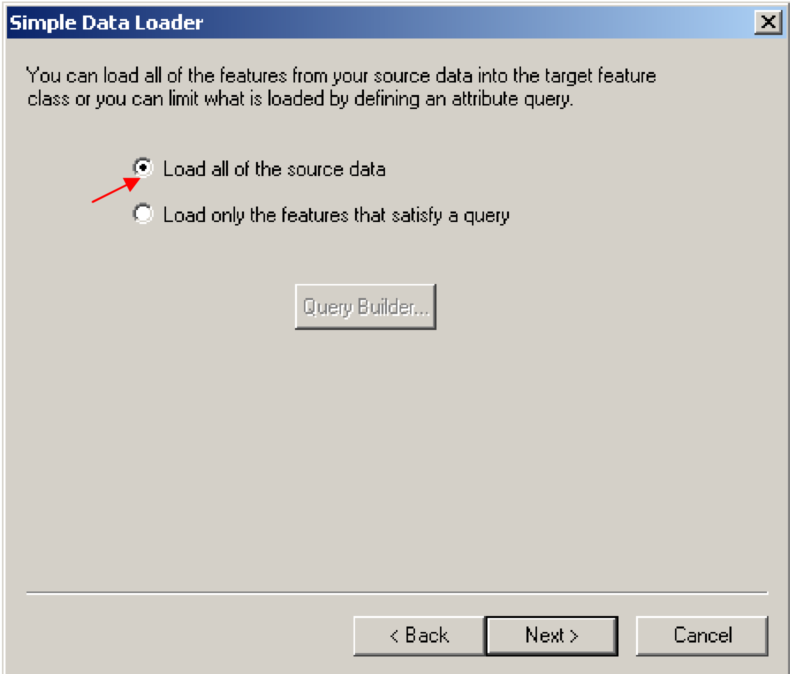
(4) Accept the option of not loading all features into a subtype. Click **Next**.



(5) Accept the default field matching, and click **Next**.



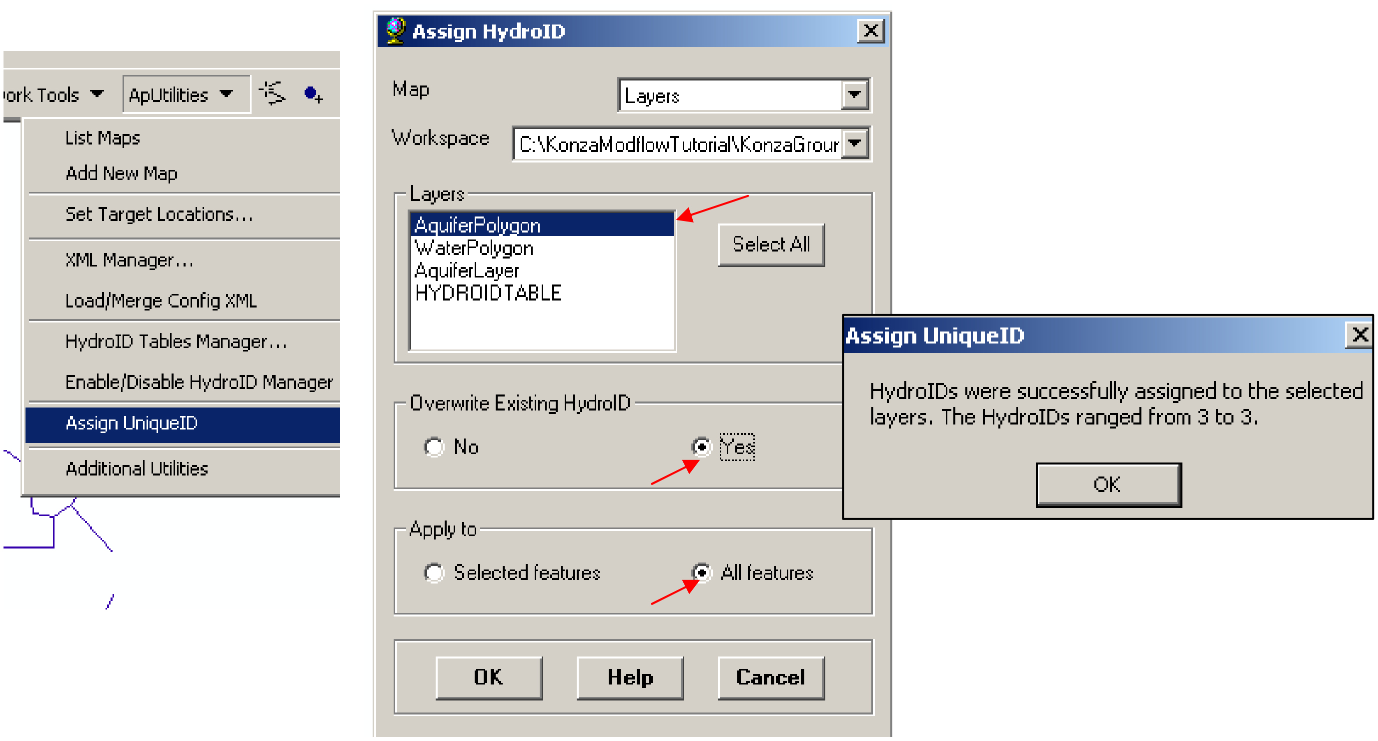
(6) Make sure to choose the option of loading all of the source data, and click **Next**.



(7) Click **Finish** on the final summary window. Examine the ***AquiferPolygon*** feature class, and your can see a new polygon feature has just been added to it.

(8) Now, we need to edit the attribute table of ***AquiferPolygon***. Add ***AquiferPolygon*** to ArcMap. Open its attribute table, and calculate the value of the field AquiferLayerID to be **1** (Please refer to step 10 in section 1.4 if you have questions).

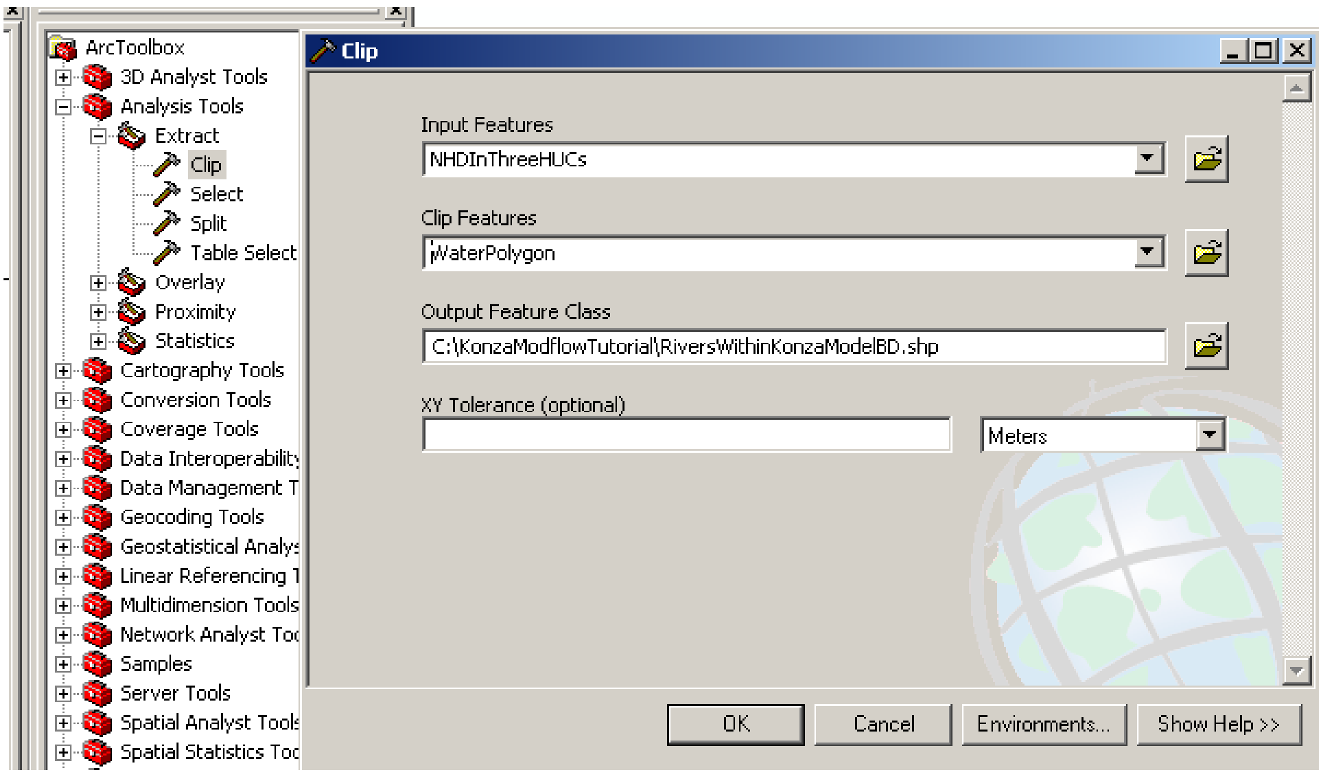
(9) Use ArcHydro toolbar to assign the unique HydroID value for ***AquiferPolygon*** in the same way we did for ***WaterPolygon*** in section 1.4.



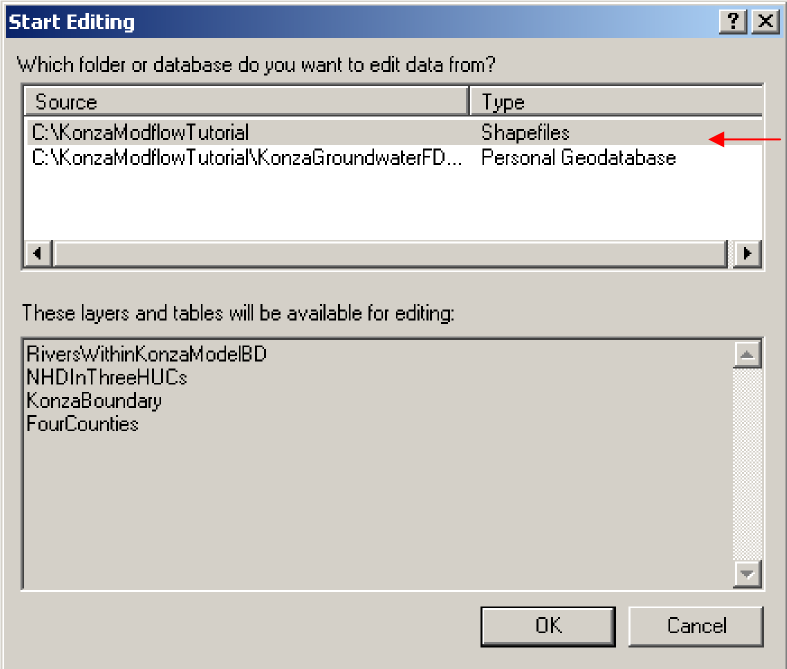
1.6.Populate the WaterLine Feature Class

WaterLine feature class is used to store the boundary conditions that are defined along lines. We will use the feature class to store the river segments in the area. Data on river networks can be obtained from the National Hydrography Dataset (NHD). For your convenience, we have provided the NHD datasets (***NHDInThreeHUCs.shp***) for three watersheds that overlaps the modeling area (HUC 10270101, HUC 10270102, and HUC 10270205).

(1) First, we will get the river segments that fall within our modeling domain by clipping the NHD river segments with ***WaterPolygon***. Add the shapefile ***NHDInThreeHUCs.shp*** to Arc Map. Open the **Clip** tool under the **Extract** toolset of the **Analysis Tools** toolbox, and specify the parameters for the tool as shown in the following figure, and click **OK**.



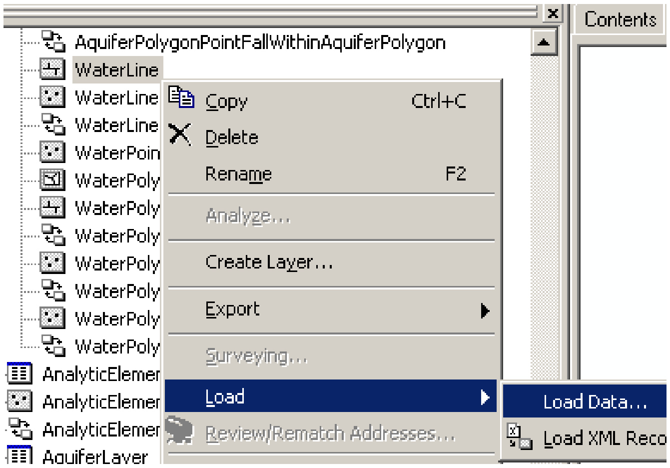
(2) Zoom to the modeling area if needed. The river segments are too detailed for our modeling purpose, and we need to simplify them. To do so, start an edit session, and specify to edit the shapefiles in your working folder.

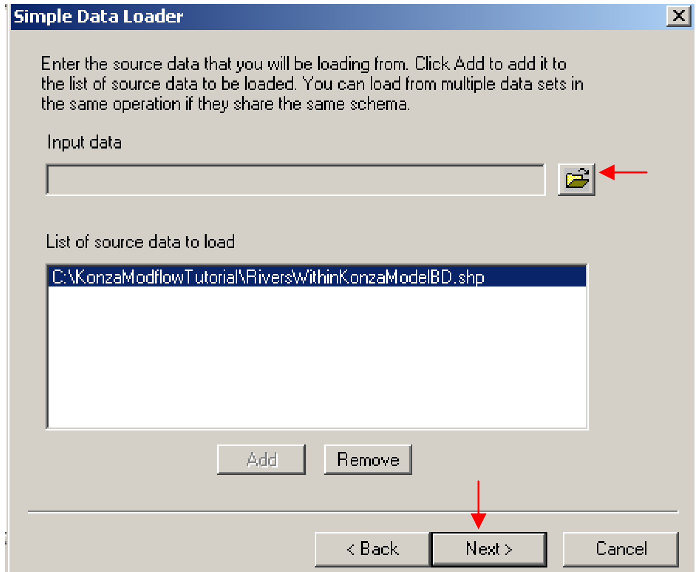


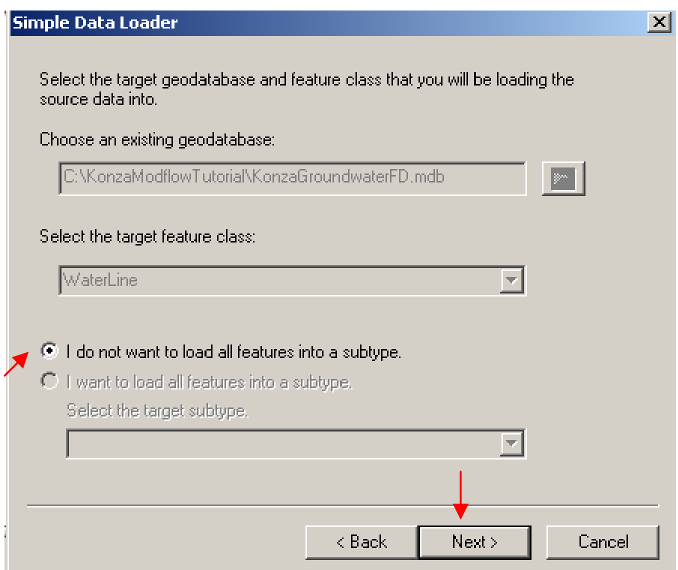
(3) Uncheck every layer except the layer **RiversWithinKonzaModelBD**. Make sure that the editing target is **RiversWithinKonzaModelBD**. Use the edit tool to select all of the river segments. Click the Generalize tool , specify the maximum allowable offset criteria to be **200**, and click OK. You will see that the river segments have been simplified to become less winding. Save the edits and exit edit session.

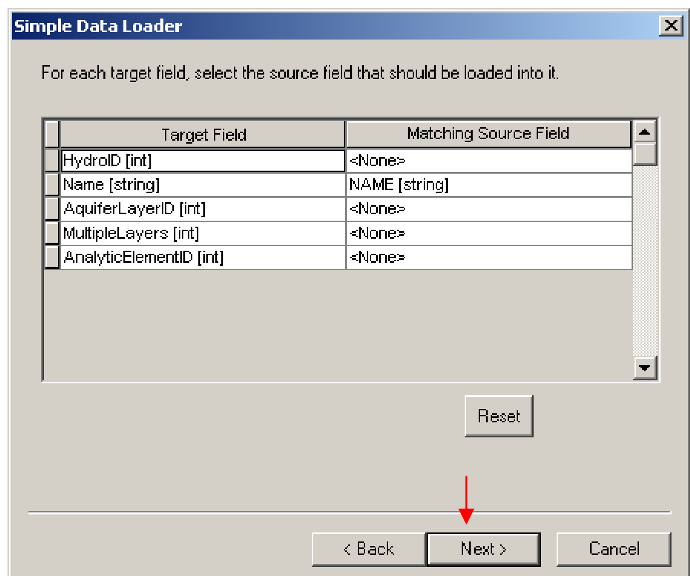
(4) On Arc Catalog, load the simplified river segments from ***RiversWithinKonzaModelBD.shp*** to the ***WaterLine*** feature class as shown in the following figures. The main loading steps are:

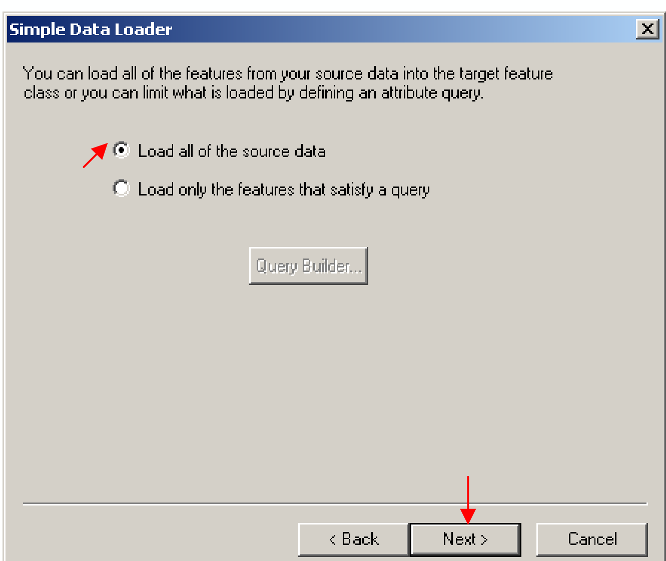
- Right click ***WaterLine***, and click "**Load – Load Data…**"
- Browse to add the shapefile – ***RiversWithinKonzaModelBD.shp***.
- Choose the option of not loading all features into a subtype.
- Accept the default field matching.
- Choose the option of loading all of the source data.

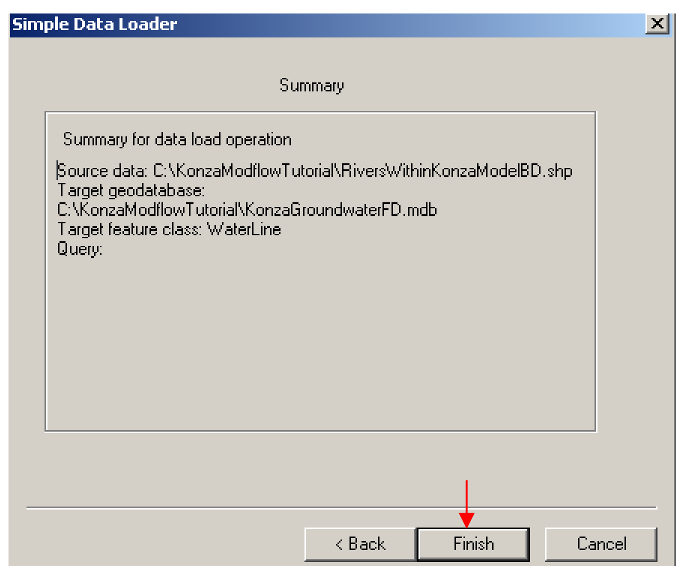

AquiferPolygonPointFallWithinAquiferPolygon
WaterLine
Contents
Copy Ctrl+C
Delete
Rename F2
Analyze...
Create Layer...
Export
Surveying...
Load
Load Data...
Load XML Reco
Review/Rematch Addresses...
AnalyticElemen
AquiferLayer


Simple Data Loader
Enter the source data that you will be loading from. Click Add to add it to the list of source data to be loaded. You can load from multiple data sets in the same operation if they share the same schema.
Input data
List of source data to load
C:\KonzaModflowTutorial\RiversWithinKonzaModelBD.shp
Add
Remove
< Back
Next >
Cancel


Simple Data Loader
Select the target geodatabase and feature class that you will be loading the source data into.
Choose an existing geodatabase:
C:\KonzaModflowTutorial\KonzaGroundwaterFD.mdb
Select the target feature class:
WaterLine
I do not want to load all features into a subtype.
I want to load all features into a subtype.
Select the target subtype.
< Back
Next >
Cancel

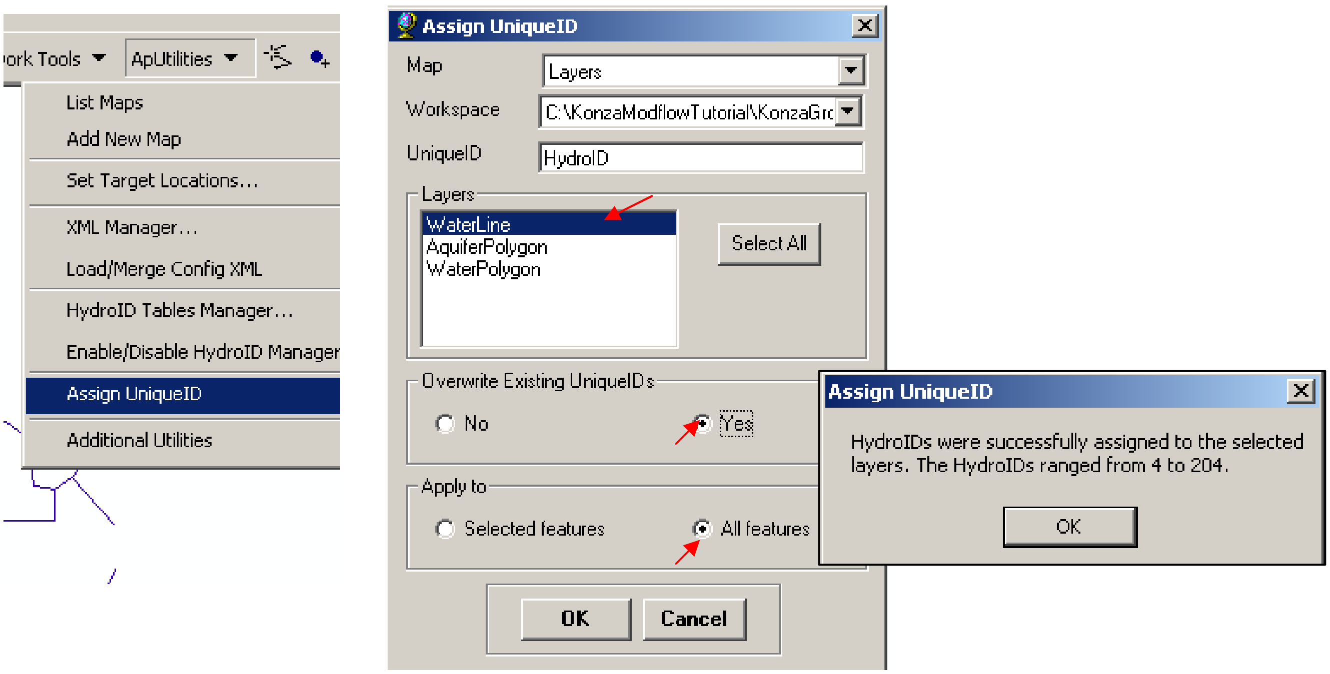

Simple Data Loader
For each target field, select the source field that should be loaded into it.
Target Field
Matching Source Field
HydroID [int]
<None>
Name [string]
NAME [string]
AquiferLayerID [int]
<None>
MultipleLayers [int]
<None>
AnalyticElementID [int]
<None>
Reset
< Back
Next >
Cancel


Simple Data Loader
You can load all of the features from your source data into the target feature class or you can limit what is loaded by defining an attribute query.
Load all of the source data
Load only the features that satisfy a query
Query Builder...
< Back
Next >
Cancel


Simple Data Loader
Summary
Summary for data load operation
Source data: C:\KonzaModflowTutorial\RiversWithinKonzaModelBD.shp
Target geodatabase:
C:\KonzaModflowTutorial\KonzaGroundwaterFD.mdb
Target feature class: WaterLine
Query:
< Back
Finish
Cancel

(5) Add the ***WaterLine*** feature class to Arc Map. Open its attribute table, and calculate the value of the field AquiferLayerID to be **1** (Please refer to step 10 in section 1.4 if you have questions).

(6) Use ArcHydro toolbar to assign unique ID values to its **HydroID** field in the same way we did for the ***WaterPolygon*** feature class in section 1.4.

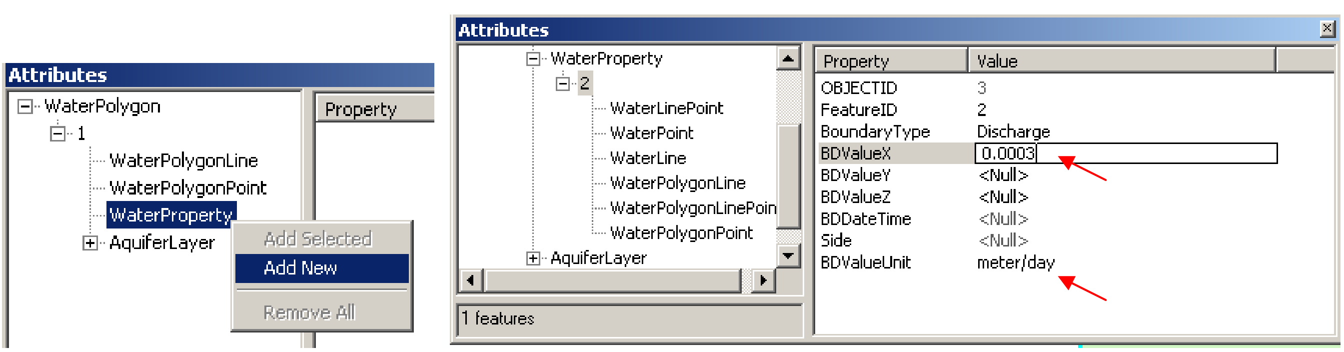


1.7. Define the Recharge Rate

In this tutorial, the recharge of the area is assumed to be uniform with a rate of a 0.0003 m/d.

(1) Add the ***WaterProperty*** table to ArcMap.

(2) Start an edit session. Use the edit tool to select ***WaterPolygon***. Click the Attributes button to display the Attributes window. Expand under ***WaterPolygon***, right click ***WaterProperty***, and click **Add New**. Set the field BDValueUnit to be equal to **meter/day**, and PropertyValueX to be **0.0003**.

