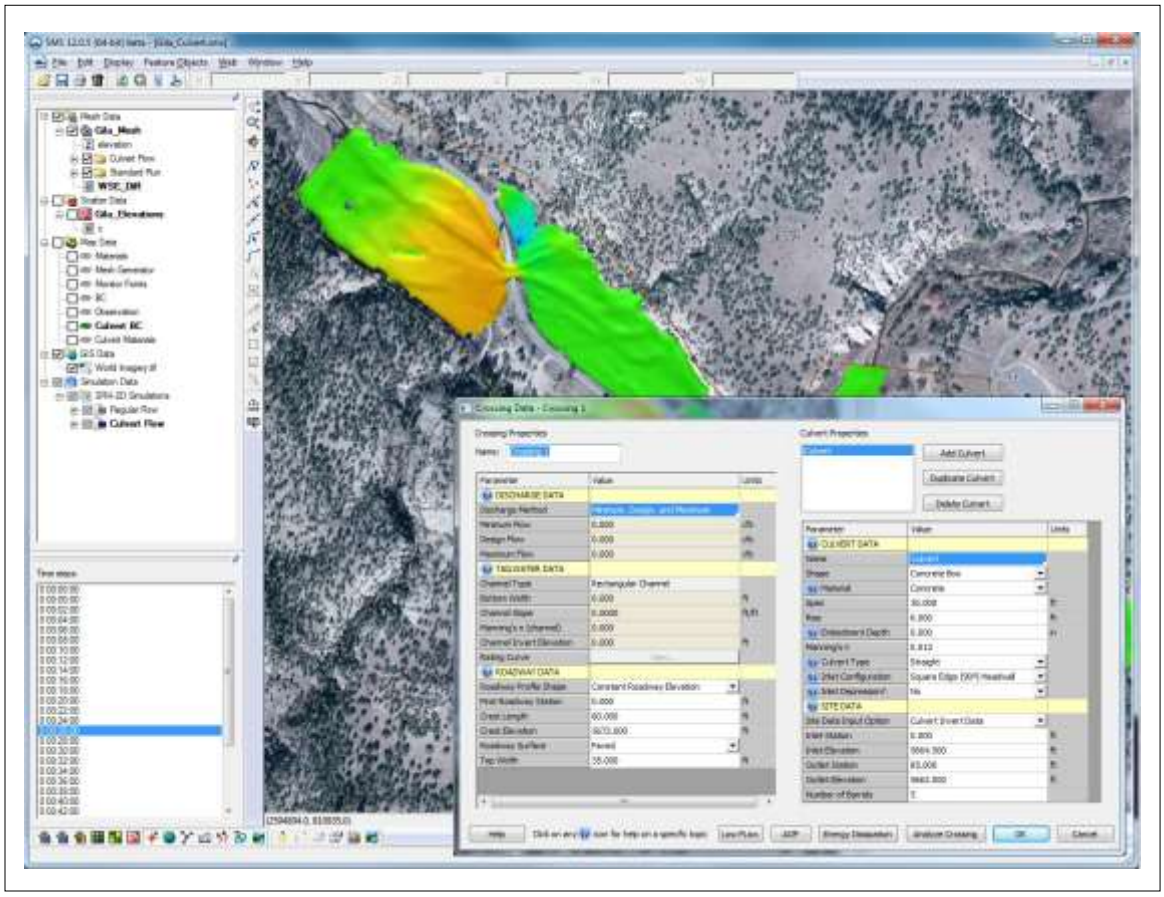
SRH-2D Tutorial

Culvert Structures with HY-8



Objectives

This tutorial demonstrates the process of modeling culverts in SRH-2D coupled with the Federal Highway Administrations HY-8 culvert analysis application. The “SRH-2D Simulations” tutorial should have been completed before attempting this one. All files for this tutorial are found in the “Input” folder within the “ SMS_SRH-2D_HY8_Culvert” tutorial folder.

Prerequisites

- SMS Overview
- SRH-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. The recommended method to simulate a culvert in SRH-2D is to couple the FHWA HY-8 culvert model with SRH-2D. This tutorial will demonstrate this. The second approach for simulation of a culvert involves incorporating the lower half of the culvert barrel into the mesh/grid. This approach is not described in this tutorial.

The area being modeled in this tutorial 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.

