

ARC HYDRO GROUNDWATER TUTORIALS

Subsurface Analyst – Adding well construction details to cross sections

Arc Hydro Groundwater (AHGW) is a geodatabase design for representing groundwater datasets within ArcGIS. The data model helps to archive, display, and analyze multi-dimensional 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. *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. 2D cross sections can be sketched interactively using information from surficial geology maps, adjacent boreholes, and lines representing the intersection with rasters. This process is illustrated in the *Subsurface Analyst – Creating 2D Cross Sections* tutorial. In this tutorial we will learn how to add to 2D cross sections plots representing construction details (screen, filter pack, riser, etc.) for wells adjacent to the cross section.

1.1 Background

Data used in this tutorial are part of a project for developing a groundwater simulation model: The Sacramento Regional Model (SRM), which encompasses an area of approximately 1,360 square miles (871,000 acres), overlying the North American and South American subbasins of the Sacramento Valley Groundwater Basin, and the Cosumnes subbasin of the San Joaquin Groundwater Basin. 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). The well construction data used in this tutorial is fictitious.



Figure 1 Location of the Sacramento Regional Model.

1.2 Outline

The objective of this tutorial is to introduce the basic workflow and tools for creating 2D well construction features. Well construction refers to the elements making up the well string and the materials used to file a borehole. This tutorial should be completed after going through the XS2D tutorial. We will complete the following tasks:

1. Review the structure of the data model classes needed for working with 2D cross sections.
2. Create XS2D Lines representing well details at specified locations.
3. Create XS2D Polygons representing well details at specified locations.

1.3 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
- AHGW Tutorial Files

The AHGW Tools require 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.

2 Getting Started

Before opening the tutorial 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 Toolbox is loaded. If it is not, add the toolbox 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 *Subsurface Analyst* toolset to expose the tools we will be using in this tutorial.

We will also be using the *Arc Hydro Groundwater 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. Select the *Geoprocessing / Options...* command.
7. Activate the option: “*Overwrite the outputs of geoprocessing operations*” as shown in Figure 2.
8. Enable the option to “*Add results of geoprocessing operations to the display*” as shown in Figure 2.
9. Select *OK* to exit the setup.

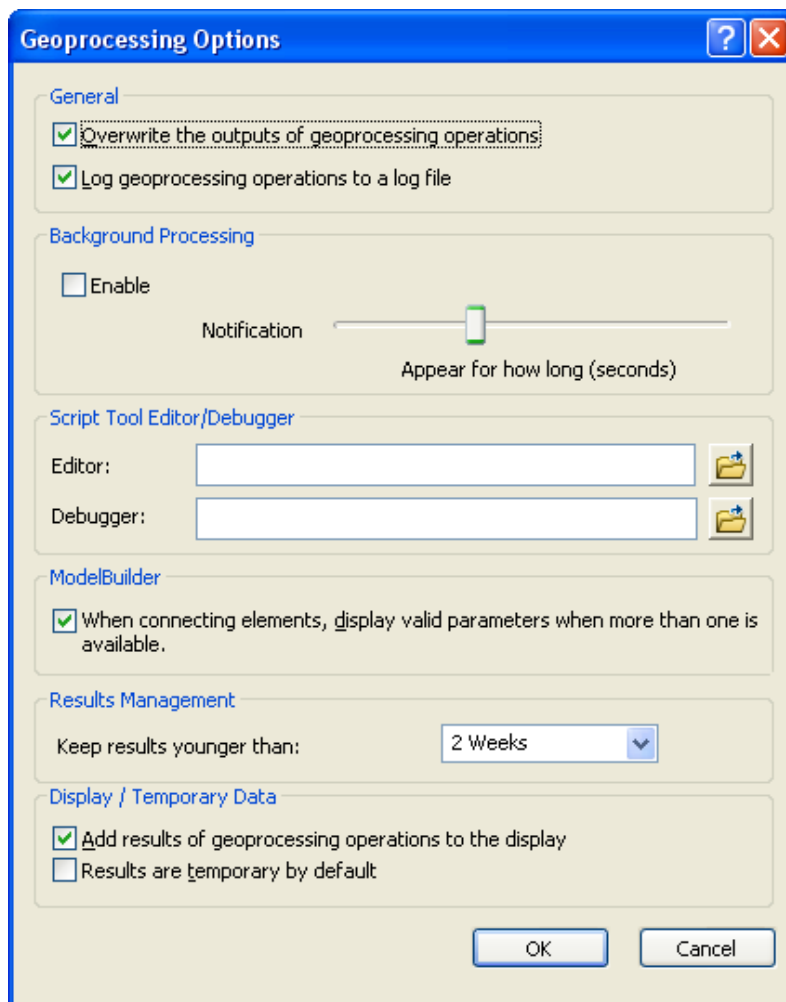


Figure 2 Setting Geoprocessing tools to overwrite outputs by default, and to add results of geoprocessing tools to the display.