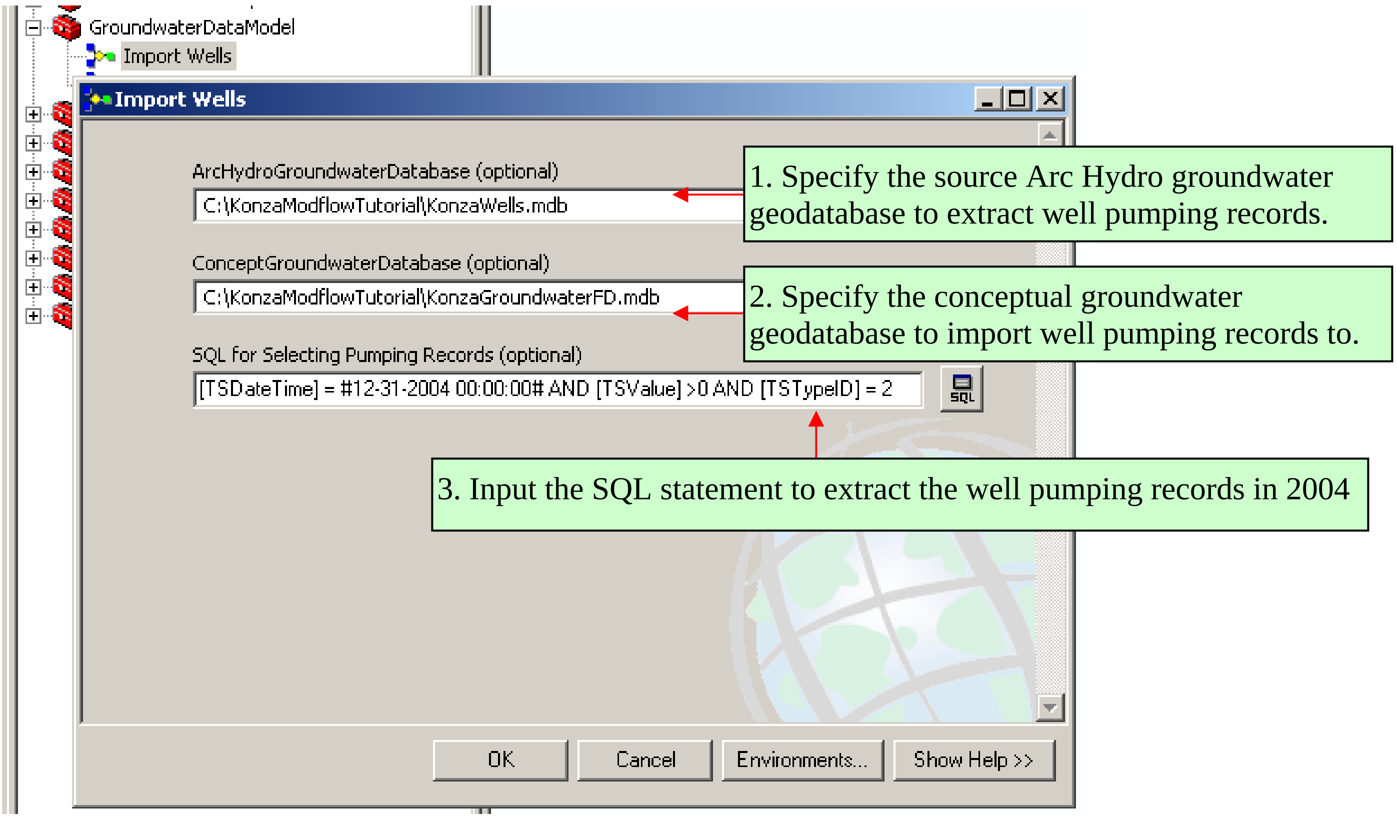


(3) Close the Attributes window. Save the edits. Open the attribute table of ***WaterProperty***, and you will find one new record has just been added with the correct FeatureID value.

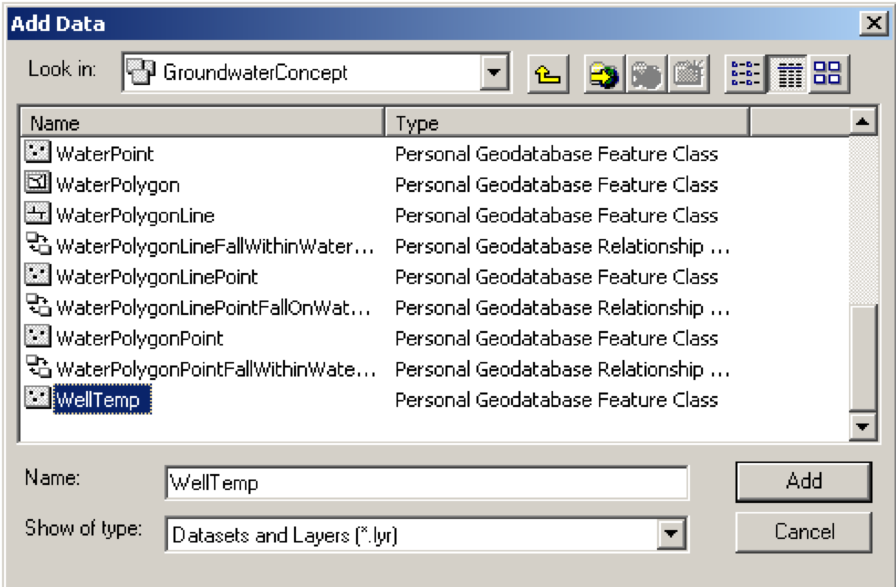
1.8.Store Well Pumping Records

Data on the pumping wells in the region are provided in the Arc Hydro groundwater geodatabase ***KonzaWells.mdb***. This geodatabase was created based on the Arc Hydro Groundwater Data Model designed at University of Texas at Austin (Strassberg 2005). For our groundwater model, we need to extract the 2004 pumping records of the wells that fall within our model domain from the Arc Hydro groundwater geodatabase.

(1) Extract the 2004 well pumping records from ***KonzaWells.mdb***. Double click the model – "Import Wells" in the GroundwaterDataModelForModflow toolbox and fill in the parameters for the model as shown in the following figure:

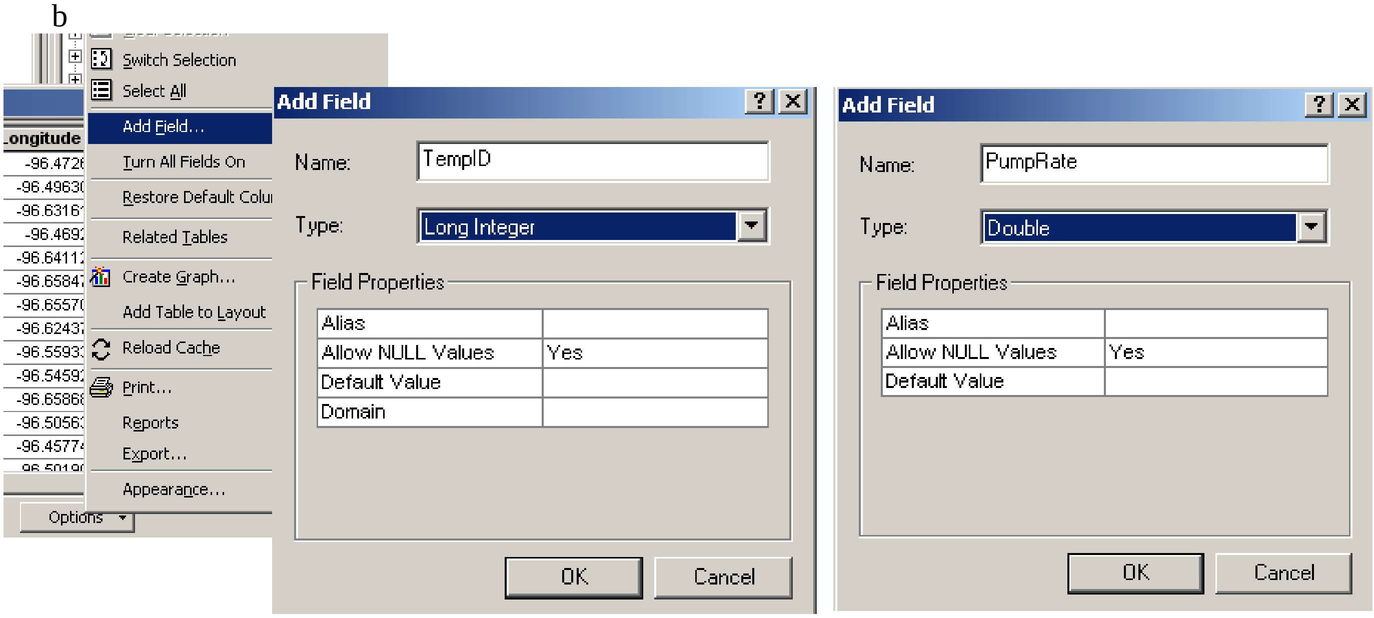


(2) The model – "Import Wells" creates a feature class named "***WellTemp***" under the ***GroundwaterConcept*** feature dataset of your groundwater geodatabase. Add the newly crated feature class "***WellTemp***" to Arc Map.

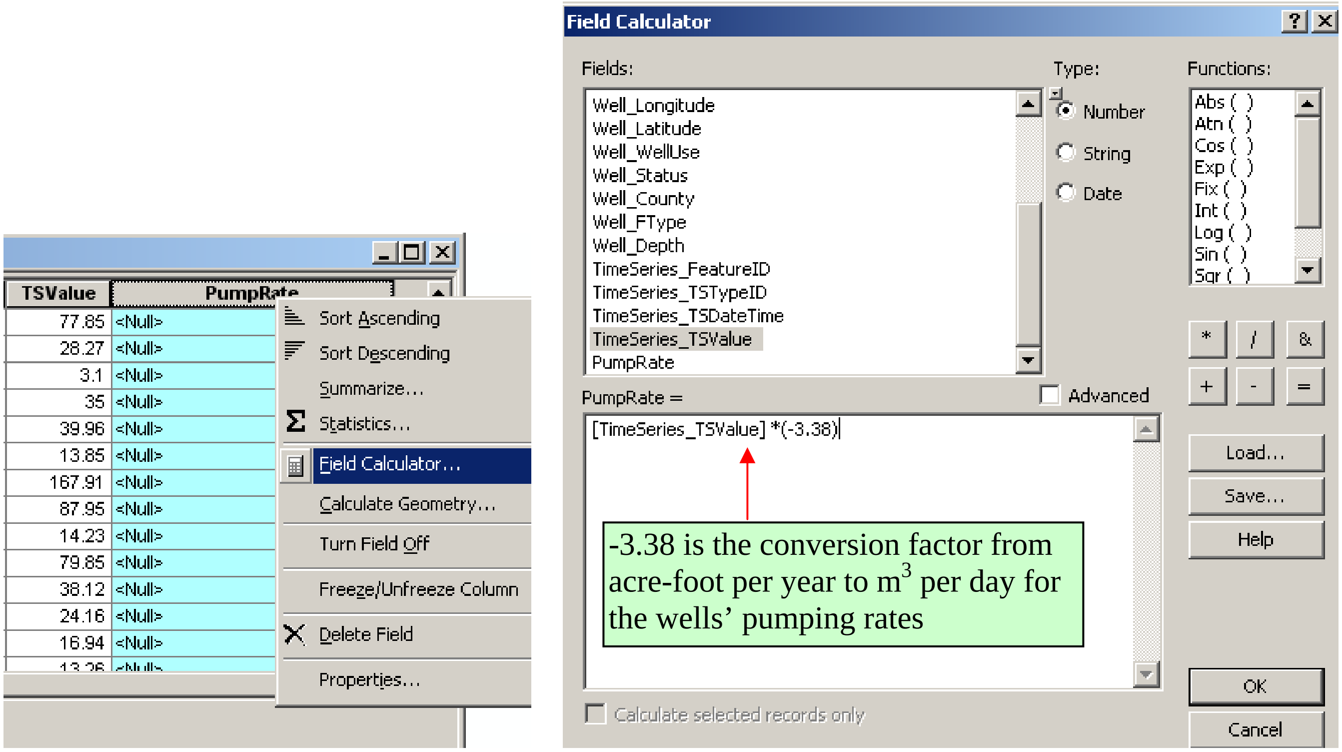


(3) Open the attribute table of the ***WellTemp*** layer, and add two fields – **TempID** (type: Long Integer) and **PumpRate** (type: Double).

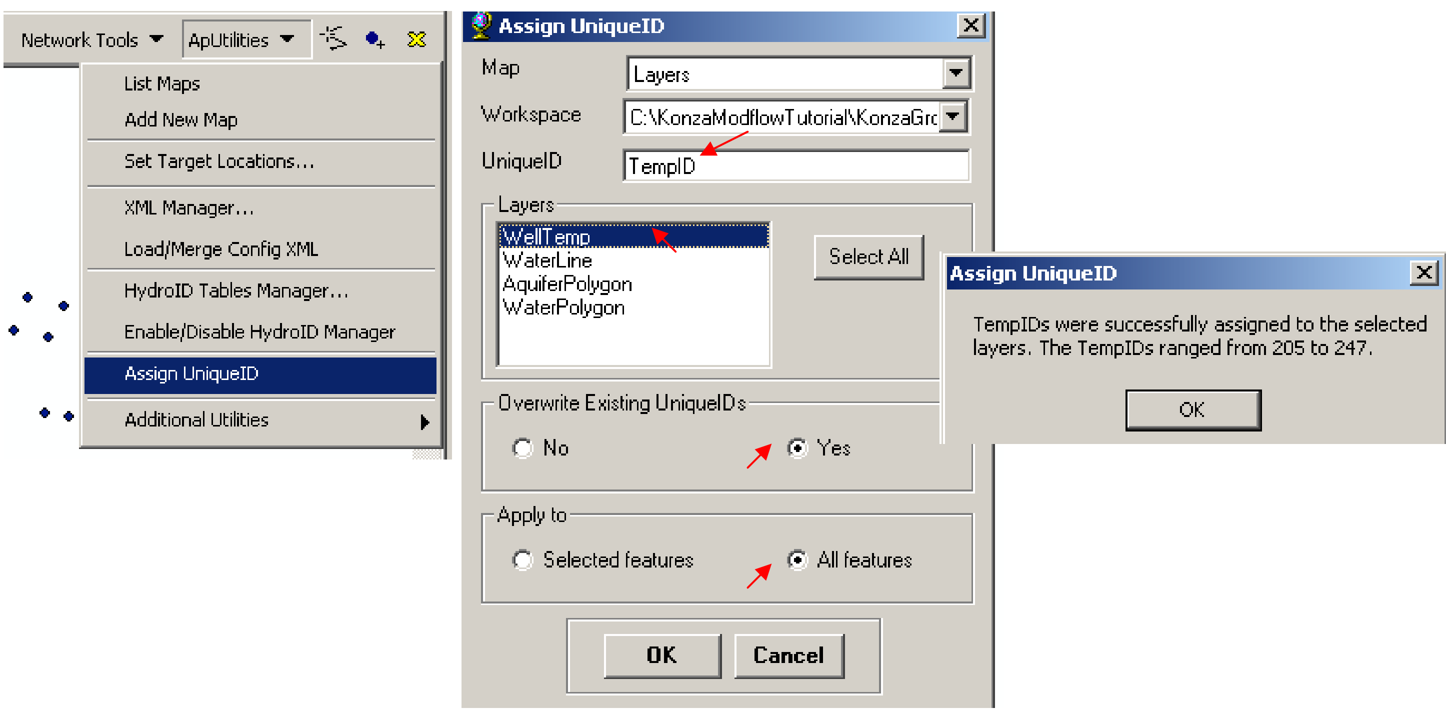
b



(4) The unit of the pumping records extracted from the Arc Hydro Groundwater geodatabase is in **acre-foot per year**. We will convert the data to the unit of **m^3 per day** and save the converted values in the field **PumpRate** by using the field calculator as shown in the following figures. Since these wells are pumping wells, their extraction rates are specified to be negative as required in PMWIN.



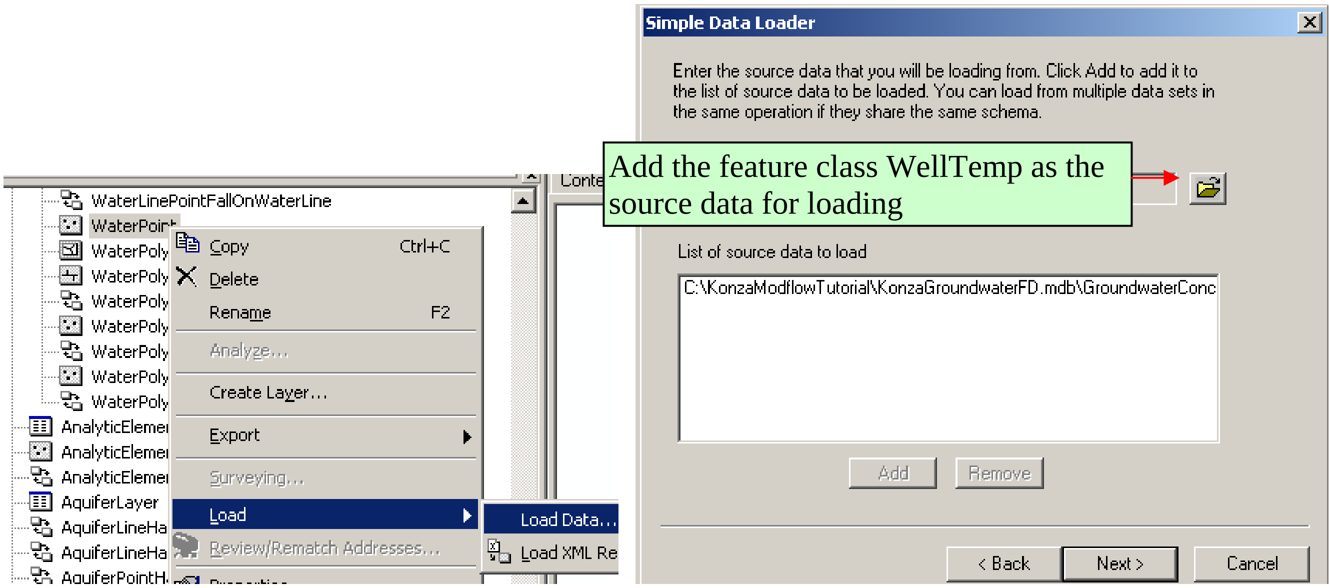
(5) Assign unique Hydro ID values for the ***WellTemp*** feature class and save it in the newly added field **TempID**.

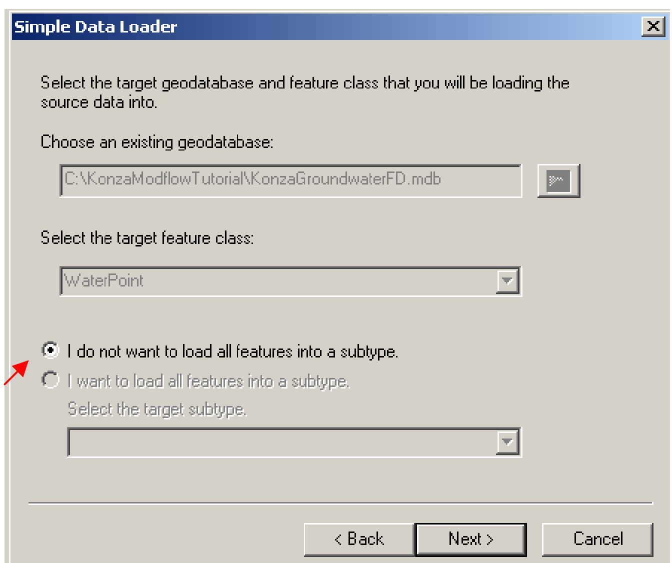


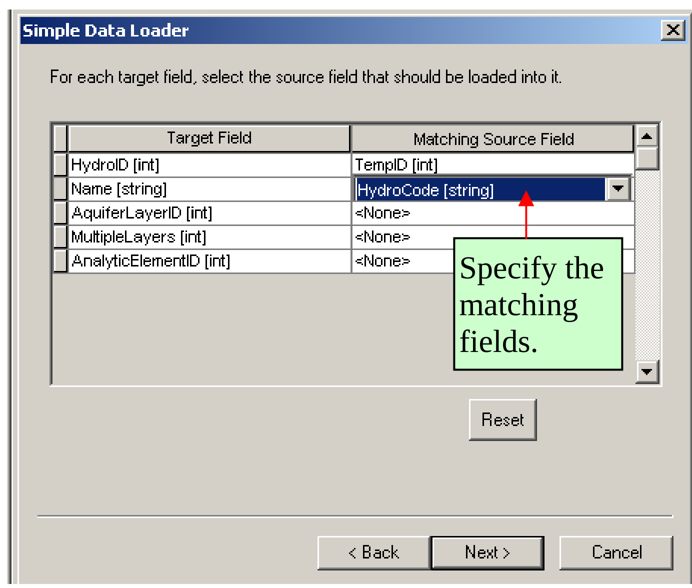
(6) On Arc Catalog, load features from ***WellTemp*** to ***WaterPoint***. The main loading steps are:

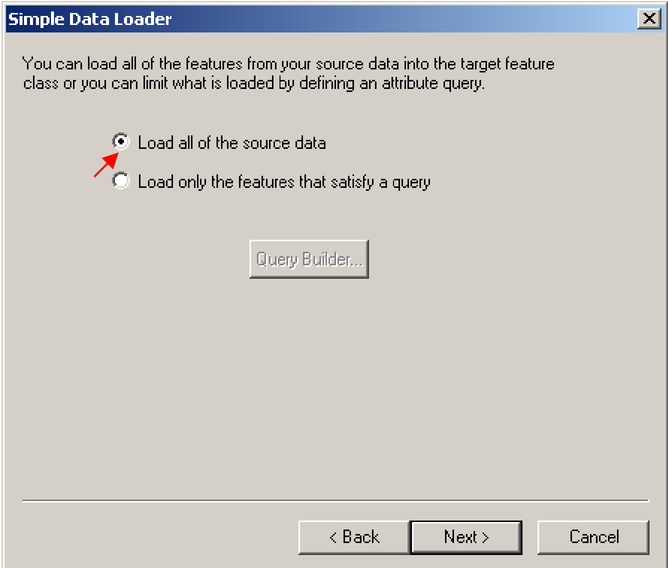
- Right click ***WaterPoint***, and click "**Load – Load Data…**"
- Browse to add the feature class ***WellTemp*** as the source data for loading.
- Choose the option of not loading all features into the subtype.

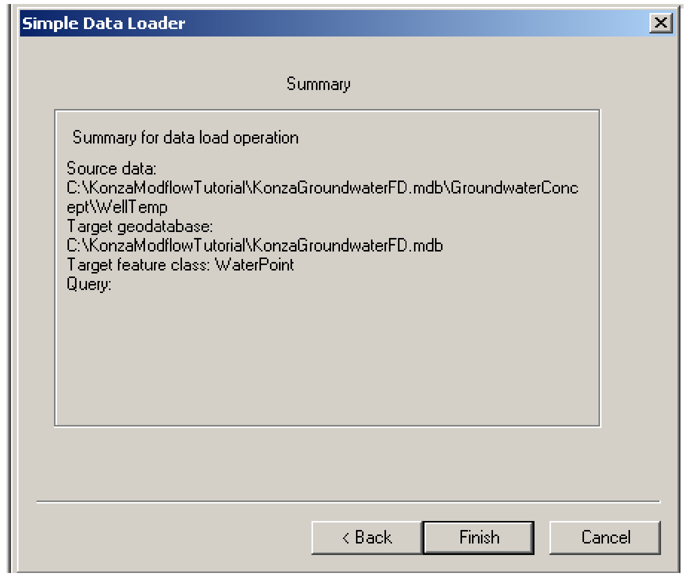
- Match the source fields **TempID** and **HydroCode** to the target fields **HydroID** and **Name**, respectively.
- Choose the option of loading all of the source data.



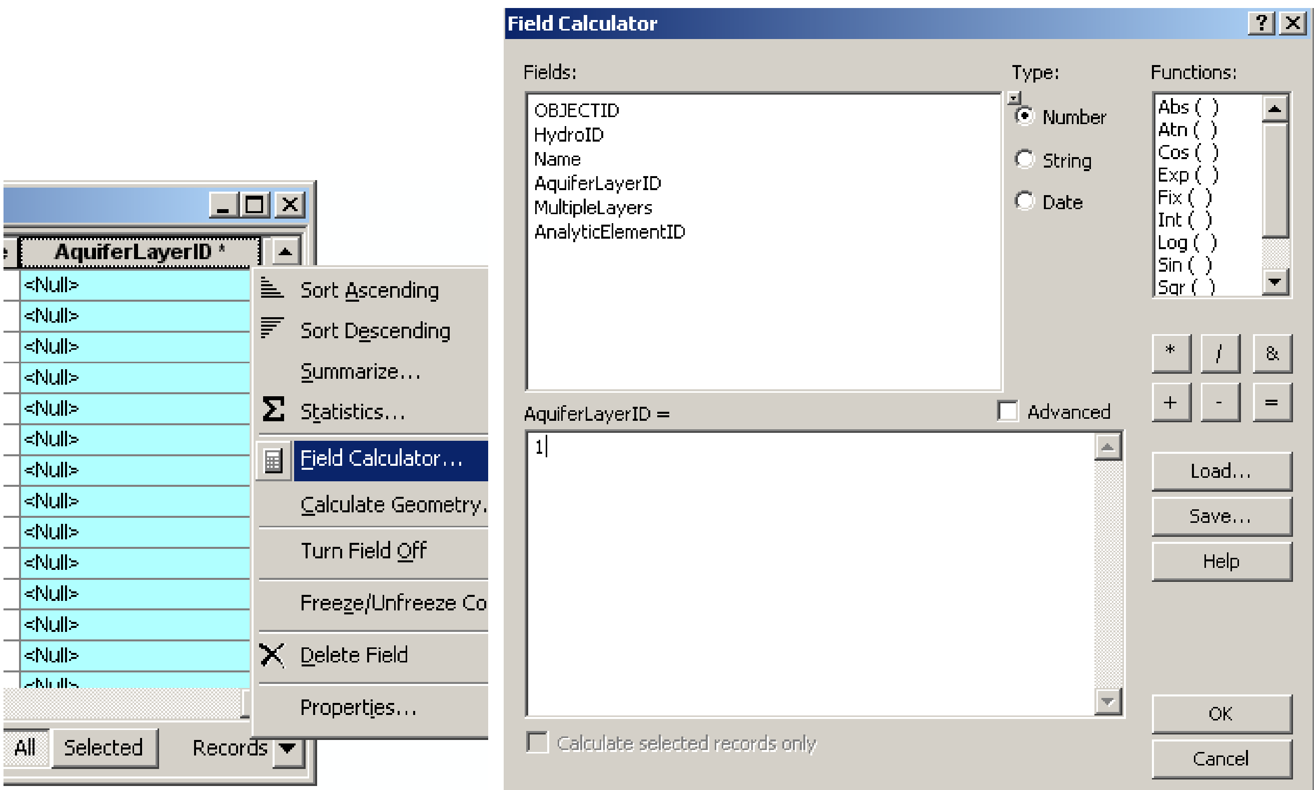








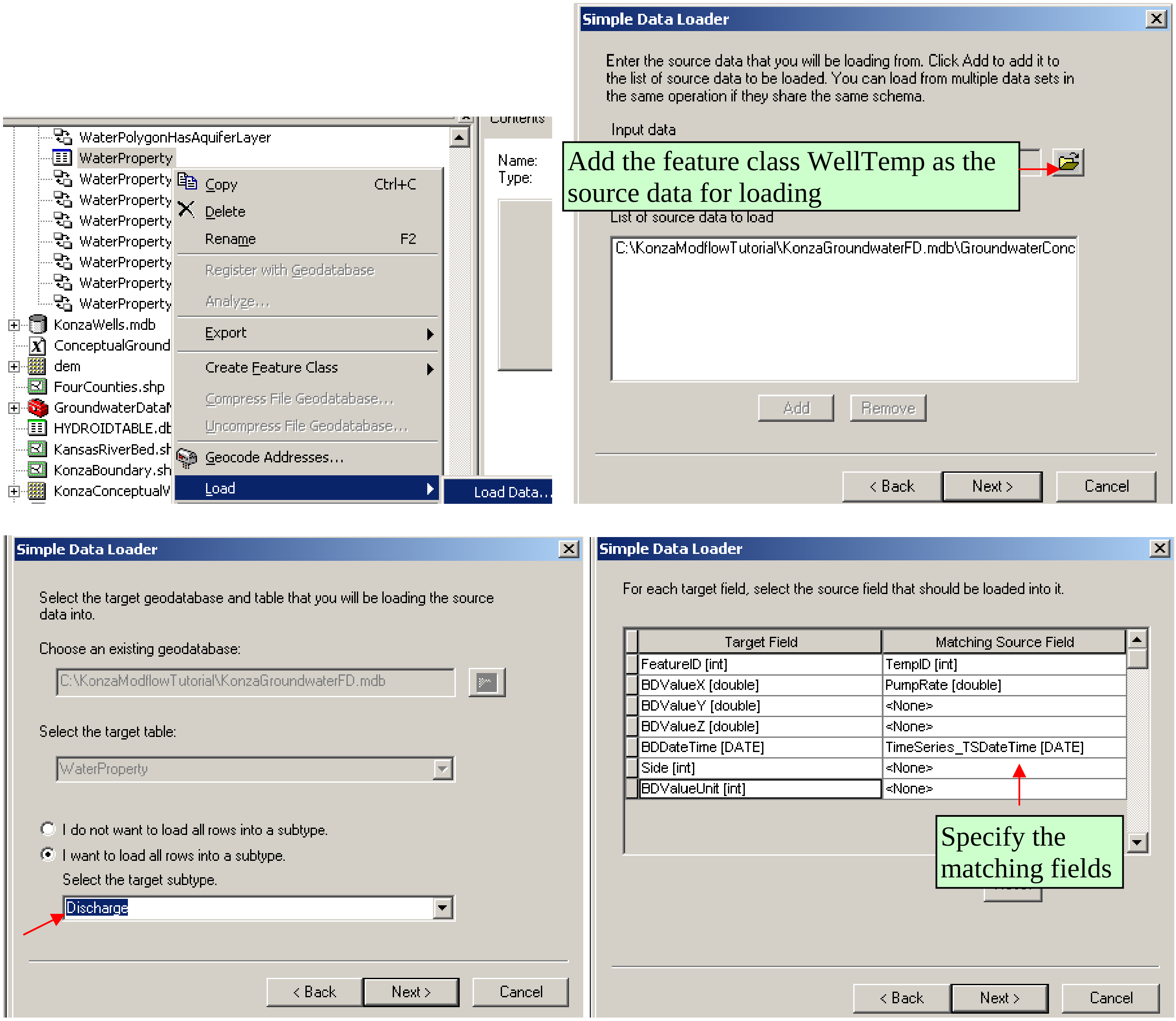
(7) Add ***WaterPoint*** to Arc Map. Calculate its field AquiferLayerID to be equal to 1.

