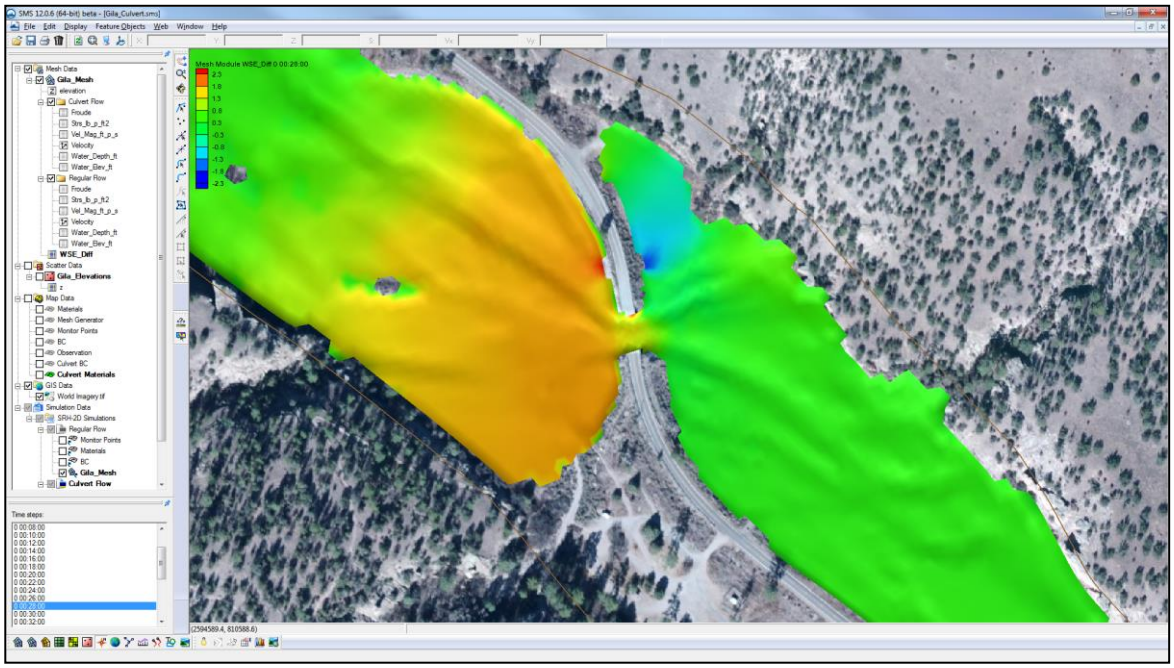
SRH-2D Tutorial

Culvert Structures



Objectives

This tutorial demonstrates the process of modeling culverts in SRH-2D. The "SRH-2D Simulations" tutorial should have been completed before attempting this one. All files for this tutorial are found in the "Data" folder within the "SMS_SRH2D_Culvert_FST" folder.

Prerequisites

- SMS Overview
- SHR-2D
- SRH-2D Simulations

Requirements

- SRH-2D
- Mesh Module
- Scatter Module
- Map Module

Time

- 15–20 minutes

1 Model Overview

An existing SRH-2D model will be used to facilitate the setup for this tutorial. SRH-2D provides two different ways to define a culvert. One way couples the FHWA HY-8 culvert model with SRH-2D and the other way utilizes the culvert definition built into SRH-2D. This tutorial will demonstrate the latter.

The area being modeled is located at the confluence of the west and middle forks of the Gila River, located in New Mexico. During high flows, a significant amount of water is backed up near one of the roadway bridges causing flooding upstream. The purpose of this tutorial is to simulate a culvert relief structure near the bridge to mitigate the flooding.

Although the SRH-2D culvert structure is a capable option for modeling culverts, there are limitations to its use. Momentum calculated in the 2D computations does not transfer through the structure. Reverse flows through the culvert are also not possible. If the scenario that is being analyzed is expected to have bi-directional flow through the culvert, it is recommended that an HY-8 culvert structure be defined for SRH-2D to use. (See the "Culvert Structures with HY-8" tutorial.)

