

ARC HYDRO GROUNDWATER TUTORIALS

Subsurface Analyst – Creating GeoRasters from Borehole Data

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. It includes several components to represent different types of datasets, such as 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. *Subsurface Analyst* is a subset of the AHGW Tools that is used to manage 2D and 3D hydrogeologic data, and create subsurface models including generation of borehole representations, cross sections, surfaces, and volumes.

This tutorial will demonstrate how to create raster surfaces from borehole data. It will also show how to load and index the surfaces in the GeoRasters raster catalog.

1.1 Background

Data used in this tutorial are part of a project for developing a groundwater simulation model: The Sacramento Regional Model, which encompasses an area of approximately 1,360 square miles (871,000 acres) near the city of Roseville in the Sacramento valley, California. The model is bounded by the Bear River and Feather River to the north, the Mokelumne River to the south, the Sacramento River to the west and by bedrock of the Sierra Nevada to the east (Figure 1).



Figure 1 Location of the Roseville Model.

As part of the model development, a set of hydrogeologic units were defined. A simplified set of units were extracted from the original list and is used in this tutorial. Figure 2 shows the sequence of formations used in this tutorial. Each of the units is indexed by a hydrogeologic unit identifier (HGUID). The unit properties are defined in the HydrogeologicUnit table. In addition, each of the units is indexed with a horizon ID.

The term “horizon” refers to the top of each stratigraphic unit that will be represented in the subsurface model. Horizons are numbered consecutively in the order that the strata are “deposited” (from the bottom up). Each contact that you wish to represent in the subsurface model must have a HorizonID. Horizons can be represented as rasters, one for each horizon ID. The rasters will typically be created by interpolating the borehole contact data for each horizon. When organized in a raster catalog, the rasters can be used to create 3D GeoSection and GeoVolume features based on an attribute field containing the horizon ID.

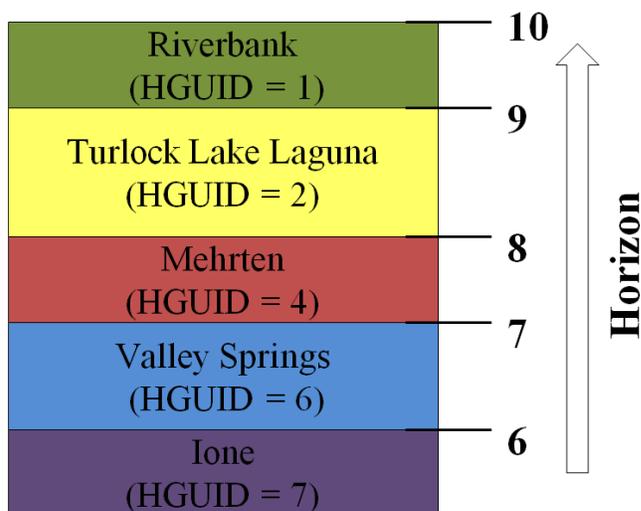


Figure 2 Hydrogeologic units indexed with a HGUID and a HorizonID.

1.2 Outline

The objective of this tutorial is to introduce the basic workflow and tools for creating raster surfaces from borehole data, and loading and indexing the rasters in the GeoRasters raster catalog. The tutorial includes the following steps:

1. Create BorePoints representing hydrogeologic units as contacts along boreholes.
2. Interpolate BorePoints to raster surfaces.
3. Load rasters into the GeoRasters raster catalog and index the rasters with appropriate attributes.
4. Visualize the resulting rasters in ArcScene.

1.3 Required Modules/Interfaces

The following components must be enabled in order to complete this tutorial:

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

The AHGW Tools require that you have a compatible ArcGIS service pack installed. Check the AHGW Tools documentation to find the appropriate service pack for your version of the tools. The tutorial files should be downloaded and saved on a local drive.

2 Getting Started

Before opening the map, let's ensure that the AHGW tools are correctly configured.

