ARC HYDRO GROUNDWATER TUTORIALS

Wells and Time Series

Arc Hydro Groundwater (AHGW) is a geodatabase design for representing groundwater datasets within ArcGIS. The data model helps to archive, display, and analyze multidimensional groundwater data, and includes several components to represent different types of datasets, including representations of aquifers and wells/boreholes, 3D hydrogeologic models, temporal information, and data from simulation models.

The *Arc Hydro Groundwater Tools* help to import, edit, and manage groundwater data stored in an AHGW geodatabase. This tutorial illustrates how to use the tools to manage well data and time series data (transient water level measurements) associated with wells. A basic familiarity with the AHGW data model is suggested, but not required, prior to beginning this tutorial.

1.1 Outline

In this tutorial, we will be working with groundwater data from the Panhandle region of Texas. We will complete the following tasks:

1. Import a set of well data into ArcGIS.
2. Modify the well attributes.
3. Generate time series plots of water level data.
4. Generate average water level maps for selected periods.
5. Build a geoprocessing model to automate running a tool.
6. Generate a flow direction map.

1.2 Required Modules/Interfaces

You will need the following components enabled in order to complete this tutorial:

- Arc View license (or ArcEditor\ArcInfo)
- Arc Hydro Groundwater Tools
- Spatial Analyst or 3D Analyst extension
- AHGW Tutorial Files

The *AHGW Tools* requires that you have a compatible ArcGIS service pack installed. You may wish to check the *AHGW Tools* documentation to find the appropriate service pack for your version of the tools. *Spatial Analyst* is required for one portion of the tutorial involving interpolation. If you do not have *Spatial Analyst*, you can skip that portion of the tutorial. The tutorial files should be downloaded to your computer and saved on a local drive.

2 Getting Started

Before opening our map, let's ensure that the *AHGW Tools* are correctly configured.

1. If necessary, launch *ArcMap*.
2. If necessary, open the *ArcToolbox* window by clicking on the *ArcToolbox* icon  .
3. Make sure the Arc Hydro Groundwater Toolboxes is loaded. If it is not, add the toolboxe by right-clicking anywhere in the *ArcToolbox* window and selecting the *Add Toolbox…* command. Browse to the top level of the *Catalog* and then browse down to the *Toolboxes*|*System Toolboxes* directory. Select the toolbox and select the *Open* button.
4. Expand the *Arc Hydro Groundwater Tools* item and then expand the *Groundwater Analyst* toolset to expose the tools we will be using in this tutorial.

Note that many of the GP tools in the *AHGW Toolbox* can also be accessed from the AHGW Toolbar. The toolbar contains additional user interface components not available in the toolbox. If the toolbar is not visible, do the following:

5. Right-click on any visible toolbar and select the *Arc Hydro Groundwater Toolbar* item.

When using geoprocessing tools you can set the tools to overwrite outputs by default, and automatically add results to the map/scene. To set these options:

6. Open ArcMap/ArcCatalog (if not already open).

7. Select the *Geoprocessing* | *Geoprocessing Options...* command and select the *Geoprocessing* tab.

8. Activate the option: "*Overwrite the outputs of geoprocessing operations*" as shown in Figure 1.

9. Enable the option to "*Add results of geoprocessing operations to the display*" as shown in Figure 1.

10. Select *OK* to exit the setup.

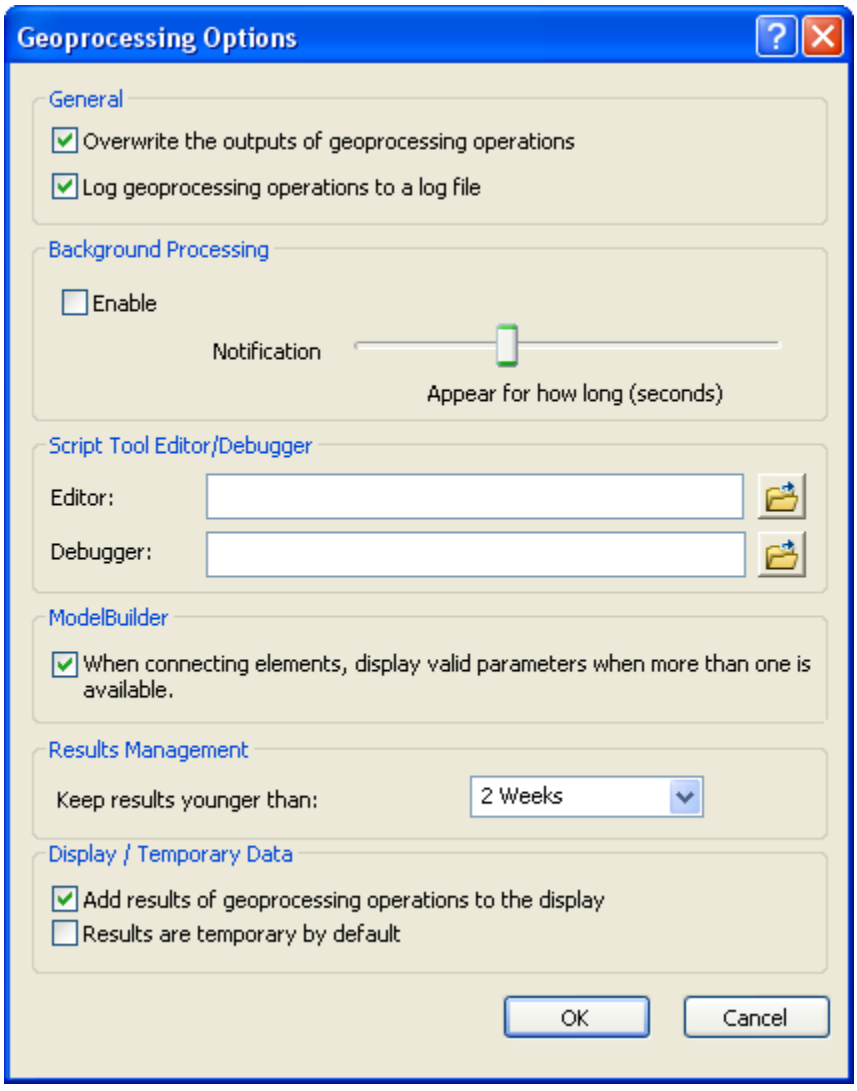


Figure 1 Setting Geoprocessing tools to overwrite outputs by default, and to add results of geoproceesing tools to the display.

3 Opening the Map

We will begin by opening a map containing county boundaries for the Panhandle region of North Texas.

1. Select the *File* | *Open* command and browse to the location on your local drive where you have saved the AHGW tutorials. Browse to the *Groundwater Analyst* | *wells and time series* folder and open the file entitled **lubbock_wells.mxd**.

Once the file has loaded you will see a map of the Panhandle region of North Texas. The filled polygon represents the boundary of the Ogallala aquifer in Texas. This data was obtained from the *Texas Water Development Board Groundwater Database* (http://www.twdb.state.tx.us/publications/reports/groundwaterreports/gwdatabasereports/gwdatabaserpt.htm).

4 Importing the Well Data

Next, we will import the well data for Lubbock County. The well data has been downloaded from the above-referenced website to a comma-delimited text file. The AHGW Tools include a tool for automating the import of text data into a AHGW geodatabase.

1. In the AHGW Toolbar, select the *Arc Hydro GW* | *Text Import* command.

2. In the *wells and time series* folder, select and open the **lubbock_well_data.txt** file.

3. At the top of the *File Import Wizard*, turn **on** the *Comma* toggle and turn **off** the *Space* toggle in the *column delimiters* section.

4. Turn **on** the *Treat consecutive delimiters as one* toggle.

5. Turn **on** the *Heading row* toggle. This indicates that the first row contains headers for the data.

At this point, the dialog should look like the example shown in Figure 2.

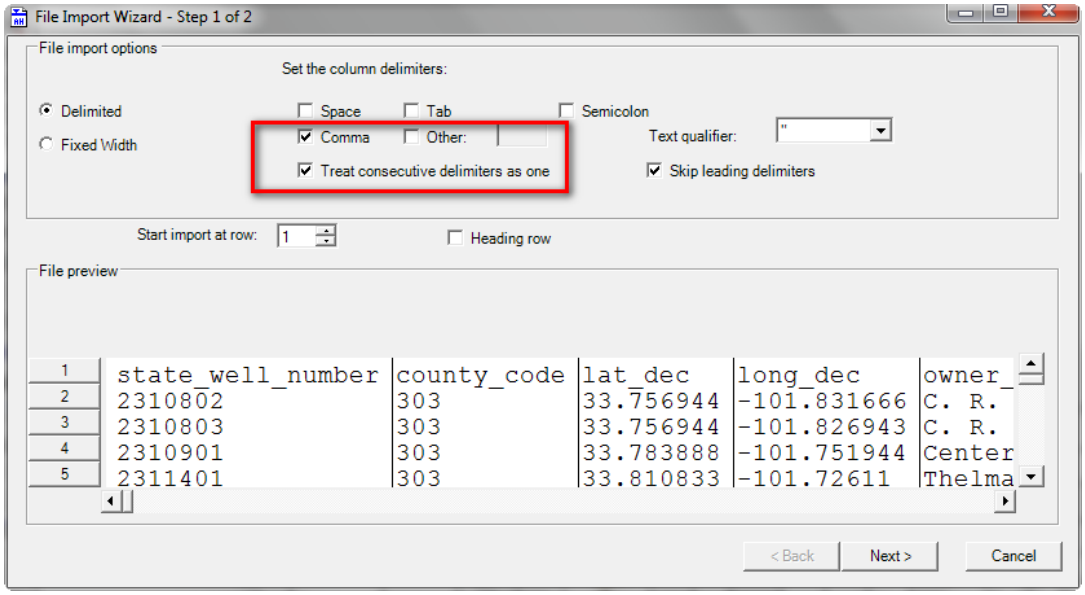


Figure 2 File Import Wizard, Step 1 of 2.

