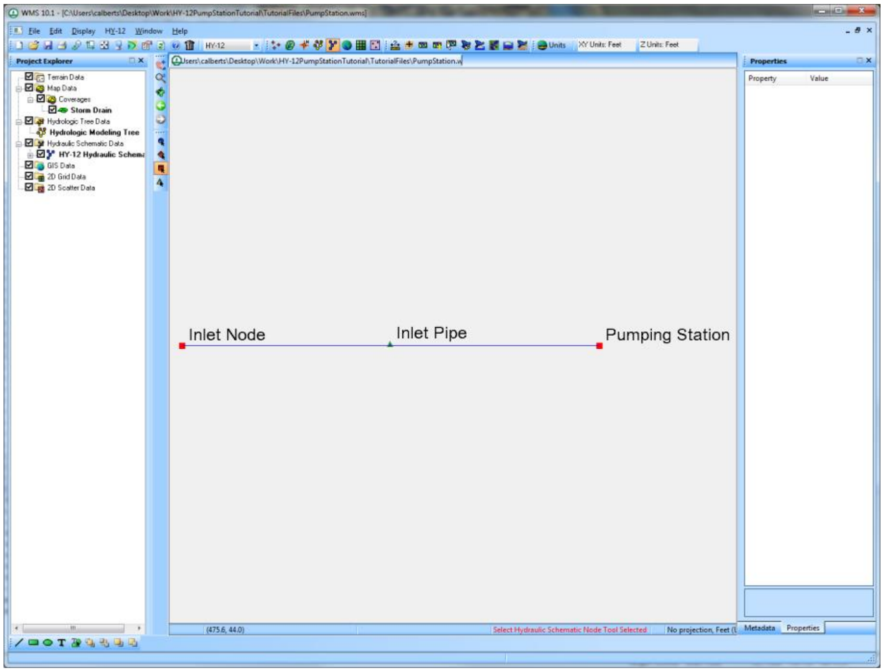
v. 10.1

WMS 10.1 Tutorial

Storm Drain Modeling – HY-12 Pump Station Analysis

Setup a simple HY-12 pump station storm drain model in the WMS interface with pump and pipe information



Objectives

Using the HY-12 advanced interface, define a simple storm drain network that includes a pump station and run HY-12 to analyze the design.

Prerequisite Tutorials

- Introduction – Basic Feature Objects

Required Components

- Data
- Map
- Hydrology
- Storm Drain

Time

- 30–45 minutes

1 Introduction

The US Federal Highway Administration's HY-12 is a DOS-based storm drain analysis program that can be used for designing inlets, pipes, and the general layout of a storm drain network. An HY-12 model can be generated by drawing the proposed pipe and inlet locations in a storm drain coverage. The map module locations are then converted to a 1D schematic where the HY-12 model parameters are defined.

Many of the HY-12 computations, such as channel calculations, curb and gutter calculations, and rational method computations, are based on computations in FHWA's Hydraulic Toolbox software.[1] Refer to the documentation in both the Hydraulic Toolbox and in HY-12 installations to learn about the specific computation methods used in HY-12. Many of the computations used in the HY-12 model are described in FHWA's *Urban Drainage Design Manual, Hydraulic Engineering Circular No. 22* (HEC-22).[2]

This tutorial demonstrates how to create, define, and analyze a simple storm drain system in a storm drain coverage, including a single pipe, a pump station with a storage well, and an outfall. The storm drain network will be converted to a 1D schematic. Usage of the HY-12 advanced user interface will be demonstrated through creating HY-12 structures and assigning parameters. HY-12 will then be run and results will be reviewed within the HY-12 report.

It is recommended to complete the "Introduction – Basic Feature Objects" tutorial prior to working on this one.

2 Getting Started

Starting WMS new at the beginning of each tutorial is recommended. This resets the data, display options, and other WMS settings to their defaults. To do this:

1. If necessary, launch WMS.

[1] See https://www.fhwa.dot.gov/engineering/hydraulics/software/toolbox404.cfm.

[2] See https://www.fhwa.dot.gov/engineering/hydraulics/pubs/10009/10009.pdf.

2. If WMS is already running, press *Ctrl-N* or select *File* | **New…** to ensure that the program settings are restored to their default state.
3. A dialog may appear asking to save changes. Click **No** to clear all data.

The graphics window of WMS should refresh to show an empty space.

2.1 Setting the New Project

Next, enter projection information and save the project.

1. Select *Display* | **Display Projection…** to bring up the *Display Projection* dialog.
2. In the *Horizontal* section, select *No Projection* and select "Feet (U.S. Survey)" from the *Units* drop-down.
3. In the *Vertical* section, select "Feet (U.S. Survey)" from the *Units* drop-down.
4. Click **OK** to exit the *Display Projection* dialog.
5. Select *File* | **Save** to bring up the *Save As* dialog.
6. Select "WMS XMDF Project Files (*.wms)" from the *Save as type* drop-down.
7. Browse to the *HY12PumpStation\HY12PumpStation* folder.
8. Enter "PumpStation.wms" as the *File name* and click **Save** to save the project and close the *Save As* dialog.