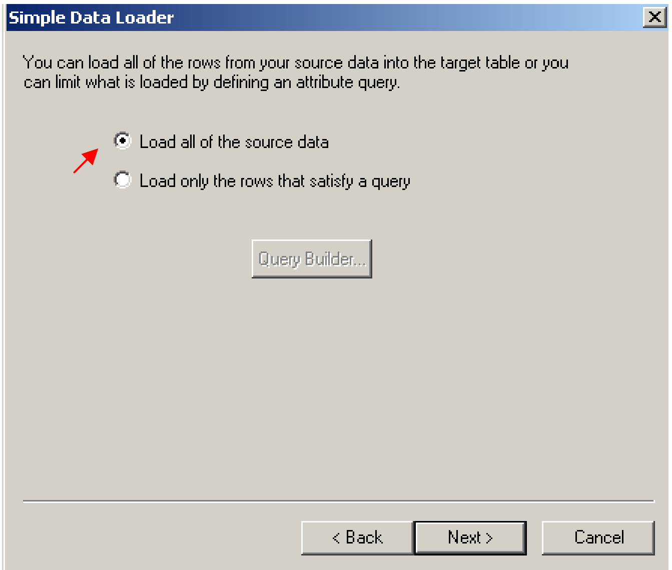


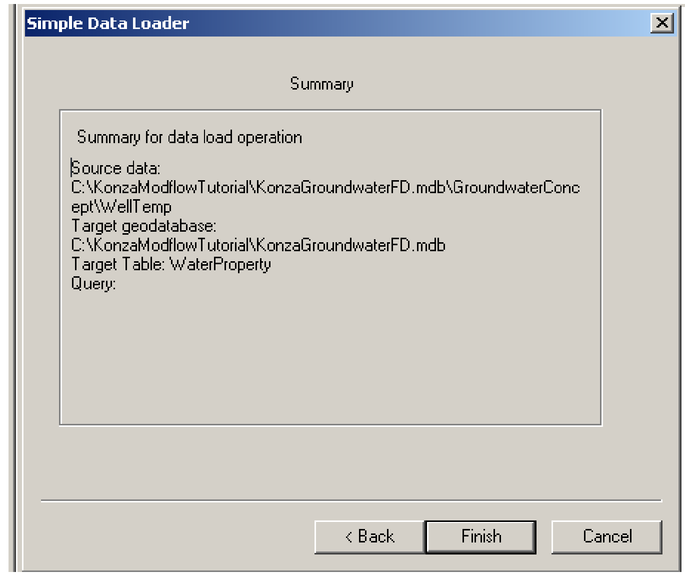
(8) On Arc Catalog, load data on pumping rates from ***WellTemp*** to the ***WaterProperty*** table. The main loading steps are:

- Right click ***WaterProperty***, and click "**Load – Load Data…**"
- Browse to add the feature class ***WellTemp*** as the source data for loading.
- Choose the option of loading all features into the **Discharge** subtype.
- Match the source fields **TempID**, **PumpRate**, and **TimeSeries_TSDateTime** to the target fields **FeatureID**, **BDValueX**, and **BDDateTime**, respectively.

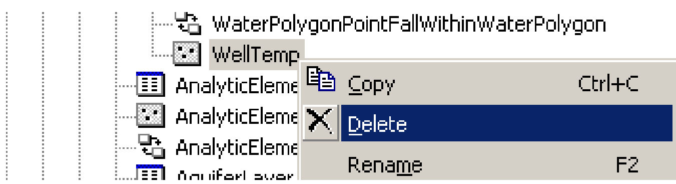
- Choose the option of loading all of the source data.







(9) Delete the ***WellTemp*** feature class. In Arc Catalog, right click ***WellTemp***, and click "**Delete**."

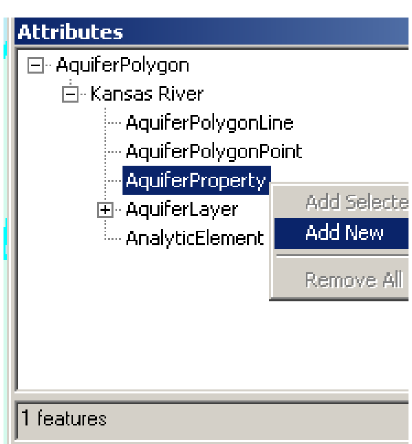


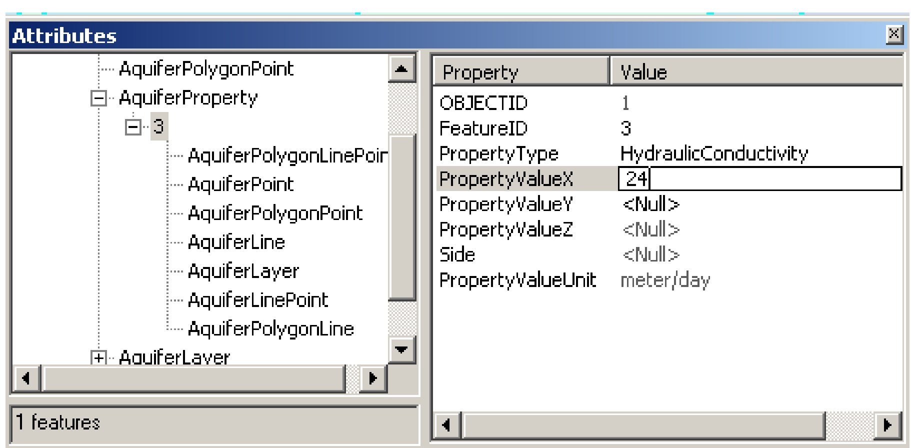
1.9.Define Hydraulic Conductivity Values

The groundwater modeling area is divided into 2 zones with different K values: Kansas River Bed with a K value of 24 m/d and the area outside Kansas River Bed with a K value of 1 m/d.

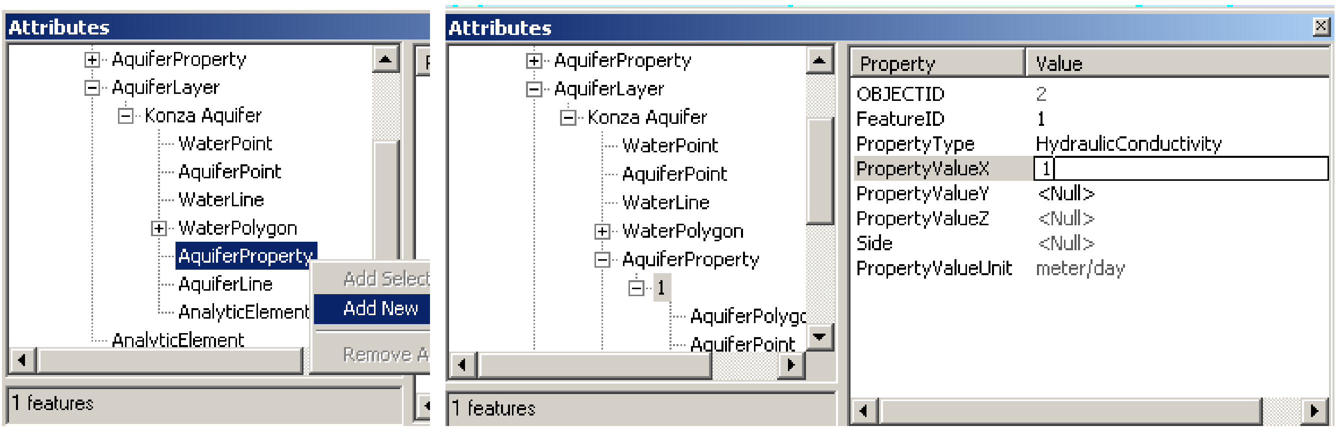
(1) Add the ***AquiferProperty*** table to ArcMap. First we will set the K value for Kansas River Bed.

(2) Start a new edit session, and use the edit tool  to select ***AquiferPolygon***. Click the Attributes button, and the Attributes window shows up. Expand under ***AquiferPolygon***, right click ***AquiferProperty***, and click **Add New**. Set the value for the field **PropertyValueX** to be **24**.





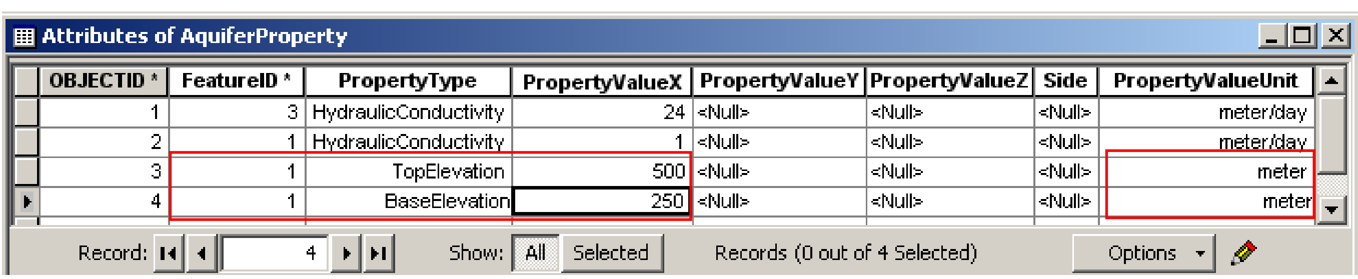
(3) Expand under ***AquiferLayer***, right click ***AquiferProperty***, and click **Add New**. Set the value for the field **PropertyValueX** to be **1**. Close the Attributes window. Save the edits. Open the attribute table of the ***AquiferProperty***, and you will find that two new records are added with the right FeatureID values.



1.10. *Define Layer Top and Bottom Elevation*

Now, we need to define the top and bottom elevation for the Konza aquifer layer. In this tutorial, we assume its top elevation to be 500 m and bottom elevation to be 250 m.

Start an edit session, if you are not in one. Open the table ***AquiferProperty***, and add two new records as in the following figure. Save the edits and stop the edit session.



Attributes of AquiferProperty

OBJECTID *	FeatureID *	PropertyType	PropertyValueX	PropertyValueY	PropertyValueZ	Side	PropertyValueUnit
1	3	HydraulicConductivity	24	<Null>	<Null>	<Null>	meter/day
2	1	HydraulicConductivity	1	<Null>	<Null>	<Null>	meter/day
3	1	TopElevation	500	<Null>	<Null>	<Null>	meter
4	1	BaseElevation	250	<Null>	<Null>	<Null>	meter

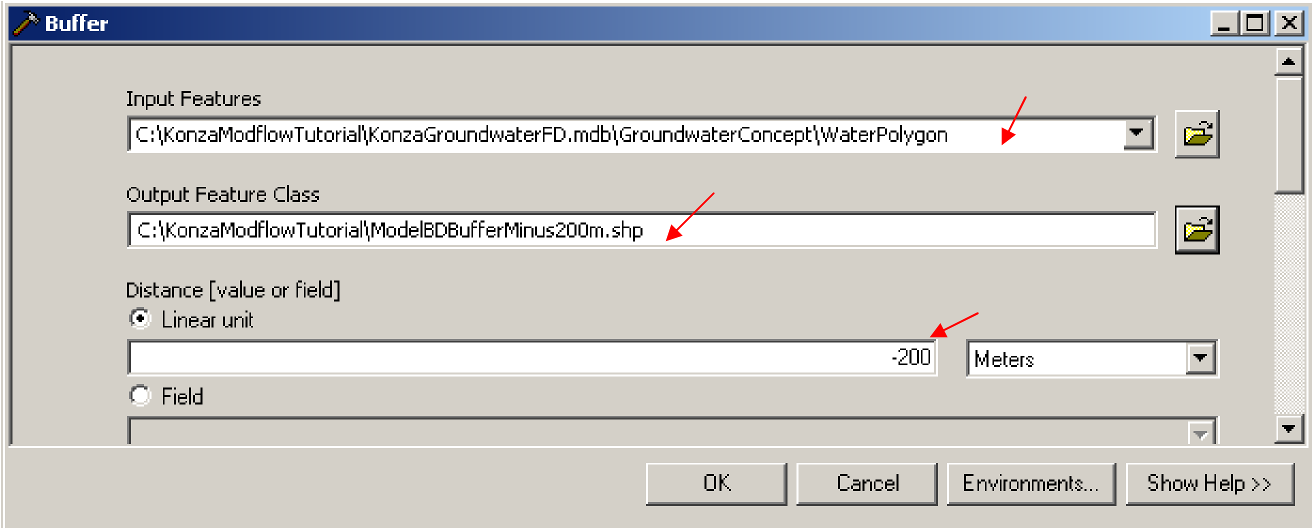
Record: 4 Show: All Selected Records (0 out of 4 Selected) Options

1.11. *Store River Conductance in WaterRaster Catalog*

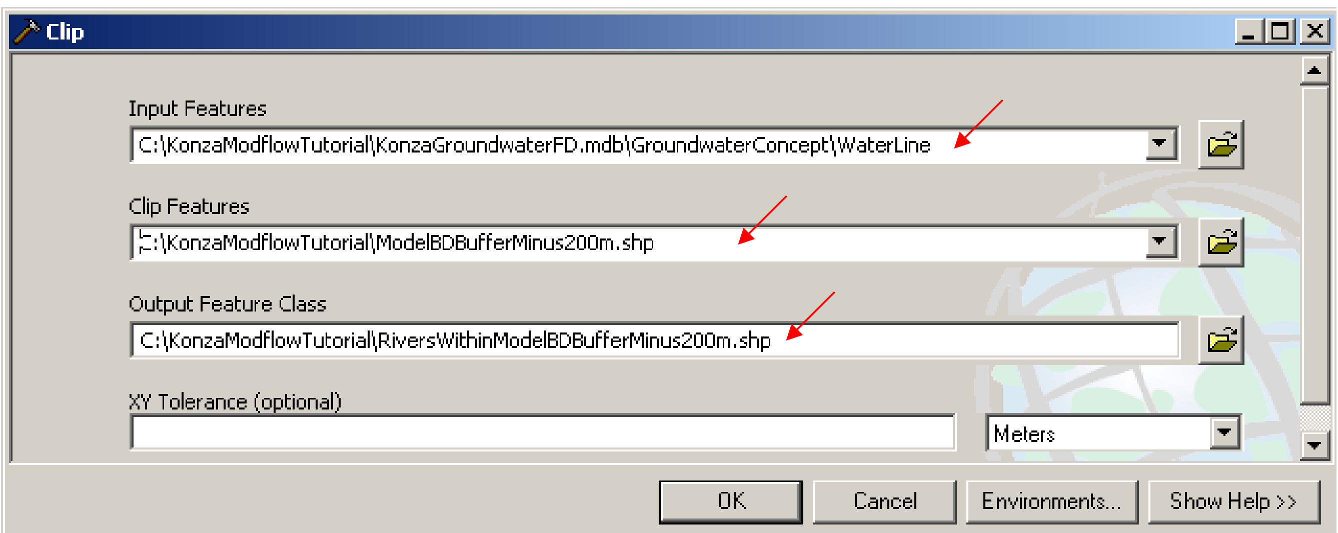
Rivers have different interaction mechanism with groundwater depending on their hydraulic head and groundwater head. PMWIN uses the **conductance** parameter to describe the interaction between river segments and groundwater. For our model, we assume that conductance differs by the size of river segments. If a river segment is part of Kansas River or it is a second or higher-order river segment, we consider it a major river segment and assume its conductance to be **141.4 m^2/d**. The rest of the river segments are considered to be small, and their conductance rates are assumed to be **0.014 m^2/d**.

(1) Rivers are defined with general head boundary conditions. Some river segments touch the model boundary. To ensure the general head boundary conditions are not defined on the model boundary and cause double definition of boundary conditions, we first get the river segments falling more than 200 meters away from the model boundary. Buffer the **WaterPolygon** feature class that defines the

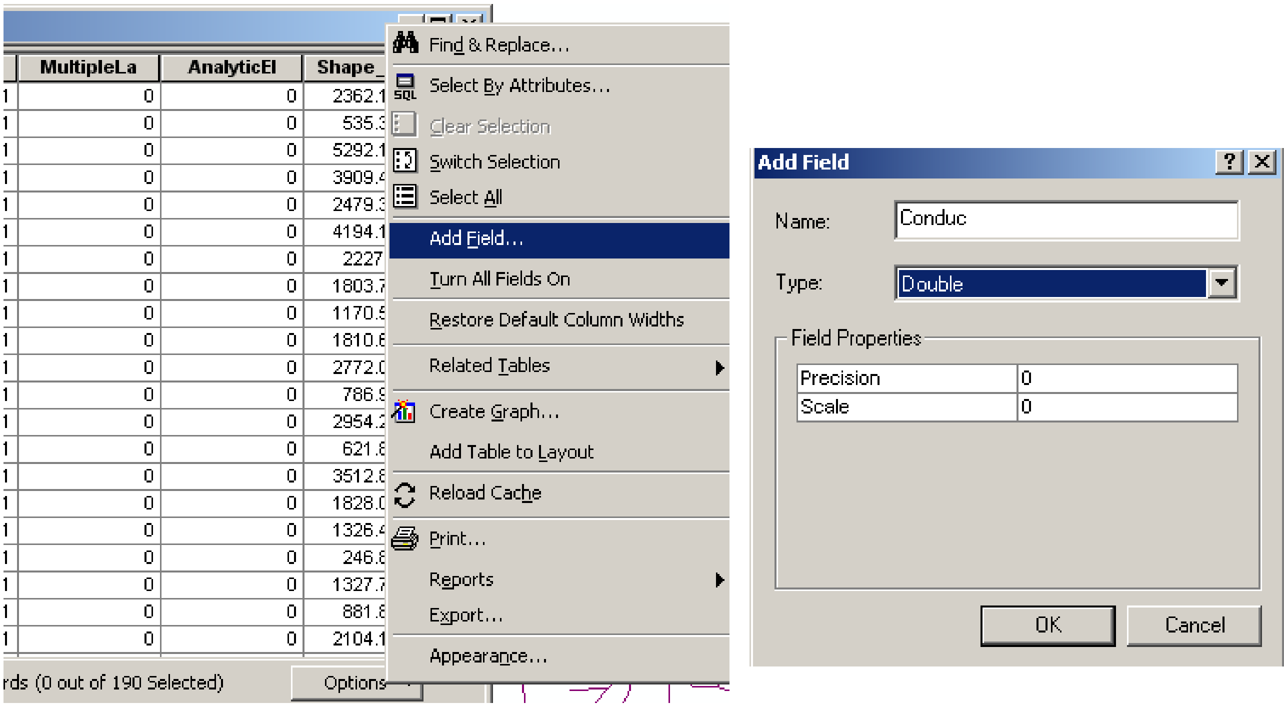
model boundary with a distance of **-200** m, as shown in the following figure, and save the output file as "**ModelBDBufferMinus200m.shp**" under your working folder.



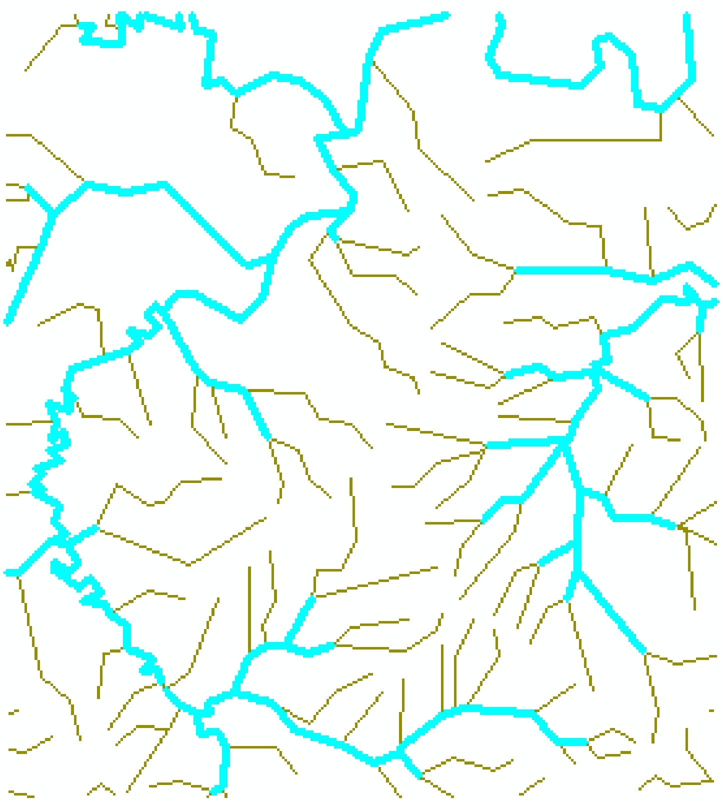
(2) Next, to get the river segments falling more than 200 meters away from the model boundary, clip the **WaterLine** feature class that contains the river segments with **ModelBDBufferMinus200m.shp,** as shown in the following figure. Save the output file as "**RiversWithinModelBDBufferMinus200m.shp**" under your working folder.



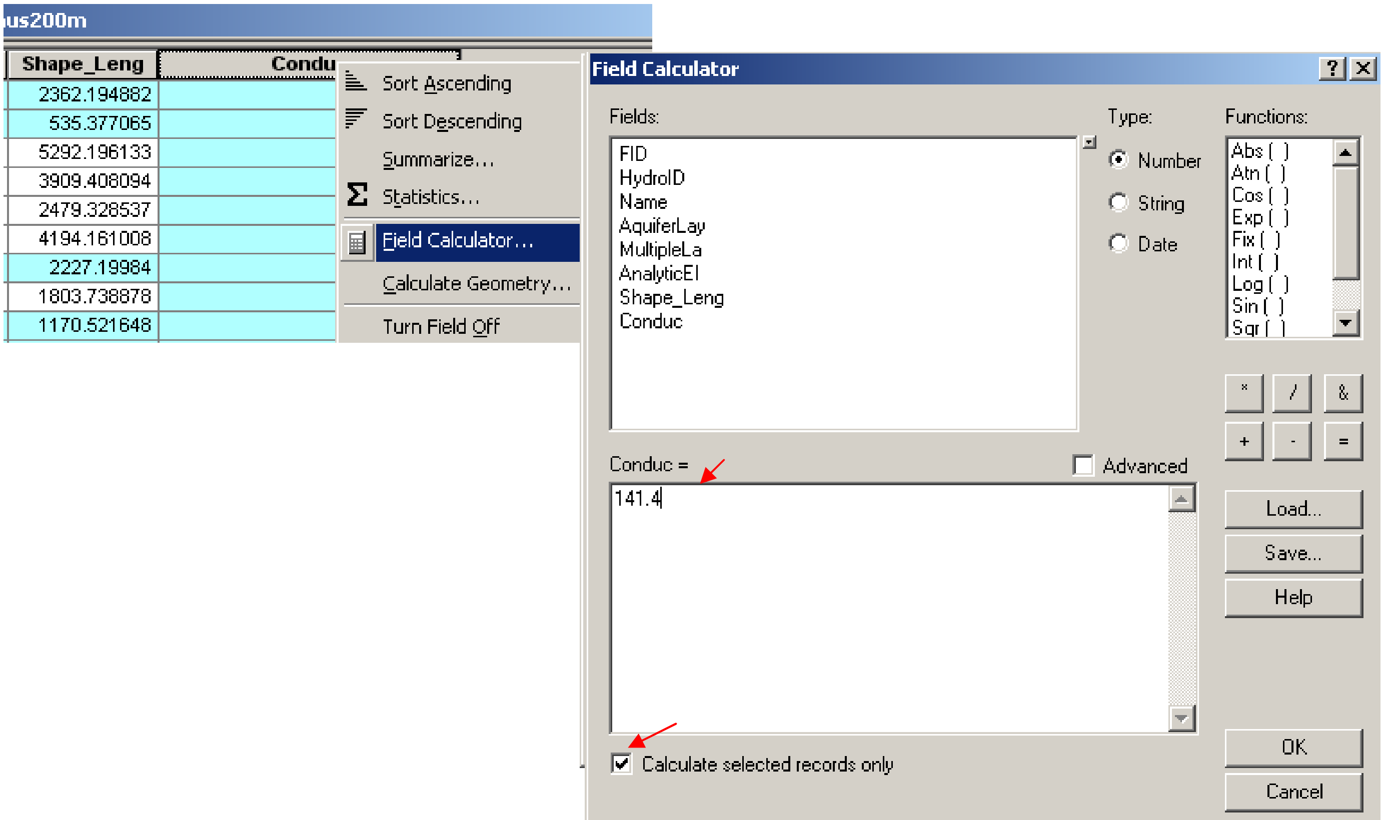
(3) Assign conductance rates to the river segments. Open the attribute table of the shapefile "**RiversWithinModelBDBufferMinus200m.shp**", and add a field "Conduc" of the type **double.**



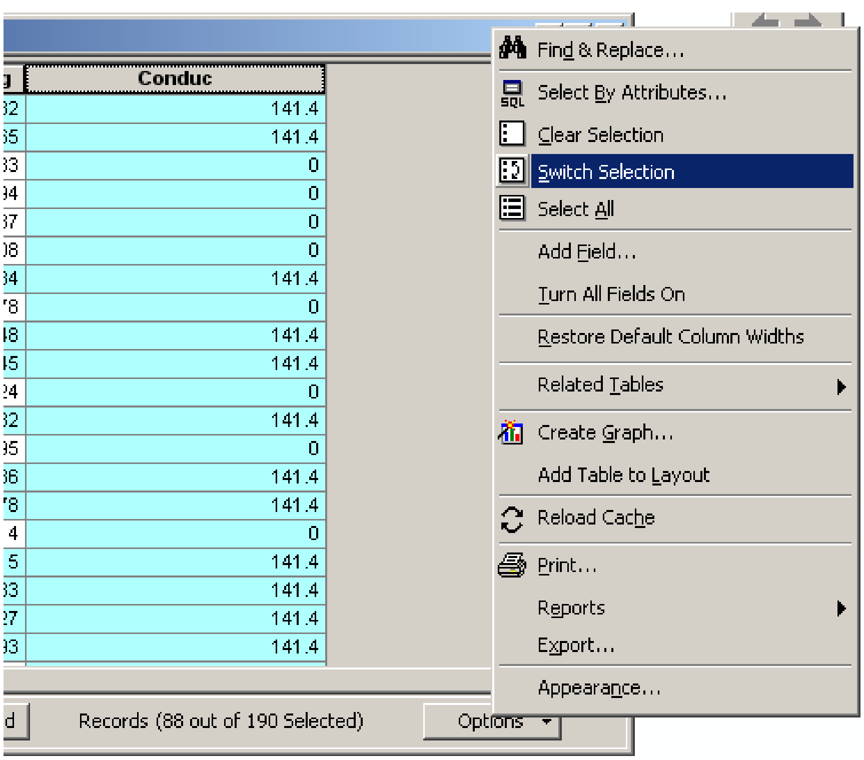
Select the major river segments as shown in the following figure:

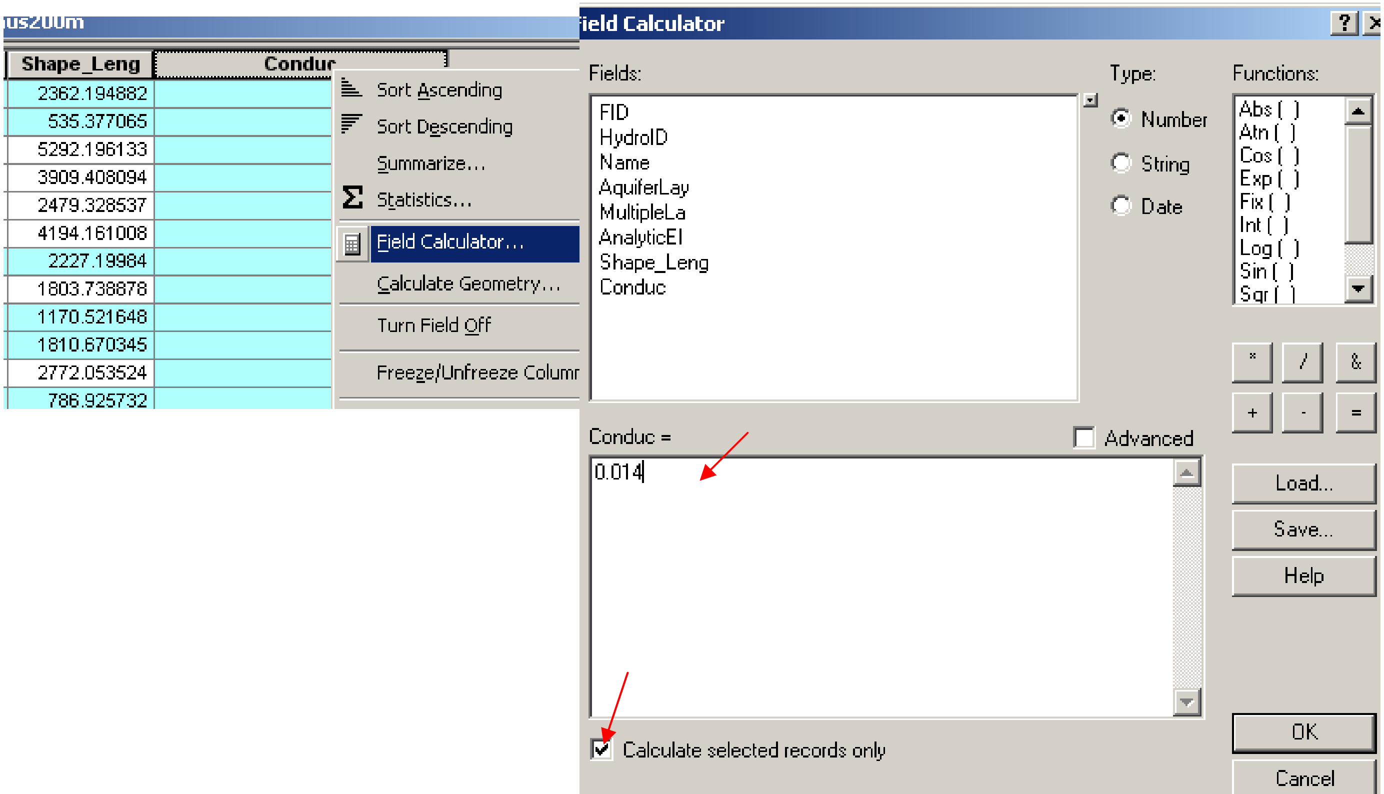


Calculate the field "Conduc" to be 141.4 for these major river segments. Right click the field Conduc, and click "Field Calculator…", and enter **141.4** in the subsequent window. Make sure to only calculate values for selected records.

