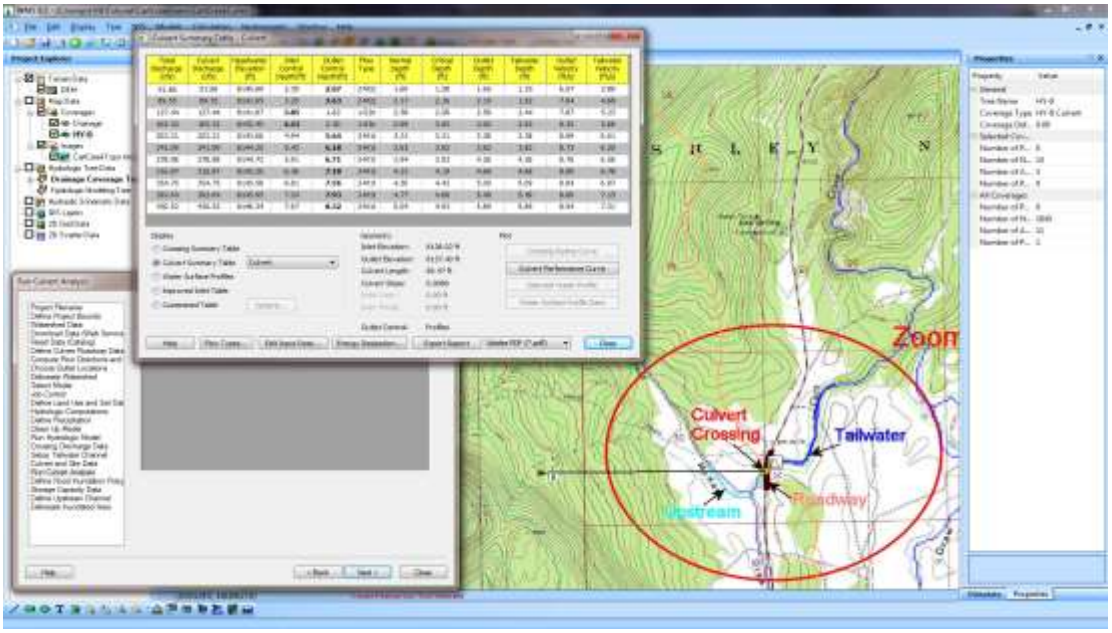
WMS

v. 10.0

*WMS 10.0 Tutorial*

# *Hydraulics and Floodplain Modeling – HY-8 Modeling Wizard*

Learn how to model a culvert using HY-8 and WMS




## Objectives

Define a conceptual schematic of the roadway, invert, and downstream tailwater associated with a culvert. Delineate the watershed upstream from the culvert and compute a discharge. Compute a storage capacity curve and route a hydrograph through the culvert. Delineate the floodplain based on the culvert hydrograph.

## Prerequisite Tutorials

- Watershed Modeling – National Streamflow Statistics Program (NSS) Interface

## Required Components

- Data
- Drainage
- Map
- Hydrology

## Time

- 20-40 minutes

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# 1 Introduction

The US Federal Highway Administration's culvert design model, HY-8, is a widely used culvert modeling program. The HY-8 Culvert design tools have been integrated with the watershed modeling tools in WMS in the HY-8 modeling wizard. Version 7.0 and later versions of HY-8 were developed by Aquaveo in cooperation with the FHWA. The primary purpose of the first Windows compatible version was to provide a graphical user interface (GUI) for the same hydraulic calculations performed in version 6.1 of HY-8, which was a DOS-based program.

The HY-8 Modeling Wizard automates steps in the hydrologic modeling process. It is recommended that users be familiar with the watershed modeling approach in WMS by following the more general watershed modeling tutorials before attempting this one.

# 2 Objectives

In this exercise, users will learn how to use the WMS HY-8 Wizard to simulate a culvert design in a rural area. In this tutorial the following will be outlined:

- Delineating a watershed
- Developing a Hydrologic model to estimate the runoff of the watershed
- Use the Hydrologic model and a digital elevation model as input for HY-8 culvert design
- Run an HY-8 culvert analysis to view the culvert performance curve, determine the routed hydrograph through the culvert, and determine floodplain depths upstream from the culvert.