2 Getting Started

To begin, do the following:

1. Open a new instance of SMS.
2. Select *File* | **Open** to bring up the *Open* dialog.
3. Navigate to the *SMS_SRH-2D_Culvert_FST /Input* folder for this tutorial and select "Gila_Structure.sms".
4. Click **Open** to import the project.

The existing project will open and appear as displayed in Figure 1.

In the Project Explorer, duplicates of the "Regular Flow" simulation and "BC" coverage have been made to expedite the model setup process. The duplicates have been renamed as "Culvert Flow" and "Culvert BC" respectively. The culvert structure will be created within the "Culvert BC" coverage and simulated in the "Culvert Flow" simulation.

The process of duplicating these items was demonstrated in the "SRH-2D Simulations" tutorial. Creating duplicates of simulations or coverages allows making modifications to a

model while still preserving the original simulation or coverages. This also enables creating several modeling scenarios in the same project and comparing the solutions.

If desired, review the "SRH-2D Simulations" tutorial before continuing.

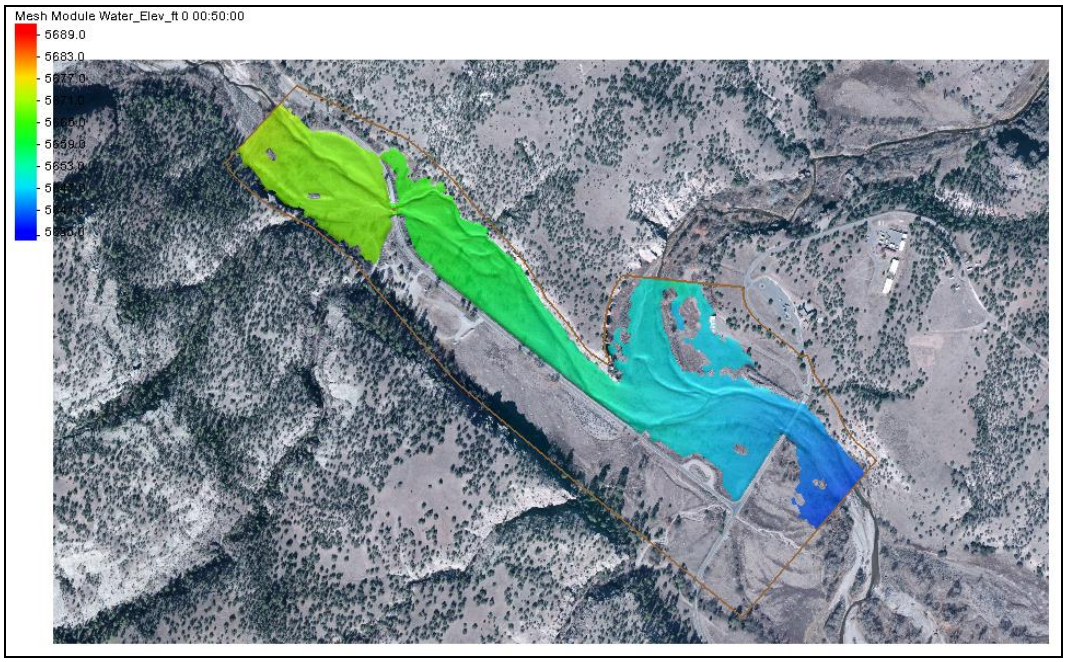


Figure 1 Gila_Structure.sms project

The mesh datasets located under the "Regular Flow" folder in the Project Explorer are from an SRH-2D solution of the existing flow conditions, without the culvert relief structure. The datasets can be used to make comparisons and visualize the effects the culvert structure will have on the model.

1. In the *Time steps* window, scroll through the time steps and select the final time interval at "0 02:30:00".

Notice that the flow is overtopping the roadway in the upper left part of the road.

3 Creating the Culvert Structure

The culvert structure will be created near the bridge location just upstream of the confluence (location displayed in Figure 2). Culvert structures are defined by creating two arcs, one on the upstream face and one on the downstream face of the structure. The arcs are then defined as a culvert structure and the attributes of the culvert are defined in the culvert definition dialog.

3.1 Creating the Structure Arcs

The first step for creating a culvert structure for SRH-2D is to create arcs representing the structure within the SRH-2D boundary condition coverage.