6. Select the *Next* button to go to the next step of the wizard.

In the next step of the wizard we indicate the type of data we are importing and specify how each of the columns in the file is linked to fields in the target feature class or table (*Well* in this case). The contents of the file are shown in the table at the bottom of the dialog. For each column that we wish to import, we will select the appropriate field name in the *Type* row. By default, *<not mapped>* is selected for each column indicating that the column will not be imported to a field in the Well feature class.

7. Make sure that the **Well** option is selected in the *Create Features/Rows in:* combo box.

8. In the first column with a *Header* value = "*state_well_number*", double-click on the *<not mapped>* item in the *Type* row, and select **HydroCode**.

9. Repeat the previous step to create the following relationships (you will need to scroll to the right to see some of the fields):

Header	Type
state_well_number	HydroCode
lat_dec	Y
long_dec	X
aquifer_id1	AquiferCode
elev_of_lsd	LandElev
well_type	FType
well_depth	WellDepth

10. Select the *Finish* button to complete the import process.

11. Select *OK* to confirm the import process.

At this point, you should see wells appear in the map.

Before continuing, let's zoom in on the wells.

12. Select the *Zoom In* tool  and drag a box around the wells.

5 Using the Feature Type Filter

Features such as wells include an FType field representing the feature type. For wells, this field is often populated with values such as "irrigation", "municipal", etc. The AHGW Toolbar includes a pair of filters that can be used to map only the features in a layer that correspond to a particular type. The Filter creates a simple definition query for the selected value (for example, FType = 'irrigation'). The Texas Water Development Board uses single character codes to identify well types. The four codes used in the wells in Lubbock County are O, S, T, and W and represent the following well types:

Code	Well Type
O	Observation
S	Spring
T	Test hole
W	Withdrawal

Before using the filter, we will first change the symbology so that the wells are colored by type.

1. In the Table of Contents, right-click on the *Well* layer and select the *Properties* command.

2. Click on the *Symbology* tab in the *Layer Properties* dialog, and change the selected options to match those shown in Figure 3 (Change the *Show:* option to **Categories | Unique values**. Choose **FType** as the value field and click the *Add All Values* button.).

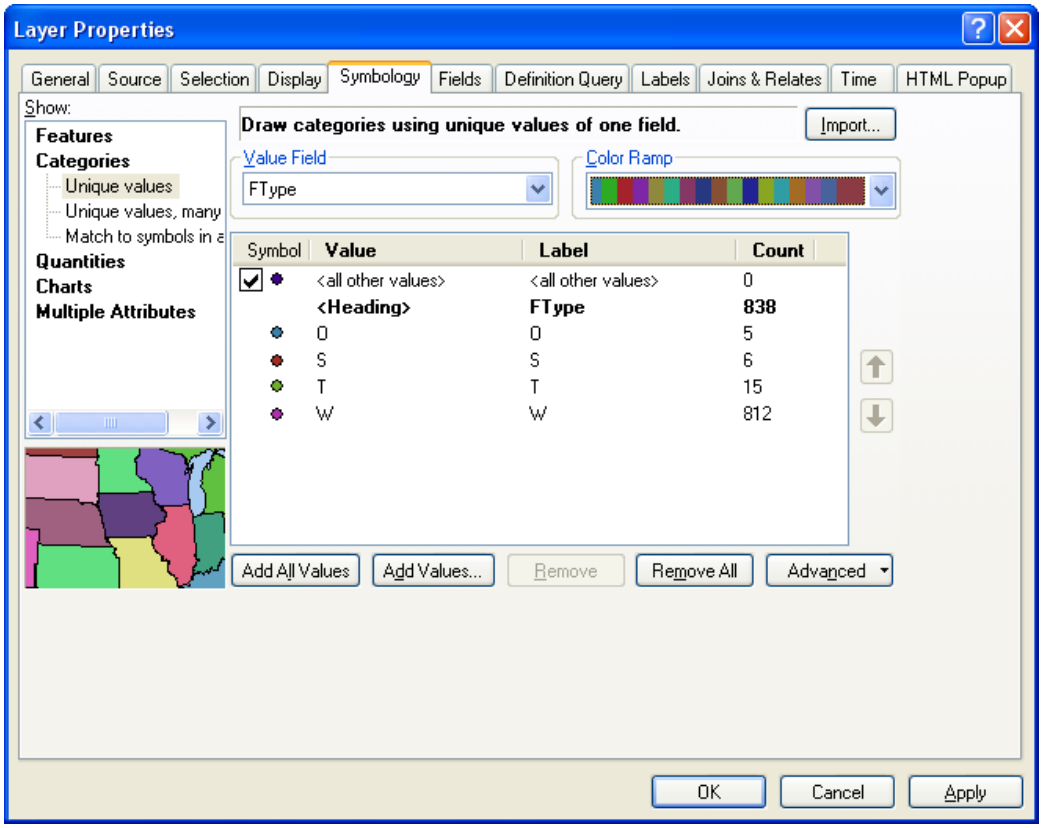


Figure 3 Symbology Options for the Well Features.

3. Click the *OK* button to exit.

Notice that most of the wells are withdrawal (W) wells. To map wells by type using the Filter:

4. Make sure the *Well* layer is selected in the ArcMap Table of Contents (TOC). The filter will be built for the selected layer.

5. In the AHGW Toolbar, click on the down arrow in the first combo box just to the right of the *Field* label on the right side of the AHGW Toolbar and select **FType**.

6. Click on the down arrow in the second combo box to the right of the *Field* label and select **W**. (Note: this sets up a new definition query for the selected layer and overwrites any existing definition queries).

7. Repeat the previous step for each of the other types.

8. When finished, select the *All* option to map all wells.

Note that the two *Field* filters can be used to set up a definition query for any field/value combination for any map layer.

6 Assigning HydroIDs

Each feature in an Arc Hydro geodatabase should have an identifier that is unique across the entire geodatabase, not just within a feature class. This unique ID is called the HydroID. The HydroID is used to build relationships between feature classes and/or tables. For example, we will use the HydroIDs of the wells to relate the wells to the corresponding water level measurements in the TimeSeries table.

In a typical project, one would normally use the Assign HydroID GW tool in the Groundwater Analyst toolset to generate unique HydroIDs for new features. This tool necessitates some additional steps to relate the wells to the time series data we will import in the next step. Therefore, in order to keep this tutorial simple we will copy over the values in the HydroCode field to the HydroID field. This will result in unique integer IDs for this exercise. To copy the values:

1. Right-click on the *Well* layer in the ArcMap Table of Contents window and select *Open Attribute Table*.

2. Right-click on the *HydroID* field and select the *Field Calculator* command. Click *Yes* if necessary at the warning about an edit session.

3. In the *Fields* section of the *Field Calculator*, double-click on the *HydroCode* item.

4. Select the *OK* button.

You should see that the values in the HydroID field match the values in the HydroCode field.

5. Close the Attributes window.

7 Importing the Time Series Data

Now that we have imported the well features, we are ready to import transient water level measurements into the *TimeSeries* table. Each record in the table will represent a water level measurement at a particular well at a particular time. The records in the *TimeSeries* table will be related to the wells using the *HydroID* field.

Once again, we will use the *Text Import Wizard* to import the data.

1. In the AHGW Toolbar, select the *Arc Hydro GW* | *Text Import* command.

2. In the wells and time series folder, select and open the **lubbock_water_levels.txt** file.

3. Turn off the *Space* toggle, turn on the *Comma* toggle, turn off the *Treat consecutive delimiters as one* toggle, and turn on the *Heading row* toggle as shown in Figure 4.