# 3 Setting up a Project with the HY-8 Modeling Wizard

## 3.1 Starting with the HY-8 Modeling Wizard

1. Open WMS. If WMS is already open, click *File* | **New**, then click **No** if asked to save changes.
2. Locate the icon for the HY-8 Modeling Wizard, which is most likely located at the top of the WMS Window. Click on the icon ( ) to open the wizard. It will appear with the title *Project Filename*.

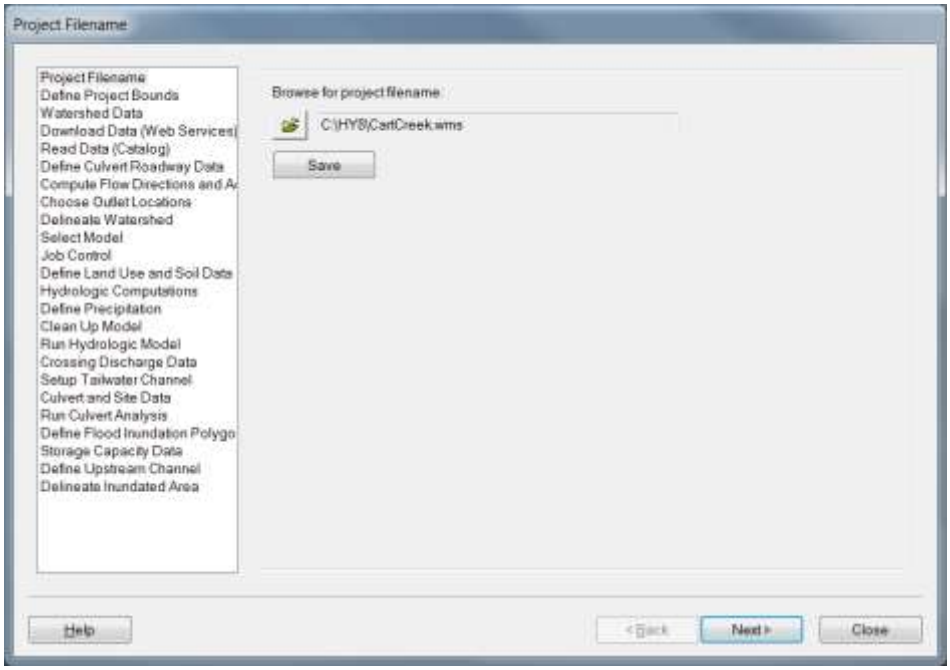


*Figure 1 HY-8 Modeling Wizard*

The *HY-8 Modeling Wizard* window shown in Figure 1 consists of two sections. The list box on the left shows the steps needed to read in data, set up a hydrologic model and input culvert information. The area on the right is used to perform specific tasks associated with the selected step. Clicking **Next** in the wizard will walk users through the steps of the wizard sequentially. However, users may move to any step in the wizard at any time by clicking on the associated heading on the left. Also, the *HY-8 Modeling Wizard* window is a non-modal window, meaning it lets users interact with the main menus and graphics window while it is open.

## 3.2 Project Filename

1. Make sure *Project Filename* is the current window in the *Hydrologic Modeling Wizard*.
2. Click on the **file browser** button to browse to a path location and select a filename for the project.
3. In the *Select WMS Project File* dialog, name the project "CartCreek.wms" and click **Save**.
4. Click **Next** to advance to the next step.

 

## 3.3 Define Project Projection System and Boundary

1. Under *Project projection*, select **Define…**
2. The *Display Projection* window will appear. Select the *Global Projection* option.
3. Click on the **Set Projection** button.
4. In the *Select Projection* dialog set:
   - *Projection* to "UTM"
   - *Zone* to "12 (114°W - 108°W – Northern Hemisphere)"
   - *Datum* to "NAD83"
   - *Planar Units* to "U.S. Survey Feet"
5. Select **OK**.
6. Set the *Vertical Projection* to "NAVD 88(US)" and *Vertical Units* to "U.S. Survey Feet".
7. Select **OK**.
8. Click **Next** to advance to the next step.