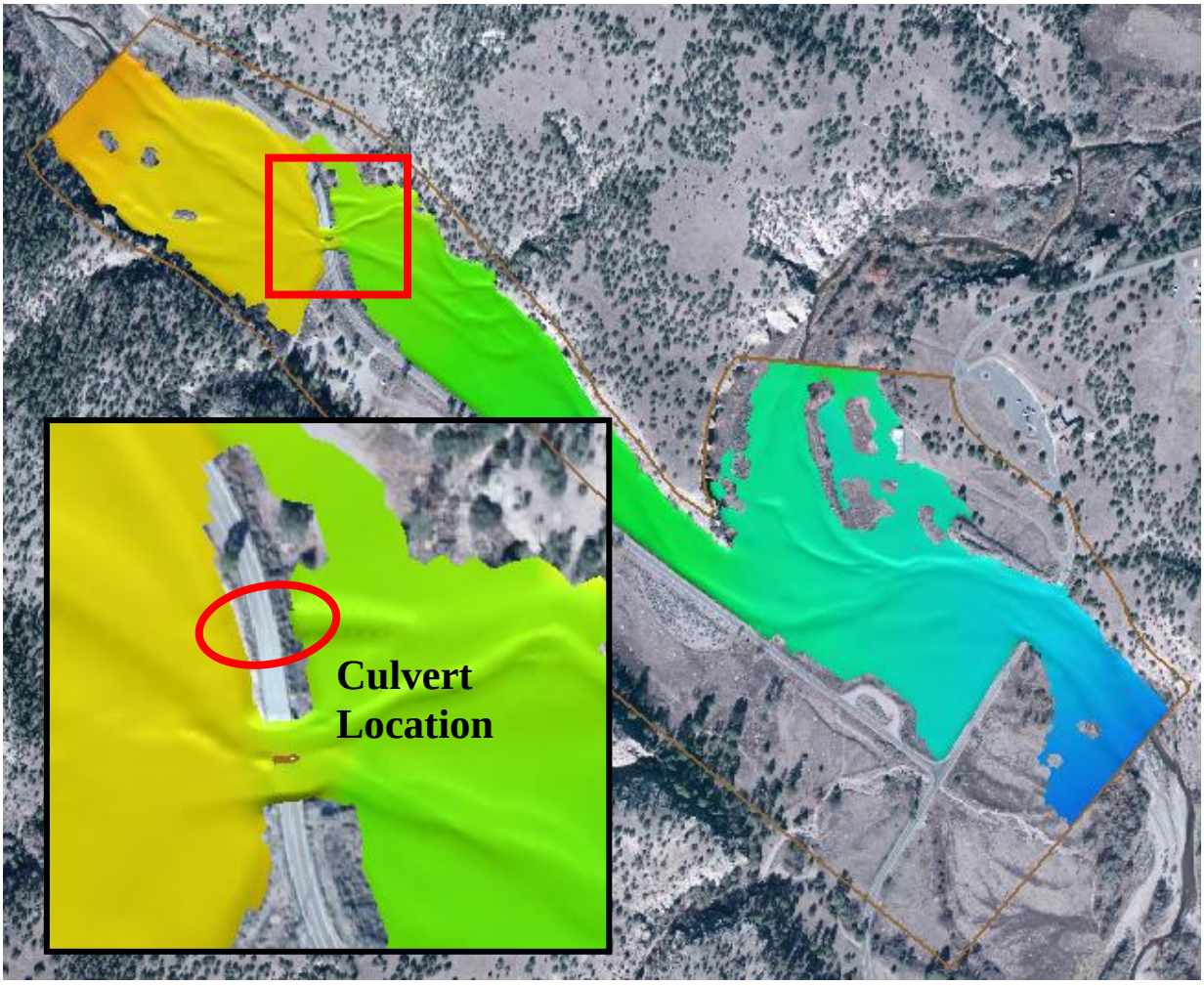


Figure 2 Culvert Location

1. Use the **Zoom** tool to zoom into the culvert location near the bridge. (Figure 2)
2. Select the "Z" dataset under "Gila_Mesh" in the Project Explorer to display the mesh elevations.
3. Select *Display* | **Display Options…** to open the *Display Options* dialog.
4. In the *2D Mesh* section, check the box next to *Elements* to turn on the display of mesh elements.
5. Select **OK** to exit the *Display Options* dialog.
6. In the Project Explorer, check the box next to the "Culvert BC" coverage and select it to make it the active coverage.
7. Use the **Create Feature Arc** tool to create two arcs, one on each side of the road. These arcs will define the upstream and downstream faces of the culvert structure. The created arcs should be placed in the locations shown in Figure 3.