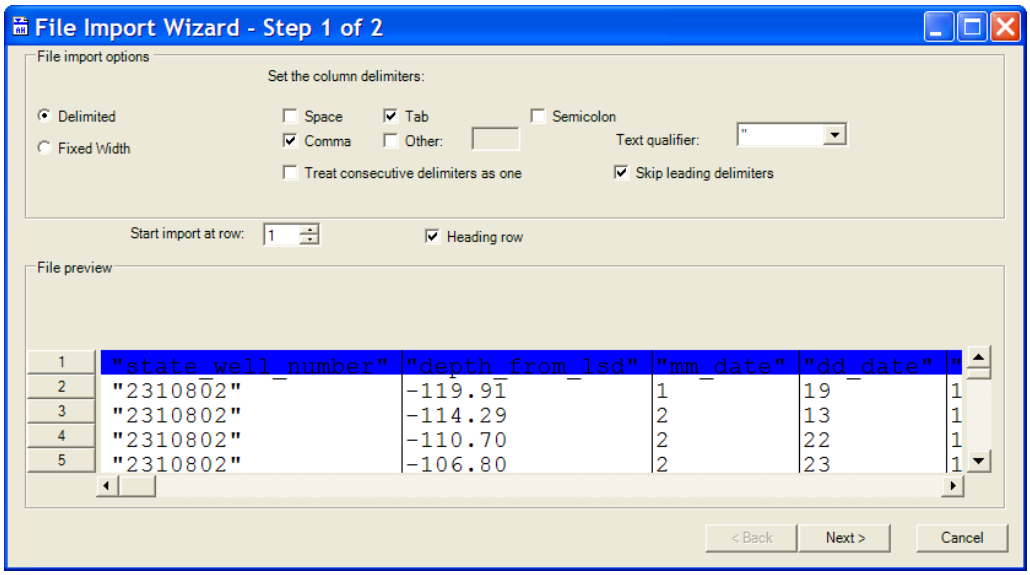


Figure 4 File Import Wizard Settings, Step 1.

4. Select the *Next* button.

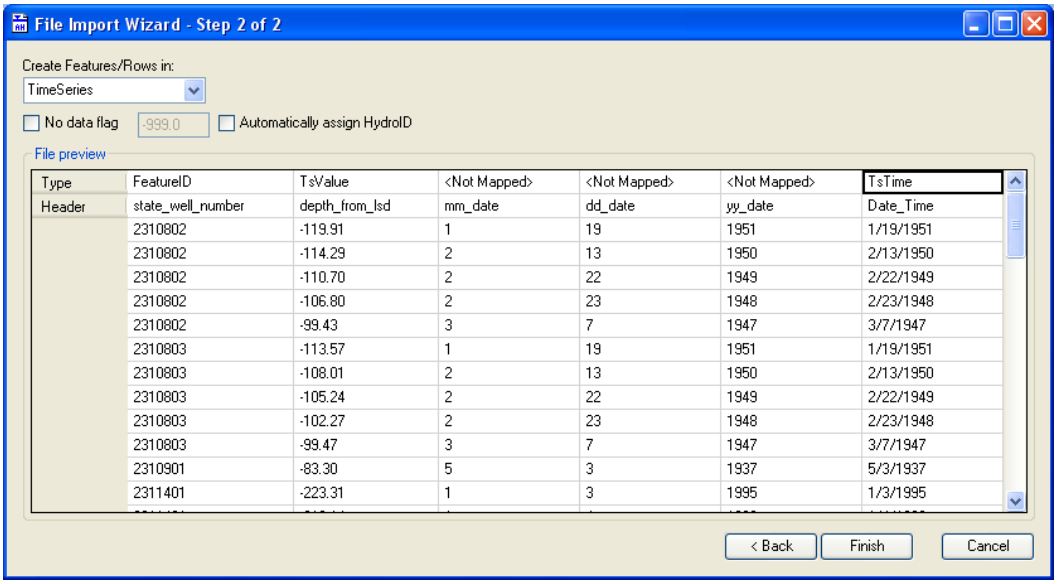
5. Make sure that the **TimeSeries** option is selected in the *Create Features/Rows in:* combo box.

6. Double-click on the <*not mapped*> items in the *Type* row and create the following relationships as shown in Figure 5:

Header	Type
state_well_number	FeatureID
depth_from_lsd	TsValue
Date_Time	TsTime

7. Click *Finish* to exit the wizard.

8. Click *OK* to confirm the import.



Type	FeatureID	TsValue	<Not Mapped>	<Not Mapped>	<Not Mapped>	TsTime
Header	state_well_number	depth_from_lsd	mm_date	dd_date	yy_date	Date_Time
	2310802	-119.91	1	19	1951	1/19/1951
	2310802	-114.29	2	13	1950	2/13/1950
	2310802	-110.70	2	22	1949	2/22/1949
	2310802	-106.80	2	23	1948	2/23/1948
	2310802	-99.43	3	7	1947	3/7/1947
	2310803	-113.57	1	19	1951	1/19/1951
	2310803	-108.01	2	13	1950	2/13/1950
	2310803	-105.24	2	22	1949	2/22/1949
	2310803	-102.27	2	23	1948	2/23/1948
	2310803	-99.47	3	7	1947	3/7/1947
	2310901	-83.30	5	3	1937	5/3/1937
	2311401	-223.31	1	3	1995	1/3/1995

Figure 5 Import Wizard Settings, Step 2.

8 Fixing the TimeSeries Table

The water level measurements are stored in the *TimeSeries* table. Let's open the table and view the contents.

1. Click on the *List by Source* button (ArcGIS 10) or *Source* tab (ArcGIS 9.3) in the Table of Contents (TOC) window.

2. Right-click on the *TimeSeries* table and select *Open*.

Notice that two of the fields contain null values. We can populate these fields using the Field Calculator. First, we will populate the VarID field. This field is typically used to identify the type of time series and is an index to a separate VariableDefinition table. The VariableDefinition table includes a record for each of the different types of time series stored in the TimeSeries table (e.g. "Water level measurement", "TCE Concentration", etc.) and provides information about the units of measurements. To keep this exercise simple, we will not be using a VariableDefinition table and we will just have one type of measurement in our table (water level).

3. Right-click on the *VarID* field in *TimeSeries* table and select the *Field Calculator* command.

4. Click *Yes* if necessary at the warning about an edit session.

5. In the bottom part of the *Field Calculator*, enter **1**.

6. Click *OK* to exit the Field Calculator.

The VarID field should now contain values of 1 for all the rows in the table.

Next, we will make an adjustment to the water level measurements in the *TimeSeries* table. The water levels we imported to the *TsValue* field are actually depths measured from the top of the well and are expressed as negative values. To get a field representing actual elevations, we will use the field calculator and add the negative depths to the well elevations. This will require a temporary join. We will put the adjusted elevation values into a field called *TSValue_normalized*.

First, we will do the join.

7. Close the *TimeSeries* table.

8. Right-click on the *TimeSeries* table and select *Joins and Relates* | *Join…*

9. Select FeatureID for *1*, Well for *2*, and HydroID for *3*, as shown in Figure 6.

10. Click on the *OK* button to complete the join. (if prompt to create an index during the join, select *Yes*)

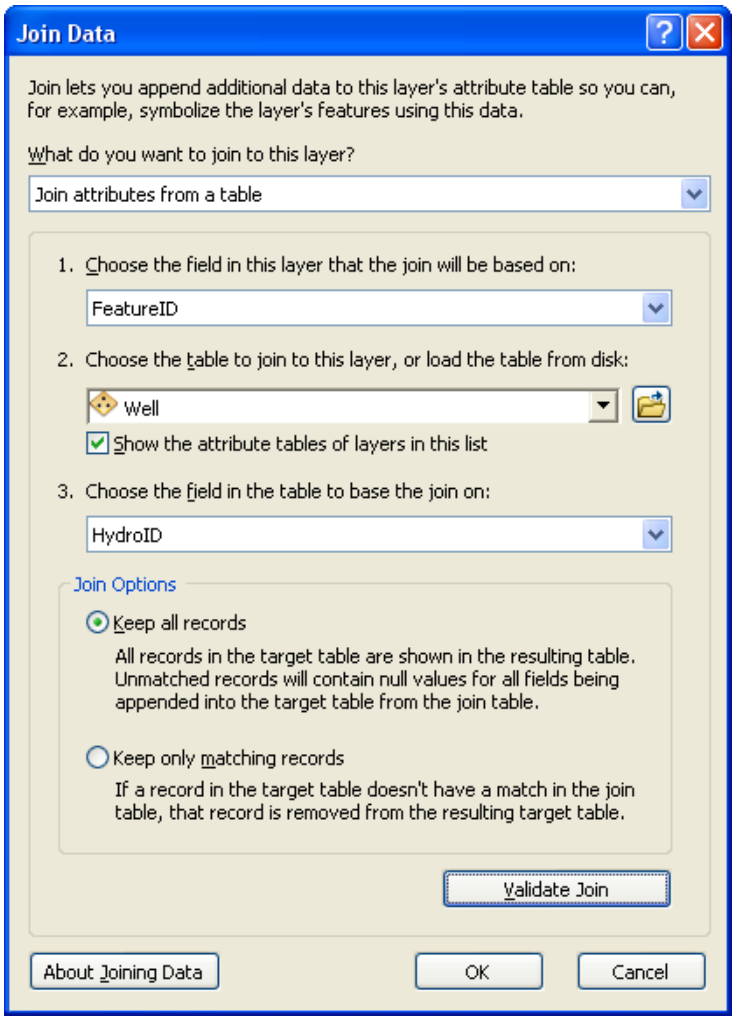


Figure 6 Join options for joining Well features to the TimeSeries table.

Next, we will compute the proper elevations.