## 3.4 Reading Files to Define Watershed Data

In this section a DEM and Topo image will be read in complete the following steps:

1. In the *HY-8 Modeling Wizard*, click on the **Open file(s)** button.
2. In the *Open* dialog, locate the "HY8\dem" folder in the tutorial files.
3. Open "CartCreek.asc".
4. Select **OK** in the *Importing ArcInfo Grid* dialog.
5. Click on the **Open file(s)** button again.
6. In the *Open* dialog, locate the "HY8\Images" folder.
7. Open "CartCreek.tstopo.web.jpg" and select **Yes** to build image pyramids if prompted.
8. Select the **Zoom** tool and zoom into the region labeled "Area of Interest" on the image.
9. Click **Next** to advance to the next step, so the top of the window reads *Define Culvert Roadway Data*.

## 3.5 Define Roadway and Culvert Crossing Centerlines

Before computing TOPAZ, it is important that users define the location of the roadway and culvert crossing. The roadway centerline and culvert location must be defined before running TOPAZ and computing flow directions because the roadway embankment impacts the direction of flow. When defining a culvert crossing, a single arc represents either a single culvert or several culverts at the culvert crossing.

1. In the *HY-8 Modeling Wizard*, click on the **Define roadway centerline** button.
2. Define an arc representing the centerline of the roadway by clicking along a few points along the roadway centerline as highlighted in the image. Users might have

 

to zoom in or out by using the mouse scroll wheel when defining the roadway centerline. The length of the arc will be mapped to the roadway length in the HY-8 model. This value is used to determine the weir length when overtopping occurs. For this tutorial, the length has been exaggerated and will be corrected later.

3. In the *HY-8 Modeling Wizard*, click on the **Define culvert crossing centerline** button.
4. Define an arc representing the culvert crossing by clicking on the beginning and then the ending points of the culvert as highlighted in the image. When defining the culvert, be sure to click far enough away from the roadway centerline arc so the culvert arc does not snap to the roadway centerline. Users might have to zoom in or out by using the mouse scroll wheel when defining the culvert crossing centerline. The length of this arc will define the length of the culvert which has been exaggerated for ease of working with the data. This will be corrected later.
5. In the *HY-8 Modeling Wizard*, click on the **Edit Crossing/Roadway Data** button.
6. In the *Properties* window, turn on the **Define Crossing** check boxes under both of the arc attributes to assign the same HY-8 crossing to both the roadway centerline and the culvert crossing centerline. Change the name of one of the crossings to "Cart Creek" (this will change the name for both). Set the *Roadway Top Width* to "26" feet.
7. Click on the **Elevation Profile** button for the roadway centerline arc.
8. In the *Edit DEM Elevations* window, select the **Set to constant elevation** option.
9. Enter a value of "8152.06" for the elevation value in the *Constant elevation* dialog, and select **OK**.
10. Select the *Snap roadway profile to culvert* option. The DEM elevation profile plot should look similar to Figure 2.