It is recommended to periodically **Save** the project throughout this tutorial.

3 Creating the Storm Drain Coverage

Now set up the storm drain coverage and draw a single arc to represent the inlet pipe to the pump station.

1. Right-click on " Drainage" and select *Type* | **Storm Drain**.

This changes the coverage type to a storm drain coverage.

2. Using the **Create Feature Arc** tool, create a single arc with no vertices from the left to the right side of the screen. The initial location is not important as it will be modified in the next steps.
3. Using the **Select Feature Point/Node** tool, select the left node.
4. In the Properties section of the Main Graphics Window, enter "0.0" for both *Feature Point X* and *Feature Point Y*.
5. Using the **Select Feature Point/Node** tool, select the right node.
6. In the Properties section of the Main Graphics Window, enter "700.0" for *Feature Point X* and "0.0" for *Feature Point Y*.
7. **Frame** the project.

The display window should appear similar to Figure 1. Coordinate annotation labels have been added to the image for convenience, but do not appear on the display.

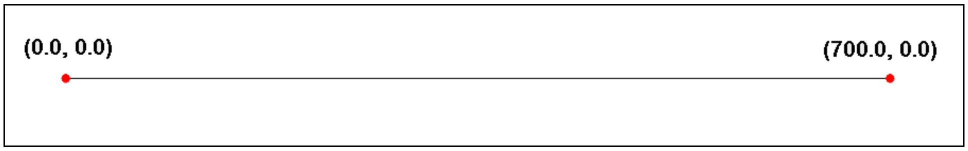


Figure 1 Storm drain arc

4 Creating and Defining the Storm Drain Network

4.1 Mapping to 1D Schematic

Once a network has been digitized in a storm drain coverage, it can then be mapped to a 1D hydraulic schematic representation where model parameters will be defined.

1. Select *Storm Drain* | **Map → 1D Schematic** to bring up the *Select Model* dialog.
2. Select “HY-12” from the wide drop-down and click **OK** to close the *Select Model* dialog.

The 1D Schematic should now be displayed with nodes and a single link that will be used to define the storm drain network (Figure 2).

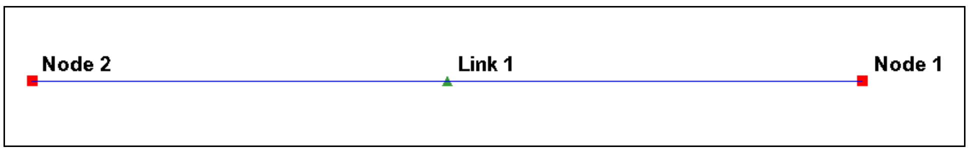


Figure 2 1D schematic with both nodes and single link

4.2 HY-12 Project Parameters

Now specify the HY-12 project parameters.

1. Switch to the **Hydraulic Modeling** module.
2. Select *HY-12* | **Edit Project Parameters...** to bring up the *HY-12 Properties* dialog.
3. In the *Project Run Parameters* section, click **Select File…** in the *Units* column on the *Material Database* row to bring up the *Select an HY-12 Material Database File* dialog.
4. Select “materialDB.txt” and click **Open** to exit the *Select an HY-12 Material Database File* dialog.

This predefined material database contains pipe geometry and materials information.

5. In the *Steady or Unsteady Parameters* section, select “Unsteady Flow” from the *Steady or Unsteady Flow* drop-down.
6. Enter “0.1” as the *Time Step*.
7. Select “Rational hydrograph method” from the *Default Hydrograph Type* drop-down.
8. In the *Interface Options* section, turn on *Use Advanced Interface*.

9. Click **OK** to exit the *HY-12 Properties* dialog.

4.3 Creating Storm Drain Structures

Next, create the storm drain and pump station structures, and define structure parameters for the link and nodes.

1. Using the **Select Hydraulic Node** tool, double-click on "Node 2" to bring up the *HY-12 Properties* dialog.
2. Enter "Inlet Node" in the *Value/HY-12 ID* column and click **OK** to close the *HY-12 Properties* dialog.

In many storm drain models, an access hole or gutter inlet could be defined at the inlet node location to allow for inflow to the pipe network. For purposes of this tutorial, no structures will be defined at this inlet node.

3. Using the **Select Hydraulic Node** tool, double-click on "Node 1" to bring up the *HY-12 Properties* dialog.
4. Enter "Pumping Station" in the *Value/HY-12 ID* column.
5. In the *Structure Type* column, select "Pump Station" from the drop-down and click **New** in the *Structure Name* column to create a new pump station structure in the spreadsheet.

The pumping discharge pipe is built into the definition of the pump station, so there is no need for another link running from the pump station to the outfall.