11. Right-click on the *TimeSeries* table and select the *Open* command.
12. Right-click on the *TsValue_normalized* field and select the *Field Calculator* command (click *Yes* if necessary at the warning about an edit session).
13. Enter the expression, [Well.LandElev] + [TimeSeries.TsValue], as shown in Figure 7 in the bottom part of the *Field Calculator*.
14. Click *OK* to complete the operation.
15. Click *Yes* at the prompt (if necessary).
16. Close the *TimeSeries* Table.

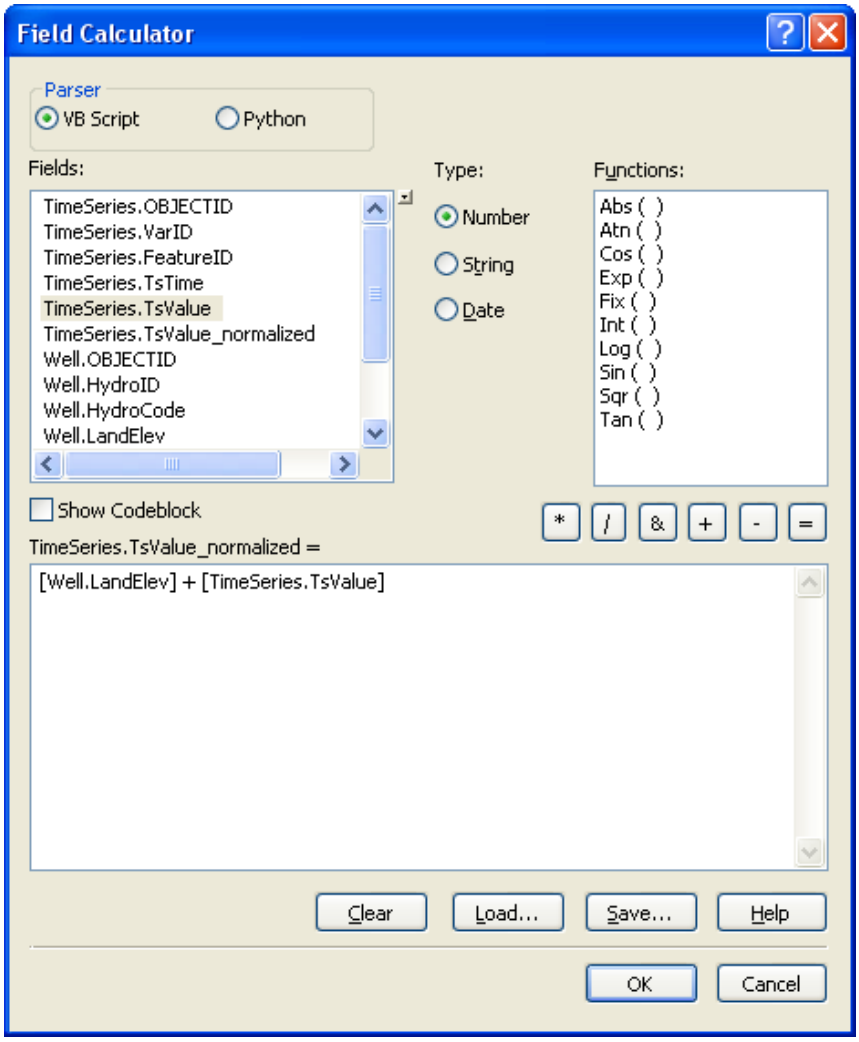


Figure 7 Computing a normalized elevation for the water level measurements.

Finally, we will remove the join.

17. Right-click on the *TimeSeries* table and select *Joins and Relates* | *Remove Join(s)* | *Well*.

9 Finding Wells with Transient Data

Some of the wells imported have transient water level measurements and some do not. We can quickly determine which wells have transient data using the *Make Time Series Statistics* tool in the Groundwater Analyst toolset. This tool can be used to derive a new feature set from an existing feature set with transient data. The new feature set includes a field representing selected statistics of the original transient data (mean, standard deviation, etc.). In this case, we will use the tool to derive a new layer containing only the wells with transient data and with a field representing the average water level over all measurements.

1. Double-click on the *Make Time Series Statistics* tool in the *AHGW Toolbox* | *Groundwater Analyst* toolset.

2. Enter the input options/selections as shown in Figure 8. For the *Output Feature Class* option, browse to the location on your local drive where the tutorial files are located and open the ***Lubbock_wells*** geodatabase so that the new features are created inside the geodatabase. Type ***water_level_all*** as the name of your new feature class.

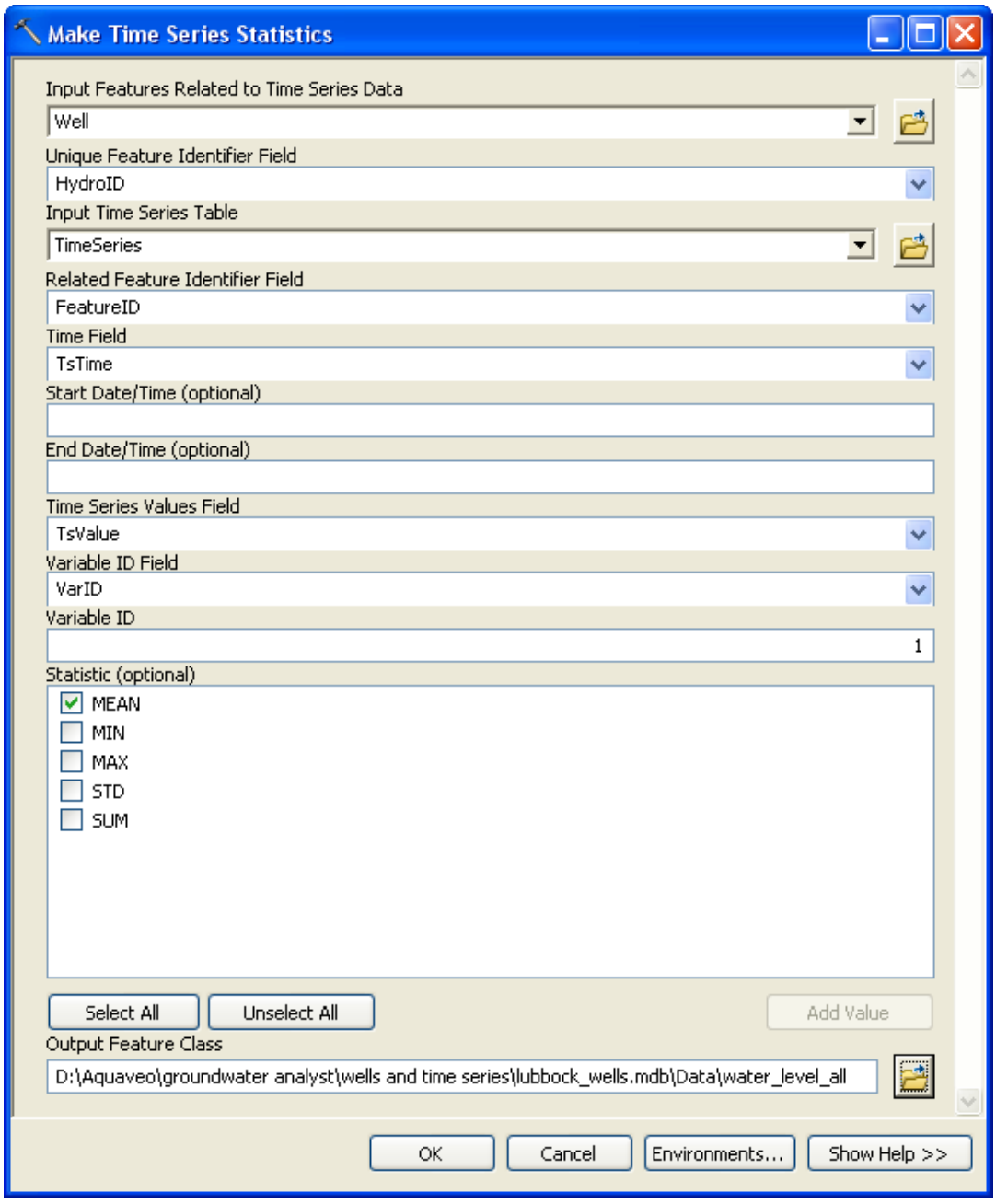


Figure 8 Input options for the Make Time Series Statistics tool.

3. Click *OK* to execute the tool.

4. Once the tool has completed its processing, select the *Close* button to close the geoprocessing window.

You should now see a new set of wells displayed on the map (if the new layer does not appear in the map browse to it and load it using the Add Data command).

10 Adjusting the Well Display

In addition to the mean water level, the *Make Time Series Statistics* tool generates a new field containing the frequency of measurements (i.e., the number of transient water level values per well). We can use ArcMap Symbology to map the sampling frequency.