It should be noted that the HY-8 culvert model was developed as a still pool calculation. Therefore, it does not simulate the change in flow due to momentum. SRH-2D includes momentum. There is an option to use total head rather than simple water level to partially account for this limitation.

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 and select the "Gila_Structure.sms" project found in the */ SMS_SRH-2D_HY8_Culvert /Input* folder for this tutorial.
4. Click **Open** to import the data.

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. In addition, the "Culvert BC" has been added to the "Culvert Flow" simulation in place of the original

"BC" coverage. The culvert structure will be created within the "Culvert BC" coverage and simulated in the "Culvert Flow" simulation.

The process of duplicating these items and swapping out the boundary condition coverage was demonstrated in the "SRH-2D Simulations" tutorial.

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

The project should appear similar to Figure 1. Notice that the flow is overtopping the roadway in the upper left part of the road.

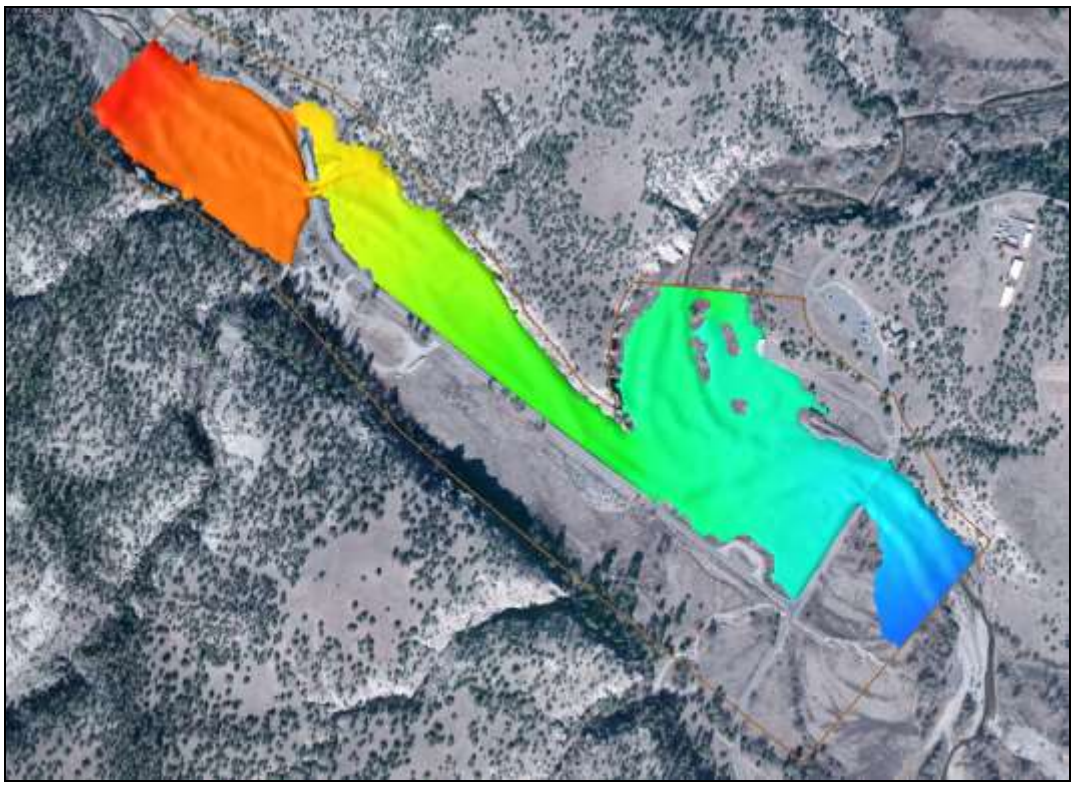


Figure 1 Gila_Structure.sms project

The mesh datasets located under the "Regular Flow (SRH-2D)" 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 boundary condition will have on the model.

3 Creating the Culvert Structure

The culvert structure will be created near the bridge location (as shown in Figure 2). Culvert structures are defined by creating two boundary condition arcs, one on the upstream face and one on the downstream face of the structure. The boundary condition

arcs are then defined as a culvert structure and the attributes of the culvert are defined in the HY-8 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.