1. If necessary, launch *ArcScene*.
2. If necessary, open the *ArcToolbox* window by clicking on the **ArcToolbox**  macro icon

The *Arc Toolbox* window should be visible. In the *Arc Toolbox*, the *Arc Hydro Groundwater Tools* should be listed. If it is not listed, do the following:

3. Right-click anywhere in the *ArcToolbox* window and select the **Add Toolbox...** command to open the *Add Toolbox* dialog.
4. Browse to the top level of the *Catalog* and then browse down to the *Toolboxes/System Toolboxes* directory.
5. Select the toolbox and select the **Open** button.

Once the *ArcToolbox* window is visible, do the following:

6. Expand the  *Arc Hydro Groundwater Tools* item then expand the  *Subsurface Analyst* toolset to expose the *Subsurface Analyst* tools.

Note that many of the geoprocessing 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:

7. 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:

8. Open *ArcScene/ArcCatalog* (if not already open).
9. Select the *Geoprocessing / Geoprocessing Options...* command to open the *Geoprocessing Options* dialog.
10. Turn on the option *Overwrite the outputs of geoprocessing operations* as shown in Figure 3.

11. Enable the option to *Add results of geoprocessing operations to the display* as shown in Figure 3.
12. Select **OK** to exit the *Geoprocessing Options* dialog.

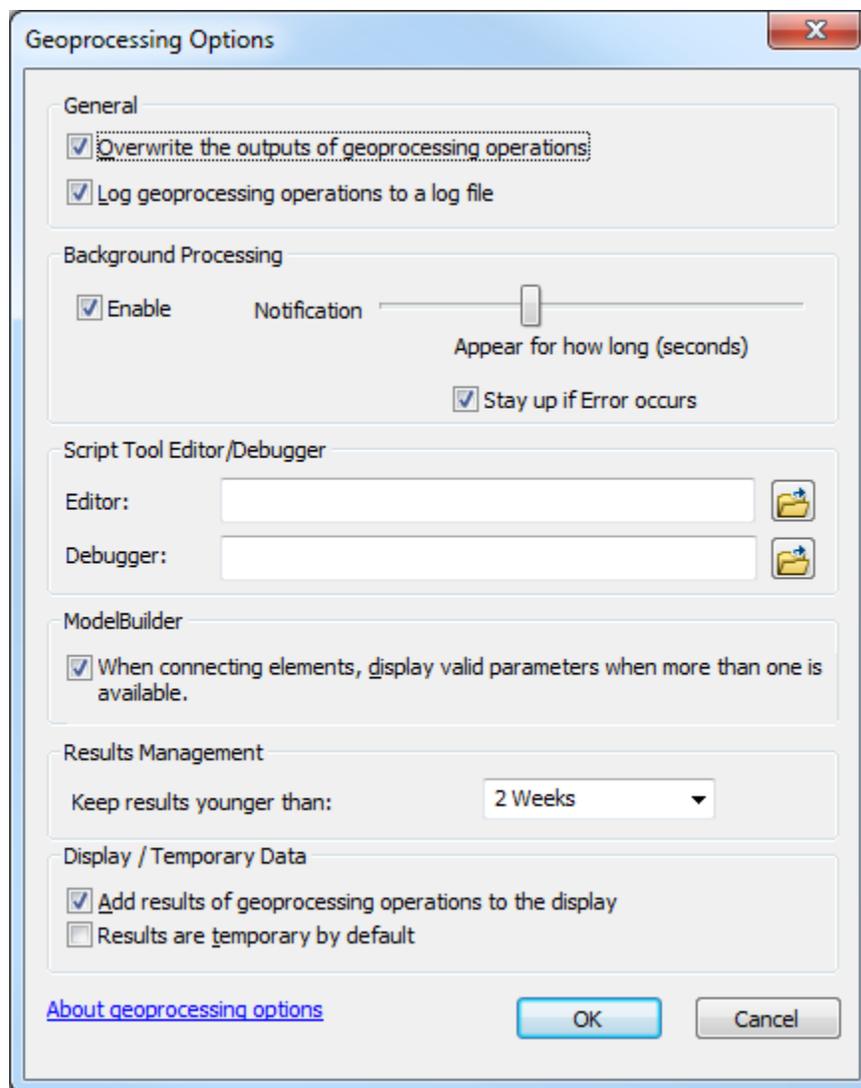


Figure 3 Setting Geoprocessing tools to overwrite outputs by default, and to add results of geoprocessing tools to the display.