It is recommended that the mesh be created to contain quadrilateral elements within the area between these two arcs which represent the culvert structure and that the structure arcs are aligned with a clean row of element edges.

Note: When drawing these arcs, they should be drawn in the same direction. After the first arc has been drawn, ensure that the second arc is drawn in the same direction (north to south or south to north). Drawing them in opposing directions may cause an error when running SRH-2D.

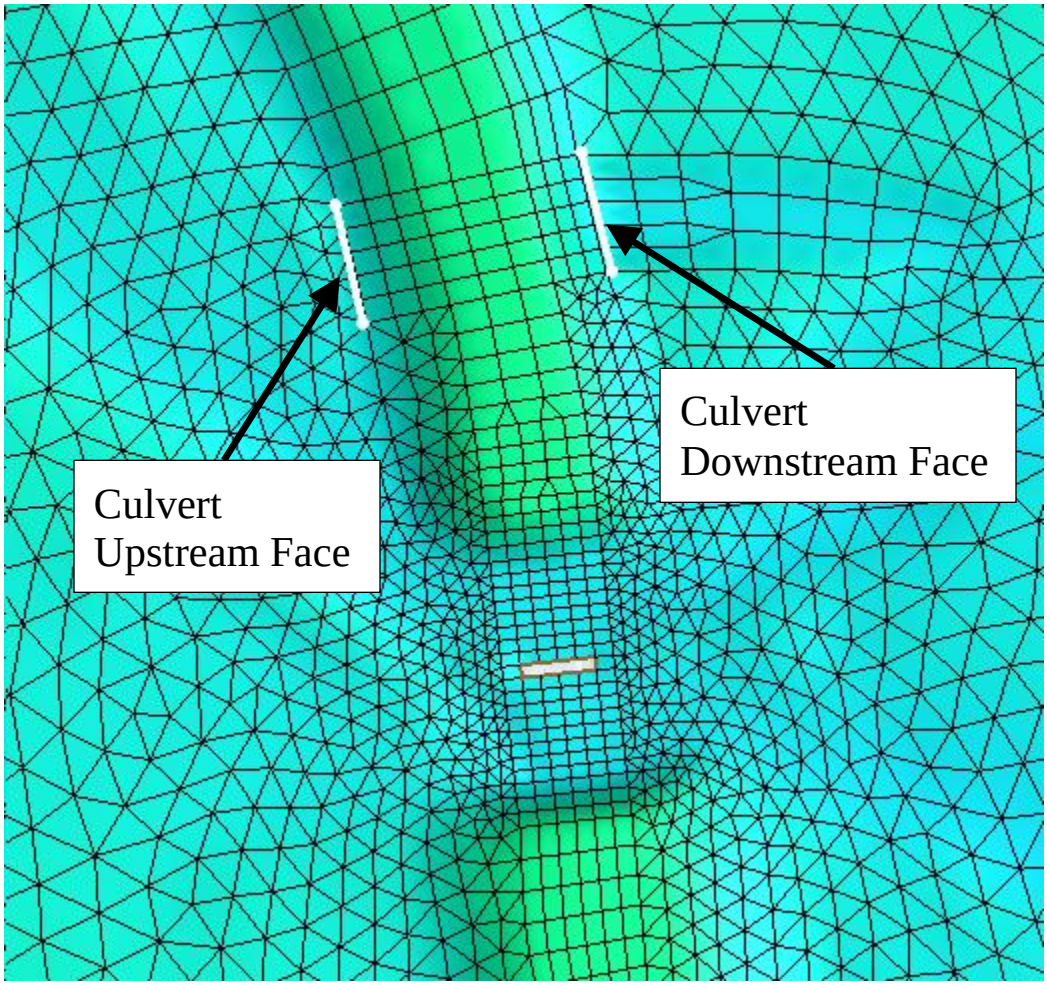


Figure 3 Upstream and Downstream BC Culvert Arcs

3.2 Assigning Culvert Structure Attributes

The next step in creating the culvert structure is to specify the boundary condition type and define the culvert attributes.