6. In the *Structure Type* column, select "Outfall" from the drop-down click **New** to create a new outfall structure.
7. Click **OK** to close the *HY-12 Properties* dialog.
8. **Save** the project.

The schematic should appear similar to Figure 3.

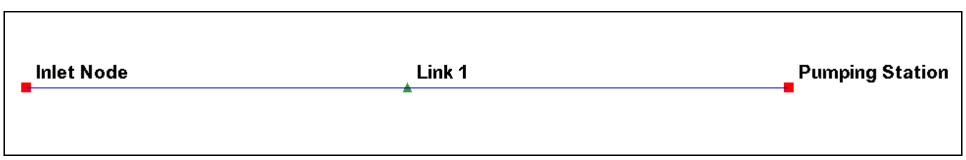


Figure 3 Storm drain structures defined

4.4 Defining Pump Station Parameters

With the pump station and outfall structures created at the node, the structure parameters can now be defined.

1. Using the **Select Hydraulic Node** tool, double-click on "Pumping Station" to bring up the *HY-12 Properties* dialog.
2. On the "ID: 0" row, click **Define…** to bring up the *HY-12 Properties* dialog where the pump station parameters can be defined.
3. In the *Input Parameters* section, click **Define…** on the *Inflow Hydrograph* row to bring up the *Hydrograph* dialog.

WMS can sometimes move this dialog behind all other windows. Moving the dialog to the side of the Main Graphics Window makes sure the dialog is still visible in such as case.

4. Move the *Hydrograph* dialog so it is to one side of the Main Graphics Window in WMS.
5. Enter “32” as the *Number of x, y points*.
6. Outside of WMS, browse to the *HY12PumpStation\HY12PumpStation* folder and open “Inflow Hydrograph.xls” in a spreadsheet program.
7. Select the cell directly below the cell containing “Time”, then hold down the *Shift* key and select the last cell in the “Inflow” column. Both should contain “0”.
8. Press *Ctrl-C* to copy the values and go back to the *Hydrograph* dialog in WMS.
9. Select the cell on row *1* in the *Time (min)* column and press *Ctrl-V* to paste the values into the table in the *Hydrograph* dialog.
10. Click **Plot** to bring up the *Hydrograph* dialog showing a plot similar to Figure 4.

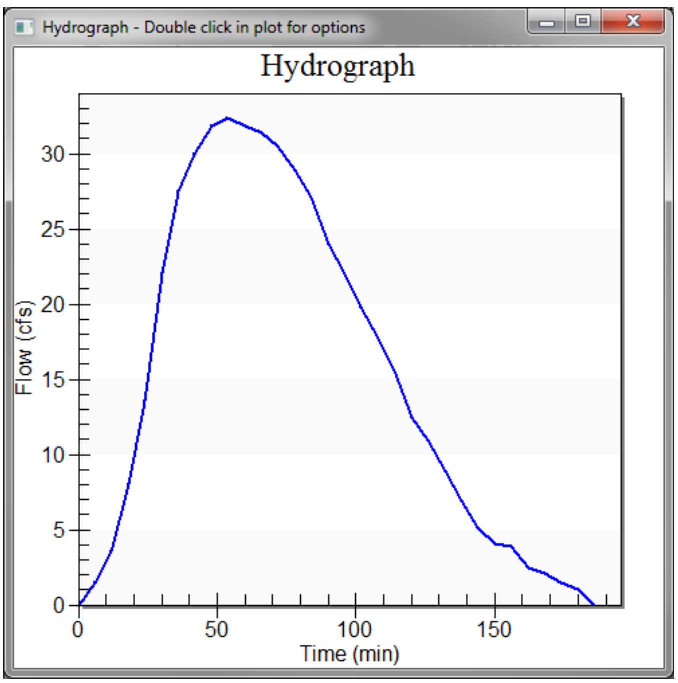


Figure 4 Hydrograph dialog showing a plot of inflow vs. time

11. When finished reviewing the hydrograph plot, click the  to close the *Hydrograph* plot dialog.
12. Click **OK** to close the *Hydrograph* table dialog.
13. In the *Input Parameters* section, enter “637.660” as the *Invert Elevation*.

This value represents the invert elevation of the sump box.

14. Enter “648.16” as the *Surface Elevation*.

This value represents the ground surface elevation at the pump station.

15. In the *Storage Well* section, click **Define…** to the right of *Define Storage Well* to bring up the *Storage Capacity Input* dialog.

16. Select *Known Geometry* and enter:
    - "14.0" as the *Length*
    - "23.0" as the *Width*
    - "10.5" as the *Depth*
    - "0.0" as the *Side Slope*
    - "637.66" as the *Base Elevation*
17. Enter "20" as the *Number of Data Points*
18. Click **OK** to exit the *Storage Capacity Input* dialog.
19. In the *Pumps* section, enter "3" as the *Number of Pumps*.