3 Opening the Scene

Begin with opening a scene of the model area by doing the following:

1. Select the *File / Open* command to bring up an *Open* dialog.
2. Browse to the location with tutorial files for this tutorial.
3. Select the file “GeoRasters.sxd” located in the *creating georasters* folder.

- Click **Open** to import the project.

A scene containing the model boundary, a DEM, and well features located within the model domain (Figure 4) should appear.

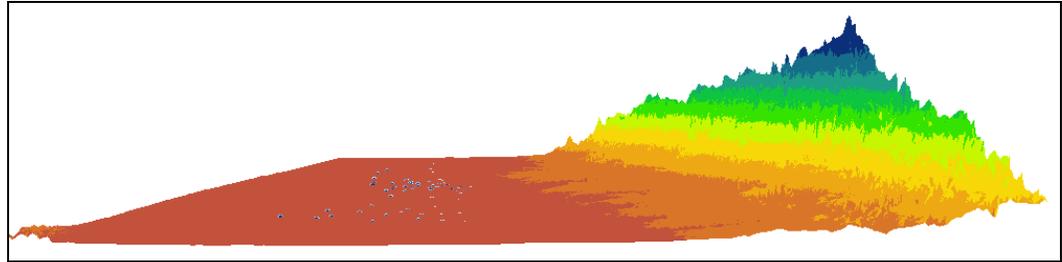


Figure 4 Initial scene containing the model boundary, a DEM and well features.

4 Creating BorePoints from Borehole Data

Borehole information is stored in the BoreholeLog table. Each row in the table represents a hydrogeologic unit observed along the borehole. Data in the BoreholeLog table are referenced to well features. The *WellID* attribute in the BoreholeLog table relates to the *HydroID* of a well feature. Figure 5 shows an example of a BoreholeLog table. Records in the table are indexed with a WellID to relate the vertical information with specific Wells. In addition, top and bottom elevations are defined for the different hydrogeologic units, and each unit is indexed with a hydrogeologic unit identifier (HGUID). Each of the units is also indexed with a HorizonID which defines the ordering of the units from bottom up and is used for indexing rasters.

WellID	HGUID	RefElev	FromDepth	ToDepth	TopElev	BottomElev	ElevUnits
6478	1	0	0	0	180.30075	155.30075	feet
6478	2	0	0	0	155.30075	105.30075	feet
6478	4	0	0	0	105.30075	-29.062442	feet
6478	6	0	0	0	-29.062442	-180.303268	feet
6478	7	0	0	0	-180.303268	-205.303268	feet
6479	1	0	0	0	118.645248	33.930549	feet
6479	2	0	0	0	33.930549	-196.842178	feet
6479	4	0	0	0	-196.842178	-246.842178	feet
6479	6	0	0	0	-246.842178	-400	feet
6479	7	0	0	0	-400	-425	feet

Figure 5 BoreholeLog table containing information on hydrogeologic units along boreholes. The WellID attribute relates vertical logs to a Well feature.