3 Opening the Map

We will begin by opening a map containing some background data for the Roseville project.

10. Select the *File/ Open* command and browse to the location on your local drive where you have saved the AHGW tutorials. Browse to the *subsurface analyst/well_construction* folder and open the file entitled **Roseville.mxd**.

Once the file has loaded you will see a map of the model area in the California Central Valley. The map includes a boundary of the model domain, a polygon of the city of Roseville, layers representing streams, lakes, surface geology, wells, and section lines.

4 Representing 2D cross sections in the AHGW Data Model

Before starting to create cross sections, it is helpful to review the components of the AHGW Data Model we will be using. The Hydrostratigraphy component includes data structures for representing 2D and 3D hydrostratigraphy, including the creation of 2D cross sections (Figure 3). SectionLine is the central feature class used to manage cross sections. Each SectionLine represents the location of a cross section in map view. SectionLine features are indexed with a HydroID, which uniquely identifies them within the geodatabase. To create a vertical (profile) view of the cross section along the SectionLine, each SectionLine feature is associated with multiple feature classes representing the two-dimensional cross section, and these are given the “XS2D” prefix.

Common XS2D feature classes are:

- XS2D_Panel – polygon features representing cross section “panels”.
- XS2D_BoreLine – vertical lines representing hydrostratigraphy along selected boreholes adjacent to the SectionLine.
- XS2D_PanelDivider – vertical guides showing the beginning and ending points of a SectionLine and where a SectionLine changes direction.
- XS2D_MajorGrid and XS2D_MinorGrid – grid lines showing the vertical and horizontal scales in an XS2D data frame.

Additional feature classes can be added to represent items such as land surface elevation, water table, faults, etc.

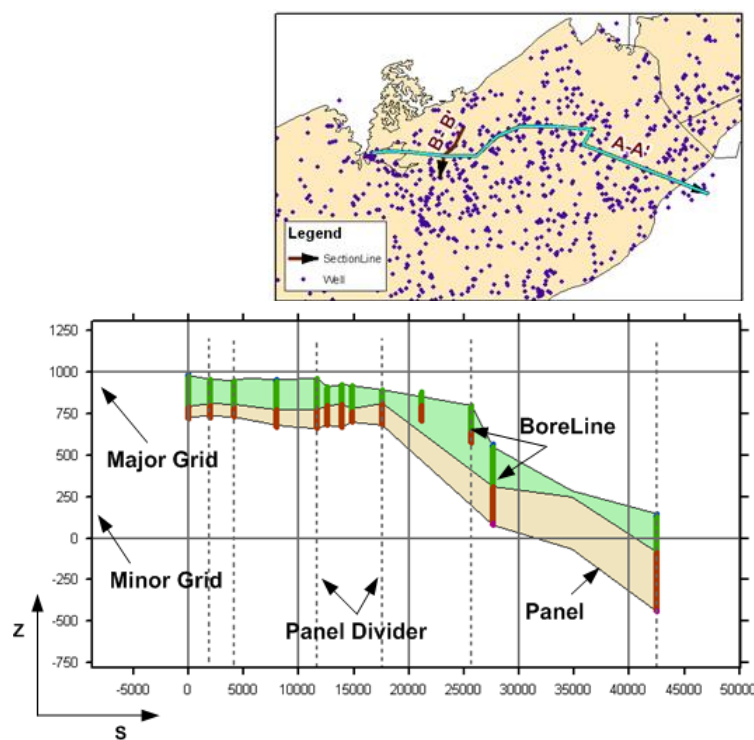


Figure 3 Datasets used for creating 2D cross sections.

Each of the 2D cross sections is generated in a separate data frame in ArcMap. The XS2D feature classes are created in an {S, Z} coordinate system that is unique for each cross section. The S coordinate represents the length along the SectionLine (equivalent to the x-direction in the XS2D data frame) and the Z coordinate represents the vertical dimension (the y-direction in the XS2D data frame). In addition, XS2D features can be scaled (exaggerated) in the Z dimension for better visualization. *Subsurface Analyst* includes a number of tools for transforming features between a “real” coordinate system (X, Y, and Z) and a 2D coordinate system (S, Z), and for scaling features.

The XS2D_Catalog table is used for managing XS2D feature classes. The Catalog lists the XS2D feature classes related with each SectionLine feature. The SectionID field in the XS2D_Catalog references a HydroID of a SectionLine feature, thus creating a relationship between SectionLines (defined in real world coordinates) and XS2D feature classes. An example of a typical XS2D_Catalog table is shown in Figure 4. For this exercise we will be creating two feature classes for well construction data (one for polygons and one for lines) and adding references to the classes in the XS2D_Catalog. For more information, see the *Creating 2D Cross Sections* tutorial.