1. Uncheck the *Well* layer to hide that layer. Only wells with transient data will still be visible in the map.

2. Right-click on the *water_level_all* layer and select the *Properties* command.

3. Edit the selection in the *Symbology* tab of the *Layer Properties* dialog to match what is shown in Figure 9. Change the *Show:* option to **Quantities | Graduated Colors**; change the *Value:* field to **FREQUENCY** and change the *Classes* setting to **4**. To change the symbol sizes, double-click on each of the symbols and edit the *Size* value. Use 4.0 for the smallest symbol and 6.0, 8.0, and 10.0 for the three larger symbols.

4. Click *OK* to exit.

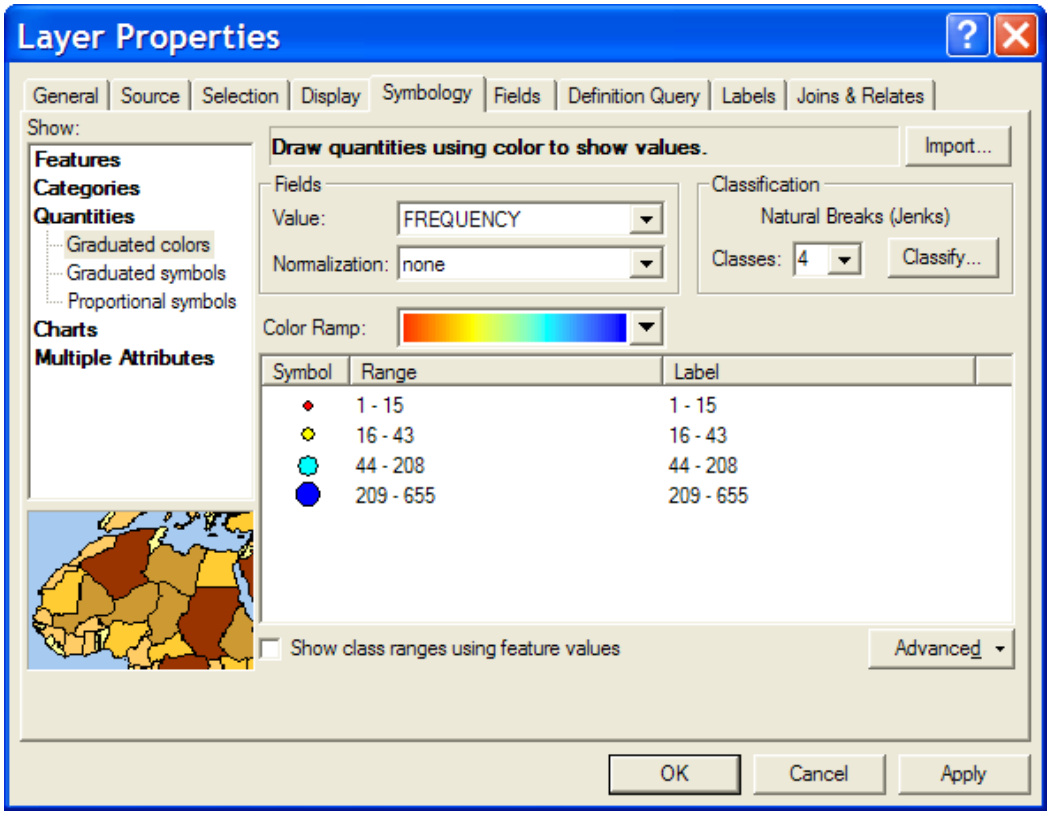


Figure 9 Symbology settings for the water level frequency data.

11 Using the Time Series Grapher

When working with transient well data, it is helpful to generate graphs illustrating the change in water level vs. time. The AHGW Toolbar includes an interactive *Time Series Grapher* tool that can be used to quickly generate time series graphs simply by clicking on wells of interest. We will use this tool to explore the Lubbock county well data.

1. Click on the *Time Series Grapher* icon  in the AHGW Toolbar.

2. Edit the options in the *Time Series Grapher Setup* dialog to match those shown in Figure 10.

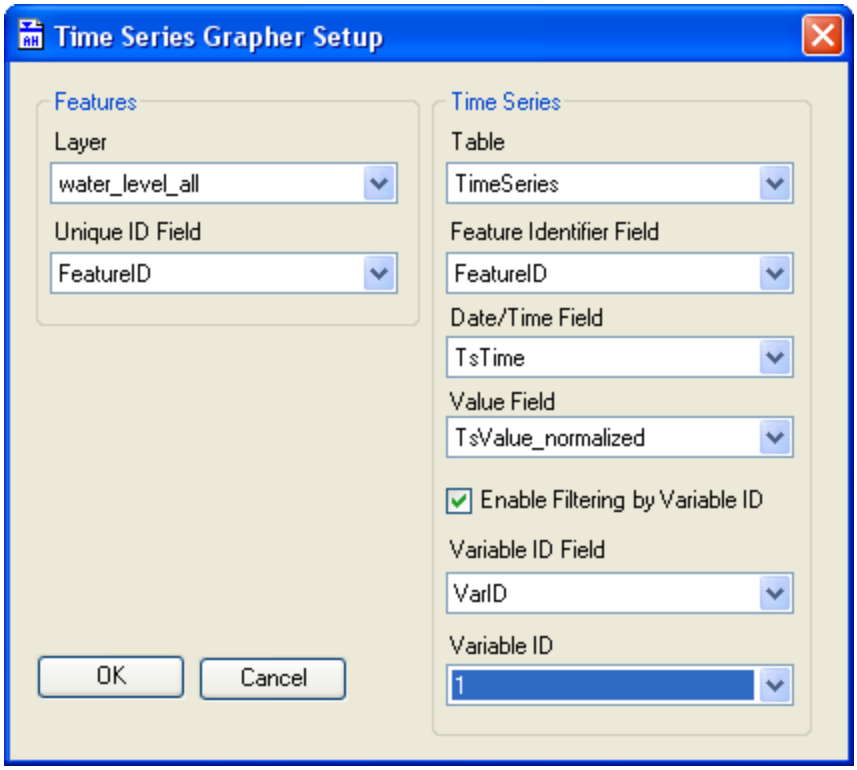


Figure 10 Time Series Grapher Setup Options.

3. Select *OK* to exit the Setup dialog.

Notice that the cursor has changed. We can now create a new graph simply by clicking on wells.

4. Click on one of the light blue wells.

A new plot window should appear (similar to the one shown in Figure 11). You may wish to reposition the window. You can right-click on the graph to modify the plot using the standard graphing options.

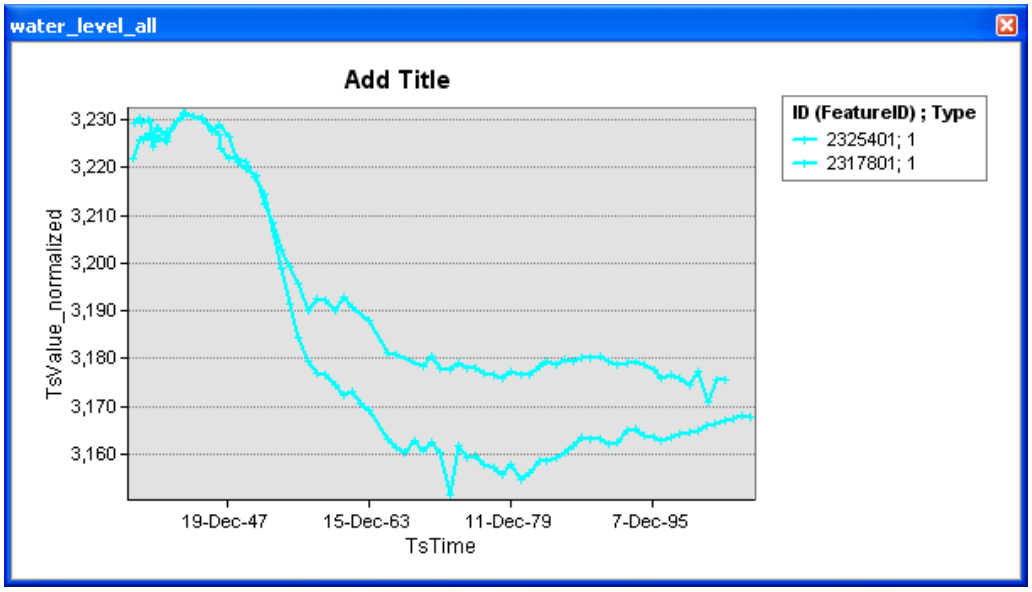


Figure 11 Example of a plot generated with the Time Series Grapher tool

5. Click on a second light blue well.

Note that subsequent well data are inserted as additional series to the current graph. To create a new graph, you can simply close the current graph and click on a new set of points. Each graph is stored with the map and can be re-opened using the *Tools* | *Graphs* menu command.

6. Click on any tool (e.g. the *Select Features* tool ) to deactivate the *Time Series Grapher* tool.

7. Close the graph.

12 Time Series Statistics for a Specific Time Interval

Earlier in this tutorial, we used the *Make Time Series Statistics* tool to derive a new feature class representing the average water levels over the entire set of measurements. The objective of that exercise was simply to identify the wells containing transient water level measurements. Next, we will use the *Make Time Series Statistics* tool to derive a set of features corresponding to mean water levels measured over a specific interval in time (first quarter of the year 2000). Then we will interpolate these values to a raster to generate a map of water levels for the county for our selected time interval.