In order to create a raster that defines a surface across the model domain, first create a set of points from which the raster will be interpolated. This is achieved by joining the Well features with the BoreholeLog table and creating a new set of points with the hydrogeologic information. Use the **BoreholeLog Table To Points** tool to automate this process:

1. Double-click the  **BoreholeLog Table To Points** tool located in the  *Subsurface Analyst | Features* toolset to open the *BoreholeLog Table to Points* dialog.
2. Select the “Well” feature class as *the Input Well Features*.
3. Select “HydroID” as the *Well Unique Feature Identifier Field*.
4. Select the “BoreholeLog” table as the *Input BoreholeLog Table*.
5. Select “WellID” as the *BoreholeLog Related Feature Identifier Field*.
6. Click the browse  button next to *Output Feature Class* to open the *Output Feature Class* dialog.
7. In the location field, double-click on “GeoRasters.mdb” then double-click on “Data”.
8. Name the feature class “BorePoint”.
9. Click **Save** to exit the *Output Feature Class* dialog.
10. Click **Select All** in the *Copy Fields* list box.
11. Turn on the *Create 3D Features* option.
12. Select the “TopElev” field as the *Elevation Field for 3D Features*.
13. Select **OK** to run the tool.

At the end of this process, there should be a new 3D point feature class that contains the BorePoints. Each point represents a horizon in the subsurface model. Next, interpolate a set of rasters based on the point features.

5 Interpolating Rasters from Points Features

To create the rasters, use any of the interpolation tools available in the 3D Analyst and Spatial Analyst extensions.

Before the interpolation we will specify a query to define a HorizonID. This will ensure that only points representing a certain horizon in the model are included in the interpolation.

1. Make sure the “BorePoint” layer is selected in the Table of Contents.

Use the *Field Filter* available in the AHGW toolbar to define a query for points with a horizon of 6.

2. Select the “HorizonID_BHL” field in the first combo box.
3. Select a value of “6” in the second combo box.



For this tutorial, use the IDW interpolation method.

4. In the  *Spatial Analyst Tools* /  *Interpolation* toolset, double-click on the **IDW** tool to open the *IDW* dialog.
5. Specify the “BorePoint” point feature class as the *Input point features*.
6. Select the “TopElev” field as the *Z value field*.
7. Click the browse  button next to *Output raster* to open the *Output raster* dialog.
8. Browse to the *creating georasters\Rasters* folder and enter “idw_horizon06” as the *Name*.
9. Click **Save** to close the *Output raster* dialog.
10. Specify an *Output cell size* of “1000”.

Before running the tool, also set the *Environment Settings* so the raster interpolation covers the whole model domain:

11. Select the **Environments** button to open the *Environments Settings* dialog.
12. Expand the *Processing Extent* section and select the “Same as layer ModelBoundary” option under *Extent*.
13. Expand the *Raster Analysis* section and select the “ModelBoundary” layer as the *Mask*.
14. Select **OK** to close the *Environment Settings* dialog.
15. Select **OK** to run the tool.
16. Repeat steps 1–15 to create rasters for horizons 7, 8, 9, and 10. Make sure you specify the definition query each time before running the interpolation tool.

Tip: To save time you can access the results of a geoprocessing tool and edit the inputs. To access the geoprocessing results window. Select *Geoprocessing* from the main ArcGIS

menu and then select *Results*. Then expand the *Current Session* and double-click the *IDW* result. You can then edit any of the inputs you supplied previously and run the tool again.

At the end of this process you should have five rasters, one for each horizon (6, 7, 8, 9, and 10).

6 Visualizing the Rasters and Points

To visualize the rasters based on the elevations, set the *Base Heights* for each raster.

1. Select a raster, right-click and select **Properties** to open the *Layer Properties* dialog.
2. In the *Base Heights* tab, select the option: *Floating on a custom surface*
3. Specify the appropriate raster. For each raster layer the custom surface is the raster itself, such that the raster will display in 3D using its values.
4. Click **OK** to close the *Layer Properties* dialog.
5. Repeat steps 1– 4 for each of the rasters representing horizons (if necessary also for the DEM raster).

If desired, change the colors of the rasters and points using the *Symbology* tab to better visualize the different horizons.

At the end of this process you will be able to visualize the raster layers and points together as shown in Figure 6.