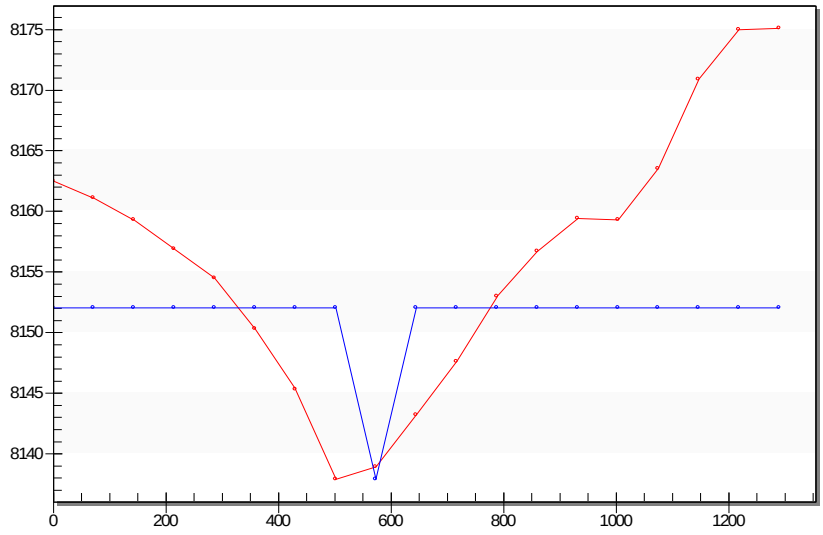


*Figure 2 DEM Elevation Profile Plot*

The *Snap roadway profile to culvert* option adjusts the DEM elevations to create a flow path through the embankment users have just defined. When WMS uses Topaz to determine flow directions, the flow will be routed to the culvert crossing. The lowest point will not be transferred to the HY-8 model. It is important to leave one location at the

 

elevation of the culvert invert elevation even if users do not use the 'Snap roadway profile to culvert' button.

11. Select **OK** to close the *Edit DEM Elevations* window, and then **OK** to close the *Properties* window.
12. Click **Next** to advance to the next step.

## 3.6 Computing TOPAZ

Now that users have defined the roadway and adjusted the DEM elevations to match their roadway elevations, users can run TOPAZ to compute flow directions and accumulations. The flow accumulations define where the stream is located.

1. In the *HY-8 Modeling Wizard*, select the option to *Compute sub-basin areas* in "Square Miles" and *Compute distances* in "Feet". Click on the **Compute TOPAZ** button.
2. The *Model Wrapper* window comes up to run TOPAZ. After TOPAZ is finished running, select **Close** on the *Model Wrapper* and the solution will be read.
3. Click **Next** to advance to the next step.

## 3.7 Defining Outlet Point

The next step is to define an outlet point that is used to delineate the watershed upstream from the culvert.

1. In the *HY-8 Modeling Wizard*, click on the **Define Outlets from Culvert Locations** button. Clicking this button should define an outlet point at the upstream end of the culvert.
2. If an outlet point is not is not created, users can also define an outlet point manually by selecting the **Create outlet point** tool and then clicking on the point where the outlet should be located.
3. Click **Next** to advance to the next step.

## 3.8 Delineating the Watershed

With an outlet point defined and the flow accumulations computed, users are ready to delineate their watershed.

1. In the *HY-8 Modeling Wizard*, make sure the *computed sub-basin areas* are set to "$mi^{2"}$ and the *computed distances* are set to "feet". If they are not, click on the **Units** button and set the *parameter units* to "square miles" and "feet". Set the *Stream threshold value* to "1.0" $mi^2$ and select **Apply to Display**.
2. Select the **Delineate Watershed** button.
3. Click **Next** to advance to the next step.

## 3.9 Selecting the Hydrologic Model

1. Select "NSS" as the desired model and select the **Initialize Model Data** button.
2. Click the **Next** button 5 times to advance to the *Clean Up Model* step in the wizard.

 

## 3.10 Cleaning the Model and Running Hydrologic Computations

With the watershed delineated and the basin data computed, users are now ready to clean up and run the NSS model. All the data required to run the NSS model has already been computed when users delineated the watershed.