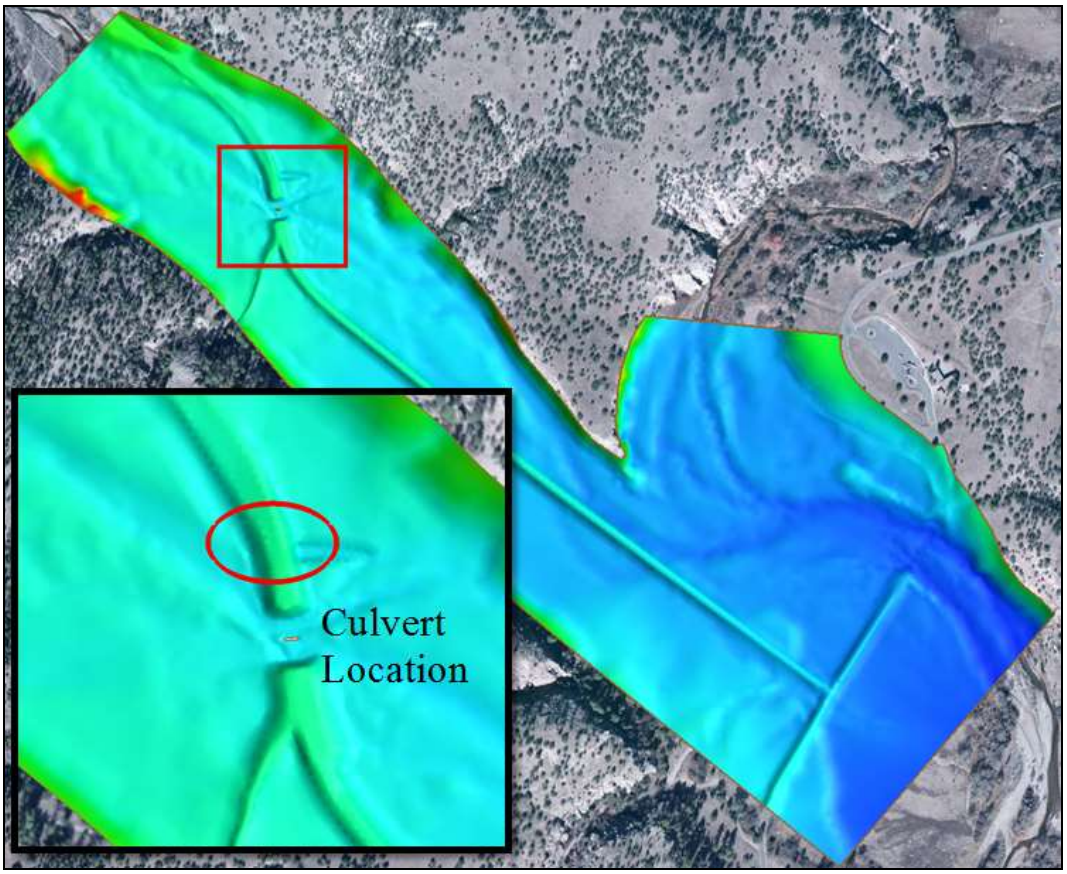


Figure 2 Culvert location

1. Select the "Z Z" dataset under "Gila_Mesh" in the Project Explorer to display the mesh elevations.
2. Use the **Zoom** tool to zoom into the culvert location near the bridge (Figure 2).
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*.
6. In the Project Explorer, check the box next to the "Culvert BC" coverage under "Map Data" and select it to make it the active coverage.

7. Review the notes below and then 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.

Remember that the arcs should be created in the same direction. For this tutorial create both arcs from south to north.

Notes: The following should be kept in mind when creating arcs for culverts:

- The downstream arc should be positioned far down the embankment. The element edges aligned with the downstream location should be at or below the culvert invert elevation.
- These arcs should be created in the same direction (north to south or south to north). After the first arc has been drawn, ensure that the second arc is drawn in the same direction. Drawing them in opposing directions may cause an error when running SRH-2D.
- It is recommended that the mesh be created to contain quadrilateral elements around the downstream arc to improve the transition of flow from 1D HY-8 model into the 2D SRH-2D model.