1. Double-click on the *Make Time Series Statistics* tool in the *AHGW Toolbox* | *Groundwater Analyst*.

2. Enter the input options/selections as shown in Figure 12. For the *Output Feature Class* option, browse to the location on your local drive where the tutorial files

are located and open the *Lubbock_wells* geodatabase. Type *wl_q1_2000* as the name of your new feature class and click *Save*.

3. Click *OK* to execute the tool.

4. Once the tool has completed its processing, select the *Close* button to close the geoprocessing window.

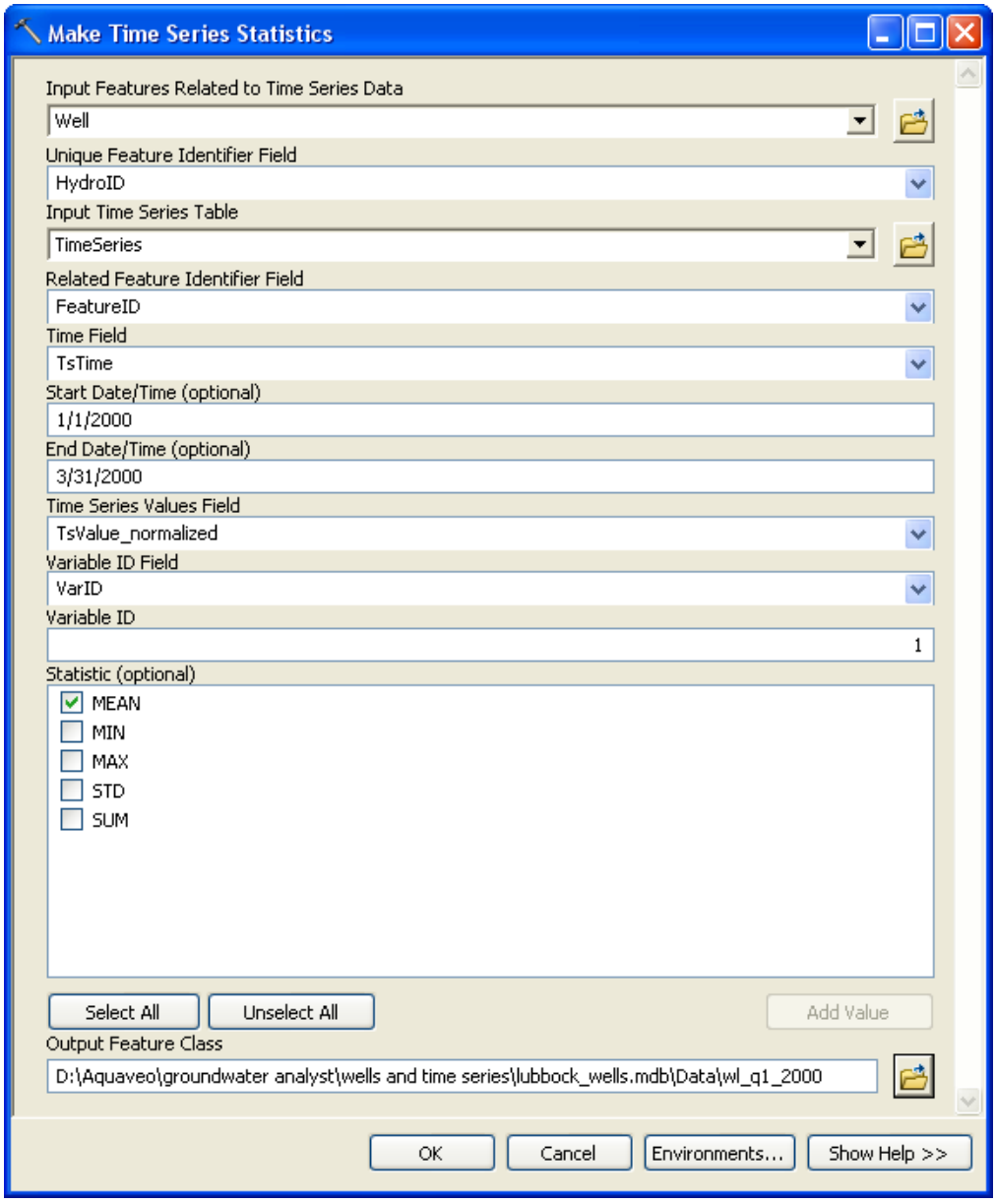


Figure 12 Input options for the Make Time Series Statistics tool.

You should now see a new set of wells displayed on the map. To simplify the map display:

5. Turn off the *water_level_all* layer in the TOC window.

13 Interpolating Water Levels

The next step is to interpolate the values from the new layer to a raster to generate a map of water levels for Q1 of 2000. This step requires *Spatial Analyst*. If you do not have *Spatial Analyst* installed, you will not be able to complete this part of the tutorial (you can use the solution files to complete the tutorial). We will use the *IDW* geoprocessing tool to perform the interpolation and we will set the *Environment* options such that the resulting raster is clipped to the Lubbock County boundary.

1. Double-click on the *IDW* tool in *ArcToolbox* (located in the *Spatial Analyst Tools* | *Interpolation*).

2. Enter the set of options shown in Figure 13. For the *Output raster* option, change the name of the output raster to **wl_2000**. Be sure to set the location of the raster such that it is in the ***rasters*** folder one level above the geodatabase. This ensures that the next step will not result in an error.

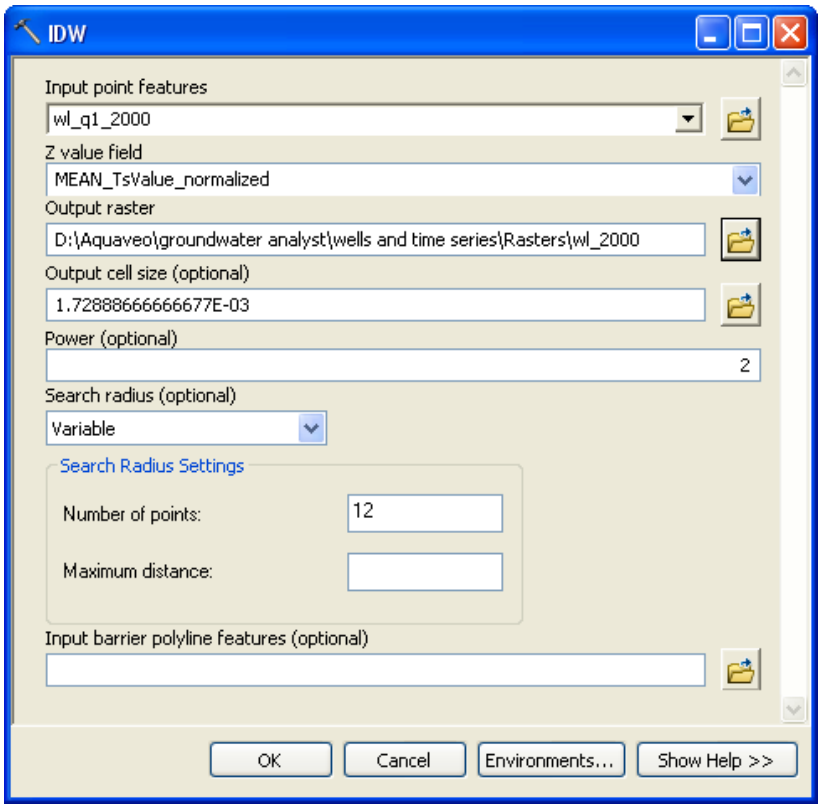


Figure 13 Input Setting for the IDW GP Tool.

3. Click on the *Environments…* button.

4. Expand the *Processing Extent (ArcGIS 10)* or *General Settings (ArcGIS 9.3)* section and change the *Extent* option to ***Same as layer lubbock_county***. This will cause the interpolation to extend out the limits of a rectangle including all of Lubbock County.

5. Scroll down and expand the *Raster Analysis Settings* section and change the *Mask* option to ***lubbock_county***. This will clip the raster to the actual boundary of Lubbock County.

6. Select the *OK* button to exit the *Environment Settings* dialog.

7. Select the *OK* button to execute the *IDW* tool.

8. When the tool has finished, click on the *Close* button.

9. You should see a new raster layer called *q1_2000* at the bottom of the TOC window. To make it visible on the map, drag it up just above the *Counties* layer.