1. Turn off the option to *Turn off the display of all non-drainage coverages*.
2. Turn off the option to *Run the model checker* and select the **Clean up Model** command.
3. In the *Redistribute Vertices* dialog, enter an *Average spacing* of "100" (feet) and select **OK**.
4. Select the **Save** button to save the project files.
5. Select **Yes** to save the image files to the project directory.
6. Click **Next** to advance to the next step.
7. Select the watershed outlet point (users may need to move the *HY-8 modeling wizard* to see this point) and then select the **Run Simulation** button.
8. In the *National Streamflow Statistics Method* window, select "Utah" for the *State* and select the *Region 4* equation from the list of *Available Equations*. Click on the correct equation to highlight it, then click the **Select** button. NOTE: there is a *Mean Flow SIR08 5230 Region 4* equation, which is not the correct equation. Select the **Compute Results** button.
9. Users will be analyzing this culvert for the 100-year storm. In the results area, select the flow associated with the 100-year recurrence interval. Select the **Compute Hydrograph** button.
10. Select the **Compute Lag Time - Basin Data** button in the *NSS Hydrograph Data* dialog.
11. The *Basin Time Computation* dialog will appear. Select the option to compute the lag time using the "Denver method" and select **OK** to use the computed lag time.
12. Select **OK** on the *NSS Hydrograph Data* dialog.
13. Select **Done** in the *National Streamflow Statistics Method* dialog.

Notice that a hydrograph icon appears at the outlet point. Users will be using this hydrograph to run an HY-8 analysis. Then, users will route the hydrograph through the culvert and determine the flood depths behind the culvert based on the culvert headwater elevations.

14. Click **Next** to advance to the next step.

## 3.11 Defining Discharge Data

After running the hydrologic model, users need to define discharge data to use in the HY-8 model. In this step, users either transfer the computed hydrograph to their HY-8 model or enter a design flow to use in their HY-8 model.

1. Notice that the outlet point is assigned to the Cart Creek HY-8 culvert crossing. Change the *Flow Source* to "Hydrograph" and click the **Select** button under *Hydrograph* to view the rising limb of the hydrograph. The flow values from this hydrograph are used to compute the headwater elevations in HY-8.
2. Close the *XY Series Editor* and click **Next** to advance to the next step.

 

## 3.12 Defining Tailwater Data

1. In the Project Explorer, turn on the "HY-8" coverage toggle box so users can see the existing roadway and culvert crossing arcs in the HY-8 coverage.
2. **Zoom** into the area surrounding the culvert crossing and around the tailwater in the model.
3. Select the **Define tailwater centerline** button.
4. Starting at the culvert outlet point (the downstream end of the culvert), draw an arc along the stream centerline as superimposed on the image. Draw the arc from upstream to downstream. This arc represents the tailwater centerline. Try to follow the flow accumulation cells on the DEM as users draw the tailwater arc. Double-click to end the arc.
5. To view the direction of flow along the arcs users have created in the HY-8 coverage, go to *Display* **| Display Options** to open the *Display Options* dialog.
6. Select *Map Data* from the list of data types. Turn on the *HY8 Stream Arrows* option and click **OK**. Users might need to toggle off the image display to see the arrows.
7. Select the **Edit Tailwater Data...** button.
8. The *Properties* dialog will appear. Check the *Define Crossing* box for the Tailwater centerline. Select a "rectangular channel" with a "10" foot *bottom width* and a *Manning's n* of "0.045".
9. Select the **OK** button.
10. Click **Next** to advance to the next step.

## 3.13 Culvert and Site Data and Running the Analysis

Most of the culvert, roadway, and tailwater data have been defined using the modeling wizard. However, there are a few more parameters that must be defined before running the culvert analysis. Also, because the DEM may not contain enough resolution to capture the roadway, culvert, and tailwater geometric properties, some of the WMS-computed data may need to be edited in the HY-8 culvert parameters based on culvert survey data.

1. Select the **Edit** button for the Cart Creek culvert.
2. The *Crossing Data – Cart Creek* dialog will open. Notice that the HY-8 crossing data window shows up with all of the roadway, culvert, and tailwater data that has been entered or computed in WMS. Users will edit some of these parameters based on existing culvert information. For more information on where WMS gathers this data, see the HY8 Modeling Wizard help in the WMS section of http://xmswiki.com.
3. Under *Roadway data*, enter a *crest length* of "100" ft and a *crest elevation* of "8152.06".

If the length of the roadway arc were correct, users would not need to change this value. In this tutorial, the roadway arc was made longer for ease in working with the data.

4. Under *Culvert data*, change the *culvert material* to "corrugated steel" and enter a *culvert diameter* of "10" ft.
5. Under *Site data*, change the *inlet elevation* to "8138.02" ft and the *outlet station* to "69.5" ft.