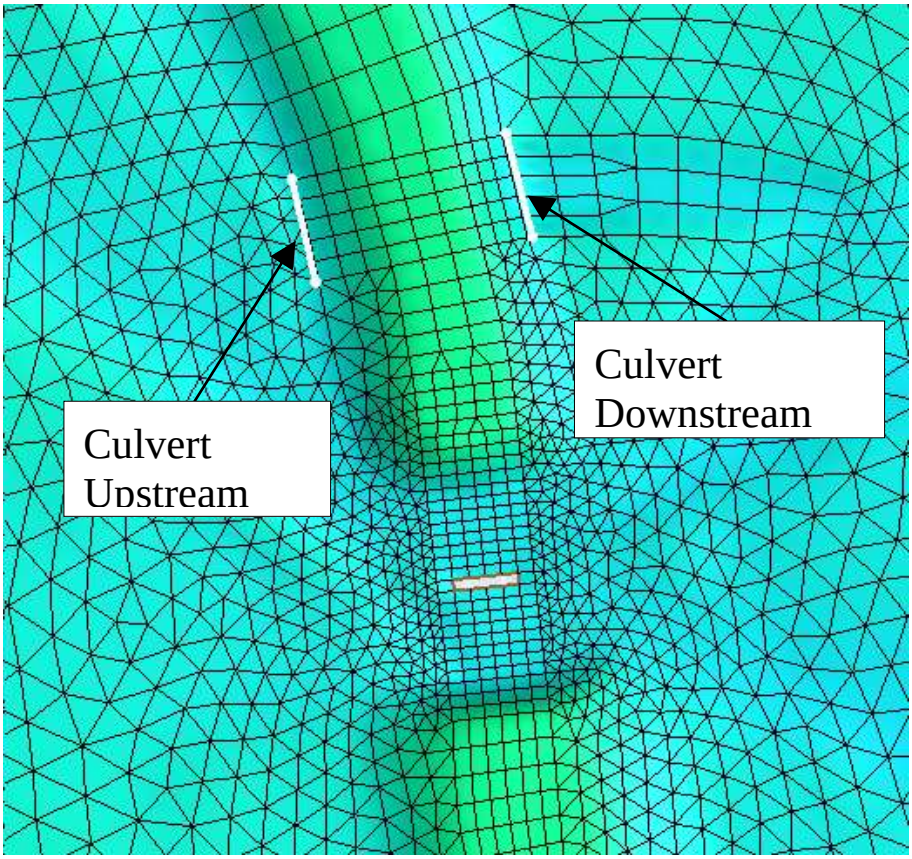


Figure 3 Upstream and Downstream BC Culvert Arcs

3.2 Assigning Culvert Structure Attributes in HY-8

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 in 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 BC...** command. SMS will bring up the *SRH-2D Assign BC* dialog.
4. In the *BC Type* combo box, select "Culvert HY-8". (Note: be sure to select "Culvert HY-8" and not "Culvert".)
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 in the *Structure boundaries* section.
6. Leave *Units for HY-8 display* as "English".

The *Use total head* option will add the velocity head to the water surface elevations for the 1D culvert calculations. It is often used when the barrels of a culvert are aligned with the flow direction upstream of the crossing in the 2D simulation domain. This is particularly true when the crossing consists of large barrels and the crossing is indeed acting more like a bridge than a culvert. In this case, SMS uses the total head (velocity head plus water surface) rather than just the water surface when getting an estimated flowrate through the crossing.

The *Use total head* option will not be used for this application.

7. Select **Launch HY-8** under *HY-8 Crossing*. This will open the HY-8 software.
8. In HY-8, right-click on "Project" in the HY-8 Project Explorer and choose **Add Culvert Crossing**.
9. In the *Crossing Data – Crossing 1* dialog, under *Crossing Properties*, change the *Name* to "Gila Crossing" and under *Culvert Data* under *Culvert Properties*, change the *Name* to "Relief Culvert". (Note: specify the culvert name in the table in the dialog, not at the top of the dialog.)
10. Define the culvert and crossing attributes as found in Table 1.

Note: When specifying the *Inlet Elevation* and *Outlet Elevation*, care must be taken such that the specified elevations are not lower than the underlying mesh node elevations. If the specified inlet and outlet elevations are lower, several approaches could be taken to remedy the issue such as specifying a higher elevation for the inlet and outlet elevations, relocating the BC arcs, refining the mesh around the culvert, or editing the mesh node elevations.