This indicates the pump station has three separate pumps. Notice that the dialog changed to show and allow defining three pumps (Figure 5).

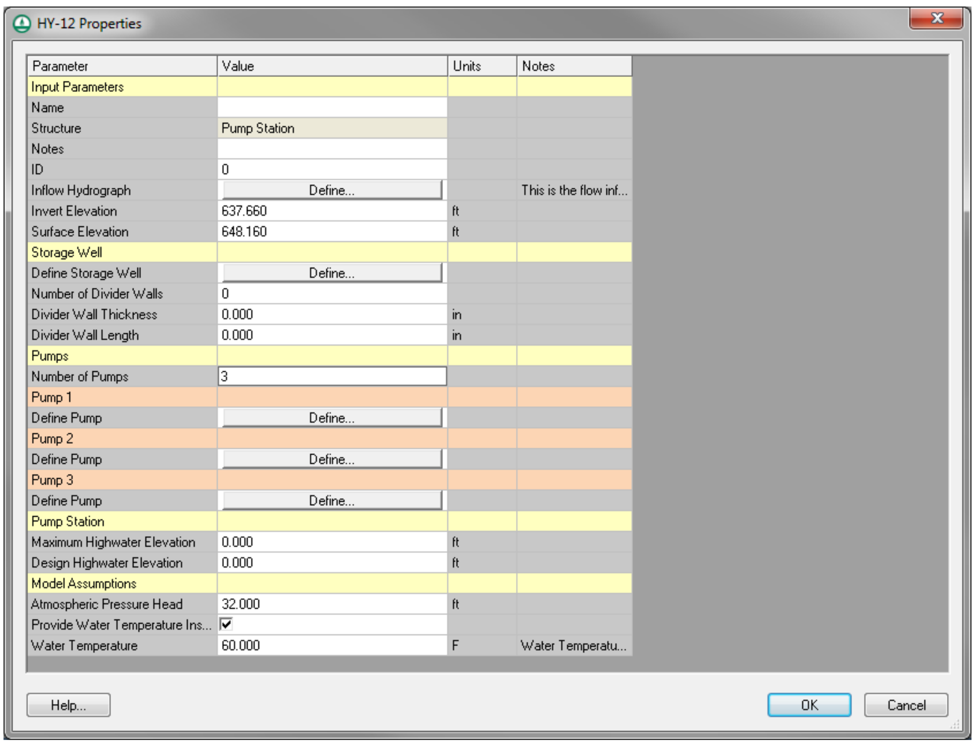


Figure 5 HY-12 Properties showing three separate pumps

20. In the *Pump 1* subsection, click **Define…** on the *Define Pump* row to bring up the *HY-12 Properties* dialog for Pump 1.
21. Move the *HY-12 Properties* dialog for Pump 1 so it is to one side of the Main Graphics Window in WMS.
22. Outside of WMS, browse to the *HY12PumpStation\HY12PumpStation* folder and open "Pump Performance.xls" into a spreadsheet editor.
23. Select cell A2 (directly below the cell containing "Flow (cfs)"), then hold down the *Shift* key and select cell B14 in the "Total Head (ft)" column.
24. Press *Ctrl-C* to copy the values and go back to the *HY-12 Properties* dialog for Pump 1 in WMS.

25. In the *Input Parameters* section, click **Define…** on the *Pump Performance Curve* row to bring up the *Pump Performance Curve* dialog.
26. Enter "13" as the *Number of x, y points* and click in the dark gray area above that.
27. Click in the cell on row *1* of the *Flow (cfs)* column, then press *Ctrl-V* to paste the values from the external spreadsheet.
28. Click **Plot** to bring up the *Pump Performance Curve* plot dialog (Figure 6).