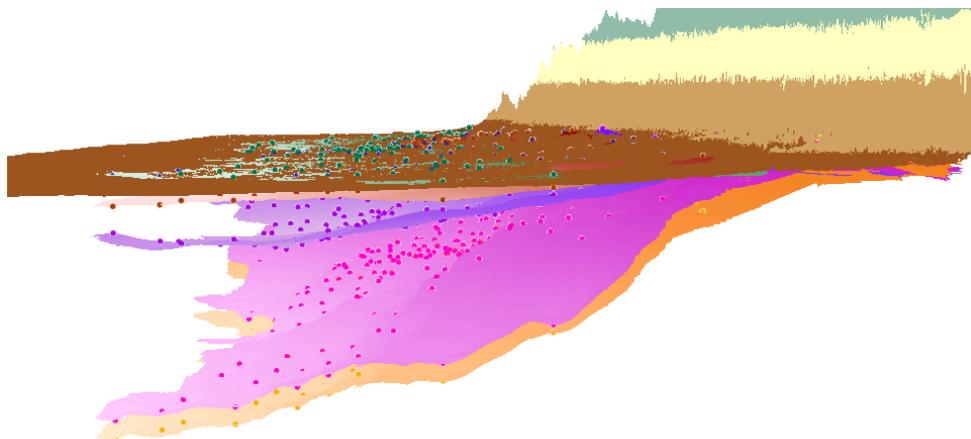


Figure 6 Visualizing rasters and points in ArcScene.

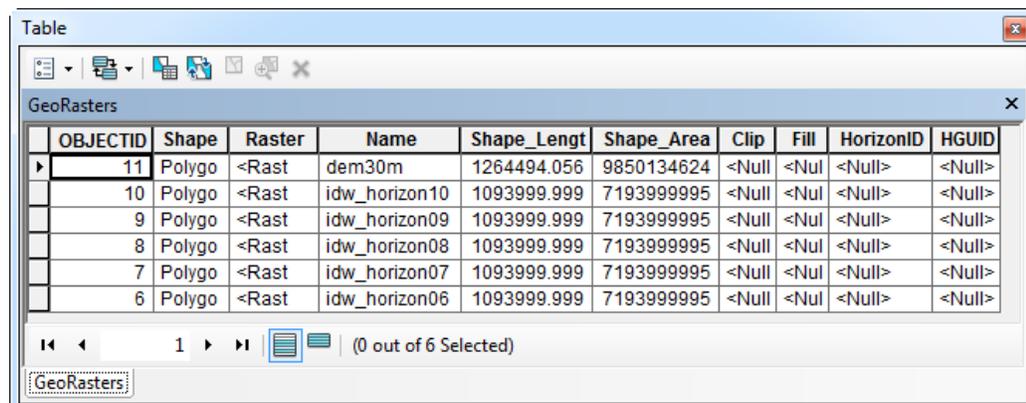
Based on the GeoRasters raster catalog 3D fence diagrams and volume models can be constructed. The creation of the 3D features is demonstrated in a separate tutorial.

7 Loading the Rasters into the GeoRasters Raster Catalog

Next, load the rasters into the GeoRasters raster catalog, and index them with the appropriate attributes.

1. In the  *Conversion Tools* /  *To Geodatabase* toolset, double-click the  **Raster To Geodatabase (multiple)** tool to open the *Raster to Geodatabase (multiple)* dialog.
2. Click the browse  button next to *Input Rasters* to open the *Input Rasters* dialog.
3. Browse to the *creating georasters\Rasters* folder and select “idw_horizon06”.
4. Click the **Add** button to close the *Input Rasters* dialog.
5. Repeat steps 2–4 for horizons 7, 8, 9, and 10 as well as for the “dem30m” raster that represents the surface terrain.
6. Click the browse  button next to *Output Geodatabase* to open the *Output Geodatabase* dialog.
7. In the browser, double-click the “GeoRasters.mdb” geodatabase and select the “GeoRaster” raster.
8. Click the **Add** button to close the *Output Rasters* dialog.
9. Select **OK** to close the *Input Rasters* dialog and run the tool.
10. Once the tool has finished, right-click on the “GeoRasters” layer and select **Open Attribute Table** to bring up the *Table* dialog showing the raster catalog.