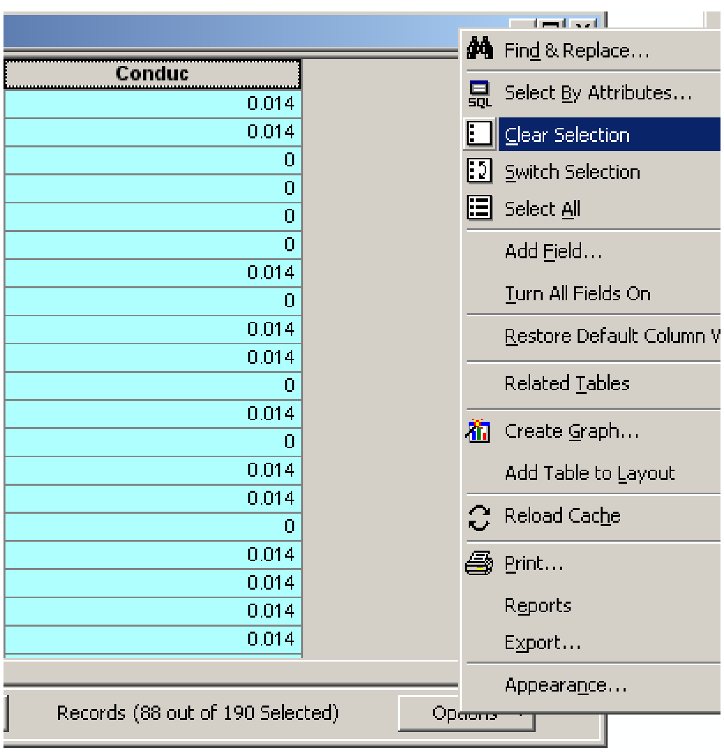


Calculate the field "Conduc" to be 0.014 for the rest of river segments. Click "**Option – Switch Selection**" to select the rest of river segments. Right click the field Conduc, and click "Field Calculator…", and enter **0.014** in the subsequent window. Make sure to only calculate values for selected records.



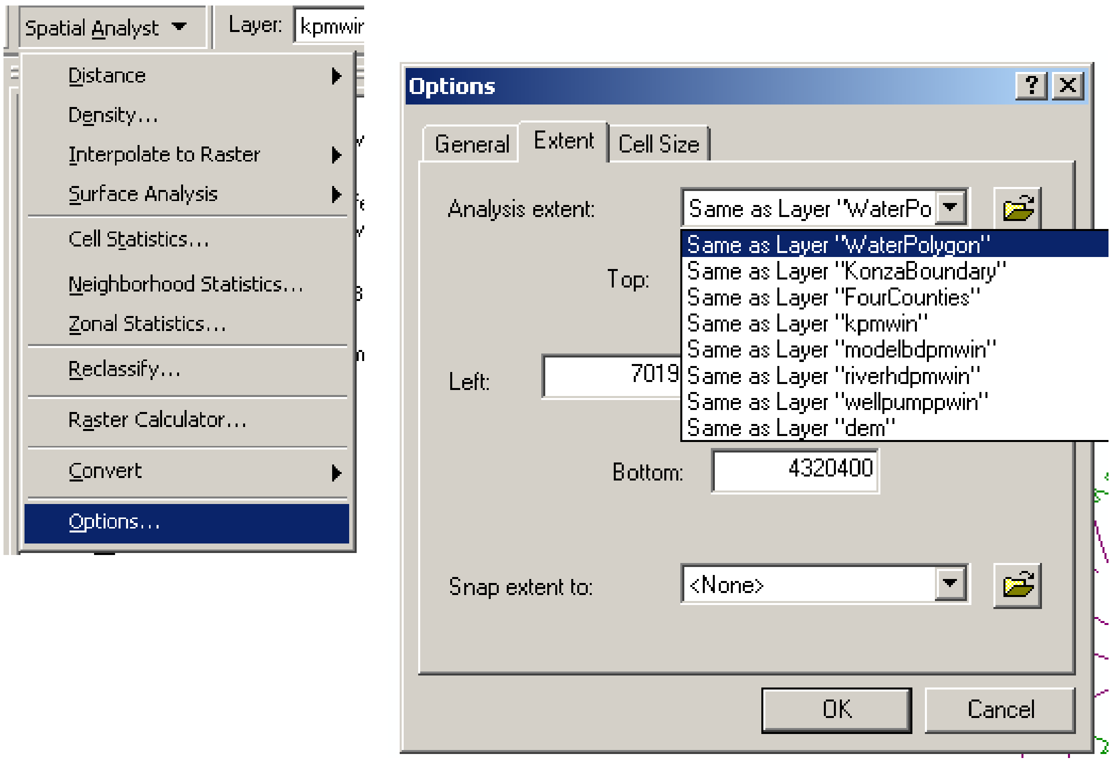


Clear the selection of the river segments by clicking "**Options – Clear Selection**." Close the attribute table.

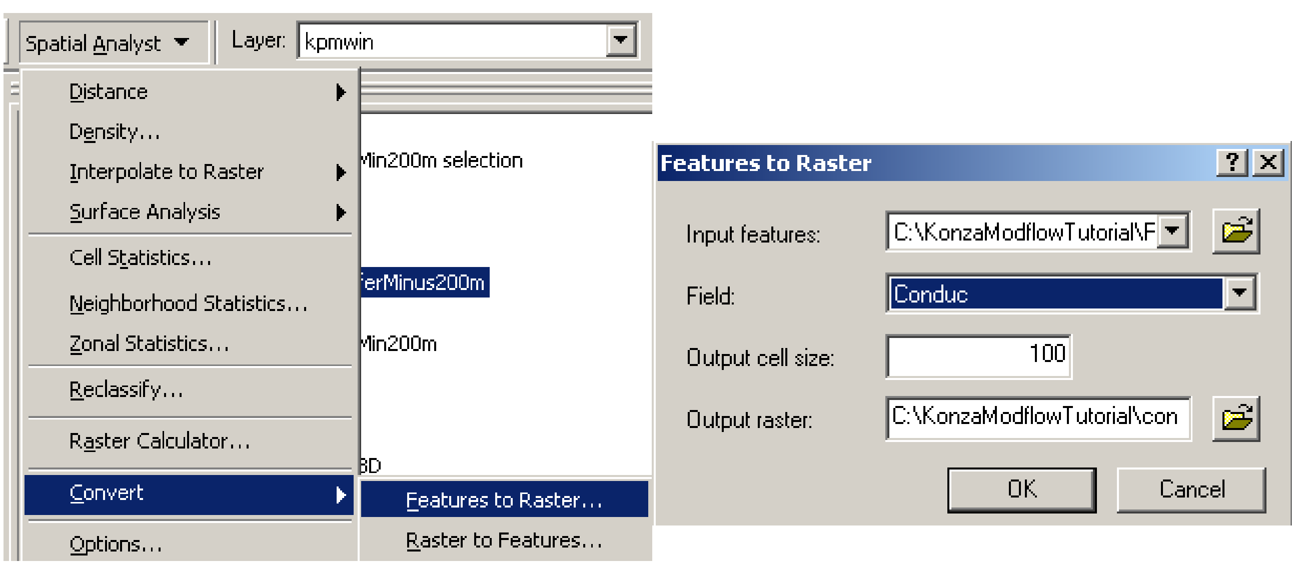


(4) Create the raster on river conductance. We will use the spatial analyst toolbar for this.

First, we need to set the analysis extent to be WaterPolygon. On the Spatial Analyst toolbar, click "**Options…**" Activate the **Extent** tab on the Options window, and set the extent to be the same as Layer "**WaterPolygon**."

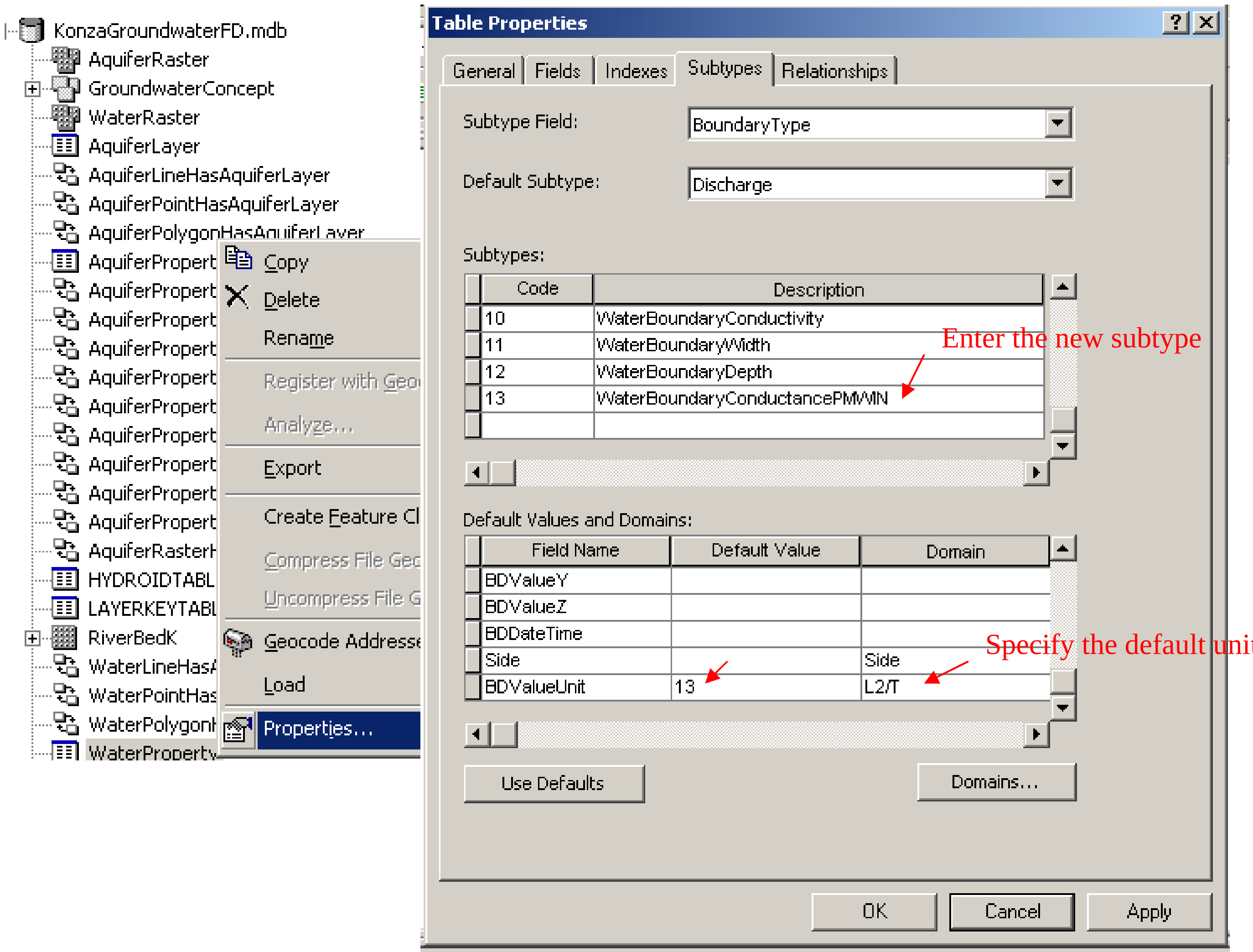


Next, on Spatial Analyst toolbar, click "**Convert – Features to Raster…**", and specify the input features to be **RiversWithinModelBDBufferMinus200m.shp**, the field to be **Condu**, the output cell size to be **100**, and save the output raster to be "**conductance**" under your working folder.

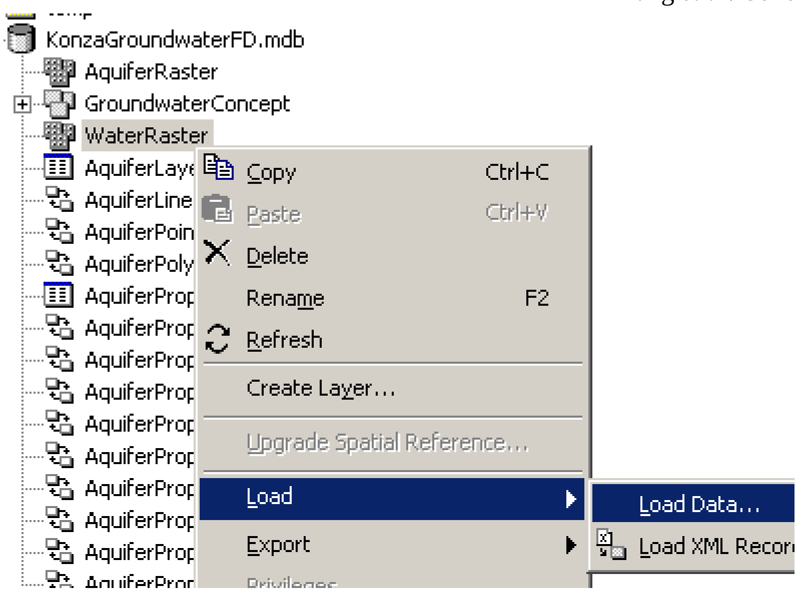


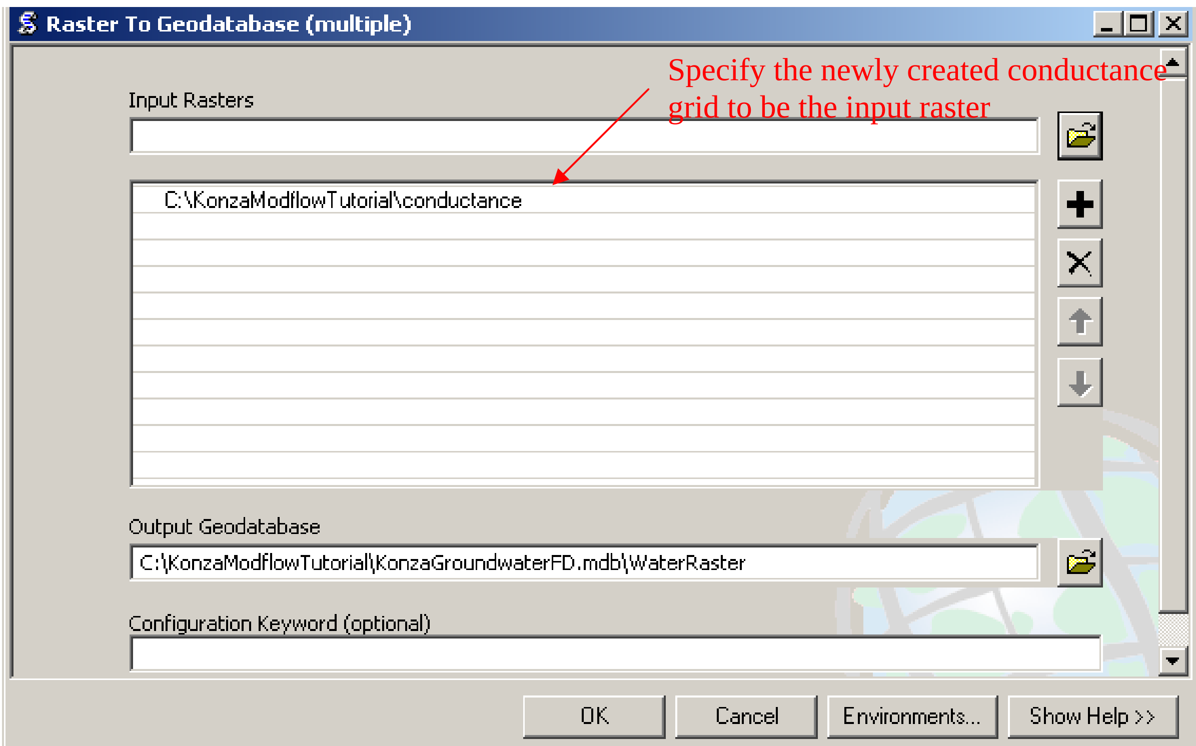
(5) Add new water boundary condition subtype for river conductance to the conceptual groundwater data model. The conductance parameter used in PMWIN is not included in the original conceptual groundwater data model. But we can extend the groundwater data model and add new boundary type

to the WaterProperty table. On the ArcCatalog window, right click the WaterProperty table, and click "**Properties…**" Activate the **Subtypes** tab, and add a new subtype named **WaterBoundaryConductancePMWIN**. Specify the unit of the boundary type to be **L2/T**, and the default unit value to be **13**, which represents **m^2/d**.



(6) Load the conductance grid to the WaterRaster Catalog. Right click the WaterRaster catalog, and click "Load – Load Data…" Specify the newly created conductance grid to be the input raster, and click OK.

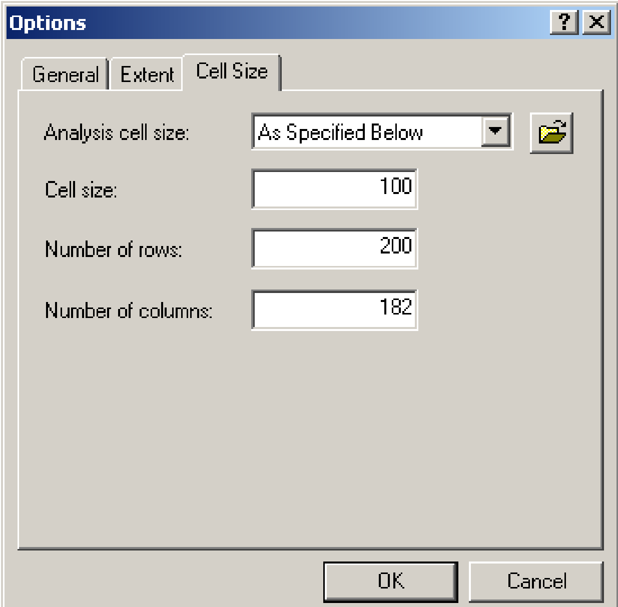




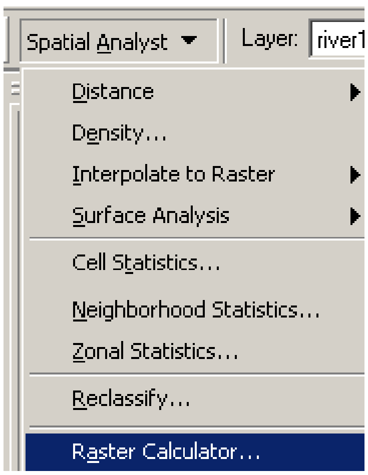
1.12. Store the Specified Head Boundary Condition in WaterRaster Catalog

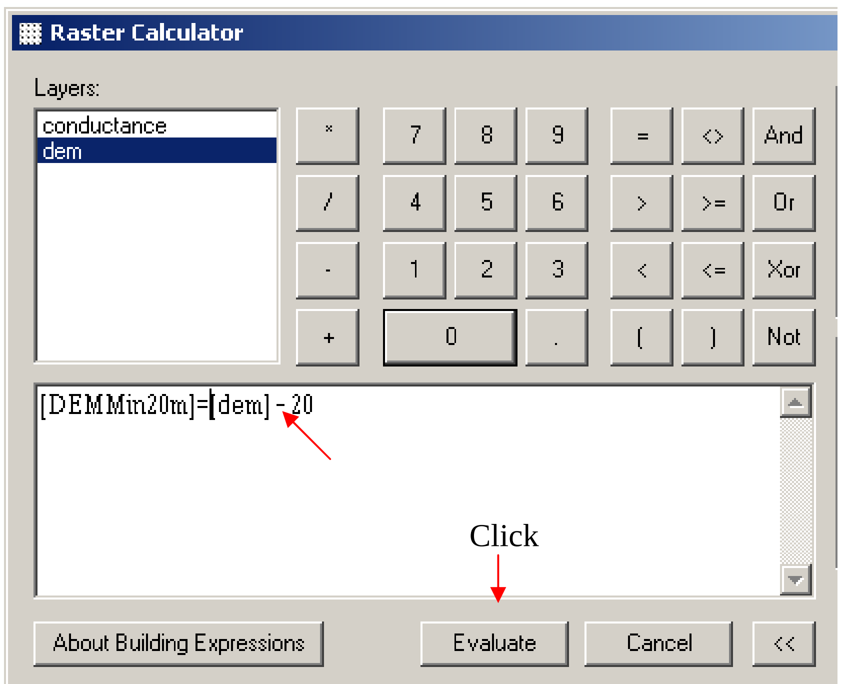
In this tutorial, the Konza Modflow groundwater model is defined with specified-head boundary condition along the model boundary. We assume the specified-head boundary values to be **20 meter** below the land surface. Let us create a grid for this.

(1) First, we need to set the output cell size to be 100. On the Spatial Analyst toolbar, click "**Options…**" Activate the **Cell Size** tab on the Options window, and set the cell size to be **100**.

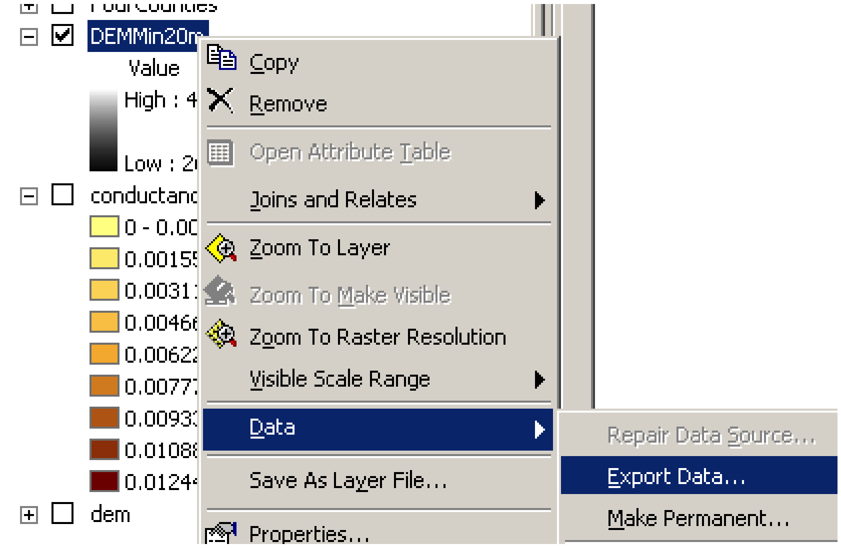


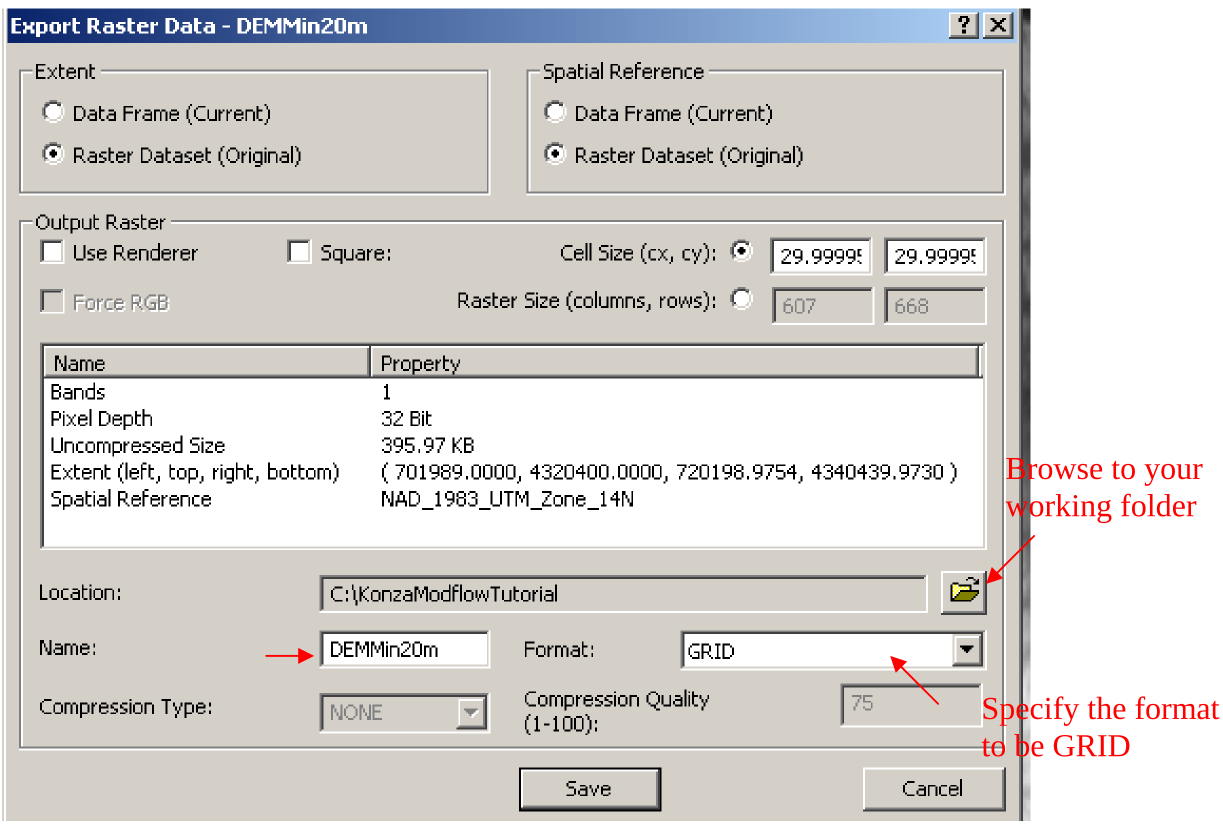
(2) Add the dem grid to Arc Map. On the Spatial Analyst toolbar, click “**Raster Calculator…**”, and enter the expression as in the following figure. Click **Evaluate**, and it will create a raster layer named “DEMMin20m” that contains values of 20 meters below land surface.