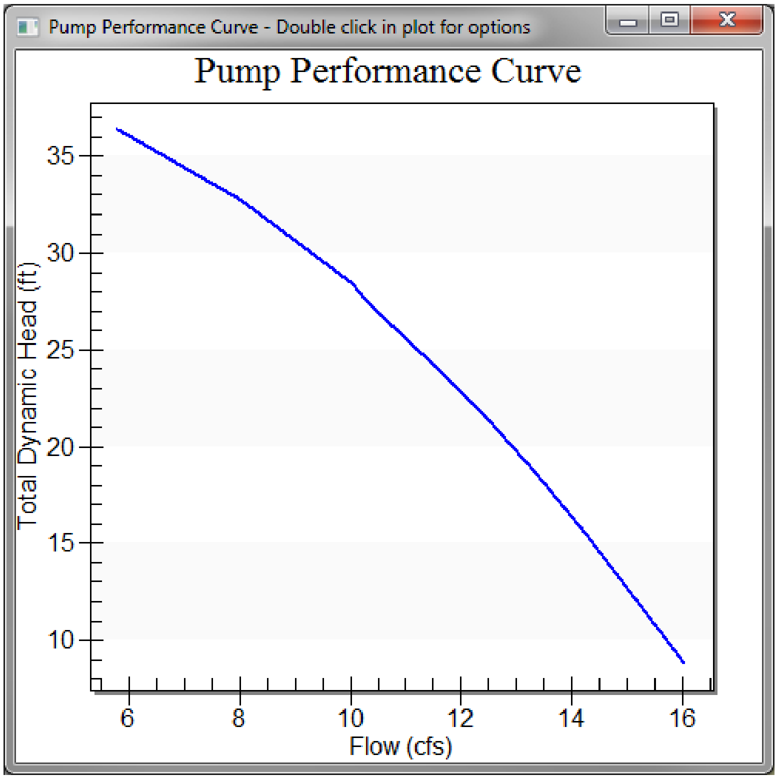


Figure 6 Pump Performance Curve dialog

29. When done reviewing the curve, click to close the *Pump Performance Curve* plot dialog.
30. Click **OK** to exit the *Pump Performance Curve* dialog.

Now specify the pump controls for Pump 1.

31. In the *Input Parameters* section, enter "641.0" for the *Elevation pump turns on*.
32. Enter "637.7" for the *Elevation pump turns off*.
33. Enter "4.0" as the *Recommended Minimum Cycle Time*.

This is the minimum cycle time provided by the pump manufacturer.

34. In the *Friction Loss* subsection of the *Friction Losses* section, enter "2.3" as the *Diameter* and "33.0" as the *Length*.
35. In the *Select Material Input Parameters* subsection, enter "0.015" as the *Manning's n Loss Coefficient*.
36. In the *Minor Losses* section, enter "1" as the *Number of Minor Losses*.

This represents the minor loss from a 90-degree elbow in the discharge pipe. Notice that a *Minor Loss* subsection appeared.

37. In the *Minor Loss* subsection, enter “2.3” as the *Diameter*.
38. Select “Long Radius flanged 90 Elbow” from the *Selected Minor Loss* drop-down.

The *HY-12 Properties* dialog for Pump 1 should appear as in Figure 7.

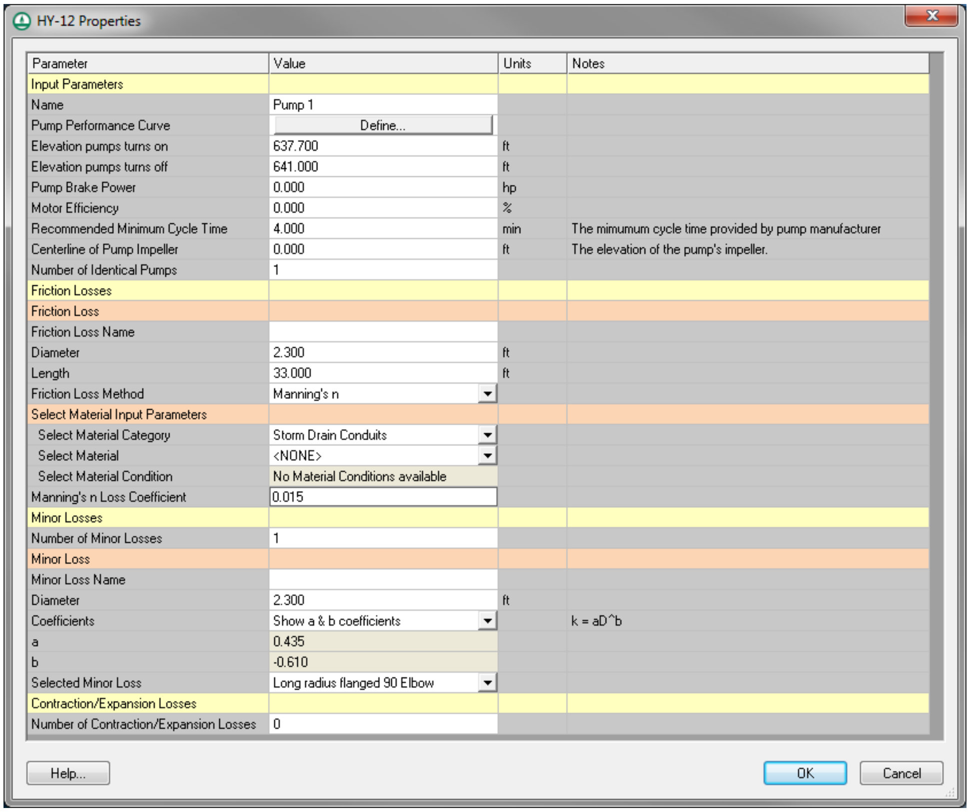


Figure 7 Pump Definition Property dialog

39. Click **OK** to close the *HY-12 Properties* dialog for Pump 1.
40. Repeat steps 20–39 for Pump 2, entering “641.5” as the *Elevation pump turns on* and “638.2” as the *Elevation pump turns off*.
41. Repeat steps 20–39 for Pump 3, entering “642.0” as the *Elevation pump turns on* and “638.7” as the *Elevation pump turns off*.