Parameter	Value	Parameter	Value
Discharge Method	Minimum, Design, and Maximum	Shape	Concrete Box
Minimum Flow	0.0	Material	Concrete
Design Flow	0.0	Span	8.0
Maximum Flow	0.0	Rise	6.0
Channel Type	Rectangular Channel	Embedment Depth	0.0
Bottom Width	0.0	Manning's n	0.012
Channel Slope	0.0	Culvert Type	Straight
Manning's n (channel)	0.0	Inlet Configuration	Square Edge (90°) Headwall
Channel Invert Elevation	5663.000	Inlet Depression	No
Roadway Profile Shape	Constant Roadway Elevation	Site Data Input Option	Culvert Invert Data
First Roadway Station	0.0	Inlet Station	0.0
Crest Length	40.0	Inlet Elevation	5664.5
Crest Elevation	5672.0	Outlet Station	85.0
Roadway Surface	Paved	Outlet Elevation	5663.0
Top Width	35.0	Number of Barrels	5

Table 1 Crossing data parameters

When done, the dialog should resemble Figure 4.

11. Click **OK** to close the *Crossing Data* dialog.

12. In the main HY-8 window, select "  Gila Crossing" to make sure it is selected for use in the model.

13. Exit the main screen of HY-8 by pressing the exit button  . All changes will be saved upon exiting.

14. In the *SRH2D Assign BC* dialog select "Gila Crossing" from the *HY-8 crossing* list. (Note: if the HY-8 crossing is already defined for a location, simply open the associated file in the HY-8 interface and select the crossing in the *SRH2D Assign BC* dialog. All crossings included in a simulation must be in the same "hy8" file.

15. Click **OK** to close the *SRH-2D Assign BC* window.

Now would be a good time to save the project.