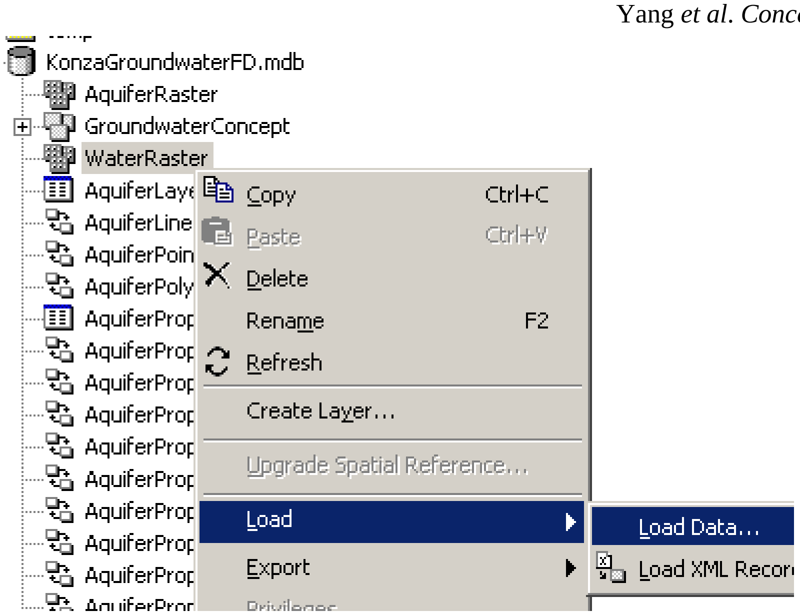


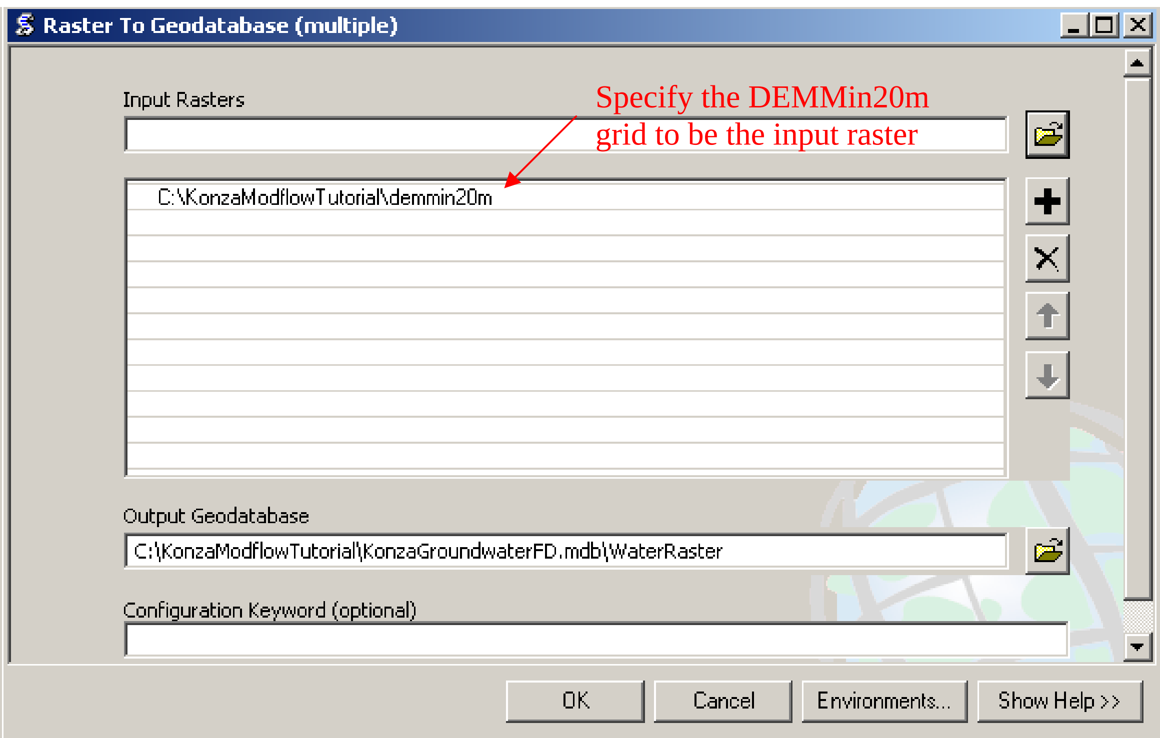
(3) Export the newly created DEMMin20m layer to a grid with the same name and save it in your working folder. Right click the layer, click “**Data – Export Data…**”, and specify the export raster data as shown in the following figure:





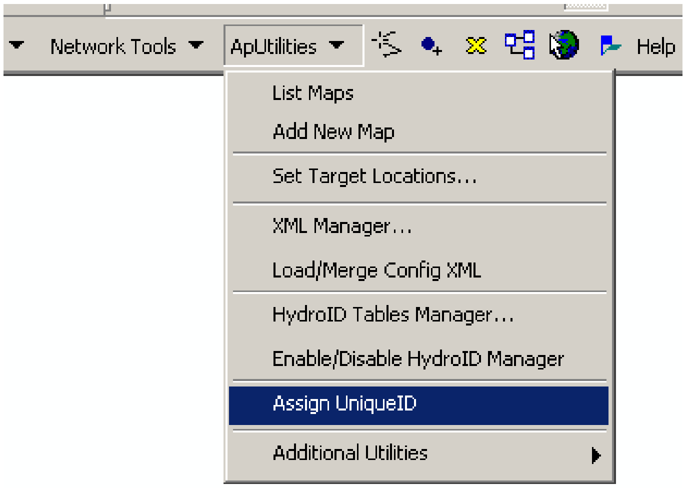
(4) Load the DEMMin20m grid to the WaterRaster Catalog. Right click the WaterRaster catalog, and click "**Load – Load Data…**" Specify the DEMMin20m grid to be the input raster, and click OK.





1.13. Populate WaterRaster Catalog

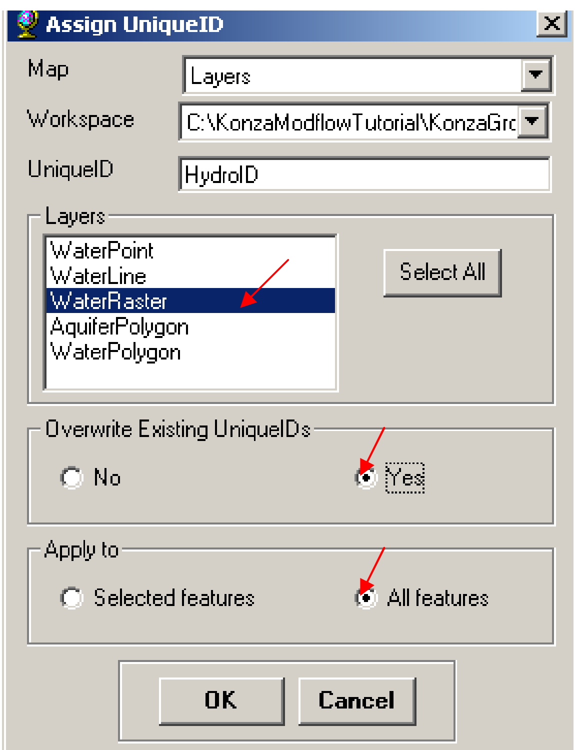
(1) Assign HydroID. Add WaterRaster to Arc Map. On the ArcHydro toolbar, click “**ApUtilities – Assign UniqueID**.”

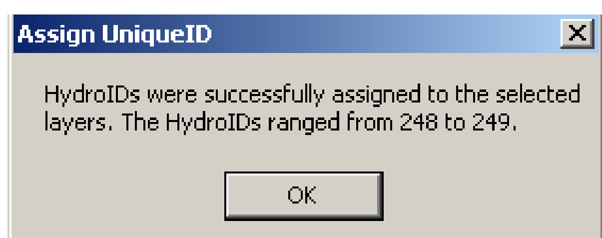


(2) On the "Assign Unique ID" window, specify the options as in the following figure:

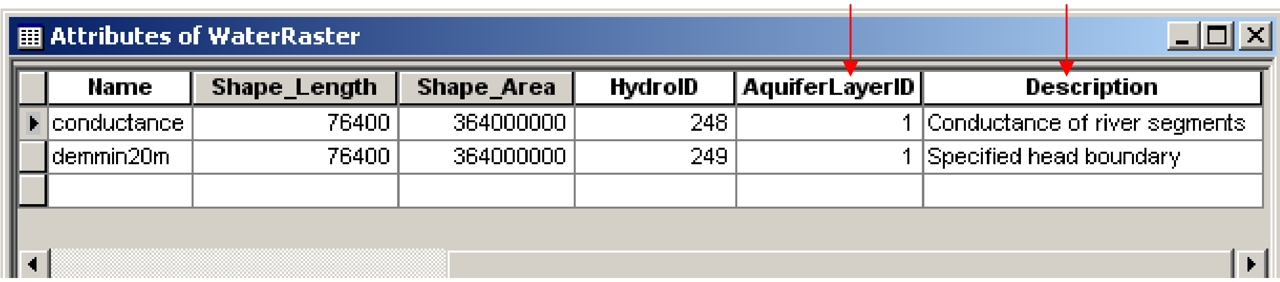
- Select the WaterRaster layer
- Select the option of "yes" to overwrite existing unique IDs
- Select the option of applying to all features

Click **OK**. Then, click **OK** on the subsequent window to accept the assigned HydroID values.





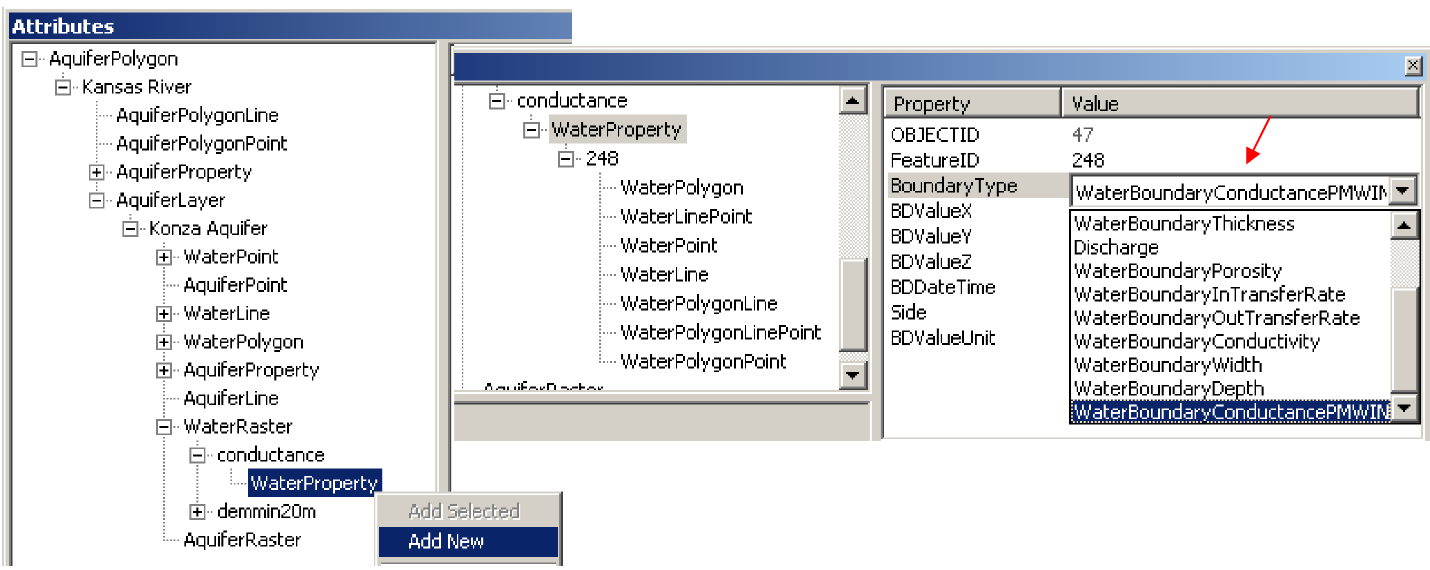
(3) Open an Edit session, and make sure the groundwater geodatabase as the target for editing. Open the attribute table of the WaterRaster Catalog, and enter the values for the field **AquiferLayerID** and **Description** as shown in the following figure:



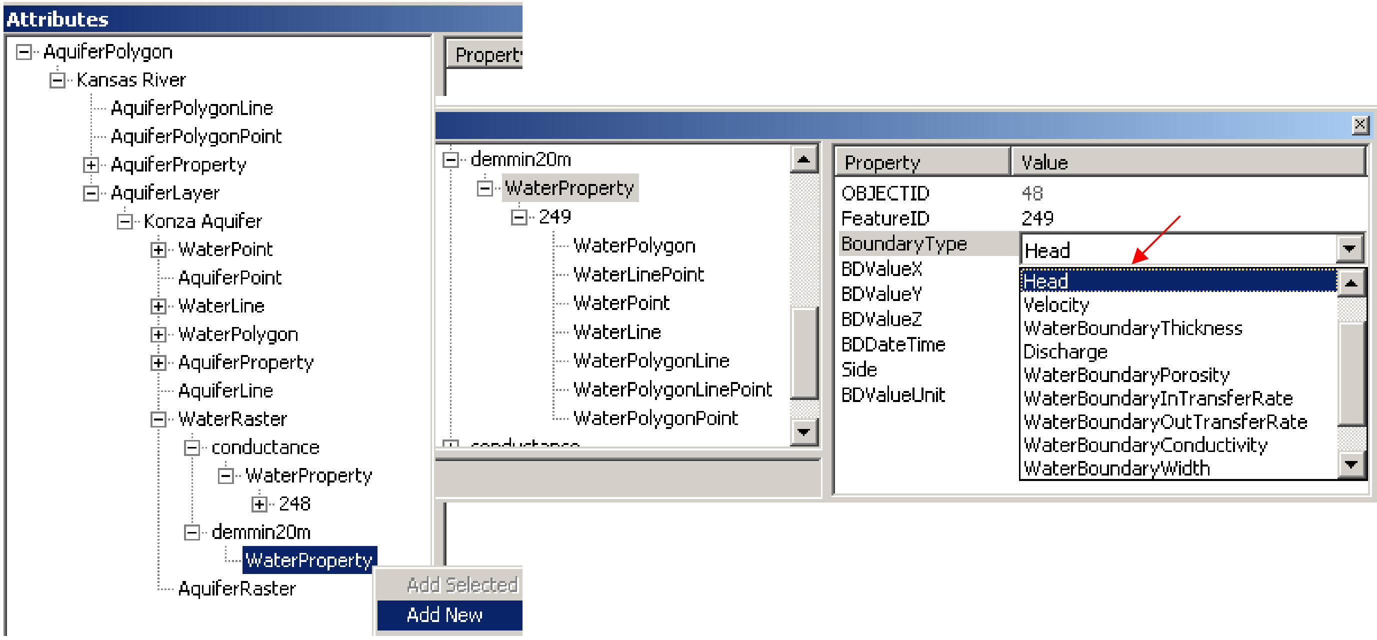
Attributes of WaterRaster

Name	Shape_Length	Shape_Area	HydroID	AquiferLayerID	Description
conductance	76400	364000000	248	1	Conductance of river segments
demmin20m	76400	364000000	249	1	Specified head boundary

(4) Update the WaterProperty table. Use the edit tool to select ***AquiferPolygon***. Click the Attributes button, and the Attributes window shows up. Expand the tree structure following the path ***AquiferPolygon - Kansas River - AquiferLayer - Konza Aquifer - WaterRaster - Conductance.*** Right click ***WaterProperty***, and click **Add New**. Set the boundary type of the water property to be **WaterBoundaryConductancePMWIN**.



(5) Expand under demmin20m. Right click ***WaterProperty***, and click **Add New**. Set the boundary type of the water property to be **Head**.

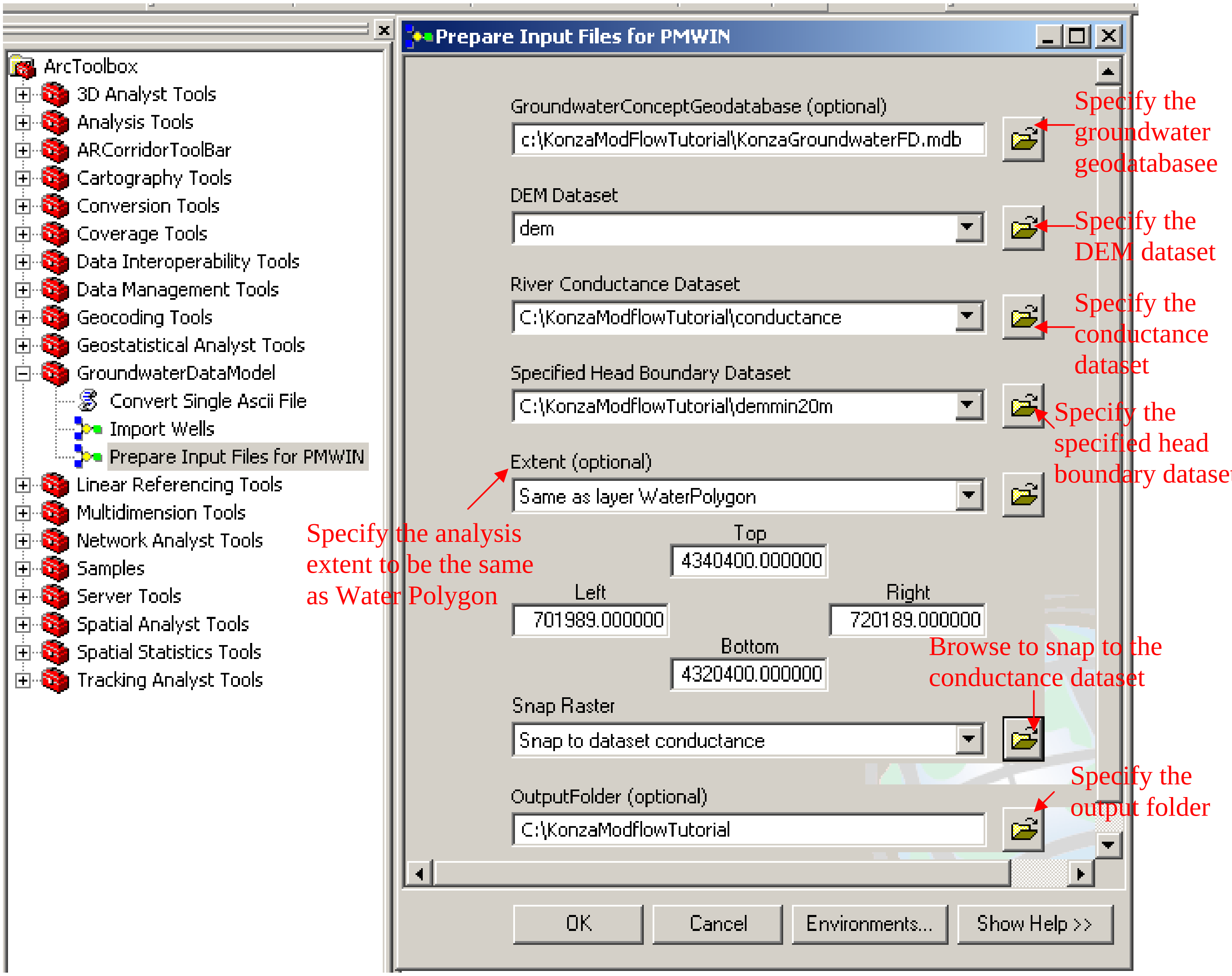


1.14. Prepare Input Files for PMWIN

Now, we have finished creating and populating the conceptual groundwater geodatabase. We will work on using the data from the newly created conceptual groundwater geodatabase to create a Modflow groundwater model with PMWIN. Here is the configuration of the grid for the Modflow groundwater model we are going to create:

- Number of layers: 1
- Cell size: 100
- Number of rows: 200
- Number of columns: 182

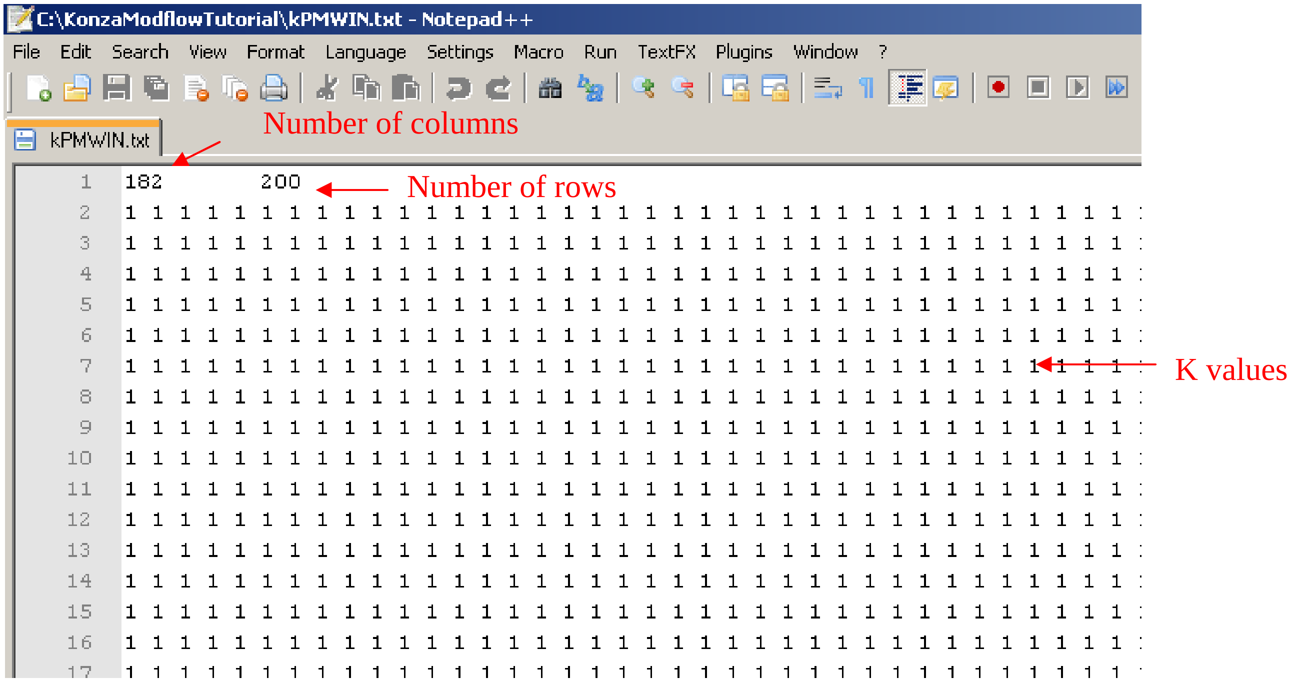
PMWIN does not work directly with GIS files. We need to create text files based on the information stored in the conceptual groundwater data model in a format compatible with PMWIN. The model "Prepare Input Files for PMWIN" in the GroundwaterDataModelForModflow toolbox can be used to create the text files. Open the model and fill in the model parameters as shown in the following figure:



After the model is executed, the following text files on groundwater parameters are created in the output folder you specified:

- ModelBdPMWIN.txt: text file on the model boundary
- InitialHeadPMWIN.txt: text file on initial hydraulic heads
- KPMWIN.txt: text file on the spatial distribution of hydraulic conductivity
- RiverHeadPMWIN.txt: text file on heads along river segments
- ConductancePMWIN.txt: text file on river segments' conductance
- WellPumpPMWIN.txt: text file on well pumping rates

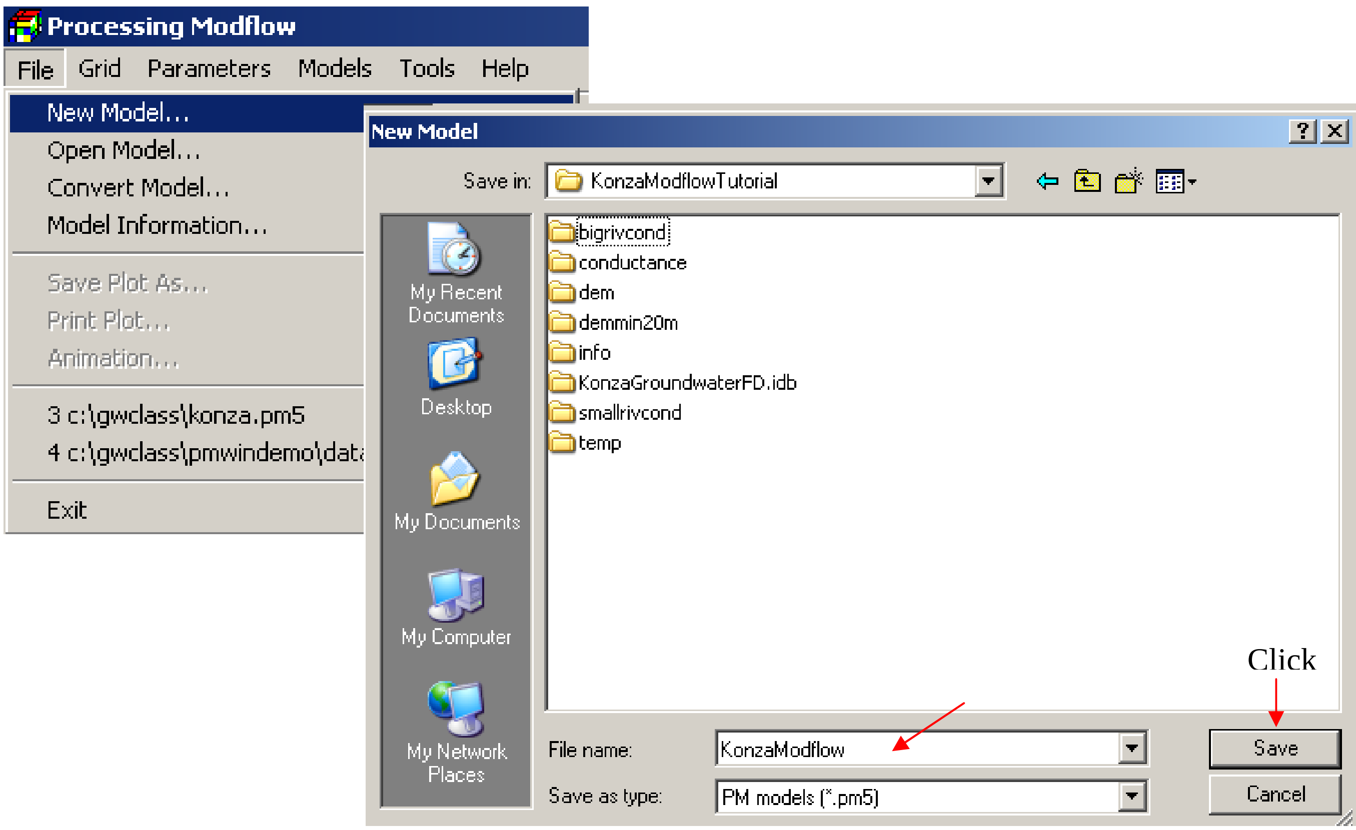
As an example, the following figure shows KPMWIN.txt that is in a format compatible with PMWIN.


C:\KonzaModflowTutorial\kPMWIN.txt - Notepad++
File Edit Search View Format Language Settings Macro Run TextFX Plugins Window ?
kPMWIN.txt
Number of columns
182 200
Number of rows
K values

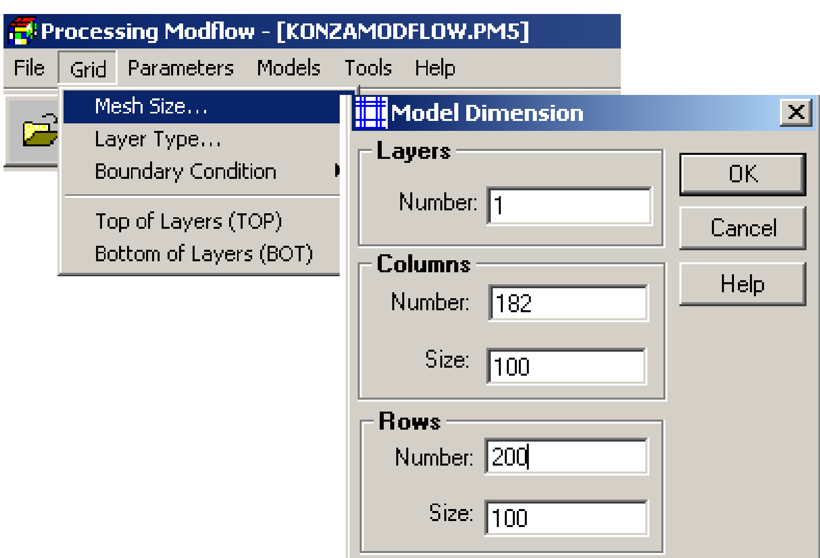
Chapter 2: Creating MODFLOW Groundwater Model

2.1 Define MODFLOW Grid

(1) Start **PMWIN** by clicking "**Start – Programs – Processing Modflow - Processing Modflow",** and Processing Modflow screen will appear as shown in the following figure. Click "**File – New Model**." Save the new model as **KonzaModflow.pm5** in your working folder.