These slight modifications to the second and third pump controls allow the additional pumps to turn on and off at different water levels to accommodate varying inflows to the storage well in the pump station.

42. In the *Pump Station* section, enter “648.16” as the *Maximum Highwater Elevation*.
43. Enter “648.16” as the *Design Highwater Elevation*.

The *HY-12 Properties* dialog for the pump station should appear as in Figure 8.

44. Click **OK** to close the *HY-12 Properties* dialog for the pump station.
45. Click **OK** to close the *HY-12 Properties* dialog.

46. **Save** the project.

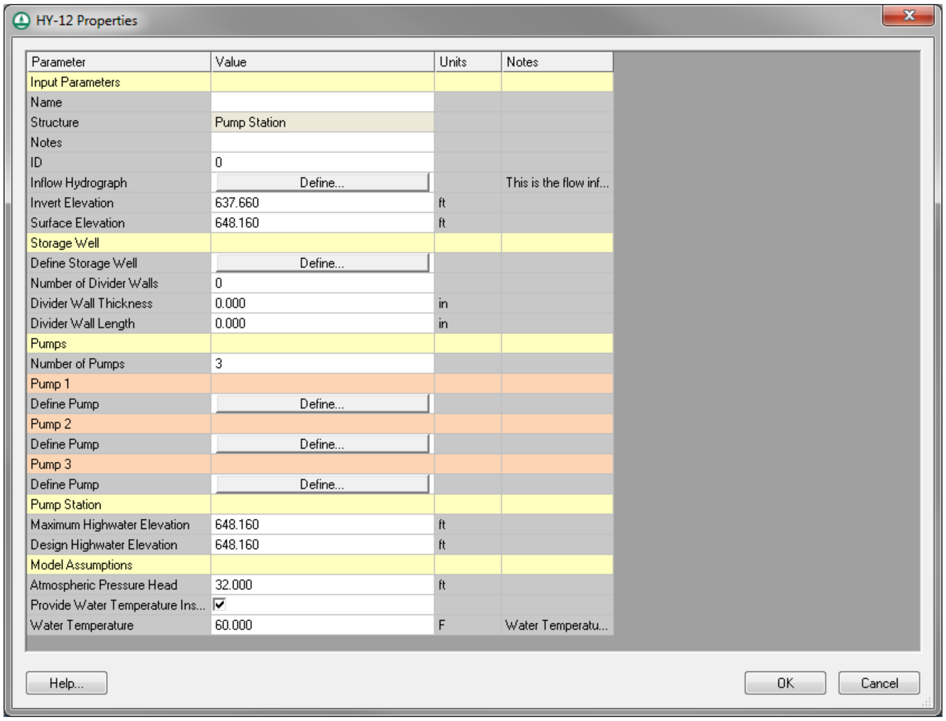


Figure 8 HY-12 Properties dialog for the pump station

4.5 Defining the Outfall Parameters

Now define the outfall structure.

1. Using the **Select Hydraulic Node** tool, double-click on the *Pumping Station* node to bring up the *HY-12 Properties* dialog.
2. Click **Define…** in the *Define Structure* column on the “ID: 1” (Outfall) row to bring up the *HY-12 Properties* dialog for the outfall.
3. In the *Input Parameters* section, enter “665.58” as the *Invert Elevation*.
4. Enter “1.0” as the *Depth*.
5. Click **OK** to exit the *HY-12 Properties* dialog for the outfall.
6. Click **OK** to exit the *HY-12 Properties* dialog.

4.6 Creating an Inlet Pipe Structure

Next, create a pipe structure within the link.

1. Using the **Select Hydraulic Link** tool, double-click on “Link 1” to bring up the *HY-12 Properties* dialog.
2. Select the cell labeled “Link 1” in the *Value/HY-12 ID* column and enter “Inlet Pipe”.
3. Select “Pipe” from the drop-down in the *Structure Type* column.

4. Click **New** in the *Structure name* column to create the new pipe structure.

Define the pipe structure parameters in the next section.

4.7 Defining the Pipe Parameters

In this case, the inlet pipe will not have any inflow. Instead, the pipe has been included in the model as extra storage. If the storage well rises to a certain level, the water will back up into the inlet pipe as needed.

1. Click **Define…** in the *Define Structure* column on the “Pipe” row to bring up the *HY-12 Properties* dialog for the pipe structure.
2. In the *Inlet Parameters* subsection, enter “645.66” as the *Invert Elevation*.
3. Enter “651.66” as the *Surface Elevation*.

There is about three feet of ground cover above the 3 ft diameter pipe (not including the pipe thickness).

4. In the *Outlet Parameters* section, enter “642.16” as the *Invert Elevation*.
5. Enter “648.16” as the *Surface Elevation*.