Section Line Feature Class	SectionID	SName	Feature Class Name	XS2D Type
SectionLine	6475	A-A'	XS2D_Panel_6475	Panel
SectionLine	6475	A-A'	XS2D_BoreLine_6475	BoreLine
SectionLine	6475	A-A'	XS2D_MajorGrid_6475	MajorGrid
SectionLine	6475	A-A'	XS2D_MinorGrid_6475	MinorGrid
SectionLine	6475	A-A'	XS2D_PanelDivider_6475	PanelDivider

Figure 4 Example XS2D_Catalog used for managing XS2D feature classes and establishing a relationship between the XS2D features and a SectionLine feature.

5 Storing well construction data

Well construction data is referenced as depth along a borehole. To represent this type of data each construction element has a WellID attribute that links it to a well feature. In addition, each element has attributes giving the top and bottom elevations of the construction element. These values are usually given as depth along the borehole (From Depth and To Depth) and measured from a reference point, either land elevation or top of casing, downwards (Figure 5).

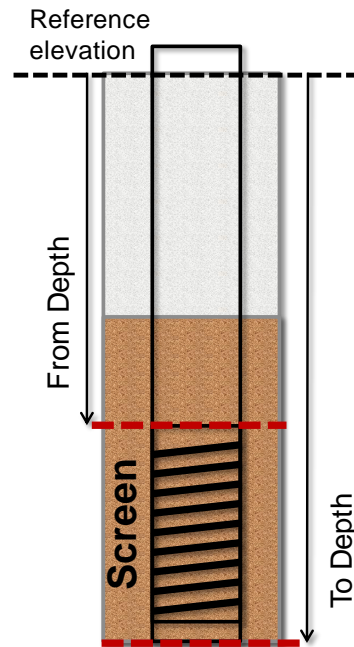


Figure 5 Representing well construction elements using *From Depth* and *To Depth* attributes.

There are different types of construction elements (e.g. risers, screens, filter pack, and grout) that can be managed within the geodatabase in a number of ways:

- All well construction elements are stored in a single table, and are differentiated by a “type” attribute.
- Elements are stored in a single table, but for each element type there are separate *From Depth* and *To Depth* fields.
- A separate table is created for each element type.

In this tutorial well construction data are stored using the first option where all elements are stored in a single table and are differentiated using a “type” field. Figure 6 shows the structure of the well construction table. The *WellID* field references a Well feature, *FromDepth* and *ToDepth* give the vertical elevations of the element, and *FType* gives its type.

OBJECTID *	WellID	FromDepth	ToDepth	FType
1	6633	0	1145	Riser
2	6634	0	1350	Riser
3	6609	0	556	Riser
4	6633	1145	1395	Screen
5	6634	1350	1550	Screen
6	6609	556	695	Screen
7	6634	1590	1620	Screen
8	6633	0	1105	Grout
9	6634	0	1310	Grout
10	6609	0	526	Grout
11	6633	1105	1430	Filter pack
12	6634	1310	1590	Filter pack

Figure 6 Example of a well construction table for storing construction elements.

6 Adding line data from well construction tables

Once a 2D cross section is constructed, it is often useful to plot well construction details for wells adjacent to the cross section. Subsurface Analyst contains tools to help add well construction diagrams to a XS2D data frame. Plots of the well screen and materials comprising the borehole can consist of lines, polygons, or some combination of both. Since well construction data can be stored in a variety of formats, the geoprocessing tools used to create the plots have been designed to be as flexible as possible. Each well construction detail is processed separately and is added to the map as either a line or rectangular polygon. The input to the tools is simply the top and bottom depths of the details and the table containing the data.

Before we continue we will need to create a new line feature class to which the output well construction polylines will be written.

1. Make sure the *Layers* data frame is the active data frame (this data frame needs to be active as the Well features are located in this data frame). You can activate the data frame by selecting it, right-clicking, and selecting the *Activate* option. You can also activate the data frame by selecting it and pressing the F11 key.
2. Open the **Create XS2D Line Feature Class** tool in the *Subsurface Analyst/XS2D Editor* toolset.

This tool will create a new XS2DLine feature class for each of the selected SectionLine features. If no section line is selected it will create feature classes for all section lines in the SectionLine feature class.

3. For the *Input Section Line Features* select the **SectionLine** feature class.
4. Specify **XS2D_Catalog** for the *XS2D_Catalog Table*.
5. Enter **Well Construction Line** as the *XS2DType value*.
6. Enter **WellConstructionLine** as the *Feature Class Name Prefix*.

The feature classes created will include the prefix specified and the HydroID of the section line feature (e.g. WellConstructionLine_6475).

At this point, your selections should be similar to those shown in Figure 7.