1. Using the **Select Feature Arc** tool, select the upstream (leftmost) culvert arc and take note of the ID for this arc, which is displayed the *Status Bar* at the bottom of the SMS application.

2. Hold the *Shift* key and select the downstream (right) culvert arc so that both of the arcs are selected.
3. Right-click on either arc and select the **Assign Linear BC...** command. SMS will bring up the *SRH-2D Linear BC* dialog.
4. In the *Type* combo box, select "Culvert". Be sure to select "Culvert" and not "Culvert HY-8".
5. Note the assignment of "Culvert Upstream" and "Culvert Downstream" to the two arcs, associated with their ID values. If the ID displayed for culvert upstream is not the same as noted above in step 1, switch the associations using the combo box for *Role*.
6. Define the culvert and crossing attributes as found in Table 1. When done the dialog should resemble Figure 4.
7. When done, click **OK** to close the *SRH-2D Linear BC* dialog.

This particular culvert crossing contains five concrete box barrels with straight headwalls. Definitions of the input parameters can be found at http://www.xmswiki.com/wiki/SMS:SRH-2D_Structures.

Parameter	Value	Parameter	Value
Type	Culvert	Number of identical barrels	5
Upstream invert elevation (ZI)	5664.5	Entrance type (m_in)	Non-mitered
Interior height of barrel (Dc)	6	Culvert inlet coefficients (Kp, M, cp, Y)	Concrete – Rectangular – Headwall; ¾ in chamfers
Length of barrel (Dc)	85	Entrance loss coeff Ke	0.5
Area of barrel (Ac)	48	Manning roughness coefficient in barrel (Nc)	0.012
Hydraulic radius of barrel (Rh)	1.714	Crest elevation	5672
Slope of barrel (Slp)	0.0176	Length of Weir over Culvert	40
Units	ft	Type	paved

Table 1 Linear BC attributes

The *Use total head* option will add the velocity head to the water surface elevations for the 1D culvert calculations. It will not be used for this application.