16. Select *File* | **Save as…** to bring up the **Save A**s dialog.

17. Enter "Gila_Culvert.sms" as the *File name* and click **Save**.

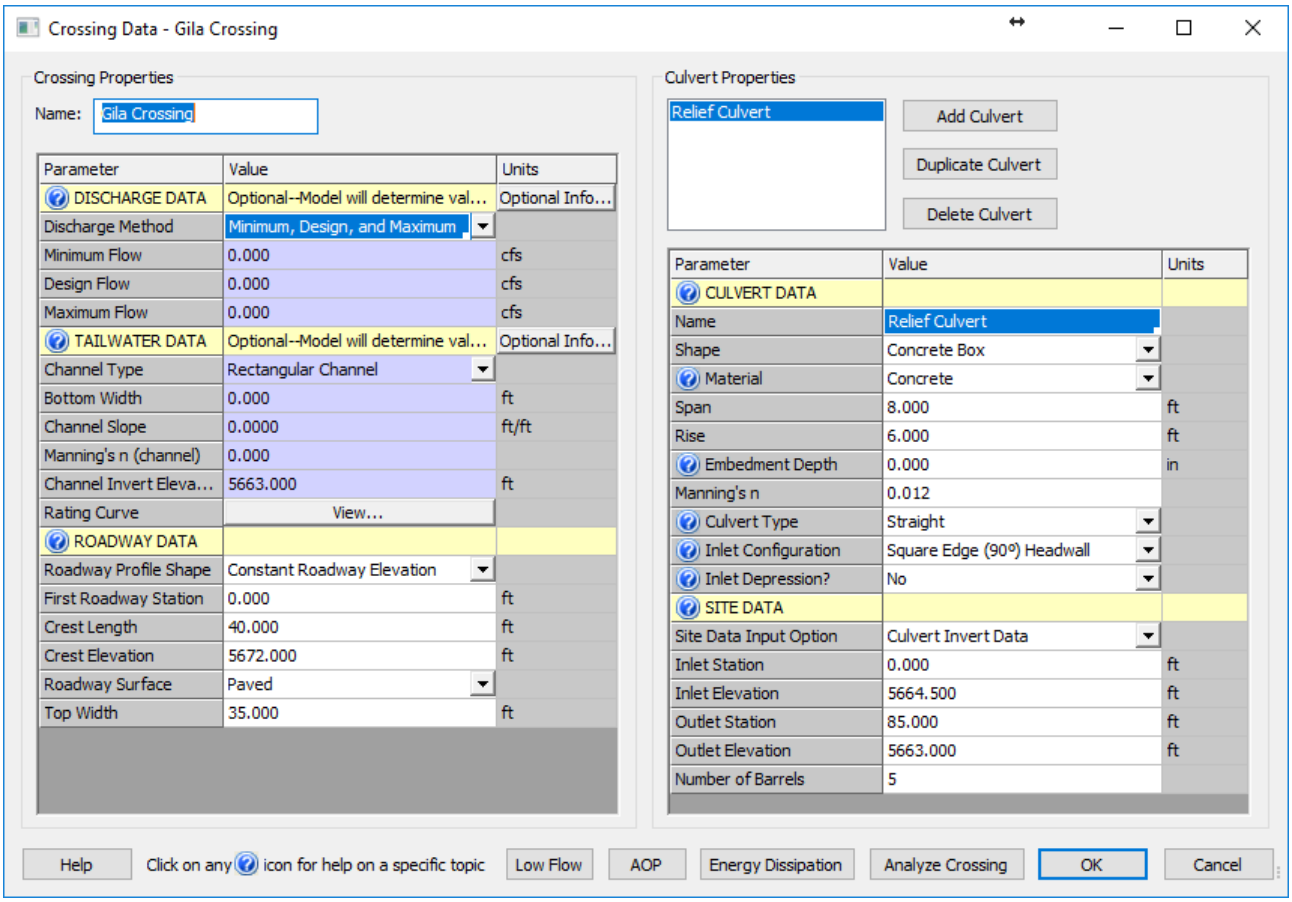


Figure 4 HY-8 Crossing and Culvert Inputs

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 Project, Simulation and Run**.
2. Select **Yes** if a warning is displayed stating that the "Culvert Materials" coverage will be renumbered before exporting.
3. When the simulation is done running, click the **Load Solution** button in the *Simulation Run Queue* dialog, as shown in Figure 5, to import the solution file.
4. Click **Close** to exit the *Simulation Run Queue*.