 

If the length of the culvert arc were correct, users would not need to change the outlet station. In this tutorial, the culvert arc was made longer for ease in working with the data.

6. Select the **OK** button to return to WMS.
7. Click **Next** to advance to the next step.
8. Select the **Run** button for the Cart Creek culvert.
9. In the HY-8 *Summary of Flows at Crossing – Cart Creek* analysis window, users can view the rating and performance curves at the culvert crossing as well as the crossing profiles. Users can also export various reports to different formats. Users can view the entire HY-8 program and save their culvert by clicking on the HY-8 button (  ) near the HY-8 modeling wizard button in the WMS toolbar. In either case, any changes made in the HY-8 interface are transferred to WMS after HY-8 is closed. Close the *HY-8 summary* window.
10. Click **Next** to advance to the next step.

## 3.14 Define Storage Capacity Data

The storage capacity data step can be used to route the hydrograph through the culvert to determine the effects of the culvert on the watershed hydrograph. WMS extracts storage information from the digital elevation model and uses the discharge and headwater elevations from the HY-8 model to get the data necessary to route the hydrograph.

1. Select the **Define** button for the Cart Creek crossing.
2. The *Storage Capacity Input* dialog will appear. The *Use DEM* button should be toggled on. WMS computes the basin storage at the headwater elevations computed from HY-8 and transfers these volumes to the detention basin calculator to route the hydrograph. Select the **OK** button.
3. Notice that the elevations, volumes, and discharges computed by HY-8 and WMS are pre-defined in the *Detention Basin Analysis* window. Select the **Plot Hydrographs** button to view the routed hydrograph.
4. Close the hydrograph and select **OK** to exit the *Detention Basin Analysis* window. Notice that the routed hydrograph is read into WMS and assigned to the outlet point associated with the Cart Creek culvert crossing.
5. Click **Next** to advance to the next step.

## 3.15 Define Upstream Data

The next step is to define a centerline representing the upstream channel. The purpose of this line is to define the upstream channel so water surface elevation points can be created along this upstream channel. These water surface elevations are then used to delineate the floodplain.

1. Select the **Define upstream channel centerline** button.
2. Zoom into the area surrounding the culvert crossing in the model.
3. Start at a point upstream from the culvert inlet point and along the upstream centerline as superimposed in the image. Trace the stream downstream until users reach the culvert inlet (the upstream end of the culvert), following the stream centerline shown on the image from upstream to downstream. This arc represents

 

the upstream centerline. Try to follow the flow accumulation cells on the DEM as users draw the upstream channel centerline. Double-click to end the arc.

4. Notice that the direction of flow is shown as arrows along the upstream channel centerline arc.
5. Click **Next** to advance to the next step.

### 3.16 Delineate Inundated Area

The final step in the wizard is to delineate the floodplain. This step determines the inundated area inside the watershed caused by the roadway and culvert.

1. Select the **Floodplain Delineation Options** button to open the *Floodplain Delineation* dialog.
2. Set the *Max search radius* to "1000" ft. Select **OK**.
3. In the *Delineate Inundated Area* step of the wizard, select the **Delineate** button for the Cart Creek crossing.
4. After the delineation is completed, turn off the TIN triangles and vertices if they are turned on. Select the "Cart Creek Flood Depth" dataset in the Project Explorer and scroll through the time steps in the Properties window. Notice how the flood depths change over time as the storm hydrograph progresses.

## 4 Conclusion

This concludes the exercise. Users should have learned to use the WMS HY-8 Wizard to simulate a culvert design in a rural area. In particular, users should have been taken through the process of:

- Delineating a watershed
- Developing a Hydrologic model to estimate the runoff of the watershed
- Using the Hydrologic model and a digital elevation model as input for HY-8 culvert design
- Running an HY-8 culvert analysis to view the culvert performance curve, determine the routed hydrograph through the culvert, and determine floodplain depths upstream from the culvert.

 