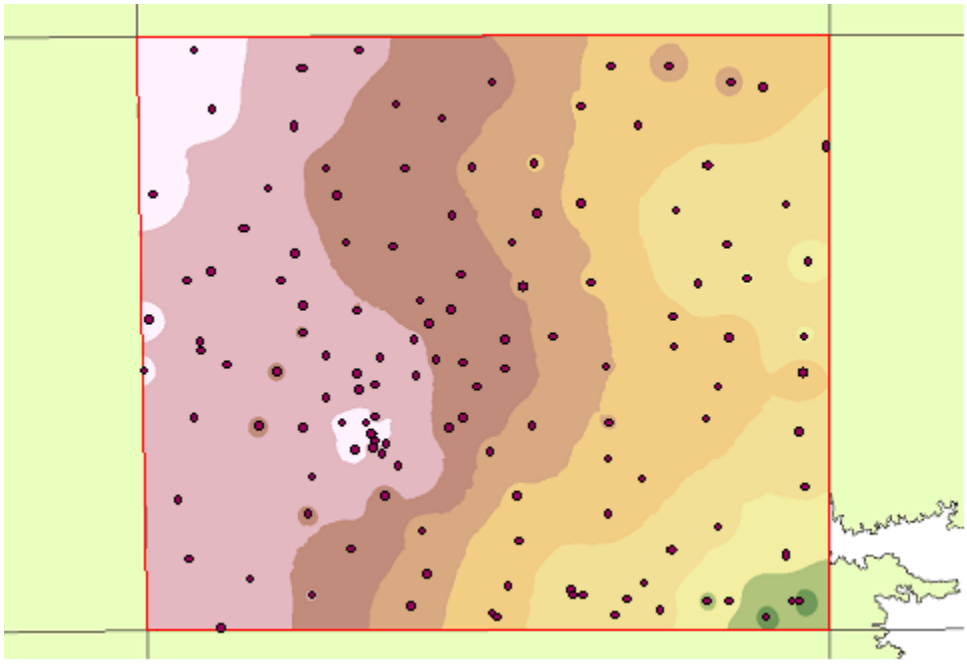


Figure 14 Raster created by the IDW interpolation

14 Using a Raster Catalog

Now that we have a water level raster, we will store it in a raster catalog. This allows us to archive the raster with the time interval (start date, end date) and other descriptive information that may be useful. Furthermore, a sequence of rasters in a raster catalog can be animated using the *Animation* tools in ArcMap. A raster can be archived in a raster catalog using the *Add to Raster Series* tool *in Groundwater Analyst*. Since our geodatabase already contains an empty raster catalog with the appropriate fields, we are ready to run the tool.

1. In ArcToolbox, Double-click on the *Add To Raster Series* tool in *Arc Hydro Groundwater Tools* | *Groundwater Analyst* toolset.

2. Enter the set of options shown in Figure 15.

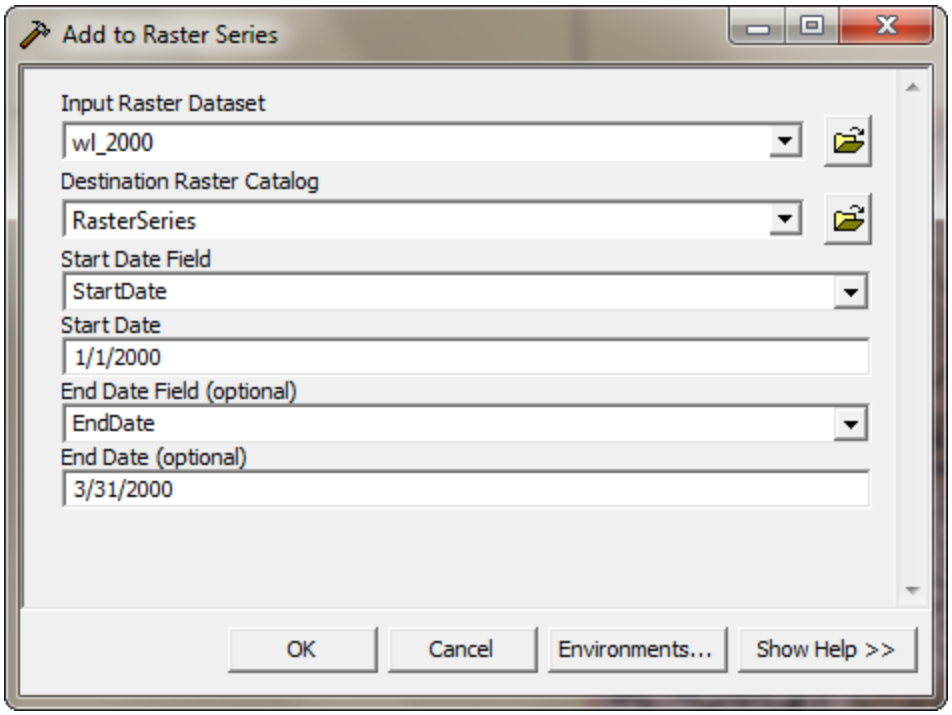


Figure 15 Settings for the Add to Raster Series Tool.

3. Click on the *OK* button to execute the tool.

4. Click on the *Close* button once the tool has completed.

You should see a *RasterSeries* layer added to the map and a grayscale version of the raster is displayed. You can right-click on the *RasterSeries* layer and edit the symbology to select a new color ramp if you wish. To view the contents of the raster catalog:

5. Right-click on the *RasterSeries* layer and select the *Open Attribute Table* item.

6. Scroll to the right to examine the fields.

7. When you are finished, close the window.

15 Creating a Model to Automate Processes

Since generating water level maps for a specific time interval is such a common procedure, it is useful to build a model that automates parts of the process. In this section you will build a model that enables automating the process of running the *Make Time Series Statistics* tool. It is possible to create fairly complex models (and scripts) to automate common tasks. Some examples are provided in the *Sample Utilities* toolset of the *Arc Hydro Groundwater Tools*.

1. In Arc Toolbox, right click anywhere in the window, and select *Add Toolbox* option. An interface will open that allows you to add existing toolboxes or to

create a new toolbox. Select the New Toolbox button  (on the upper right). A new toolbox should be added to the toolbox list. Select the new toolbox and select the *Open* command. A new empty toolbox should be added to the Arc Toolbox window.

2. Select the new toolbox, right click and select *New Model*. A new empty model should be added to the toolbox.

3. Drag the *Make Time Series Statistics* tool into the model (you can also drag the tool from the *Results* tab, this way you will already have the parameters defined in the previous run set for the model).

You can expose tool parameters as model parameters. In this example we will set the input feature classes, tables, and fields as constants and only expose the start date, end date, and output features as model parameters.

4. Select the *Make Time Series Statistics* tool in the model, right click and select *Make Variable* | *From Parameter* | *Start Date*. The Start Date parameter should appear in the model as a circle

5. Do the same to add the *End Date* parameter to the model.

6. The parameters may appear on top of each other, you can select the Auto Layout  button to reorganize the parameters in the model display.

7. Select the *Start Date* parameter, right click, and select the *Model Parameter* option. A "*P*" should appear beside the *Start Date* parameter. Do the same for the *End Date* and *Output Feature Class* parameters. You model should look like the one shown in Figure 16. Save your model.

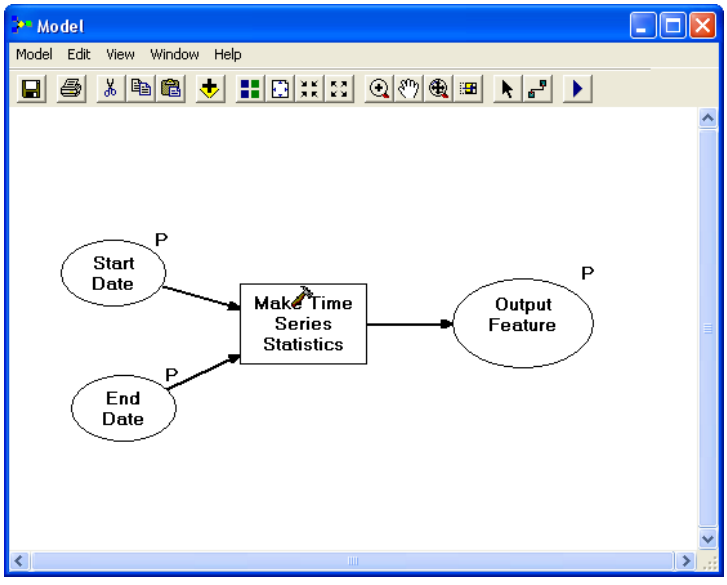


Figure 16 Creating a model including the Make Time Series Statistics tool

Next, you will set the other tool parameters.