7. Select the *OK* button to execute the tool.
8. Select the *Close* button when the tool has finished.

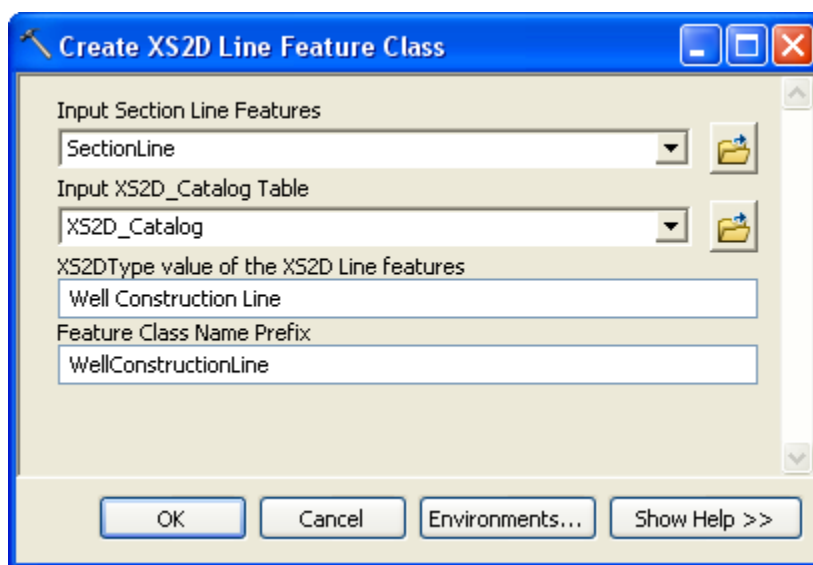



Figure 7 Settings for the Create XS2D Line Feature Class Tool.

A new feature class named WellConstructionLine_6475 should be added to the map.

9. Add the *WellConstructioLinen_6475* feature class to the *Section A-A'* data frame (you can select the layer and drag it to the data frame, or activate the *Section A-A'* data frame and use the Add Data  tool).

Next, you will add well construction features to the feature class just created. Each line in the feature class represents a part of the overall well or borehole, and can be classified by a feature type, such as riser, screen, filter pack, etc.

To add well construction data along the cross section we will apply the **Transform Well Detail Line tool**. But first we will need to select the wells we want to use. We will be working with a subset of wells that have well construction information (the tool works on a selection set of wells). Select wells with well construction data:

10. Make sure the *Layers* data frame is active.
11. Open the *Select By Attributes* command in the *Selection* menu.
12. In the “*Layer:*” section, choose the **Well** layer.
13. In the “*Method:*” section, choose the **Create a new selection** option.
14. For the query, enter the following: `[HasWellConstruction] = 1`.

At this point, your dialog should be similar to that shown in Figure 8.

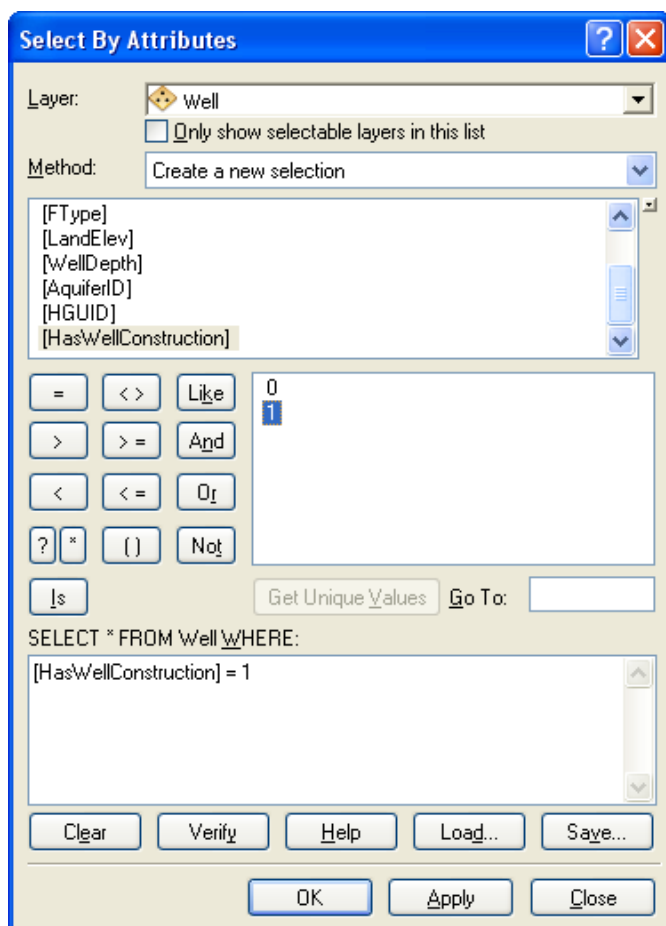


Figure 8 Settings for the *Select By Attributes* dialog

15. Click the **OK** button.

Three well features along the SectionLine should be selected. Now that wells are selected we are ready to run the tool that transforms and creates the line features.