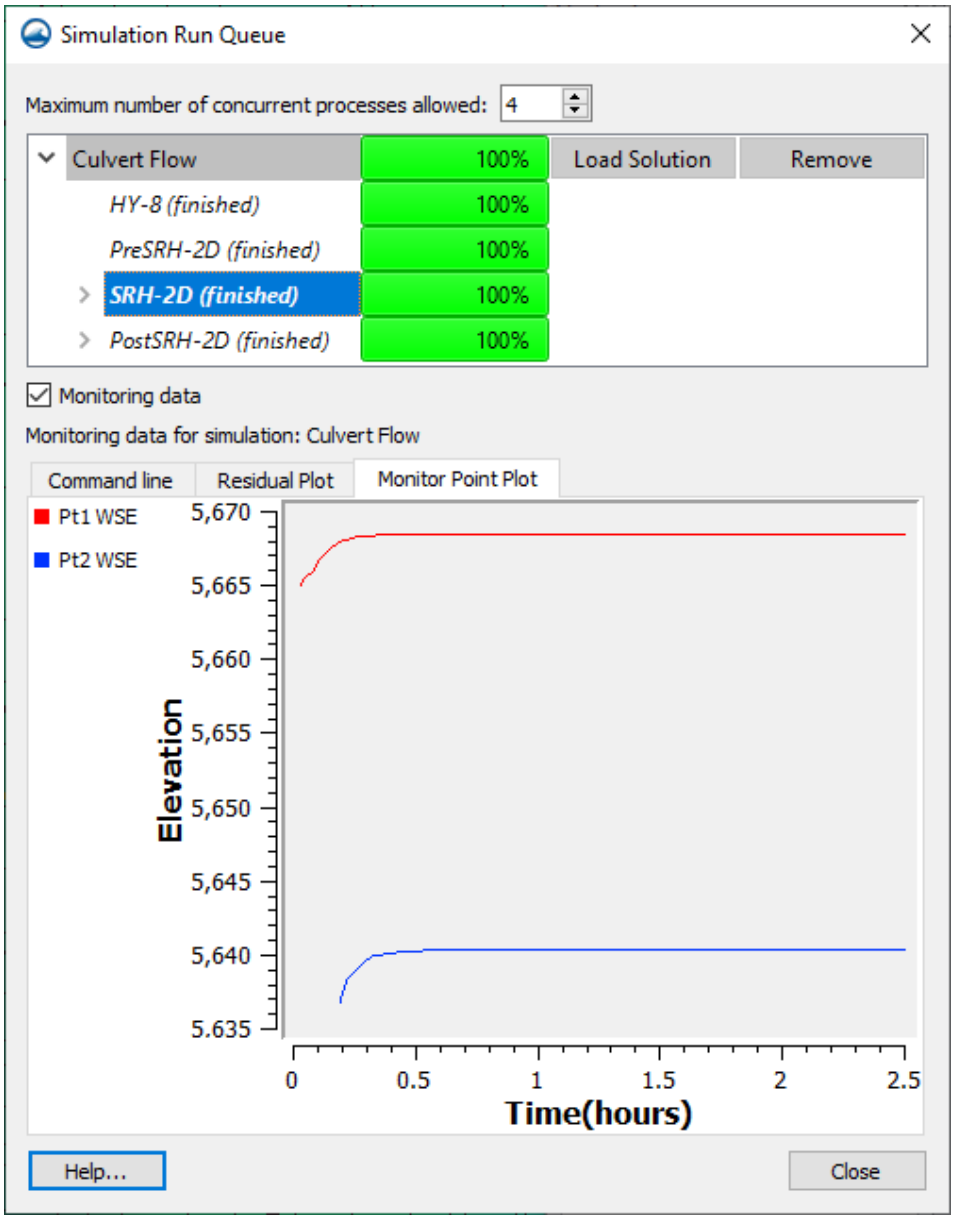


Figure 5 SMS Model Wrapper

SMS loads the solution datasets which are now to be listed in the Project Explorer under the "Culvert Flow (SRH-2D)" folder under "Gila_Mesh", as well as in the solution folder in the simulation.

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, under 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 under 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* | **Data Set 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: "d6:30-d11:30".

10. Specify the name of the dataset as "WSE_Diff" in the *Output dataset name* box. The window should look like Figure 6.

11. Select **Compute** to create the new dataset.

12. Select **Done** to close the *Dataset Toolbox*.

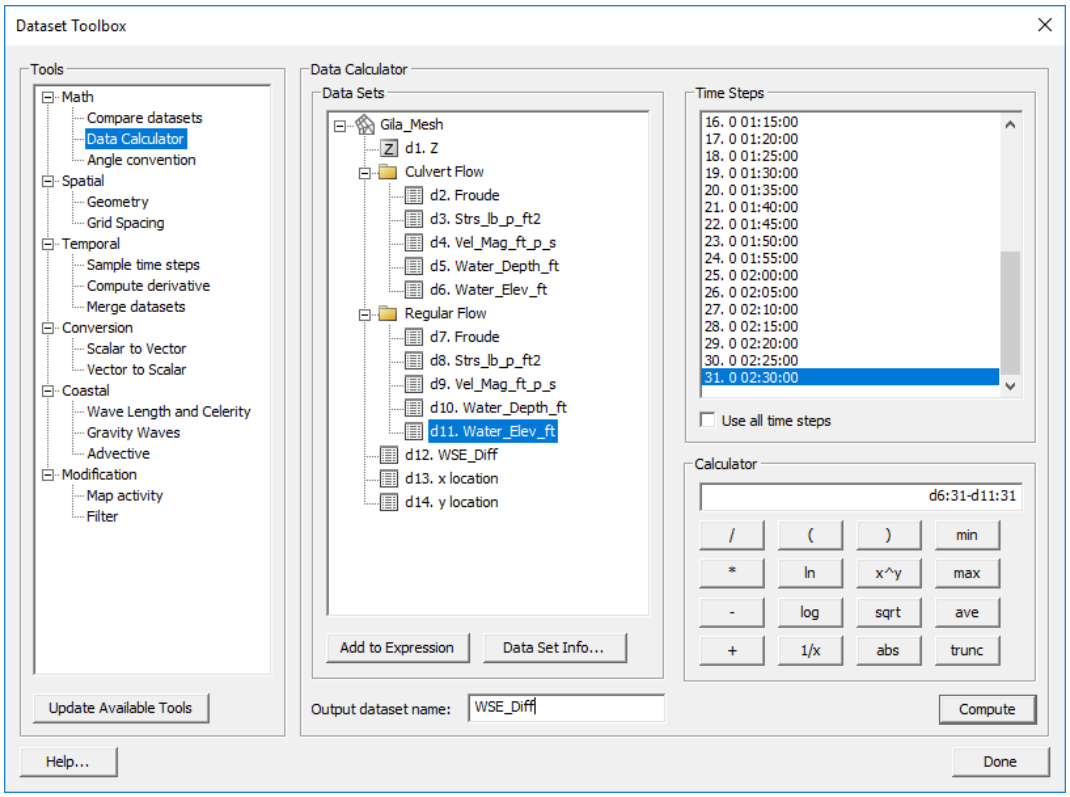


Figure 6 Data Calculator Expression

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_HY1.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 with HY-8" 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 with HY-8"[1] tutorial. Topics covered in this tutorial included:

- 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.