This defines the downstream end of the pipe at the pump station. At this location, there is about three feet of ground cover above the 3 ft diameter pipe (not including the pipe thickness).

6. Enter “0.015” as the *Manning’s n*.
7. Enter “700.0” as the *Length*.
8. Enter “0.25” as the *Wall Thickness*.
9. Enter “3.0” as the *Diameter*.
10. Enter “90.0” as the *Inlet Angle*.

When finished entering the parameters, the pipe structure definition dialog should appear similar to Figure 9.

11. Click **OK** to close the *HY-12 Properties* dialog for the pipe structure.
12. Click **OK** to close the *HY-12 Properties* dialog.
13. **Save** the project.

An alternate to entering the Length and Inlet Angle manually is to use the *HY-12* | **Assign Lengths and Orientations** menu command to do it automatically. This method is especially useful when the model has a large network consisting of numerous links.

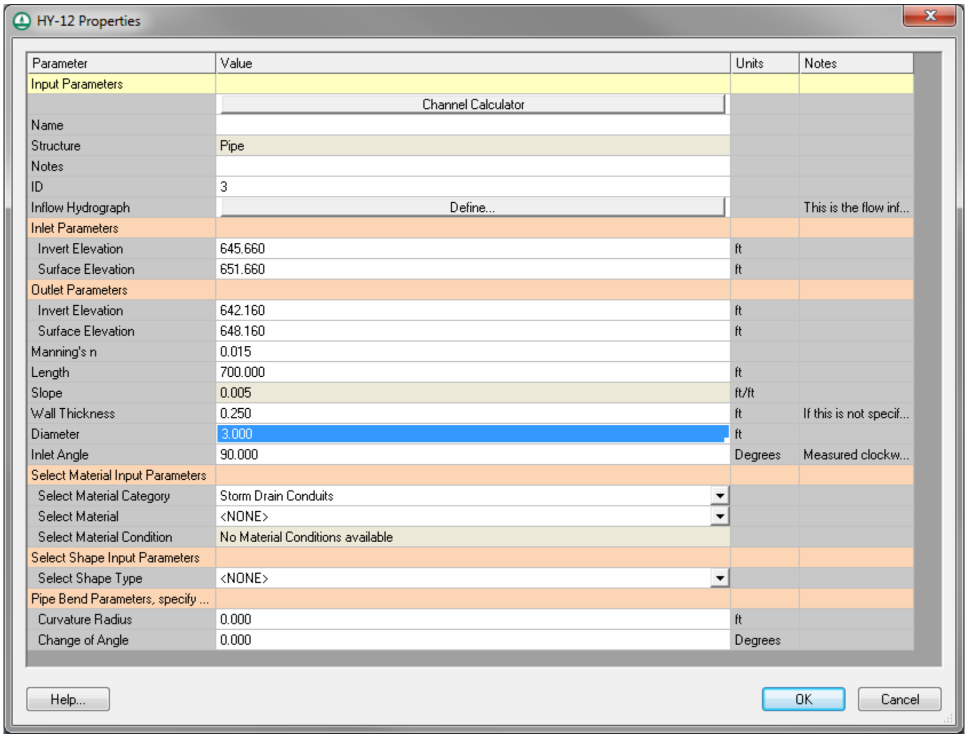


Figure 9 HY-12 Properties dialog for the inlet pipe

5 Running the Simulation and Viewing the Report File

Now that the storm drain network and pump station have been completely defined, the model is ready to be run.

1. Select *HY-12* | **Run HY-12…** to bring up the *Run HY-12 Simulation* dialog.
2. If the *Filename and path* for the *HY-12 executable* is blank, click **Select File…** to bring up the *Select an HY-12 Executable* dialog.
3. Browse to the location of HY-12 (the default location is *C:\Program Files (x86)\HY-12*), select it, and click **Open** to exit the *Select an HY-12 Executable* dialog.
4. Verify that *Selected Material Database* states “File Exists and Read Correctly”. If it does not, click **Select File…** and locate it in the *HY12PumpStation\HY12PumpStation* folder.
5. Make any other desired changes to the *Input Files* and *Result Files*, then click **Run Simulation** to bring up the *Model Wrapper* dialog.
6. When the HY-12 model finishes, turn on *Read solution on exit*.
7. Click **Close** to exit the *Model Wrapper* dialog and bring up the *View Data File* dialog. If *Never ask this again* was previously turned on, this dialog will not appear. If this is the case, skip to step 9.
8. Select the desired text editor from the *Open With* drop-down and click **OK** to exit the *View Data File* dialog and open the results in the selected external text editor.

The report file contain the results from the HY-12 model run, including a discharge hydrograph at the outfall, HGL/EGL summary, discharge hydrograph at the pump station, depth vs. time at the pump station, loss information, and several other pump station outputs.