16. Double-click on the ***Transform XS2D Well Detail Line*** tool in the *Subsurface Analyst/XS2D Editor* toolset.
17. Select the ***XS2D_Catalog*** table as the *Input XS2D_Catalog Table*.

18. Select **Well** as the *Input Well Features* parameter.
19. Select **LandElev** as the *Well Ground Elevation*. This represents the field in the Well feature class containing the ground surface elevation. This is used by the tool to convert the depths associated with the well construction details to elevations.
20. Select **SectionLine** as the *Input SectionLine Features* value.
21. Enter **6475** for the *SectionLine ID*.
22. Select **Well Construction Line** for the *XS2DType*.
23. Enter **Riser** for the *FType*. This is the feature type attribute added to the feature class referenced in the XS2D_Catalog table we are writing to.
24. Select **WellConstruction** for the *Input Well Construction Table*.
25. Select **WellID** for the *Well Construction WellID Field*. This field contains the HydroID of the associated well.
26. Select **FromDepth** for the *Well Construction From Depth Field*.
27. Select **ToDepth** for the *Well Construction To Depth Field*.
28. Select **FType** for the *Data Type Field for filtering*.
29. Select **Riser** for the *Data Type Value for filtering*.

At this point, the settings for the tool should match those shown in Figure 9.

30. Click **OK** to launch the tool.
31. When the tool is finished, click the **Close** button.

Transform XS2D Well Detail Line

Input XS2D_Catalog Table
XS2D_Catalog

Input Well Features
Well

Well Ground Elevation (if not Z enabled) (optional)
LandElev

Input SectionLine Features
SectionLine

SectionLine ID
6475

XS2DType
Well Construction Line

FType
Riser

Input Well Construction Table
WellConstruction

Well Construction WellID Field
WellID

Well Construction From Depth Field
FromDepth

Well Construction To Depth Field
ToDepth

Data Type Field for filtering (optional)
FType


Data Type value for filtering (optional)
Riser

OK Cancel Environments... Show Help >>

Figure 9 Settings for the Transform XS2D Well Detail Line tool.

When the tool is done, activate the data frame Section A-A'. You should see a new set of lines in your cross section representing the risers, extending from the ground surface to a point at about mid-depth in the cross section (if the line does not appear, refresh the map and ensure that the *WellConstructionLine_6475* feature class is listed first in the *Section A-A'* data frame).

To symbolize the risers:

32. Open the Symbology tab of the *WellConstructionLine_6475* feature class by selecting the layer, right clicking and selecting Properties and then the Symbology tab.
33. Select the Import option  on the upper right.

34. Browse to the **Riser.lyr** file located in the Symbology folder. Select the file and select the **Add** command. Select **OK** in the next interface and **OK** again to exit the properties window.

Your cross section should be similar to the one shown in Figure 10.

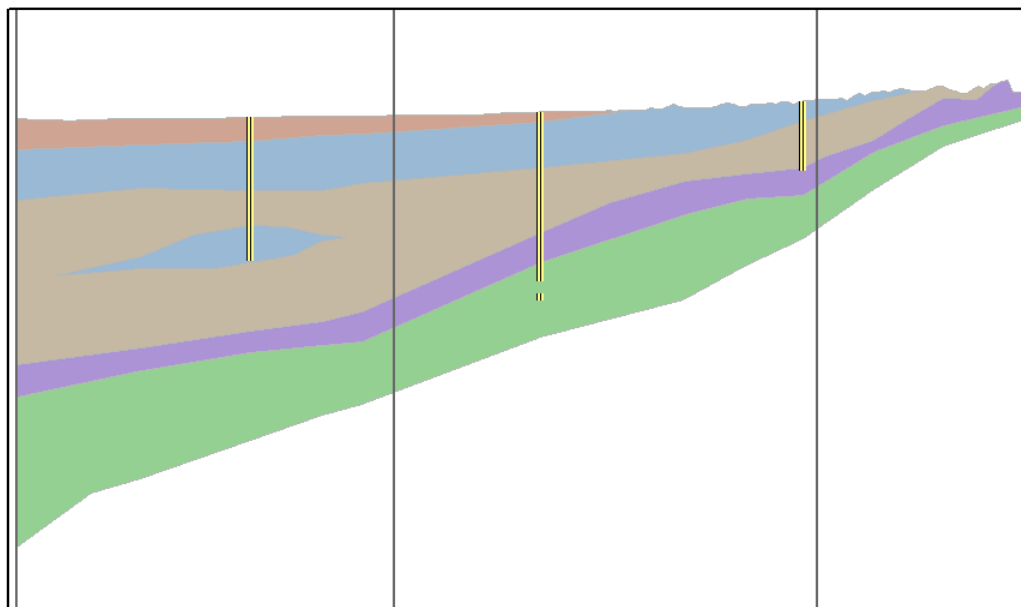


Figure 10 Risers elements added to the cross section data frame.