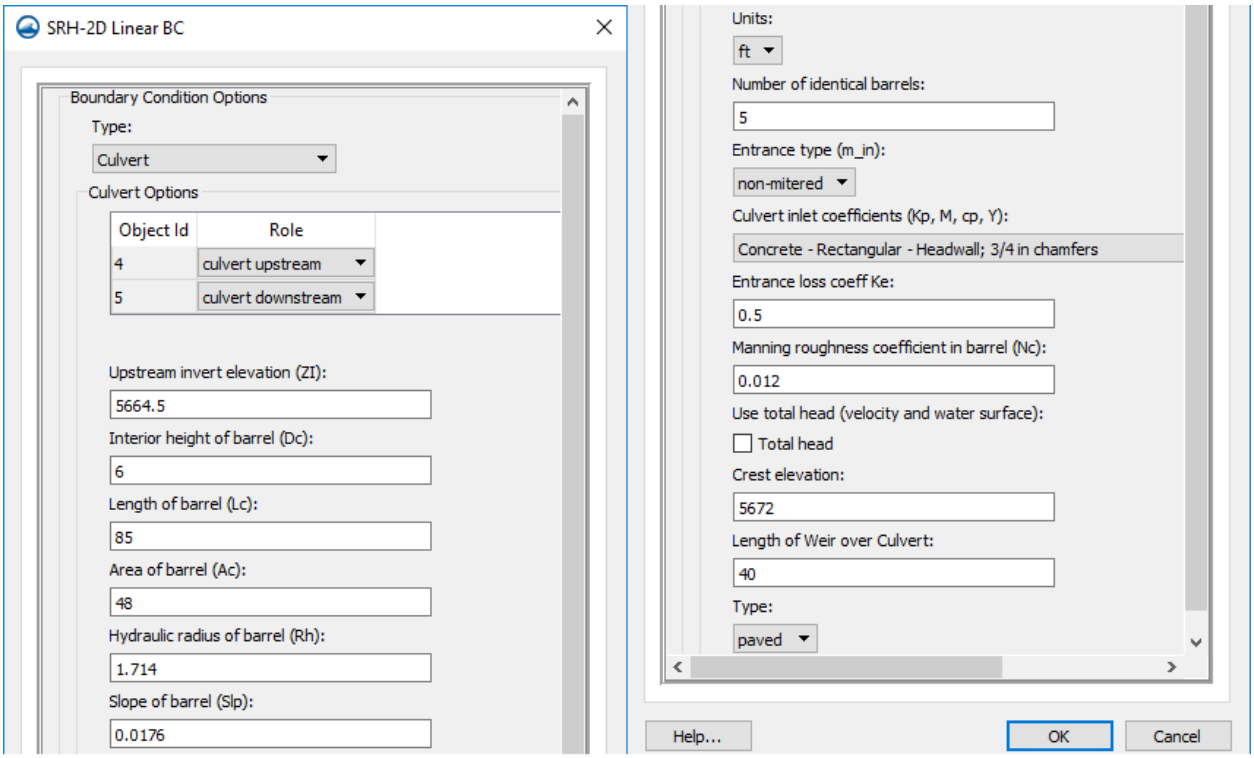


Figure 4 Culvert Parameters

4 Saving, Exporting, and Launching the Simulation

Now that the culvert structure has been created and defined, the model is ready to run.

1. Right-click on the "Culvert Flow" simulation and choose **Save, Export, and Launch SRH-2D**.
2. Select **OK** if a warning is displayed stating that the "Culvert Materials" coverage will be renumbered before exporting.
3. When the run completes, a message stating "Program terminated with exit code 0, Exit Window?" will appear. Select **Yes**.
4. Make sure *Load Solution* is checked in the SMS model wrapper (as in Figure 5) and click **Exit**.

The solution datasets will now be listed in the Project Explorer under "Gila_Mesh".

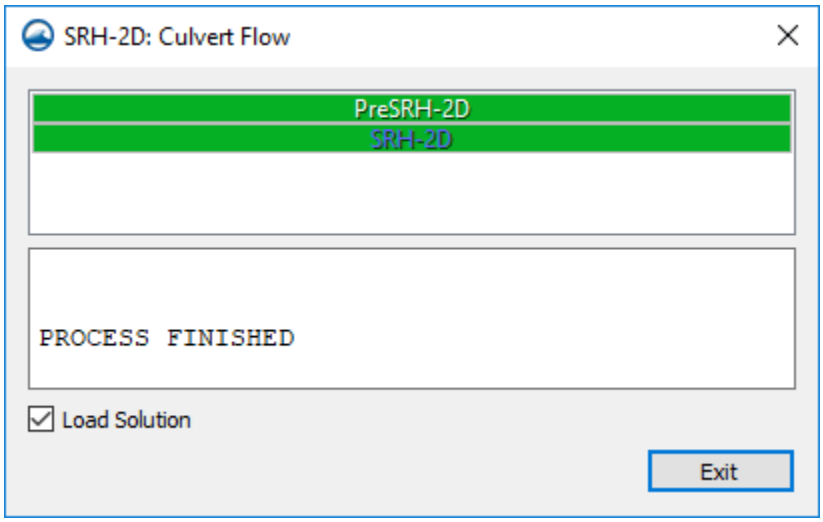


Figure 5 SMS Model Wrapper

4.1 Organizing the Solution Datasets

For better dataset organization, a folder will be created where the culvert solution datasets may be stored.

1. Right-click on "Gila_Mesh" and select **New Folder**.
2. Rename the new folder "Culvert Flow".
3. Select the 6 mesh datasets that correspond to the culvert solution by holding down the *Shift* key and selecting these datasets: "Froude", "Strs_lb_p_ft2", "Vel_Mag_ft_p_s", "Velocity", "Water_Depth_ft", and "Water_Elev_ft".
4. Drag the selected datasets below the "Culvert Flow" folder that was created in steps 1 and 2. The datasets should be organized as shown in Figure 6.