Results can be copied out of the report file and plots could be generated in an external spreadsheet program. The report output can also be customized by changing the material database. For guidance on customizing the output, refer to the HY-12 documentation.[3]

To view pump station outputs within the report file:

9. In the report file, use the text editor search function to find the line labeled "Pump Station". The section should appear similar to Figure 10.

```
//-------------------
Pump Station    ID: 0

-----------
Pump Station Hydrographs
        time (min)      inflow (cfs)     outflow (cfs)    Depth (ft)      Storage (ft^3)

        0.00            0.00             0.00             0.00            0.00
        0.10            0.03             0.00             0.00            0.15
        0.20            0.05             0.00             0.00            0.45
        0.30            0.08             0.00             0.00            0.90
        0.40            0.10             0.00             0.00            1.50
        0.50            0.13             0.00             0.01            2.25
        0.60            0.15             0.00             0.01            3.15
        0.70            0.17             0.00             0.01            4.20
        0.80            0.20             0.00             0.02            5.40
        0.90            0.22             0.00             0.02            6.75
        1.00            0.25             0.00             0.03            8.25
        1.10            0.27             0.00             0.03            9.90
```

Figure 10 Pump station outputs in the report file

10. Scroll down to view the outflow hydrograph and the corresponding depth in the pump station well.

This data could be copied over to a spreadsheet allowing for the creation of the outflow hydrograph curve. An example spreadsheet, "Example Excel Plot.xlsx", is found in the *HY12PumpStation\HY12PumpStation\Solution* folder.

After scrolling through the outflow hydrograph, specific outputs related to each pump will be listed (Figure 11 shows the outputs for Pump 1). They will include losses, the number of times each pump turned on, min/max/average discharge rates, and min/max/average total dynamic head (TDH). If other parameters in the pump station definition were defined, other outputs such as wire to water power and efficiency would be calculated and shown here.

The outputs for Pump 1, Pump 2, and Pump 3 should be similar to those shown in Figure 11, Figure 12, and Figure 13 (respectively).

14. When done reviewing the HY-12 results file in the external editor, click to close the text editor and return to WMS.

HY-12 uses and creates a number of text files when it runs. These are available for review in the *Run HY-12 Simulation* dialog.

[3] See http://wmsdocs.aquaveo.com/HY-12_User_Manual.pdf.


```
Pump 1
        Pump Name:      Pump
        Brake Power:    0.00     hp
        Motor Efficiency:        0.00
        Outfall Elevation:       666.73  ft
        Elevation pump begins pumping:   637.70  ft
        Elevation pump stops pumping:    641.00  ft
        Pump Efficiency:         0.00
        Water power:    28.26    hp
        Wire-to-water power:     0.00     hp
        Maximum Possible Flow:   13.35    cfs

        Minimum Volume for Specified Minimum Cycling Time:      801.10  ft^3
        Computed Minimum Cycling Time (from equation, not simulation):  -6.27   min
        Runtime Data from Pump

        Number of times pump switched on:       384
        Minimum Length of Cycle (From Simulation):      0.10    min
```

Figure 11 Pump 1 outputs

```
Pump 2
        Pump Name:      Pump
        Brake Power:    0.00     hp
        Motor Efficiency:        0.00
        Outfall Elevation:       666.73  ft
        Elevation pump begins pumping:   641.50  ft
        Elevation pump stops pumping:    638.20  ft
        Pump Efficiency:         0.00
        Water power:    22.18    hp
        Wire-to-water power:     0.00     hp
        Maximum Possible Flow:   13.35    cfs

        Minimum Volume for Specified Minimum Cycling Time:      801.10  ft^3
        Computed Minimum Cycling Time (from equation, not simulation):  6.27    min
        Runtime Data from Pump

        Number of times pump switched on:       1
```

Figure 12 Pump 2 outputs

```
Pump 3
        Pump Name:      Pump
        Brake Power:    0.00     hp
        Motor Efficiency:        0.00
        Outfall Elevation:       666.73  ft
        Elevation pump begins pumping:   642.00  ft
        Elevation pump stops pumping:    638.70  ft
        Pump Efficiency:         0.00
        Water power:    22.57    hp
        Wire-to-water power:     0.00     hp
        Maximum Possible Flow:   13.35    cfs

        Minimum Volume for Specified Minimum Cycling Time:      801.10  ft^3
        Computed Minimum Cycling Time (from equation, not simulation):  6.27    min
        Runtime Data from Pump

        Number of times pump switched on:       1
```

Figure 13 Pump 3 outputs

6 Conclusion

This concludes the "Storm Drain Modeling – HY-12 Pump Station Analysis" tutorial. The following key concepts were discussed and demonstrated:

- Creating a storm drain coverage containing an inlet, inlet pipe, and a pumping station
- Mapping the coverage to a 1D schematic
- Defining the HY-12 parameters of a pump station with multiple pumps
- Creating storm drain structures
- Defining outfall and pipe parameters and inlet pipe structure
- Running HY-12, then viewing and analyzing the results