7 Adding polygon data from well construction tables

In addition to creating well construction polyline features, *Subsurface Analyst* also has a tool for creating the same features as polygons instead. The tools work similarly, but in some cases you might want to use a polygon instead of a polyline depending on how you wish to symbolize the feature. Each polygon created represents a part of the overall well or borehole, and can be classified by a feature type, such as riser, screen, filter pack, etc.

First we will create the XS2D polygon feature class:

1. Make sure the *Layers* data frame is the active data frame. You can activate the data frame by selecting it, right-clicking, and selecting the *Activate* option. You can also activate the data frame by selecting it and pressing the F11 key.
2. Open the **Create XS2D Polygon Feature Class** tool in the *Subsurface Analyst/XS2D Editor* toolset.

This tool will create a new XS2DPolygon feature class for each of the selected SectionLine features. If no section line is selected it will create feature classes for all section lines in the SectionLine feature class.

3. For the *Input Section Line Features* select the **SectionLine** feature class.
4. Specify **XS2D_Catalog** for the *XS2D_Catalog Table*.

5. Enter **Well Construction Polygon** as the *XS2DType* value.
6. Enter **WellConstructionPolygon** as the *Feature Class Name Prefix*.

The feature classes created will include the prefix specified and the HydroID of the section line feature (e.g. WellConstructionPolygon_6475).

At this point, your selections should be similar to those shown in Figure 11.

7. Select the *OK* button to execute the tool.
8. Select the *Close* button when the tool has finished.

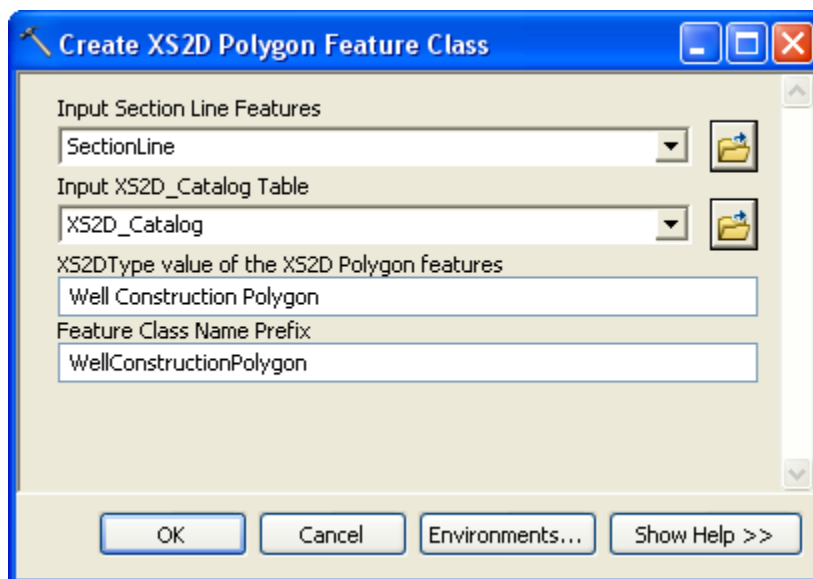



Figure 11 Settings for the Create XS2D Polygon Feature Class Tool.

A new feature class named *WellConstructionPolygon_6475* should be added to the map.

9. Add the *WellConstructionPolygon_6475* feature class to the *Section A-A'* data frame (you can select the layer and drag it to the data frame, or activate the *Section A-A'* data frame and use the Add Data  tool). Drag the *WellConstructionPolygon_6475* feature class just above the *WellConstructionLine_6475* feature class.

To add well construction data along the cross section we will apply the **Transform XS2D Well Detail Polygon** tool. Since the three wells are still selected, we are ready to use the *Transform Well Detail Polygon* tool (if the wells are not selected reselect them as shown previously).

10. Make sure the *Layers* data frame is active.
11. Double-click on the **Transform XS2D Well Detail Polygon** tool in the *Subsurface Analyst/XS2D Editor* toolset.