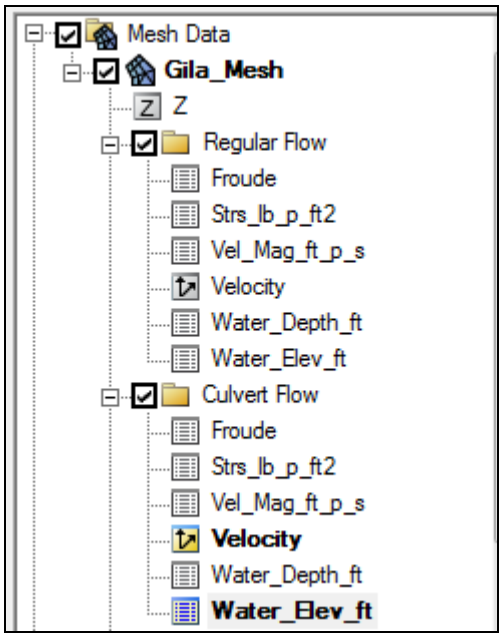


Figure 6 Mesh Dataset Organization

5. Select the "Water_Elev_ft" mesh dataset within the "Regular Flow" folder to make it the active dataset for viewing.

5 Visualizing the Results

SMS has several ways by which results can be visualized.

One method is to toggle through the datasets and time steps to see the results in the main Graphics Window.

1. View the final time step "0 02:30:00" of the "Water_Elev_ft" solution dataset, below the "Regular Flow" folder. Notice that water flows over a portion of the road to the north of the bridge.

2. View the final time step "0 02:30:00" of the "Water_Elev_ft" solution dataset below the "Culvert Flow" folder. With the current culvert design, the flooding across the road has been mitigated. Modifications of the current culvert design could be created to attempt to further mitigate flooding. However, for the purposes of this tutorial, this culvert design will be used.

Another useful way to compare the effects of the culvert on the channel is to create a new mesh dataset representing the differences in water surface elevations between the culvert solution and the existing condition solution. The difference dataset can be created using the *Data Calculator*.

1. Select *Data* | **Dataset Toolbox…** to bring up the *Dataset Toolbox* dialog.

An expression will be created in the calculator that uses the final time step of the results and takes the difference between both water surface elevation datasets, existing conditions "Water_Elev_ft" and the proposed culvert conditions "Water_Elev_ft"

2. Select "Data Calculator" in the *Tools* section.
3. Click on the "d6. Water_Elev_ft" dataset under the "Regular Flow" folder to select and make it active.
4. In the *Time Steps* section, scroll down and select the final time step "0 02:30:00".
5. Select the **Add to Expression** button to add the final time step of the "d6. Water_Elev_ft" dataset to the expression.
6. Select the subtract button.
7. Select the "d11. Water_Elev_ft" dataset under the "Culvert Flow" folder.
8. In the *Time Steps* section, scroll down and select the final time step "0 02:30:00".
9. Select the **Add to Expression** button to add it to the expression. The expression should now look like the following expression: "d6:31-d11:31".
10. Specify the name of the dataset as "WSE_Diff" in the *Output dataset name* box. The window should look like Figure 7.
11. Select **Compute** to create the new dataset.
12. Select **Done** to close the *Dataset Toolbox*.