8. Double click on the *Make Time Series Statistics* tool in the model. This should expose the tool parameters.

9. Fill in the tool parameters as shown in Figure 17.

10. Select *OK* when finished.

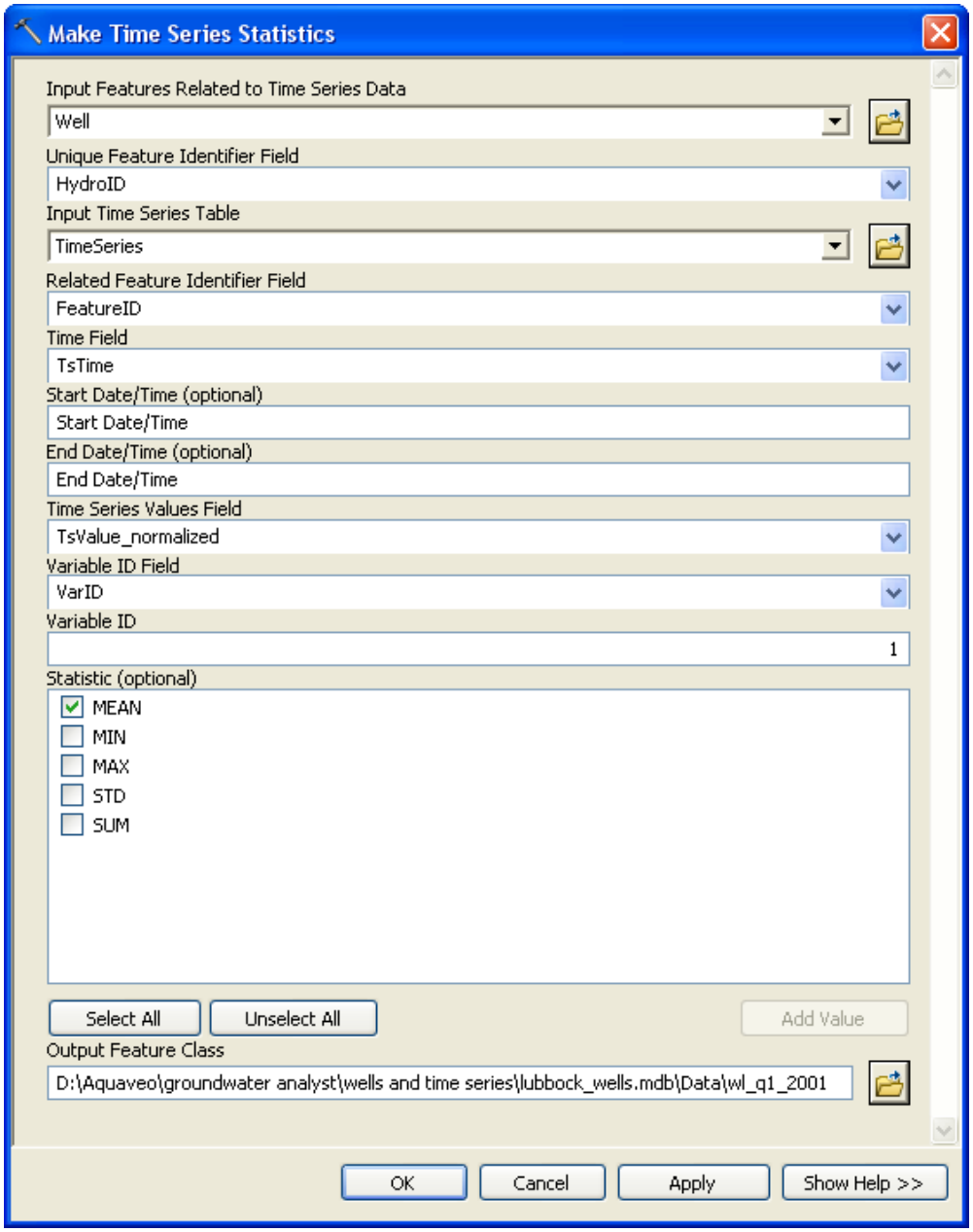


Figure 17 Make Time Series Statistics parameters

11. Save the model and close it and then reopen it from the toolbox (by double clicking on the model) you will see only the *Start Date*, *End Date*, and *Output Feature Class* parameters exposed as input parameters. The rest of the parameters are defined in the model and will remain constant.

12. Set the *Start Date* to ***1/1/2001*** and the *End Date* to ***3/31/2001***.

13. Set the *Output Feature Class* by browsing to the lubbock_wells geodatabase and name the new feature class ***wl_q1_2001***.

Your model should look the same as the model shown in Figure 18

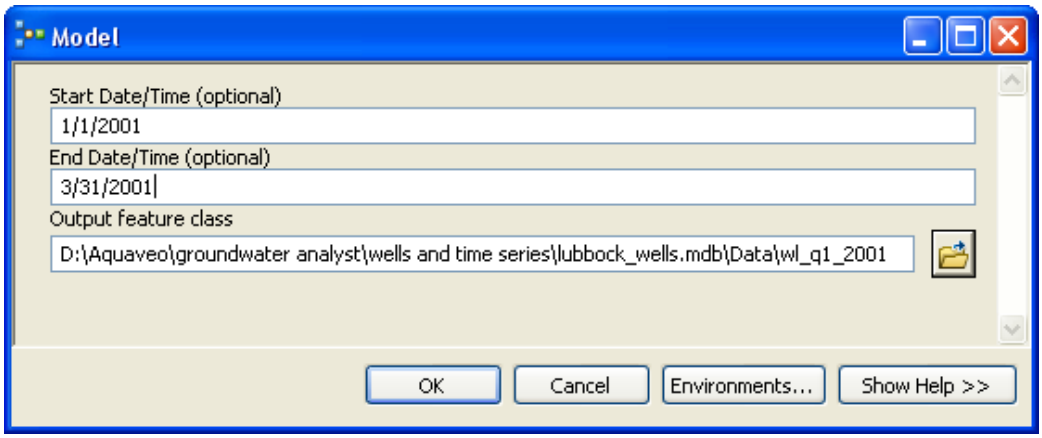


Figure 18 Make Time Series Statistics parameters exposed as model parameters.

14. Select *OK* to run the model.

A new layer should be added to the map representing the mean water level for the first quarter of 2001.

If you want to run this process for multiple years you can batch process the model.

15. Right click on the model and select Batch.

In the Batch grid input the following parameters, as shown in Figure 19. By running the model in batch mode you will create a new feature class for the first quarter of each year from 2002 to 2005 (to add a new row to the batch grid you simply select the  icon).

Start Date	End Date	Output Feature Class
1/1/2002	3/31/2002	…\lubbock_wells.mdb\wl_q1_2002
1/1/2003	3/31/2003	…\lubbock_wells.mdb\wl_q1_2003
1/1/2004	3/31/2004	…\lubbock_wells.mdb\wl_q1_2004
1/1/2005	3/31/2005	…\lubbock_wells.mdb\wl_q1_2005

16. Select *OK* to run the model.

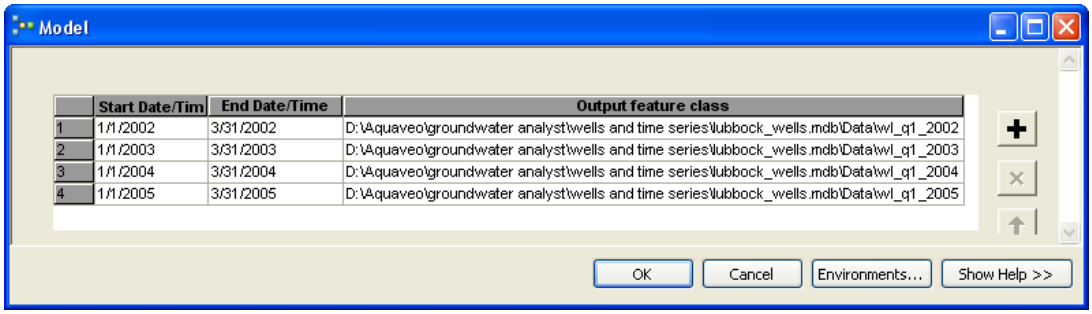


Figure 19 Model parameters in batch mode

By creating more complex models and scripts you can automate the process of creating water level maps and generate a sequence of maps for different time periods. These maps could then be animated using the ArcGIS Animation tools. See the *Arc Hydro Groundwater Tools* | *Sample Utilities* and *Arc Toolbox* | *Samples* for sample models and scripts.

16 Generating a Flow Direction Map

As the final step of the tutorial, we will generate a flow direction map using the *Flow Direction Generator* command in the AHGW Toolbar. This tool generates a set of flow arrows on top of a water level raster. The arrows are generated as graphic elements and can be managed/deleted using the standard ArcMap drawing tools. The arrows are generated such that they point in the direction of maximum downward gradient in the water level elevations (i.e. "downhill").

To generate the map:

1. Turn off the *RasterSeries* map layer.
2. Select the *wl_2000* raster in the TOC window.
3. In the AHGW Toolbar, Select *Arc Hydro GW* | *Flow Direction Generator*.
4. Enter a value of **7** for the *Arrow Spacing*.

At this point your tool should be similar to the one shown in Figure 20.

Figure 20 Flow Direction Generator parameters

5. Click on the *Generate* button.

At this point, the arrows should be added to the raster. To experiment with the settings, you can click the *Clear* button to remove the current arrows and *Generate* to build new arrows.

6. Click on the *Quit* button when you are finished.

17 Conclusion

This concludes the tutorial. Here are some of the key concepts in this tutorial:

- The *Text Import Wizard* is used to quickly import wells and time series data into an AHGW geodatabase.
- The *Make Time Series Statistics* tool is used to identify wells with transient data and to illustrate the frequency of the data.
- The *Time Series Grapher* is used to explore transient data.
- The *Make Time Series Statistics* tool is used to map statistics (e.g. mean, min, max) values for a specific time intervals. This output can then be interpolated to a raster to generate water level maps.
- Raster catalogs are useful for managing raster series.
- Models are used to automate processes.
- The *Flow Direction Generator* tool is used to create a map of flow directions.