12. Select the **XS2D_Catalog** table as the *Input XS2D_Catalog Table*.
13. Select **Well** as the *Input Well Features* parameter.
14. Select **LandElev** as the *Well Ground Elevation*.
15. Select **SectionLine** as the *Input SectionLine Features* value.
16. Enter **6475** for the *SectionLine ID*.
17. Select **Well Construction Polygon** for the *XS2DType*.
18. Enter **Screen** for the *FType*. This is the feature type attribute added to the feature class referenced in the XS2D_Catalog table we are writing to. This will allow us to identify these features when doing queries or setting up symbology.
19. Select **WellConstruction** for the *Input Well Construction Table*.
20. Select **WellID** for the *Well Construction WellID Field*.
21. Select **FromDepth** for the *Well Construction From Depth Field*.
22. Select **ToDepth** for the *Well Construction To Depth Field*.
23. Enter **2000** for the *Display Width*. This indicates that the polygons to be created are 2000 units wide in the linear unit of the target polygon feature class.
24. Select **FType** for the *Data type field for filtering*.
25. Select **Screen** for the *Data type value for filtering*.

At this point, the settings for the tool should match those shown in Figure 12.

26. Click **OK** to launch the tool.
27. When the tool is finished, click the **Close** button.

Transform XS2D Well Detail Polygon

Input XS2D_Catalog Table
XS2D_Catalog

Input Well Features
Well

Well Ground Elevation (if not Z enabled) (optional)
LandElev

Input SectionLine Features
SectionLine

SectionLine ID
6475

XS2DType
Well Construction Polygon

FType
Screen

Input Well Construction Table
WellConstruction

Well Construction WellID Field
WellID

Well Construction From Depth Field
FromDepth

Well Construction To Depth Field
ToDepth

Display Width
2000

Data Type Field for filtering (optional)
FType

Data Type value for filtering (optional)
Screen

OK Cancel Environments... Show Help >>

Figure 12 Settings for the Transform XS2D Well Detail Polygon tool.

When the tool is done, activate the data frame *Section A-A'*. You should see a new set of polygons in your cross section representing the well screen (if the polygon does not appear, refresh the map).

To symbolize the polygons:

28. Open the Symbology tab of the WellConstructionPolygon_6475 feature class by selecting the layer, right clicking and selecting Properties and then the Symbology tab.

29. Select the Import option  on the upper right.

30. Browse to the **WellPolygon.lyr** file located in the Symbology folder. Select the file and select the **Add** command. Select **OK** in the next interface and **OK** again to exit the properties window.

Your cross section should be similar to the one shown in Figure 13.

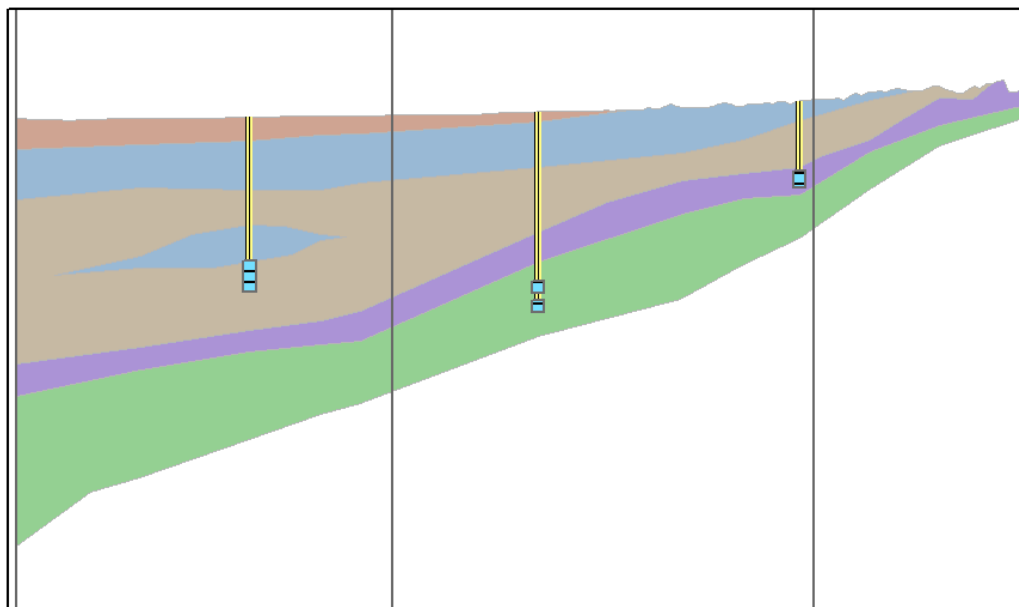


Figure 13 Riser and screen well construction elements.

Next, you can add filter pack and grout elements as polygons.

31. Repeat steps 10 – 27 to add the filter pack elements. Make sure to specify **Filter Pack** in the *FType* parameter. Make sure to select **Filter Pack** for the *Data Type Value for filtering*. Select a width of **4000** for the *Display Width*.
32. Repeat steps 10 – 27 to add the grout elements. Make sure to specify **Grout** in the *FType* parameter. Make sure to select **Grout** for the *Data Type Value for filtering*. Select a width of **4000** for the *Display Width*.