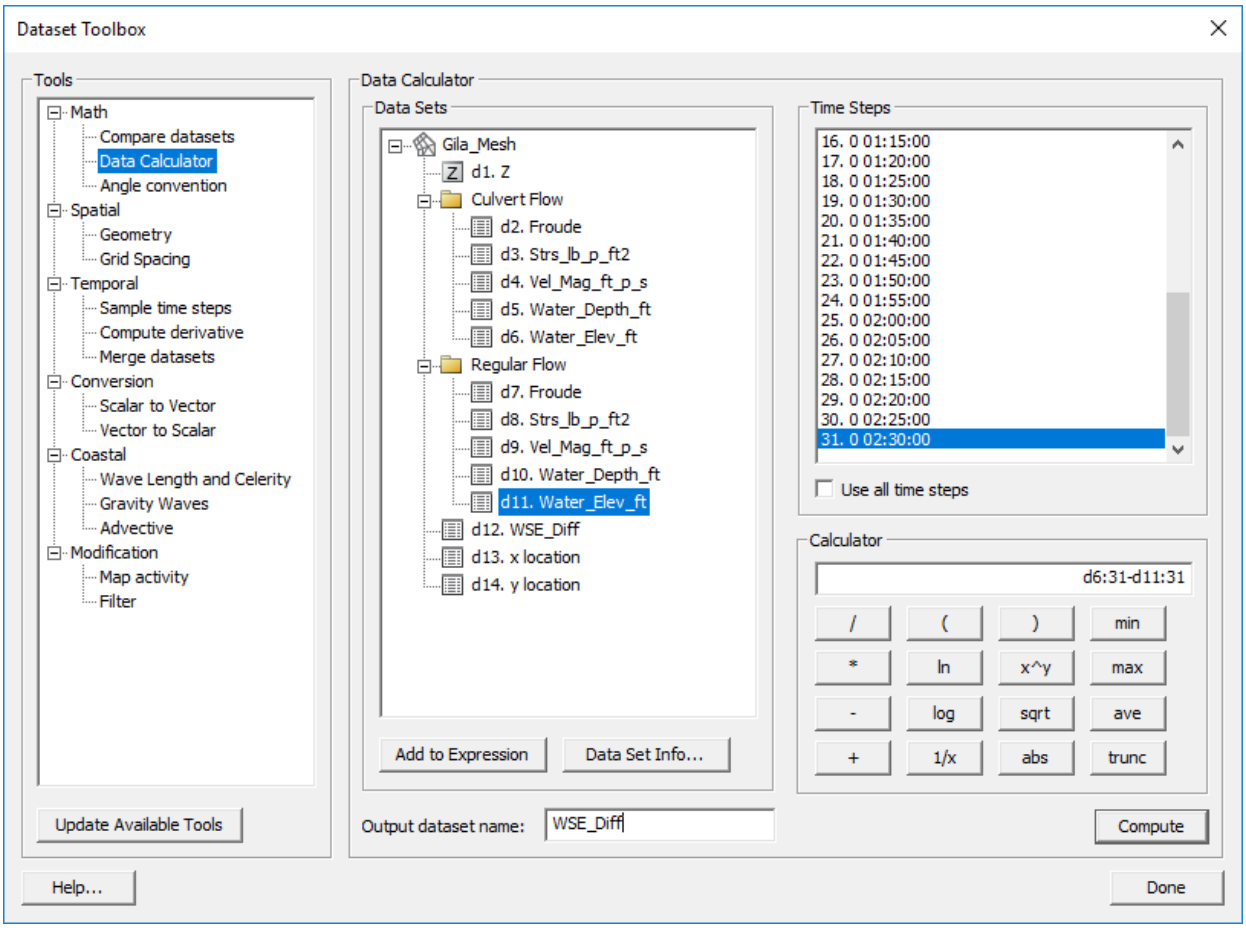


Figure 7 Data Calculator Expression

13. Select the "WSE_Diff" dataset to view the differences.

The positive values represent water surface elevations that were higher in the existing condition solution and negative values represent water surface elevations that were higher in the culvert solution. Upstream of the bridge, the reduction in WSE is evident with the largest differences being located near the culvert structure.

When SRH-2D was run, an output file was created for the culvert structure that includes diagnostic information for the culvert. This file can be a useful way to understand what is happening within the culvert structure. It can be found within the output file directory and is called "Culvert_Run_CULV1.dat". It can be opened in a text editor for viewing the flows through the culvert and water surface elevations at the faces of the structure.

This concludes the "SRH-2D – Culvert Structures" tutorial. If desired, further analysis could be performed on the solution to evaluate other possible effects of the culvert on the channel.

6 Conclusion

This concludes the "SRH-2D – Culvert Structures"[1] tutorial. If desired, further analysis could be performed on the solution to evaluate other possible effects of the culvert on the channel.

Topics covered in this tutorial include:

- Opening an existing SRH-2D project
- Creating a culvert structure
- Saving and running SRH-2D
- Organizing mesh datasets into folders
- Visualizing and comparing solution results
- Using the data calculator

Continue to experiment with the SMS interface or quit the program.

[1] This tutorial was developed by Aquaveo, LLC under contract with the Federal Highway Administration.