Notice that the rasters were added to the raster catalog. The raster catalog should be similar to the one shown in Figure 7. Keep the *Table* dialog open to complete the rest of the tutorial.



OBJECTID	Shape	Raster	Name	Shape_Length	Shape_Area	Clip	Fill	HorizonID	HGUID
11	Polygo	<Rast	dem30m	1264494.056	9850134624	<Null	<Nul	<Null>	<Null>
10	Polygo	<Rast	idw_horizon10	1093999.999	7193999995	<Null	<Nul	<Null>	<Null>
9	Polygo	<Rast	idw_horizon09	1093999.999	7193999995	<Null	<Nul	<Null>	<Null>
8	Polygo	<Rast	idw_horizon08	1093999.999	7193999995	<Null	<Nul	<Null>	<Null>
7	Polygo	<Rast	idw_horizon07	1093999.999	7193999995	<Null	<Nul	<Null>	<Null>
6	Polygo	<Rast	idw_horizon06	1093999.999	7193999995	<Null	<Nul	<Null>	<Null>

Figure 7 Example of a populated GeoRasters raster catalog.

Next, edit the attributes of the raster catalog to add the appropriate indexes.

11. Right-click on any visible toolbar and select the **3D Editor** item.
12. Select *3D Editor* | **Start Editing**.
13. In the *Table* dialog, edit the *HorizonID* attribute such that each raster is indexed with the appropriate horizon ID.
14. Set the *Clip* attribute to “0” and the *Fill* attribute to “1”.
15. For the DEM, set the *Clip* attribute to 1. A value of 1 means that when creating 3D fence diagrams and volumes features extending above the DEM will be clipped at the DEM elevation (for more details see a separate tutorial – Building 3D Models with the Horizons Method).

At this point your catalog attributes should be similar to the one shown in Figure 8.

OBJECTID	Shape	Raster	Name	Shape_Length	Shape_Area	Clip	Fill	HorizonID	HGUID
11	Polygo	<Rast	dem30m	1264494.0569	9850134624	1	1	11	<Null>
10	Polygo	<Rast	idw_horizon10	1093999.9996	7193999995	0	1	10	<Null>
9	Polygo	<Rast	idw_horizon09	1093999.9996	7193999995	0	1	9	<Null>
8	Polygo	<Rast	idw_horizon08	1093999.9996	7193999995	0	1	8	<Null>
7	Polygo	<Rast	idw_horizon07	1093999.9996	7193999995	0	1	7	<Null>
6	Polygo	<Rast	idw_horizon06	1093999.9996	7193999995	0	1	6	<Null>

Figure 8 GeoRaster raster catalog after editing the *HorizonID*, *Clip*, and *Fill* attributes.

16. Save the edits by selecting the *3D Editor* | **Save Edits**.
17. Close the edit session by selecting the *3D Editor* | **Stop Editing** command.

Note: If you are save, then close ArcScene and attempt doing the same process in ArcMap. Then open the project again in ArcScene.

At the end of this process you have interpolated a set of rasters from borehole data and loaded and indexed the rasters in a GeoRasters raster catalog. The GeoRasters raster catalog can be used to create 3D GeoSection and GeoVolume features for representing the hydrogeologic units as fence diagrams and volume objects. This process is illustrated in a separate tutorial.

Conclusion

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

- 3D BorePoint features can be created from tabular bore log data associated with well features.
- The *BoreholeLog Table To Points* tool is used to create 3D point features from tabular bore log data – a set of points can be created for each horizon in the subsurface model.
- The *Field Filter* is used to query for specific sets of points based on a HorizonID.
- Rasters representing top/bottom of units can be interpolated from the BorePoints.
- The rasters are loaded into the GeoRasters raster catalog and indexed with the appropriate HorizonID, Clip, and Fill attributes.
- The rasters and points created can be visualized in ArcScene.