To view the different polygon construction elements we need to set the symbol levels:

33. Open the *Symbology* tab in the *Layer Properties* of the WellConstructionPolygon layer.
34. Select the **Advanced | Symbol Levels** option on the bottom right.
35. Enable the option *"Draw this layer using the symbol levels specified below"*, as shown in Figure 14.

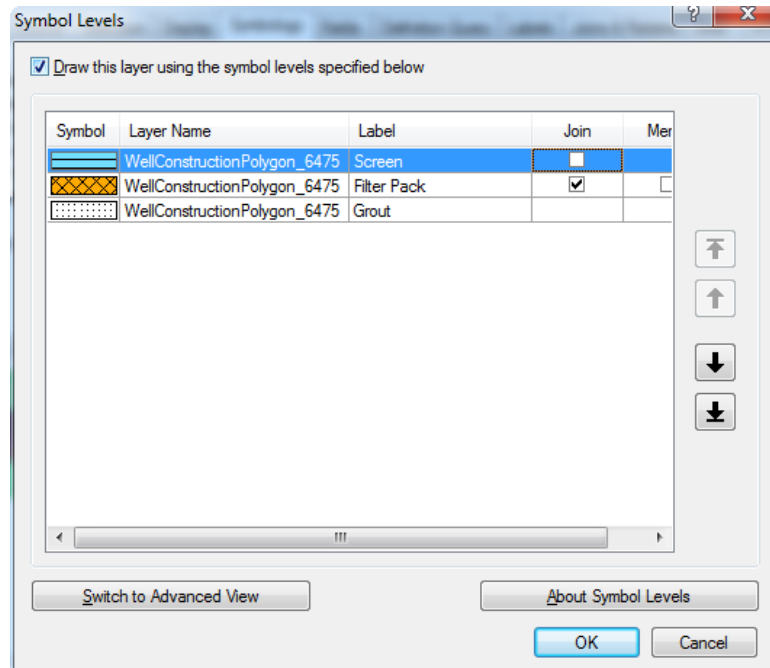


Figure 14 Enabling the Symbol Levels option on well construction polygons.

At this point your cross section should include all elements and should be similar to the one shown in Figure 15.

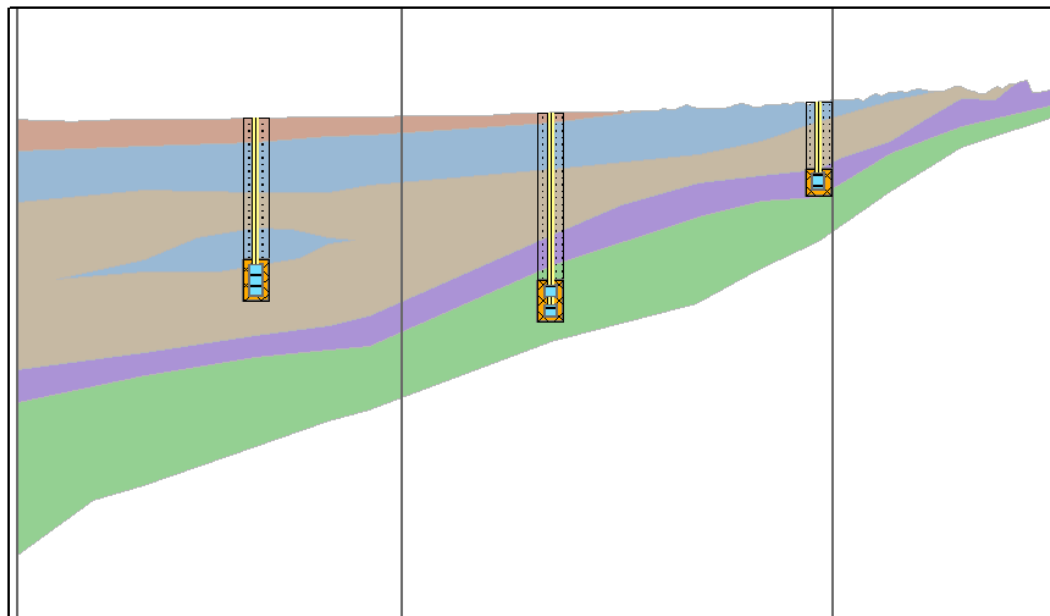


Figure 15 Detail of the well construction features including risers, screens, grout, and filter pack elements.

8 Conclusion

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

- The Arc Hydro Groundwater data model includes XS2D feature classes that provide the framework for working with 2D cross sections in ArcMap.
- The *Transform XS2D Well Detail Line* geoprocessing tool can be used to create line data associated with well features along a 2D cross section.
- Similarly, the *Transform XS2D Well Detail Polygon* geoprocessing tool can be used to create polygon data associated with well features along a 2D cross section.