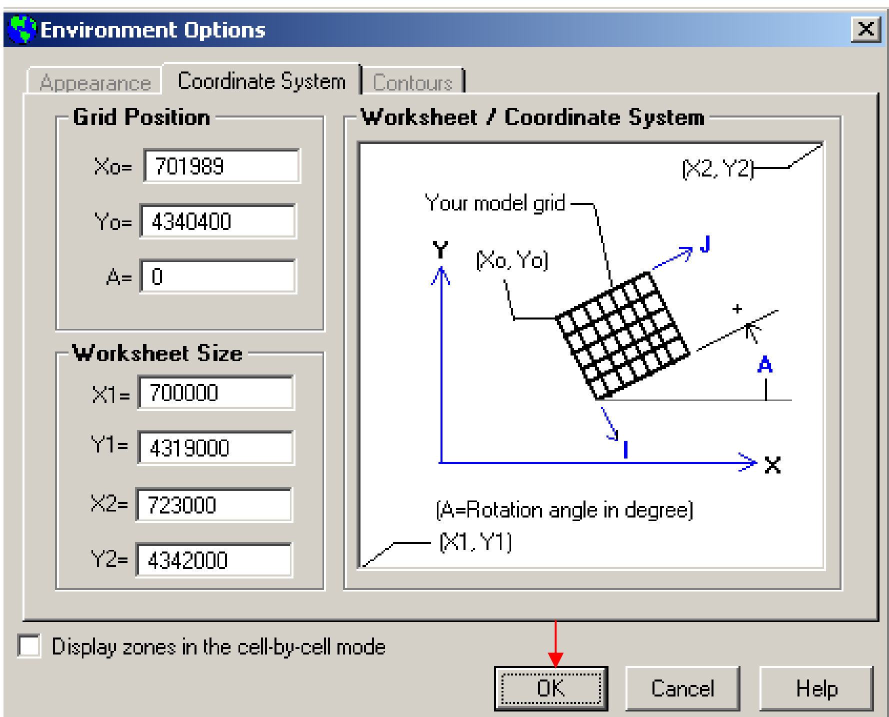
(2) Define model dimension. Click "**Grid – Mesh Size…**", specify the number of layers to be **1**, the number of columns to be **182**, the number of rows to be **200**, and both sizes to be **100,** and click OK.



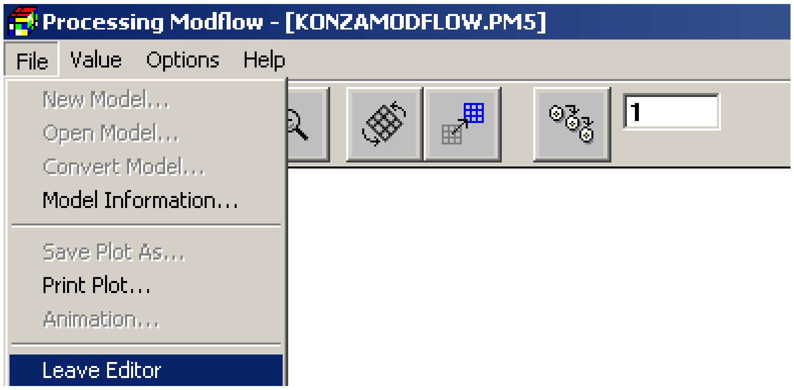
A grey grid should appear in the PMWIN window. Now, we need to define the coordinate system for the grid. Click “**Options – Environment…**”

Activate the Coordinate System tab, and enter the coordinates like the following:

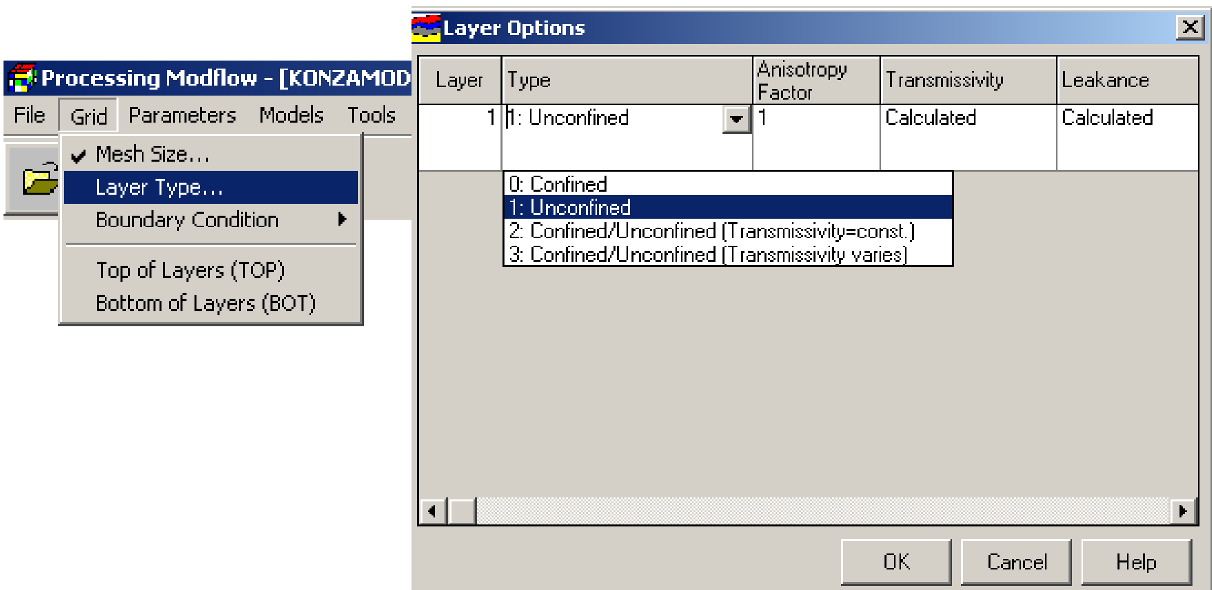
X0 = 701989
Y0 = 4340400
X1 = 700000
Y1 = 4319000
X2 = 723000
Y2 = 4342000



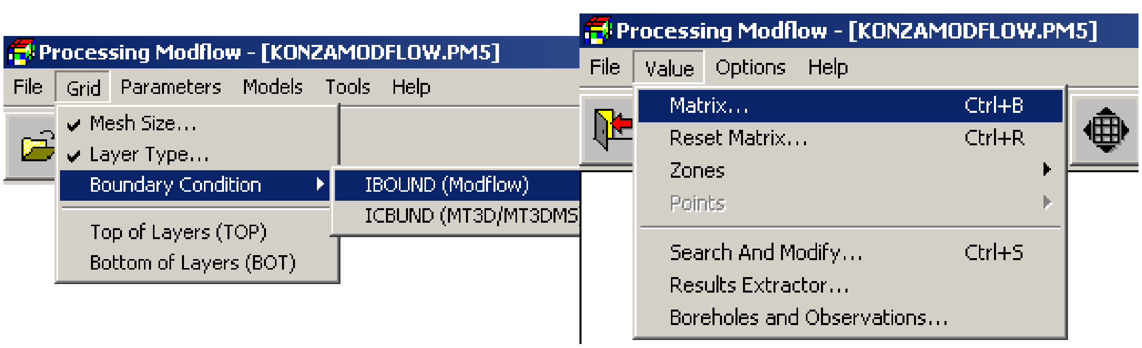
Click “**File - Leave Editor**.” Click **Yes** to save the changes.

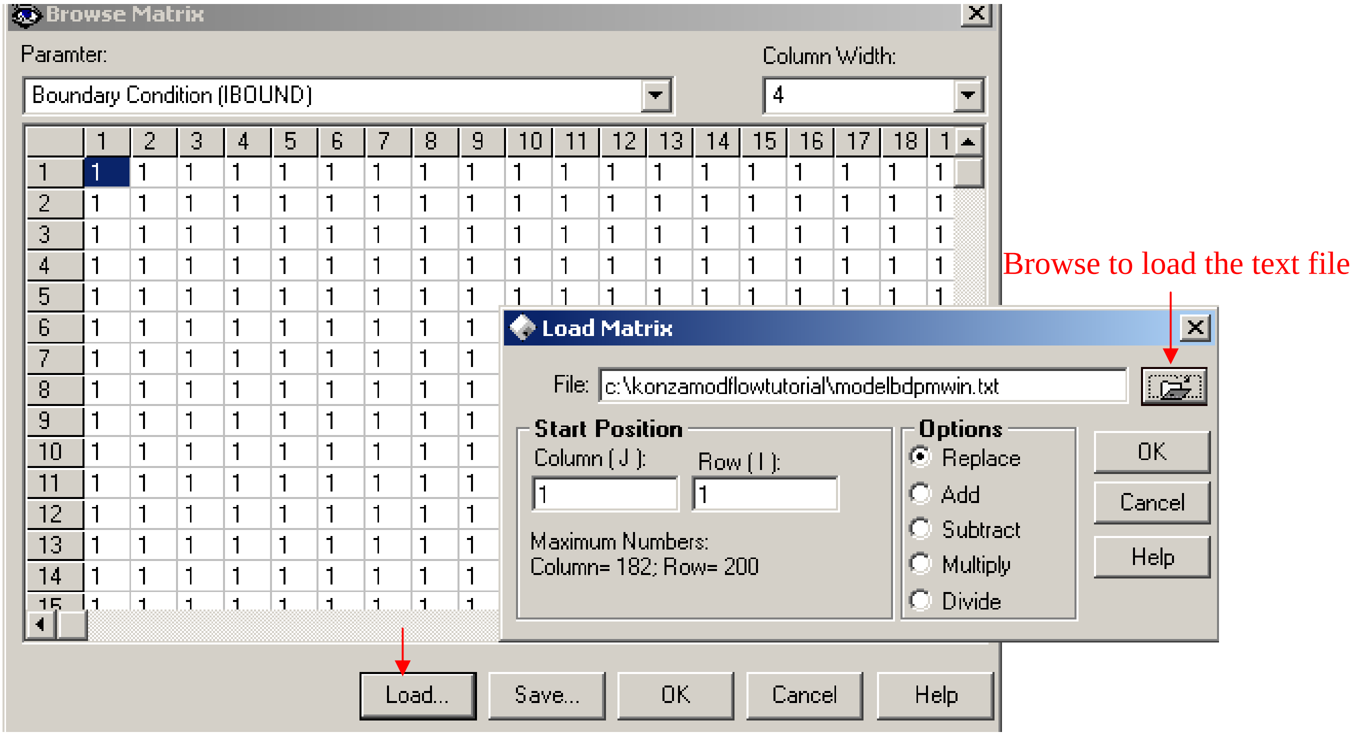


(3) Define the layer type. Click "**Grid – Layer Type…**", specify the aquifer type to be **unconfined**. Click OK.

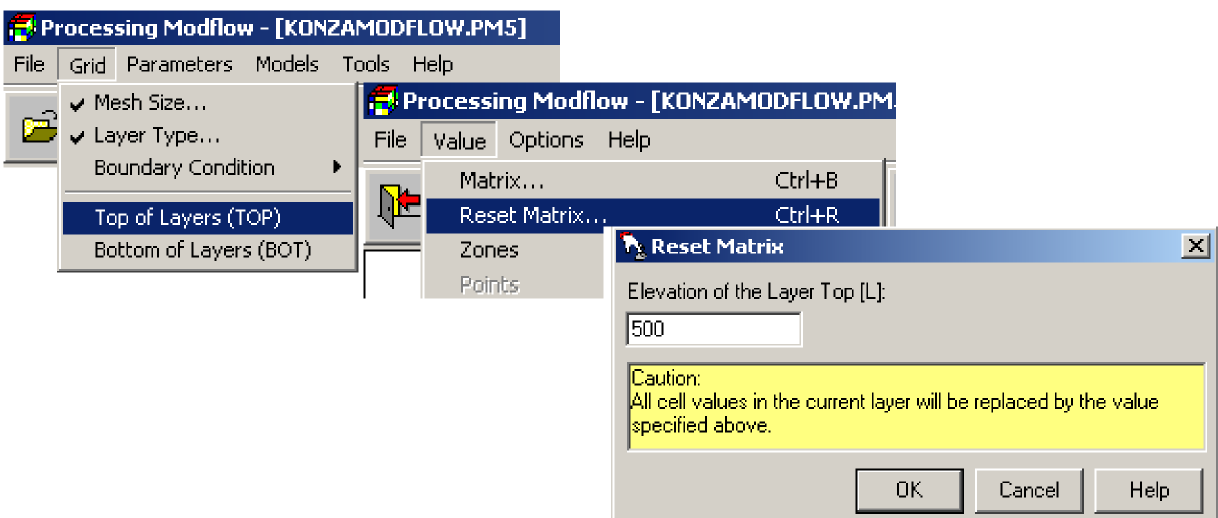


(4) Define boundary condition. Click "**Grid – Boundary Condition – IBOUND.**" The text file ModelBdPMWIN.txt contains the definition of the model boundary. Click "**Value – Matrix...** ", and browse to load ModelBdPMWIN.txt. Leave the editor and save the changes.

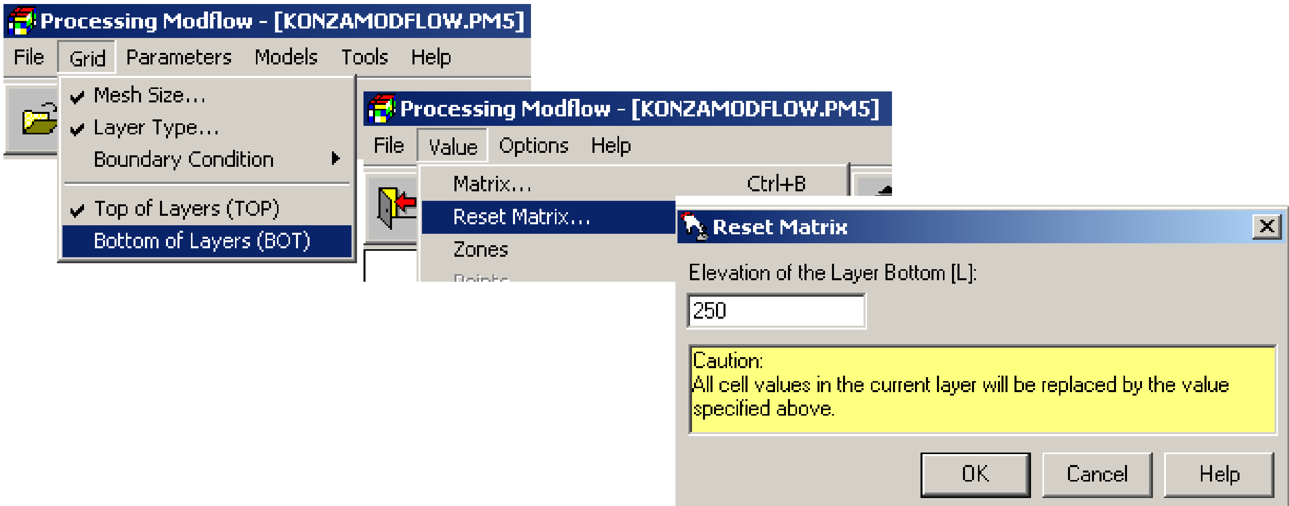




(5) Define the top elevation of the layer to be **500** m. Click "**Grid – Top of Layers**". To define a uniform value for the parameter, click "**Value – Reset Matrix...** ", and enter **500** in the subsequent window. Leave the editor and save the changes.

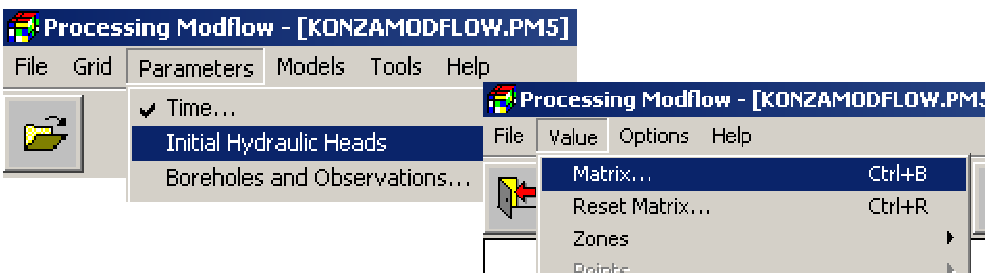


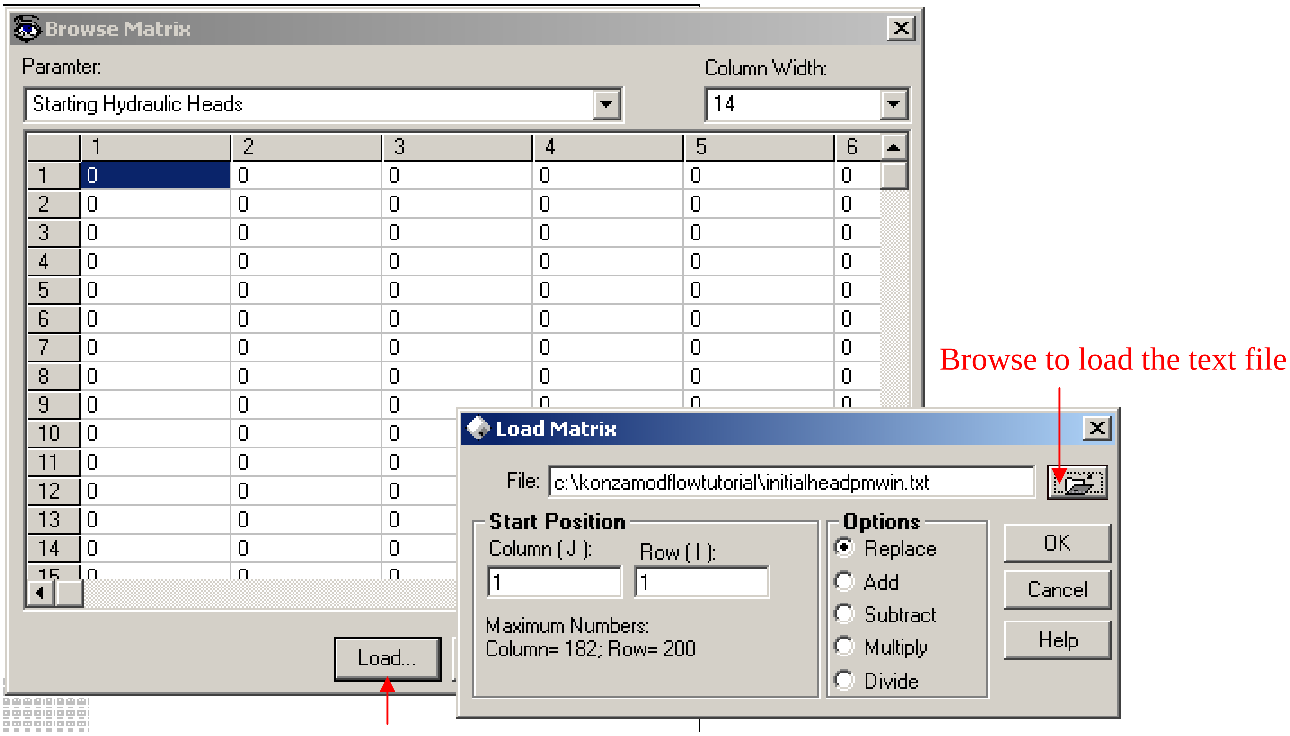
(6) Follow similar procedures as in step 5 to define the bottom elevation of the layer to be **250** m. Leave the editor and save the changes.



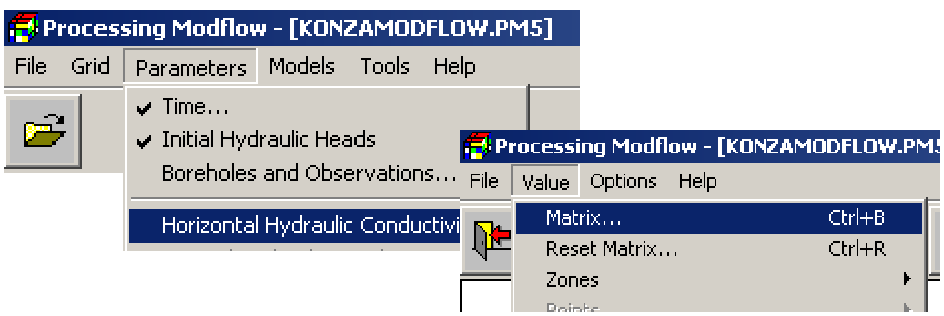
2.2 Define Model Parameters

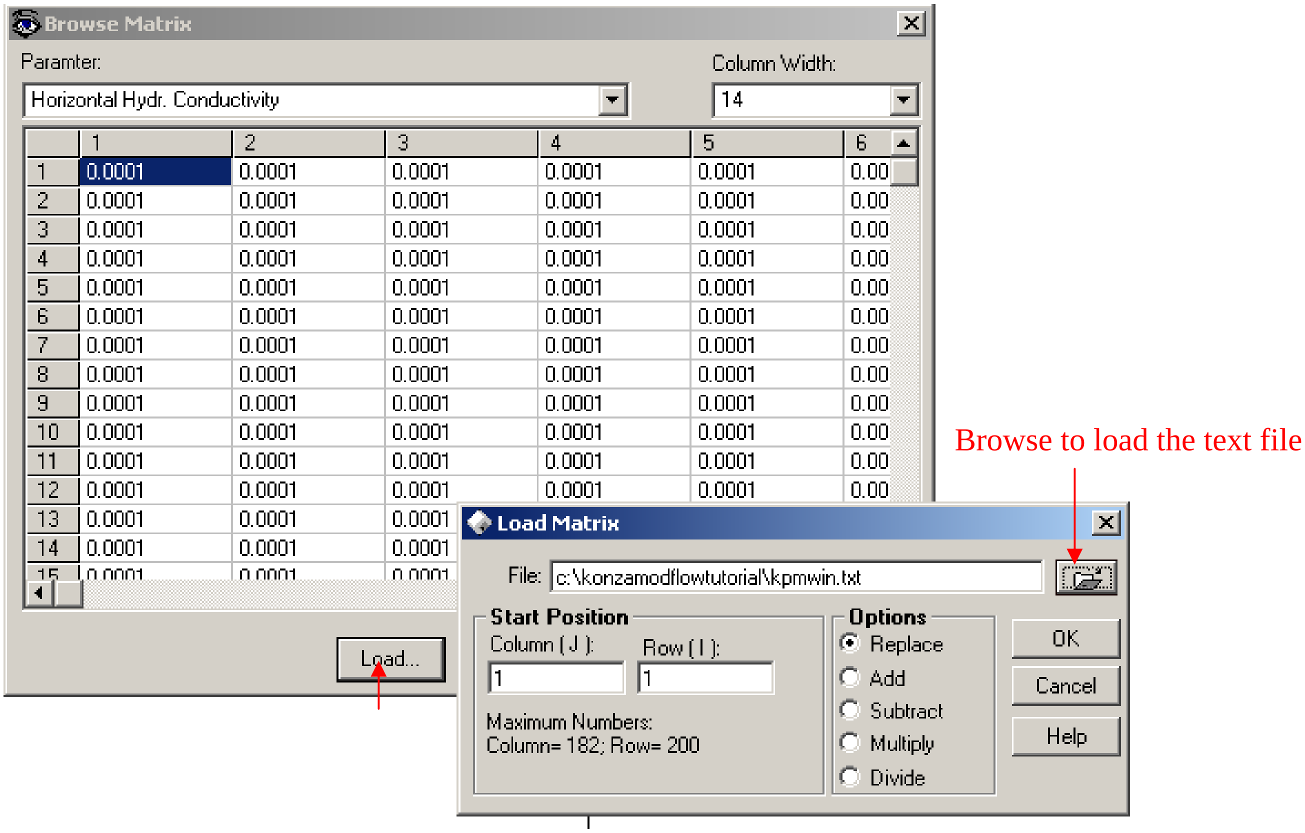
(1) Define initial hydraulic heads. The text file **InitialHeadPMWIN.txt** generated by the GroundwaterDataModelForModflow Toolbox contains information on the distribution of initial hydraulic heads. Click "**Parameters – Initial Hydraulic Heads**." To load the text file, click "**Value – Matrix…**", and browse to load the text file **InitialHeadPMWIN.txt**. Leave the editor and save the changes.





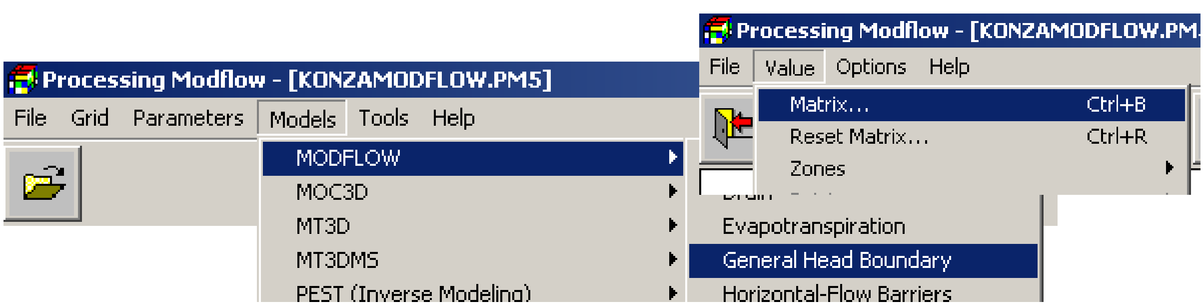
(2) Define horizontal hydraulic conductivity. The text file **KPMWIN.txt** generated by the GroundwaterDataModelForModflow Toolbox contains information on the distribution of hydraulic conductivity. Click "**Parameters – Horizontal Hydraulic Conductivity**." To load the text file, click "**Value – Matrix…**", and browse to load the text file **KPMWIN.txt.** Leave the editor and save the changes.



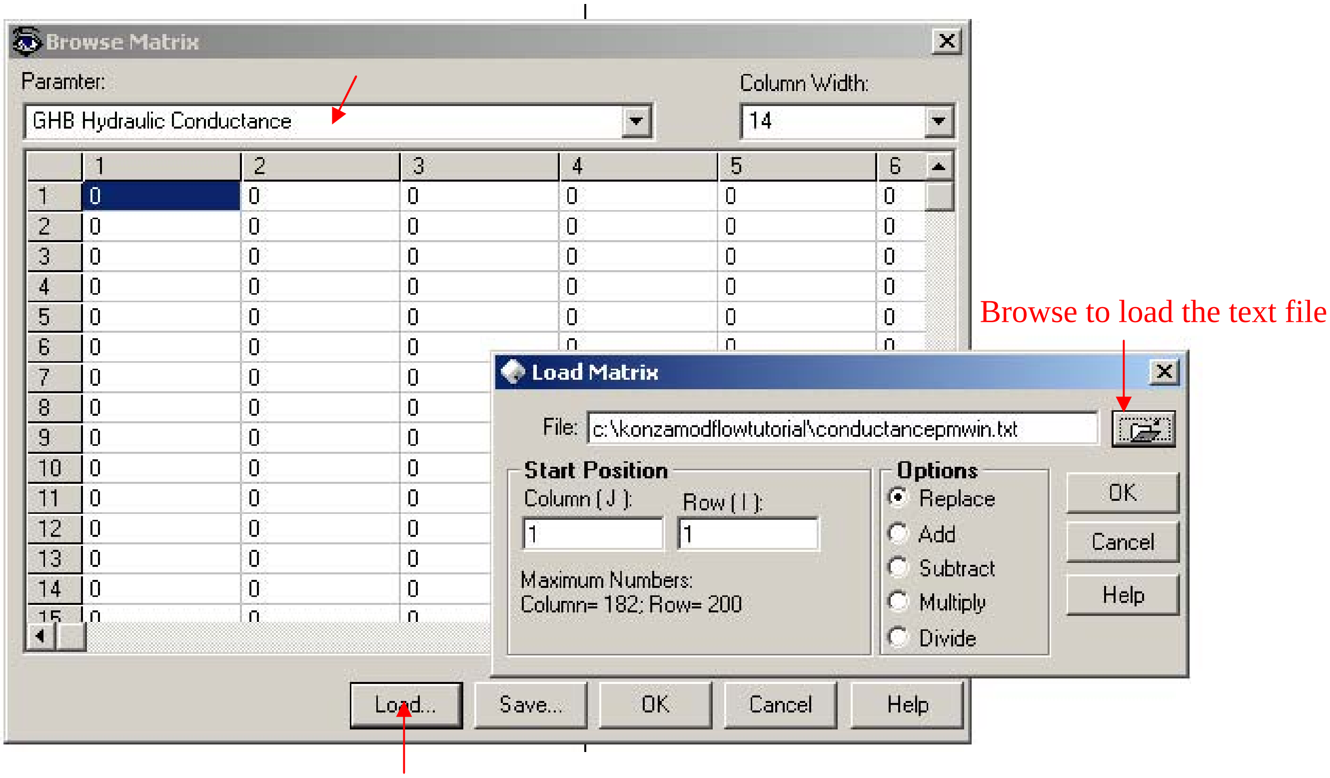


2.3 Define General Head Boundaries for River Segments

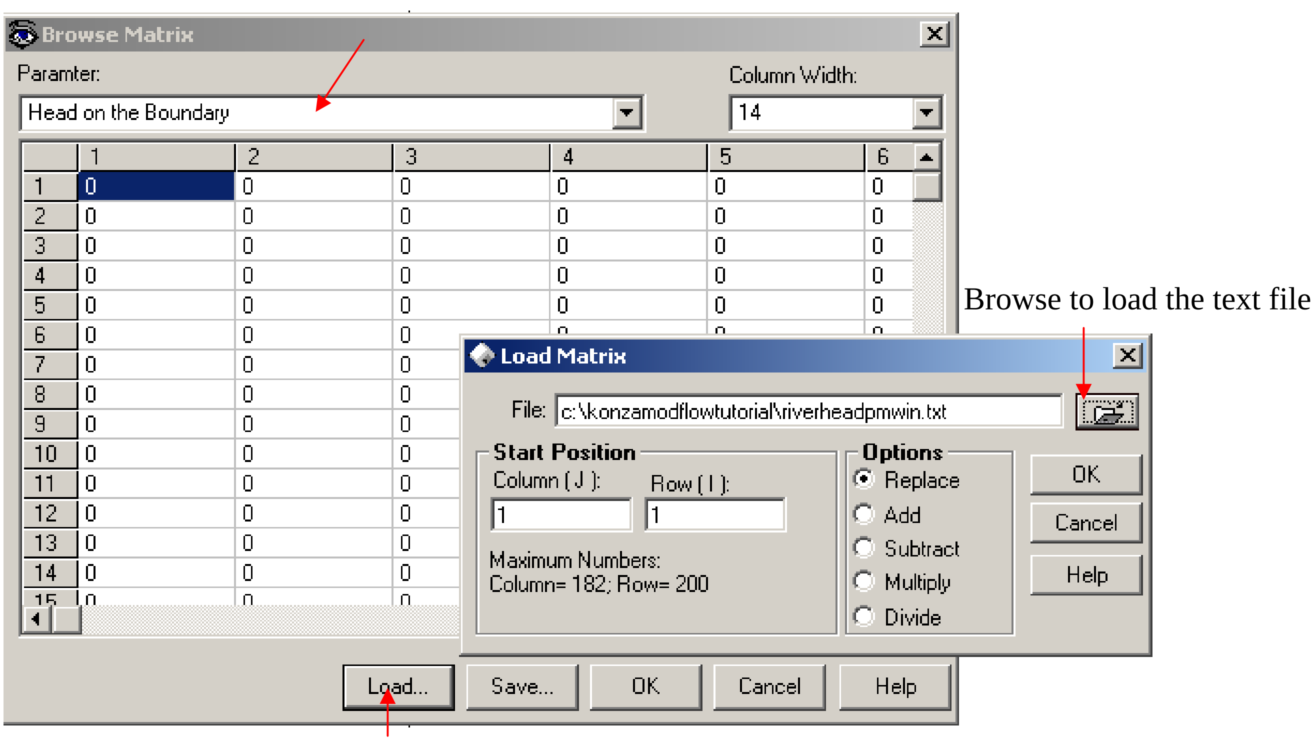
Click "**Models – MODFLOW – General Head Boundary**." The text file **ConductancePMWIN.txt** contains conductance values, and the text file **RiverHeadPMWIN.txt** contains information on head along the river segments. To load the two text files, click "**Value – Matrix…**"



First, load information on conductance. Make sure "GHB Hydraulic Conductance" is the parameter to load. Browse to load **ConductancePMWIN.txt**.



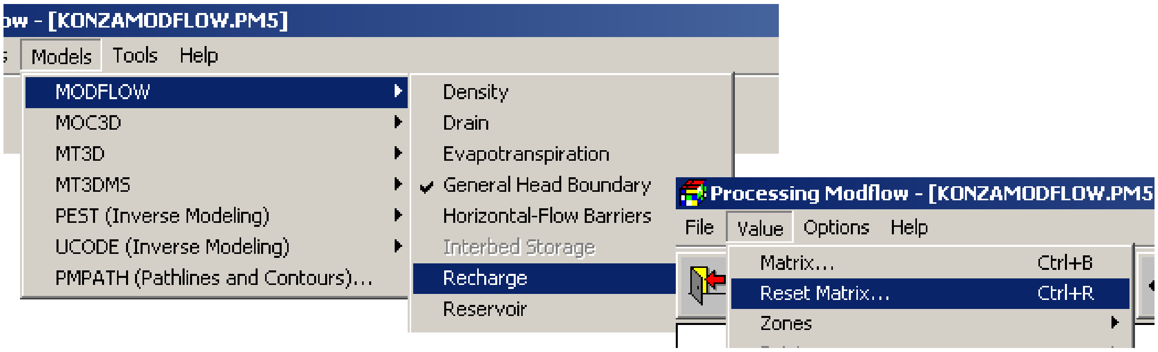
Next, load information on hydraulic head. Specify "Head on the Boundary" as the parameter to be loaded. Browse to load **RiverHeadPMWIN.txt**.

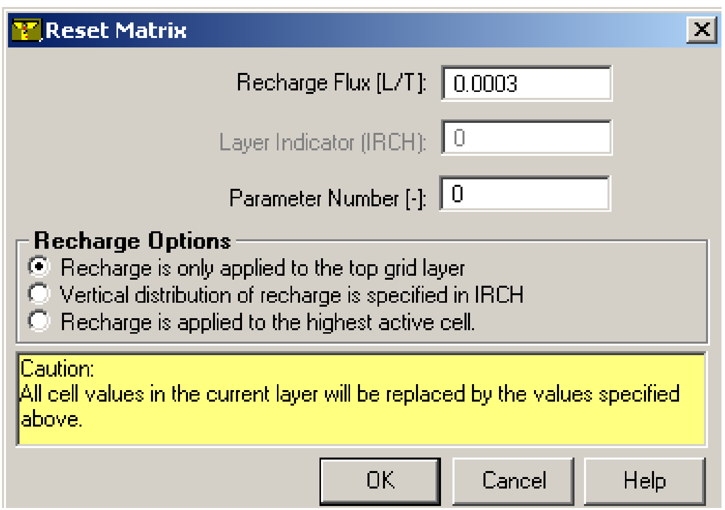


River segments should appear on the screen after loading the two parameters. Leave the editor and save the changes.

2.4 Define Recharge

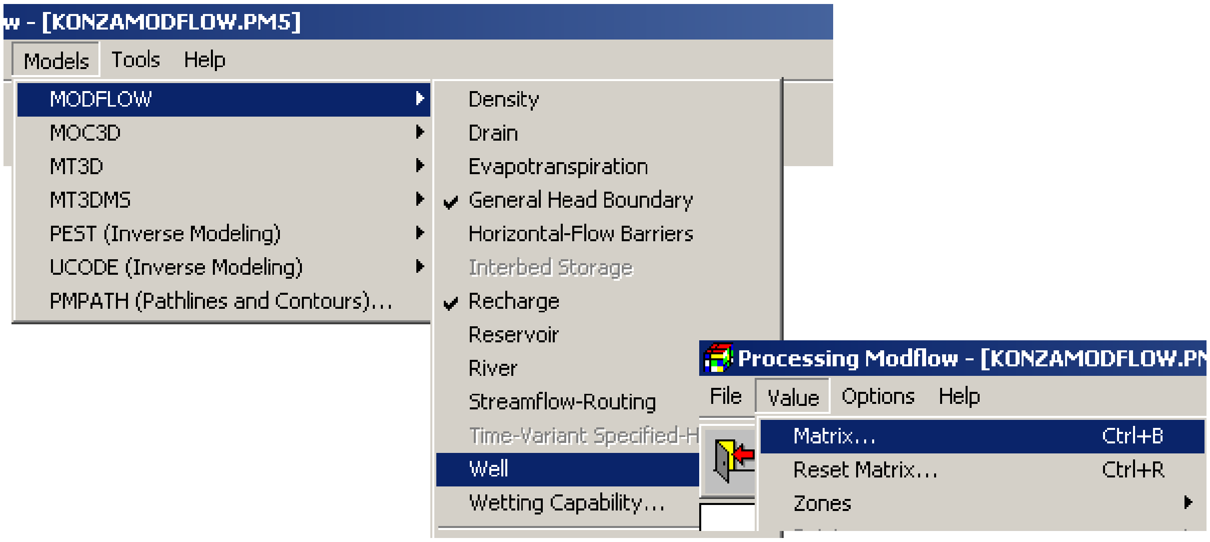
Click “**Models – MODFLOW – Recharge.**” To define a uniform recharge rate of 0.0003 m/d, click “**Value – Reset Matrix...** ”, and enter **0.0003** in the subsequent window. Leave the editor and save the changes.

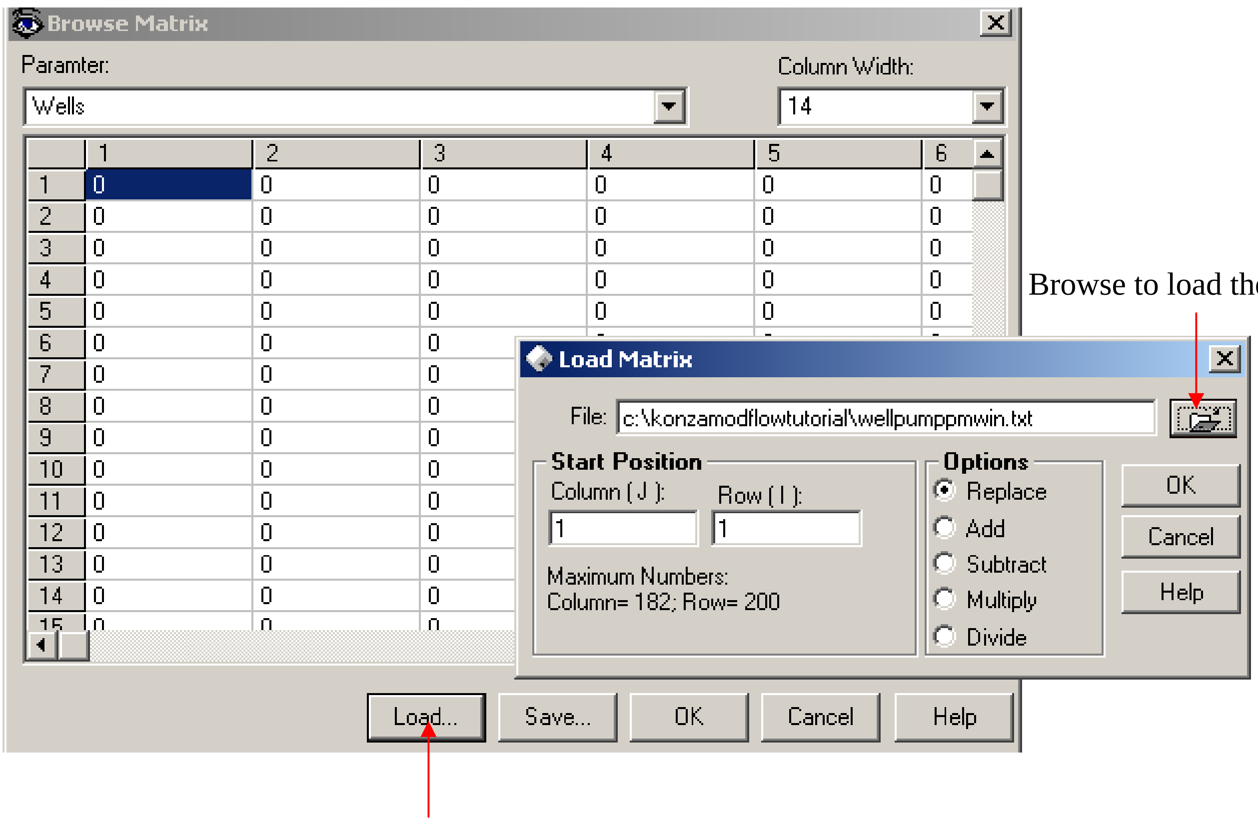




2.5 Define Well Pumping Rates

Click “**Models – MODFLOW – Well**.” The text file **WellPumpPMWIN.txt** contains information on the spatial distribution of well pumping rates. To load the information, click “**Value – Matrix…**” Browse to load **WellPumpPMWIN.txt.**



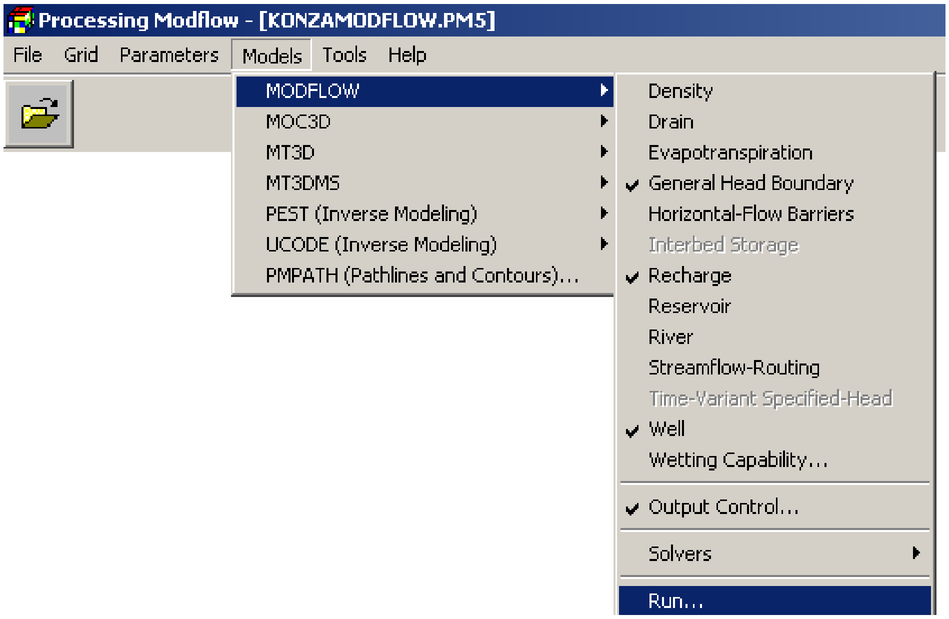


Browse to load the text file

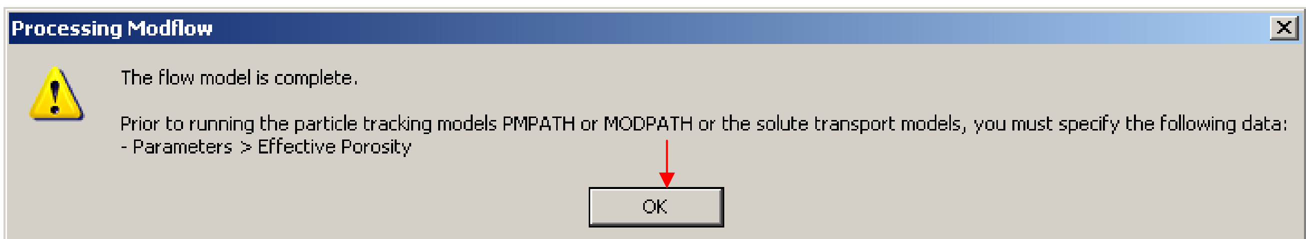
Well points should appear on the screen after loading the text file. Leave the editor and save the changes.

2.6 Run the Konza Groundwater Model

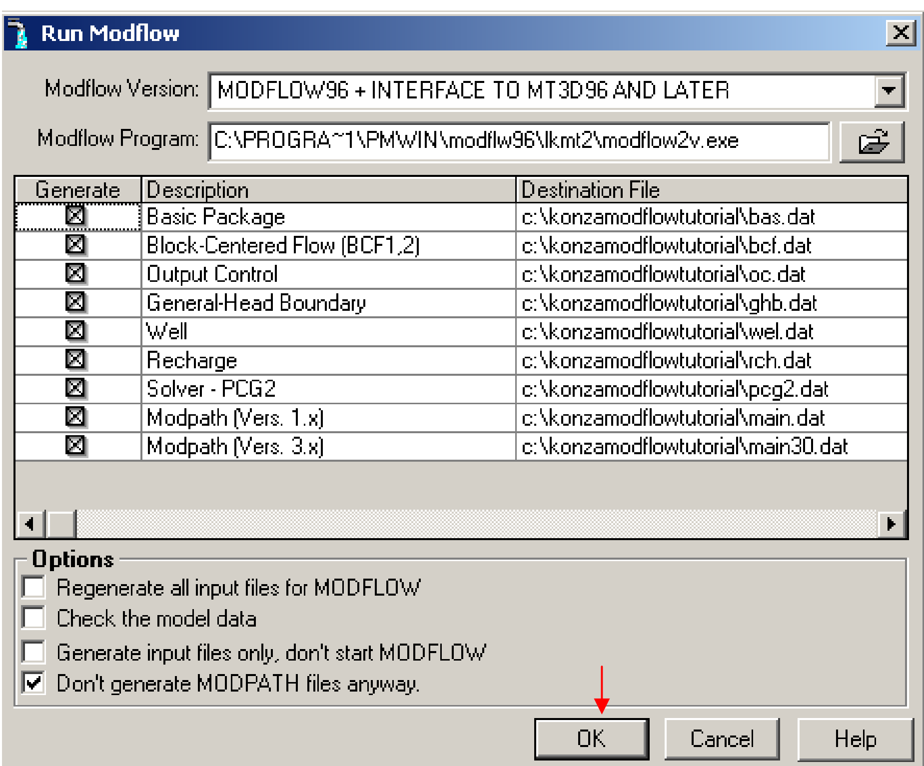
So far, we have finished defining parameters for the Konza Modflow groundwater model. Now, it is ready to run! Click "**Models – MODFLOW – Run...** "



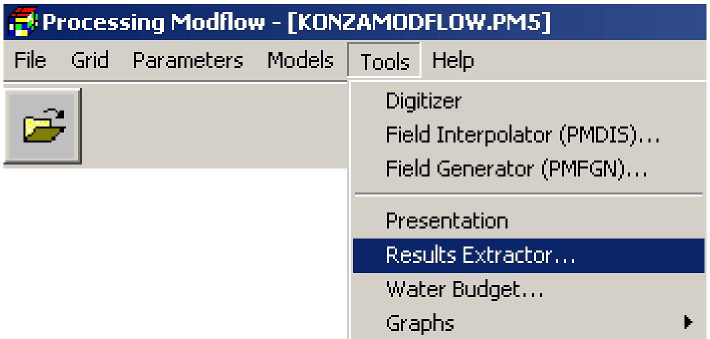
Click OK on the Processing Modflow window.



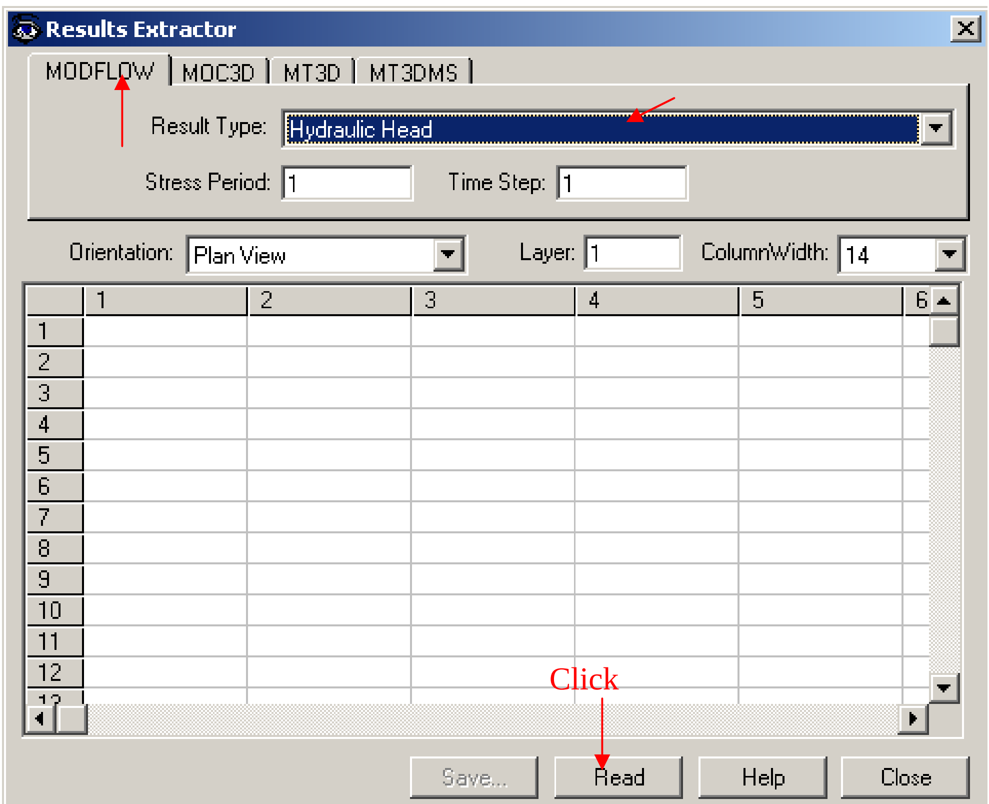
Click OK on the Run Modflow window.



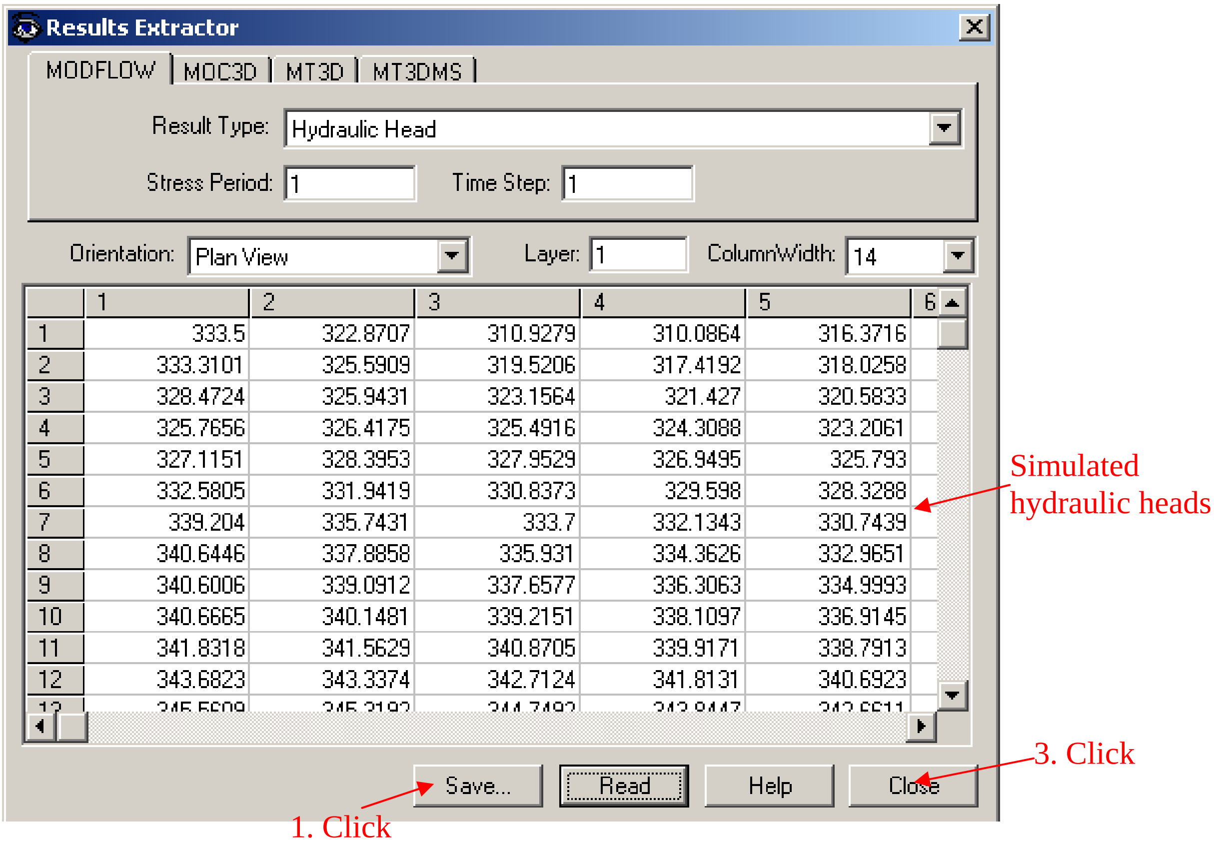
After the model run is finished, we can examine the simulated hydraulic heads as well as export the results to a text file. Click "**Tools – Result Extractor...** "

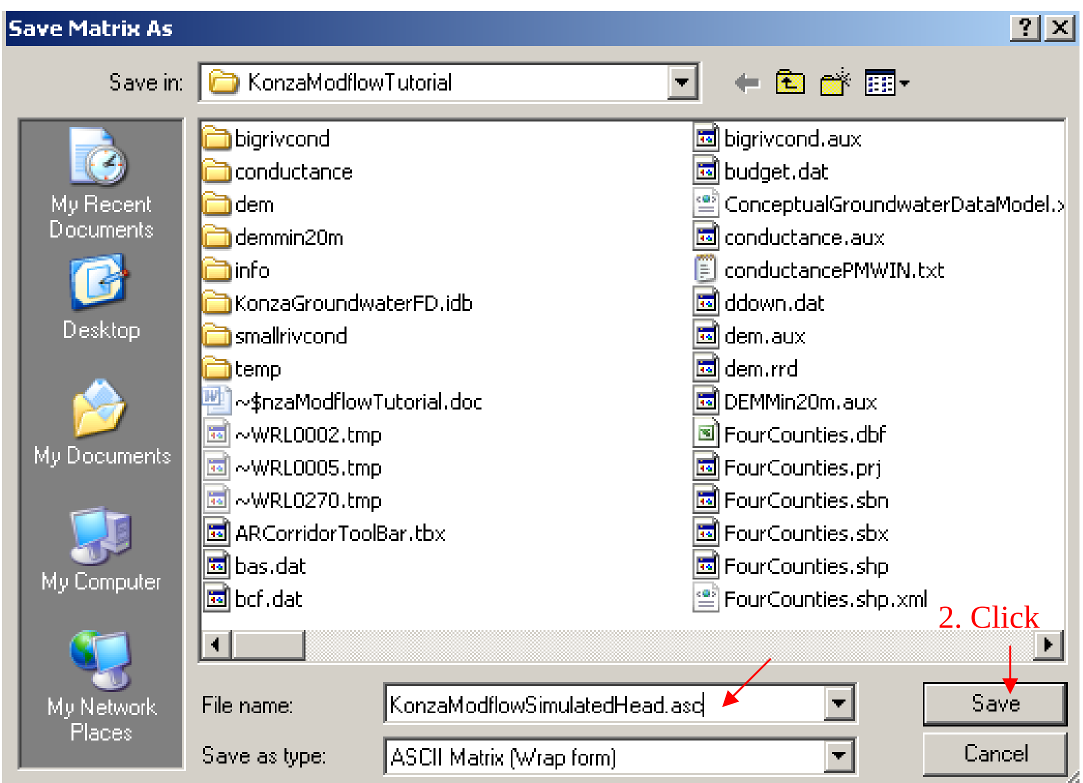


On the Results Extractor window, make sure that the **MODFLOW** tab is activated, and the result type is **Hydraulic Head**. Click the **Read** button, and the simulated hydraulic heads will show up on the screen.

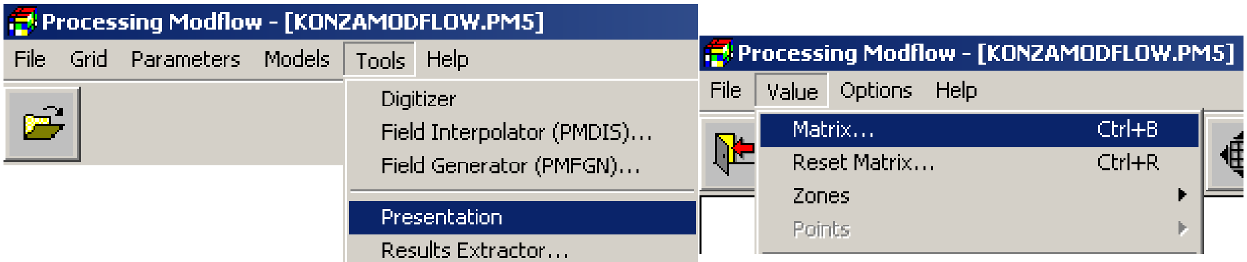


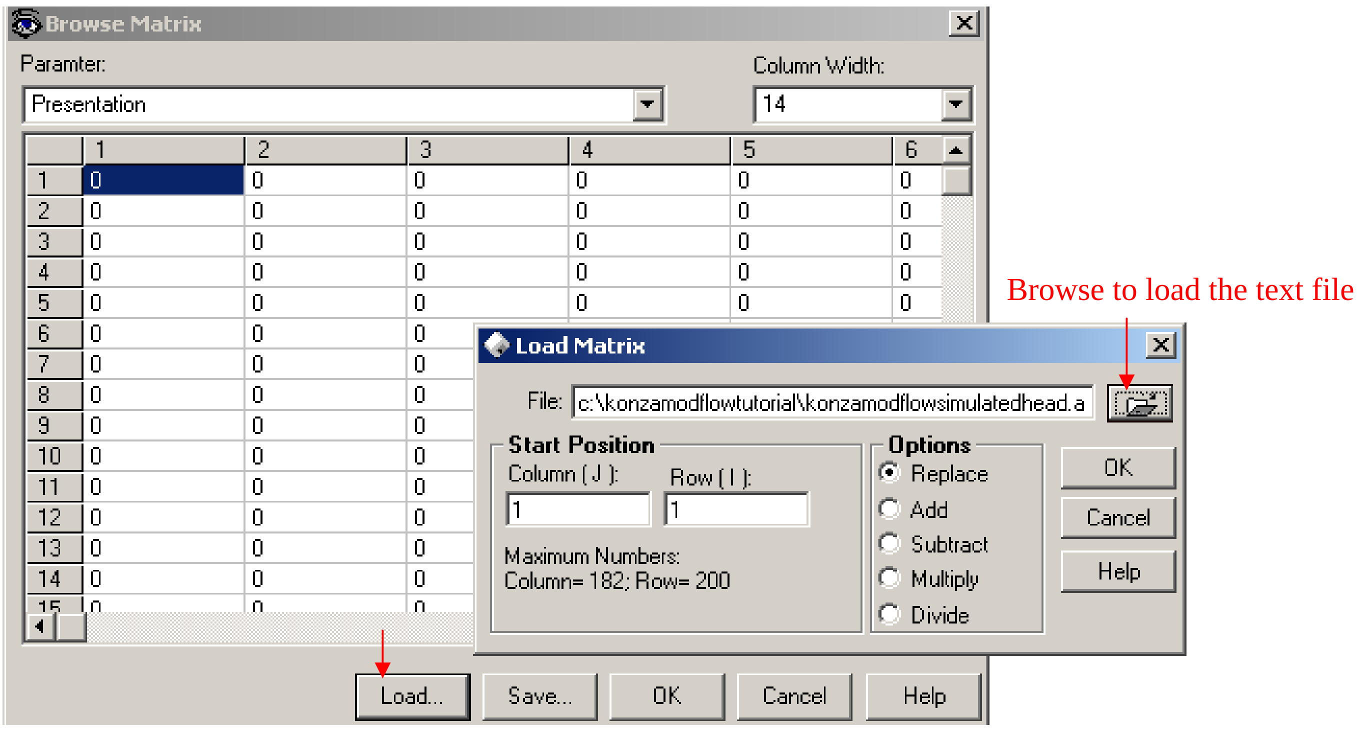
Click the **Save** button to save the simulated hydraulic heads to a text file - **KonzaModflowSimulatedHead.asc** under your working folder. Click the **Close** button to close the Results Extractor window.



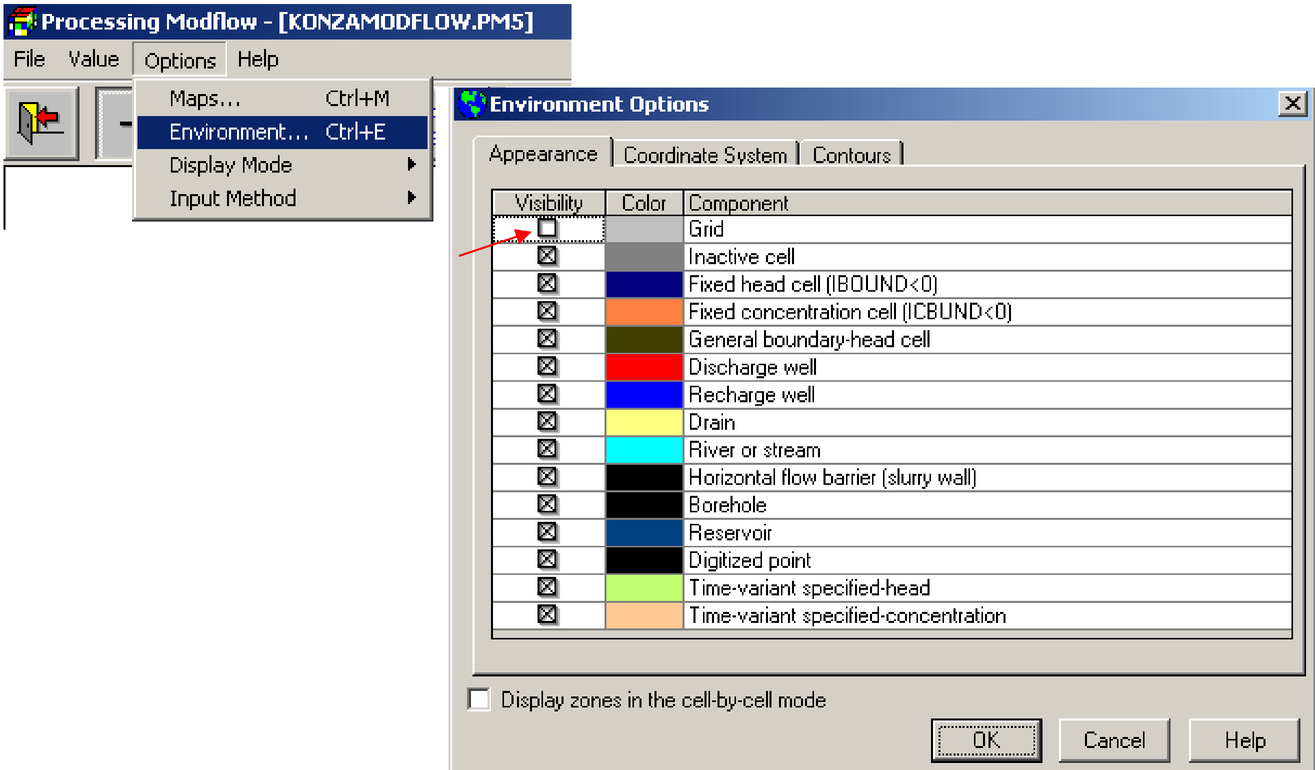


Now, we are ready to visualize the simulated hydraulic heads. Click “**Tools – Presentation,**” then click “**Value – Matrix…**” to load the text file **KonzaModflowSimulatedHead.asc** that contains values on simulated hydraulic heads.

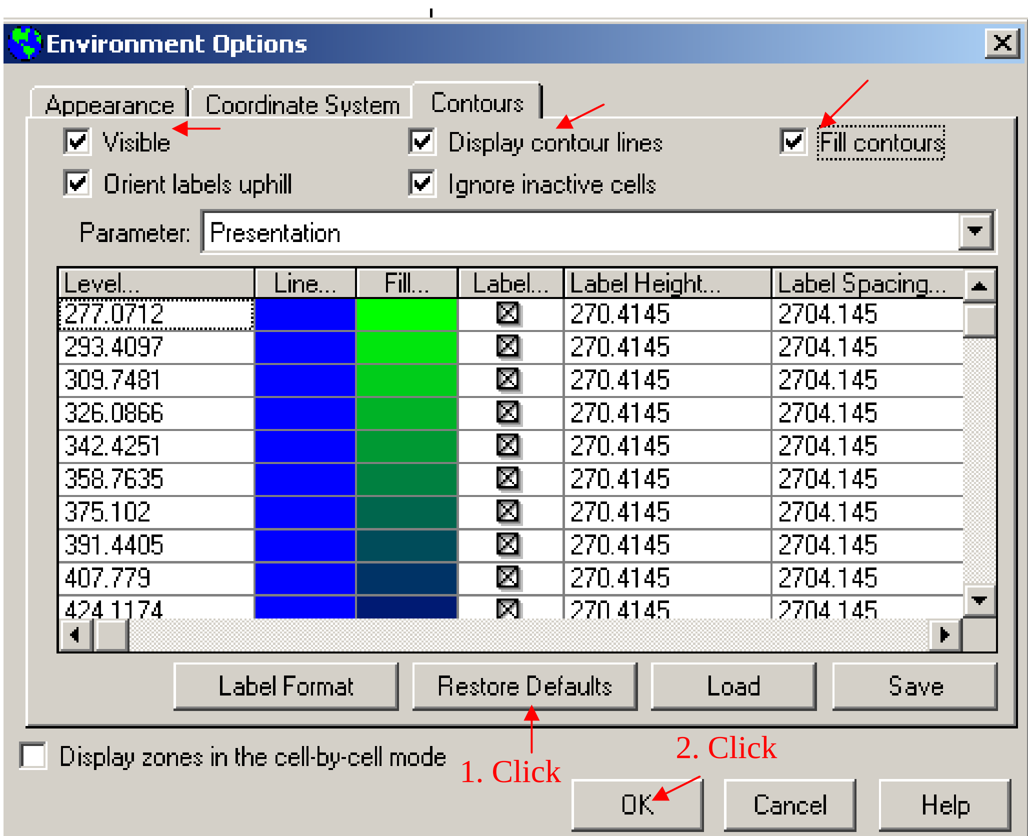




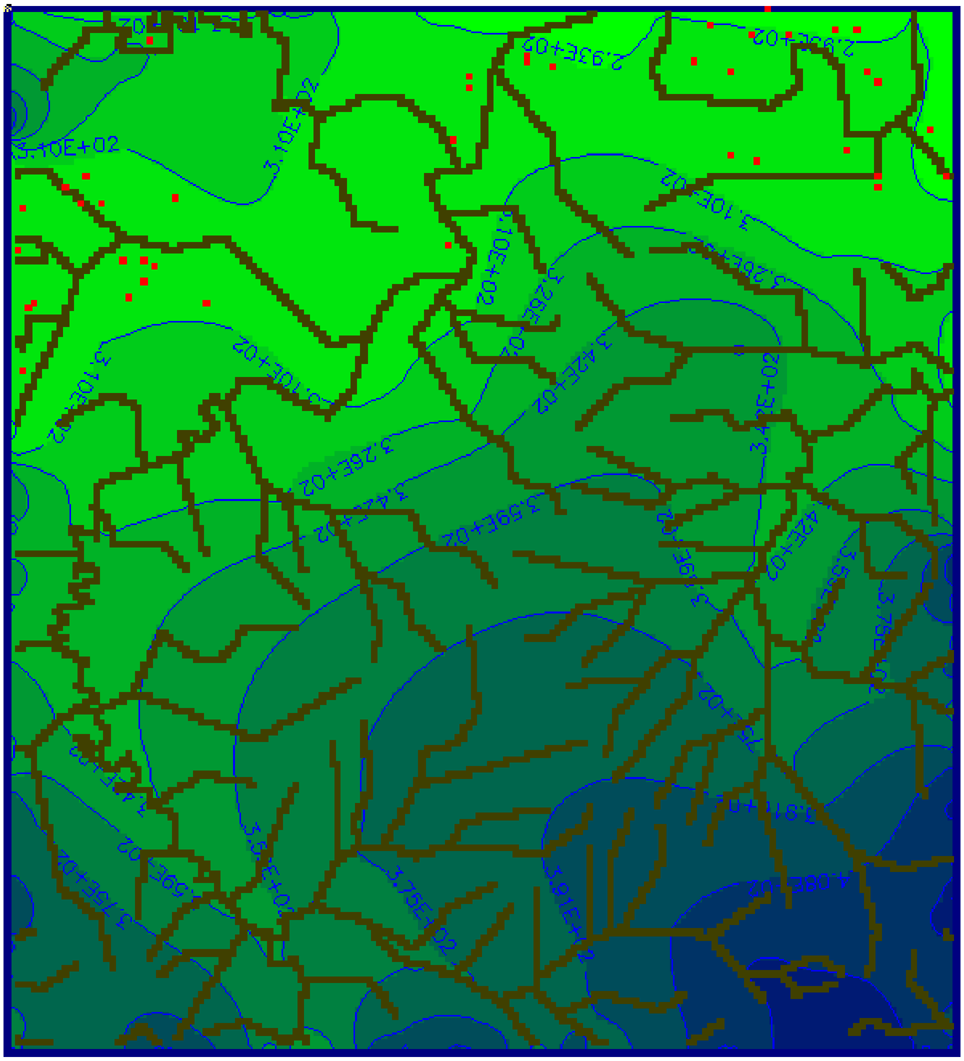
Click "**Options – Environment...** ", and uncheck the **Grid** component on the **Appearance** tab so that the grid cells of the modflow model will not show on the screen.



Activate the **Contours** tab. Make sure that the options of **Visible**, **Display contour lines**, and **Fill contours** are checked. Click the **Restore Defaults** button.

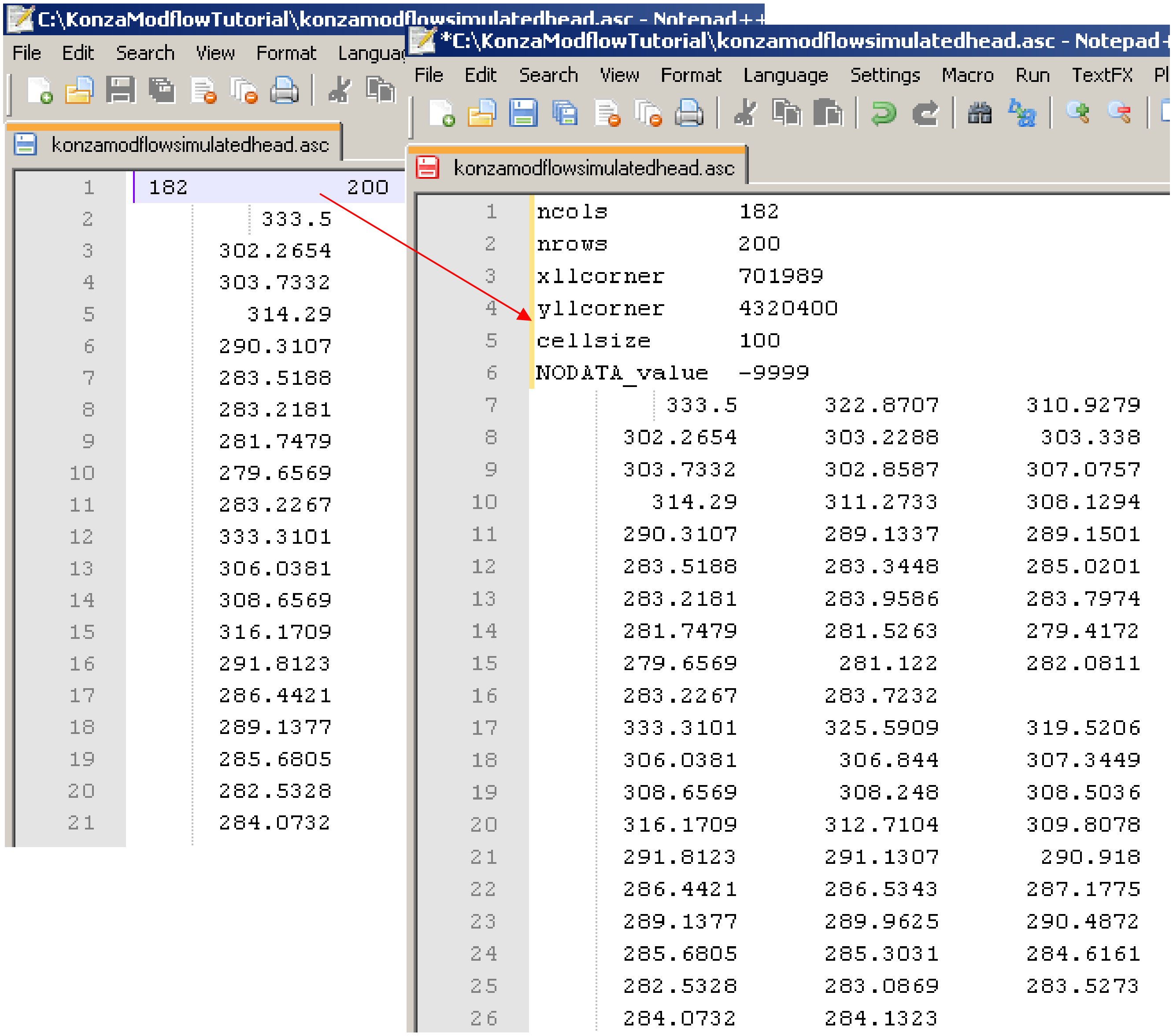


The contours of the simulated hydraulic heads are shown as in the following figure:

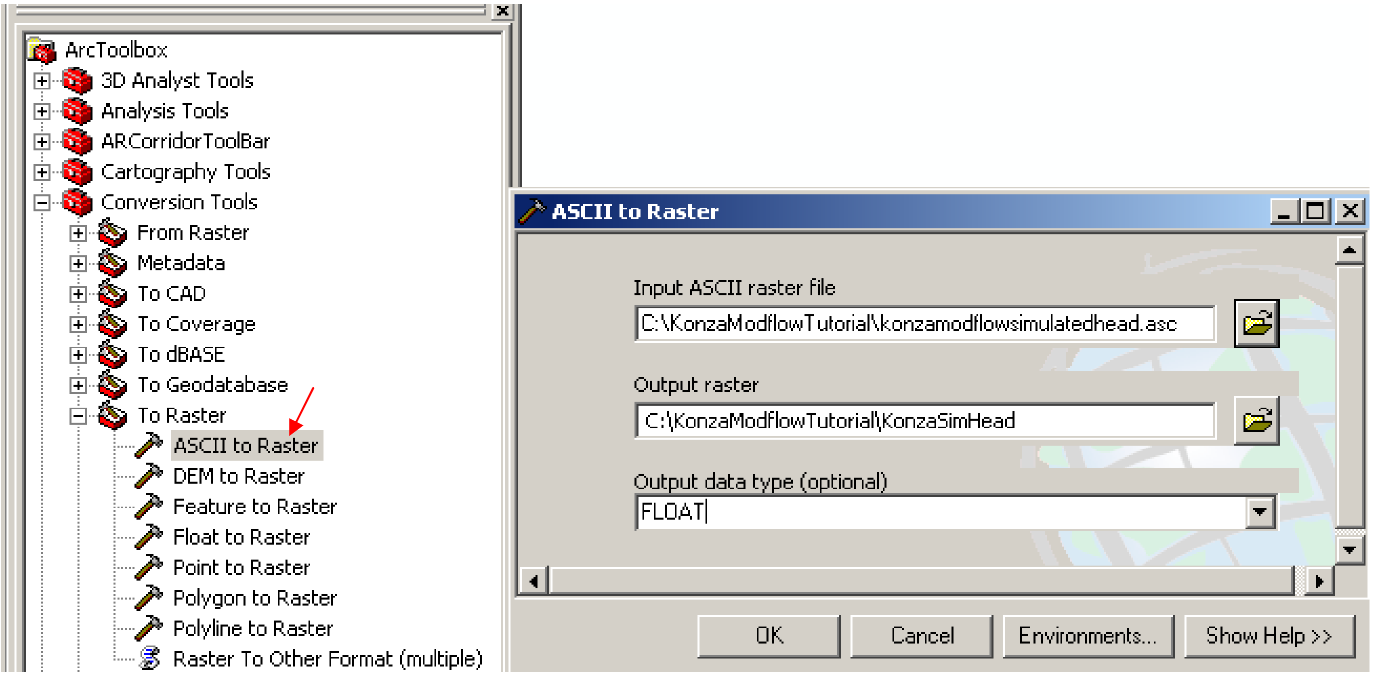


We can also visualize simulated hydraulic heads in Arc Map. To do this, we first need to modify the header of the text file **KonzaModflowSimulatedHead.asc** as in the following so that it can be imported to a raster file:

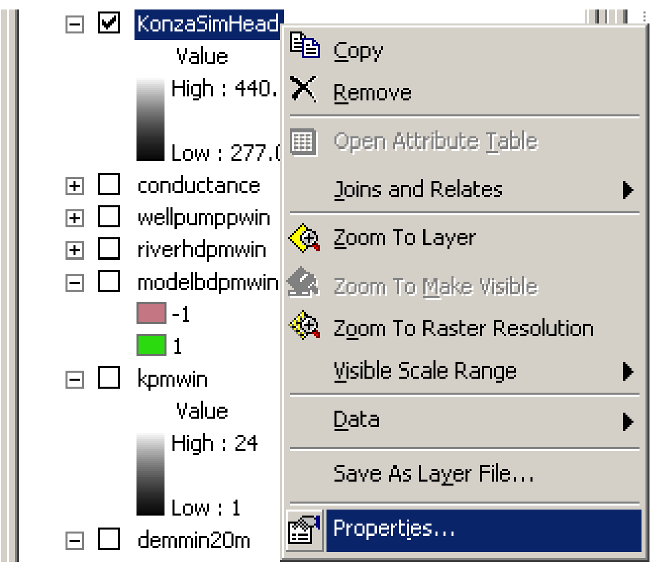
```
ncols        182
nrows         200
xllcorner     701989
yllcorner     4320400
cellsize      100
NODATA_value  -9999
```



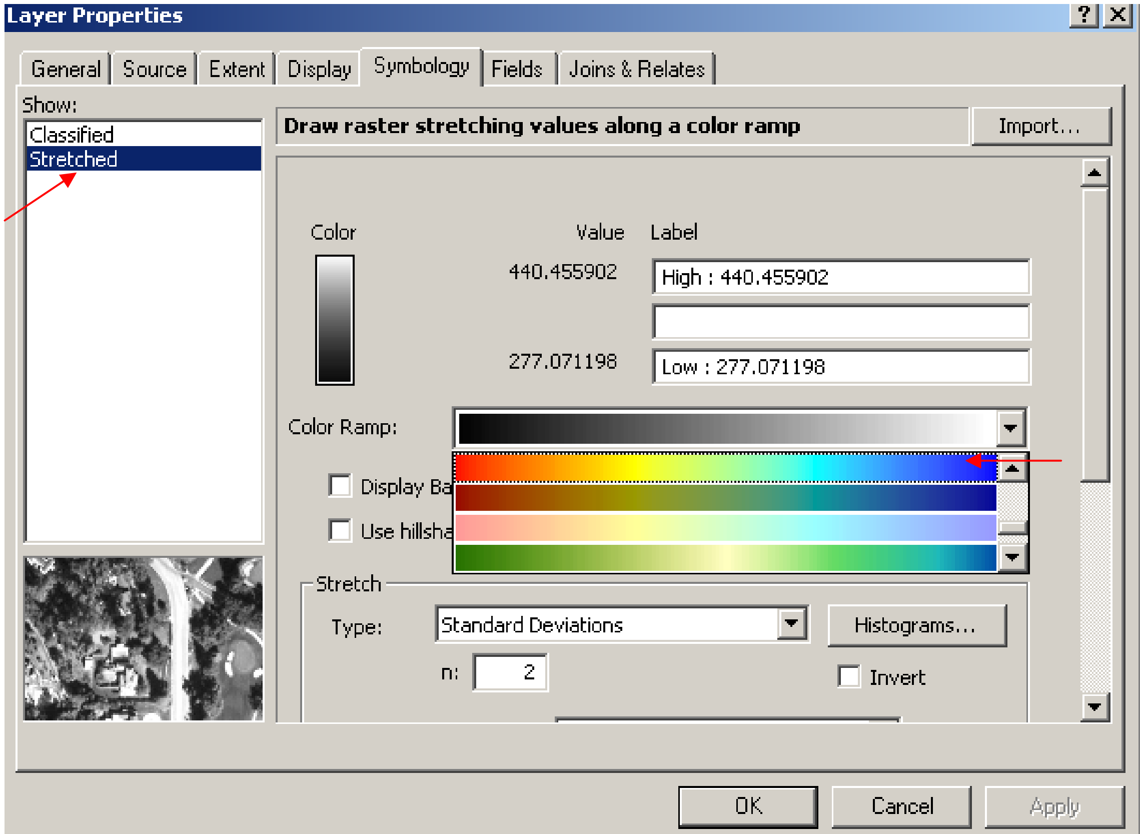
Open the tool “Ascii To Raster” under the “To Raster” toolset in the Conversion Tools toolbox. Specify **KonzaModflowSimulatedHead.asc** as the input ASCII raster file, save the output raster as KonzaSimHead in your working folder, and specify the output data type to be float.



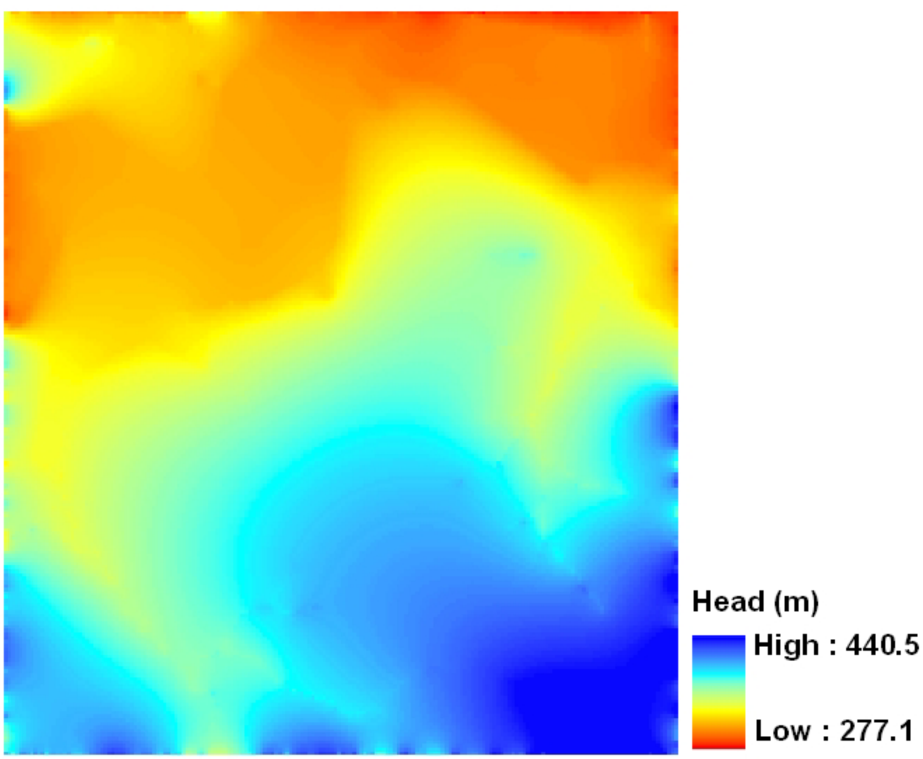
After the tool is executed, a layer KonzaSimHead will appear in Arc Map. Let us change the symbology of the layer. Right click the layer, and click "**Properties...**"



On the Layer Properties window, activate the **Symbology** tab. Make sure to draw raster in a stretched way. Choose the color ramp streching from red to blue.



The newly symbolized layer on hydraulic head is like the following:



2.7 Conclusion

In conclusion, we have gone over the steps of creating a conceptual groundwater geodatabase to store the conceptual view of a groundwater system and transferring the data from the geodatabase to PMWIN to develop a finite difference groundwater model in this tutorial. What needs to be pointed out is that the conceptual groundwater data model is flexible enough to work with various types of numerical groundwater methods. Two other tutorials have been also developed to illustrate its use with the finite element and analytical element methods.

Reference

Strassberg, G., 2005, *A geographic data model for groundwater systems*. PhD thesis, University of Texas at Austin

Chiang, W.H., 2001, *3D-Groundwater modeling with PMWIN: A simulation system for modeling groundwater flow and transport processes*, 2 (New York: Springer).